World Soils Book Series

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The Soils of the Philippines

Springer

World Soils Book Series

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Aims and Scope

The *World Soils Book Series* brings together soil information and soil knowledge of a particular country in a concise and reader-friendly way. The books include sections on soil research history, geomorphology, major soil types, soil maps, soil properties, soil classification, soil fertility, land use and vegetation, soil management, and soils and humans.

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This book is dedicated to Luis Alfonso Carating and Andrei Sebastian Carating who serve as the senior author's inspiration to leave an important legacy to the succeeding generations

This book is also dedicated to all Filipino natural resource managers, practitioners, and students, who have untiringly and unselfishly sacrificed their time, assets, and effort to conserve the nation's wealth so that we would have valuable heritage to bequeath to the future Filipinos

And finally, this book is dedicated to you, the reader. I hope this is as much as a learning experience for you, as it is for the authors

Foreword

Soils are unique compared to most other natural resources. One can readily see vegetation types and tell the difference between one animal from another. Every individual makes the most of the sense of sight, smell, and taste to assess general differences in air or water quality. One who wants to study soils and sees the differences must have a good dose of curiosity, which many do not have. Often, people simply take the soil for granted without realizing that our very existence depends on soil.

Pedologists are always curious to see the unique and fascinating world unlike any other, through opening up a soil pit. By looking at several pits, one can tell that soils are different from each other. There are so far almost 400 different soil series, the lowest category in soil classification, identified in the Philippines. Surveyors, researchers, and even farmers can attest that often, these differences in the characteristics of soils mean differences in yield of the same crop. Further, one cannot expect to manage all soils the same way, and we cannot expect all soils to be equally suitable for building streets and houses. Studying the soil becomes vital for its sustained use, particularly in producing food for the present and future generations. Knowledge of the characteristics and behavior of different soils is key to the proper use and management of this very important natural resource.

The Philippines is a small country with land areas dominated by rolling to very steep terrain. Because of its limited land resources, even the more fragile lands are utilized for crop production, especially for subsistence farming. As early as 1994, almost 80 % of our lands were under severe to very severe state of degradation. Unless we learn how to properly manage our land, we will continuously be losing more of our arable land to degradation, and this will exacerbate further our problem with food supply.

Early survey activities done in our country have given us some knowledge indicating that much of our soils are in the more advanced stage of geological development. This implies a serious degree of infertility and nutritional imbalance. Other related constraints inherent in our soils include sloping terrain, shallow depth, coarse texture, low pH, high shrink/swell potential, high phosphorus fixation, among others. While we have this general understanding, we need to locate specific areas and their specific constraints to guide us to manage properly our remaining arable lands and provide proper conservation measures to the rest of our land. Thus, this book was written to elaborate occurrence of different types of soils in the country, a useful guide in developing soil management strategies for balanced fertilization and maintaining soil health.

The book contains the historical development of soil survey and classification in the country. It discusses the basic concept of pedology to provide readers a better appreciation of how surveyors study soils in the field. The presentation of different soils in the country is organized based on three major land units, namely soils of the lowlands, soils of the uplands, and soils of the hills and mountains. The book relates how the kind of soil affects the economy of the country and highlights the soil issues and challenges within the context of sustaining crop production in intensively used soils.

This book is certainly very useful to graduate and undergraduate students of soil science, professional pedologists, ecologists, and all others interested in or directly involved with the use of land. Planners, engineers, even public health officials engaged in wastes disposal would find this book useful. Knowledge in soil is basic to sound land-use planning and land management.

December 2012

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Preface

Ever since I came to the Soil Survey Division of the Bureau of Soils and Water Management (BSWM) in the early 1990s, I have but only one dream—to consolidate our knowledge and understanding of Philippine soils. I stood in awe before the foremost Filipino pedologists and colleagues who could identify and delineate a soil series by just looking and studying a soil profile during our fieldwork. With literally hundreds of soil series in the Philippines, 375 established soil series in my last count, of which 12 soil series are yet to be given new code numbers, having been left out since the 2009 publication of our *Manual of Map Standards and Symbols for Soil and Water GIS*, how could our experienced soil surveyors immediately recognize the soil series in the field? With further retirement of these eminent and highly experienced soil surveyors, we need to pass on to the next generation their knowledge and understanding of Philippine soils.

Soil is a continuum and at ground level, there is no way to distinguish where one soil mapping unit ends and another begins. As such, soil mappers use more visible indicators like geomorphology, land cover, and soil parent material from which the soil developed and can be either residual (in situ) from the underlying rock below, or transported by water and gravity, and consider other important factors or indicators to delineate one soil mapping unit from the other. The *soil series*, as the lowest category in soil classification, is introduced in order to organize our knowledge of soils. A soil series is named after the place it was first described, and not necessarily limited to one area but could also occur in other areas and across landscapes as well. It is interesting to note that some places in the Philippines are named after people who have made significant contributions to Philipino society and thus, we do have many soil series named also after people.

The Soils of the Philippines presents the original soil series concept or the "genetic key" as defined by the early Filipino pedologists, who during those decades of the 1940s, 1950s, and 1960s, generally had a strong geological background. By soil concept, we refer to a conceptual entity or thought pattern that describes the "central nucleus" or essential characteristics that distinguish one soil series from another soil. This is based mainly on soil morphology as an expression of pedogenesis. A soil series consists of pedons with soil horizons similar in soil color, soil texture, soil structure, other properties, and similar arrangement in the soil profile. We emphasize *arrangement* because it is the presence or location of a specific feature within the profile that makes one soil series different from another, considering variability of many measurable properties even within the same soil series in a given soil mapping unit. For example, soils in former tidal flats characterized by the presence of coralline materials below the control section (150 cm) or the substratum is specific to Obando soil series. If the coralline materials are found within the control section, it will be another soil series—such as Pulupandan series if found in the substratum and consists of pure marine shells. The similarity of arrangement as described or compared with the genetic key defined for the soil series makes the soils being classified to belong to that particular soil series even if it is located in another area.

These basic soil concepts like what is a pedon, what is soil morphology, and what is pedogenesis will be explained in the introductory pages. The soil morphology represents an important diagnostic criterion for a particular soil profile to be classed under a specific soil series. Those unfamiliar with soils would notice that in distinguishing one soil series from the other, an important criterion is the nature of the substratum. We go down the soil profile because the surface soil can be subjected to changes with time such as thinning out due to erosion, and changes in physical and chemical properties because of human activities and interventions. Soil color (usually at moist condition), texture, and clay downward movement are also important criteria because these properties do not easily change with time.

A look at the unpublished master list of the established soil series of the Philippines (possibly circa mid-1960s) mentioned that this was adopted from the "Key to Soil Series of California" by Storie and Weir (1941) of the University of California. There were nine groupings of the Philippine soil series, based on physiography, the kind of parent material and mode of formation, and the kind of soil profile. The alluvial soils were placed in groups 1–5, group 6 was basically a mix of alluvial and residual soils, and groups 7–9 were residual soils. The underlying substratum, whether unconsolidated (groups 1–4) or consolidated (groups 5–9) was a major differentiating factor. We have maintained these concepts of grouping soils based on the kind and nature of the substratum, incorporating redefinitions for those soil series revisited decades later to facilitate field identification.

The Soils of the Philippines is actually the first published consolidation of the Philippine soil legacy data, the fulfillment of that dream. With over a 100 years of soil survey work, certainly many changes have occurred with the passing of time as we revisited some soil series in the succeeding decades while other soil series remained untouched since initially surveyed and mapped. It is inevitable that we find ourselves faced with two similar soil series almost similar in morphology but different in physiographic position, one located in a higher position than the other. This would be easier to differentiate and recognize in the field. Worst, we find ourselves with soil series of similar geomorphic characteristics such as depositional process, geomorphic position or micro-landscape location, the nature of parent material, and the topographic expression. We have encountered two different soil series in two different islands, the same alluvial plain landscape position, the same soil series concept by having similar substratum of unconsolidated materials, the same stony subsoil characteristics, and the same drainage properties; in fact, exhibiting the same redoximorphic features, specifically orange mottles.

Soil profile description alone would not suffice in this case as we expect variation in morphological properties given a soil series. The *Typical Pedon* is the central concept pedon that readers will find in this book. Surveyors would observe a certain degree of differences from the Typical Pedon during actual field survey. Without anymore the retired Filipino pedologists to assist us to differentiate these similar established soil series, we redefine such two similar soil series that we come across with by introducing the concept of *geomorphic surface*, defined as a landform or group of landforms that represents an episode of landscape development. Traditionally in the study of soils, the concept of geomorphic surface is used to explain why for instance, younger soils like those classified as Entisols, are side-by-side with an old soil like Ultisols in a given landscape. We try to extend this concept to differentiate very similar soil series by recognizing the major geomorphic surface units where they are found. Despite the fact that the senior author is not aware how these geomorphic surface units are named or officially recognized in the geological literature, in which case we improvise the nomenclature to facilitate the identification, the geological history provides a clue about the geological episode of landscape development. Since the soil is weathered parent material, we would have to go to mineralogy as possibly confirmed by the geomorphological nature and age of the soil parent material to be able to differentiate such similar soil series. This is the only way we could move forward to completing the Philippine soil legacy data.

When the initial outputs of this study, Keys to the Soil Series of the Lowland Soils of the Philippines, was presented during the 6th East and Southeast Asia Federation of Soil Science Societies (ESAFS) held in Taipei, Taiwan, November 24–29, 2003, the eminent Dr. Hari Eswaran of USDA commented that such effort would tend to restrict initiatives to establish new soil series. Future surveyors would just depend on the key for soil series classification. On the contrary, the senior author believes that coming up with a systematics of the soil series of the Philippines will enable us to see the "box gaps" in the classification system where soils that do not fit into any of the existing soil series "boxes" definitely demands that such a soil series be newly established. Since this research effort provides us an inventory of existing soil series, we will also avoid establishing a new soil series where we have already an existing soil series of similar morphology, physiographic position, nature of parent material, and genetic history. Were it not for the concept of geomorphic surface, it would be almost impossible to complete this book by differentiating those similar soil series in every respect. This book is certainly not the final list, but should serve as the initial inventory of Philippine soils.

The Soils of the Philippines is part of the *World Soils Book Series* that contain details on the soils of various countries. The World Soils Book Series features soil survey history, climate, geology, geomorphology, major soil types, soil maps, soil properties, soil classification, soil fertility, land use and vegetation, soil management, soils and humans, soils and industry, and future soil issues. The importance and relevance of this book becomes more significant considering that rapid urbanization and the dynamic transformation of Philippine economy from agricultural to industrial brings to extinction vast areas of prime agricultural lands. As a number of animal and plant species that represent our biodiversity heritage are threatened by extinction, so are our soil resources.

The Soils of the Philippines represents the current state of the art in our understanding of Philippine soils. The international soil science scene advances in leaps and bounds as we in BSWM make the effort to keep in pace with the developments. Much of these developments especially in soil survey and classification are already reflected in our newly released soil survey manual, but a few of the major changes are yet to be implemented in actual field survey work and in our data and information warehousing (the Soil Information System) which needed also to be overhauled, and not just updated nor just upgraded. This will be Version 3 as the first version was mainframe-based and the second version was a subsystem under the Agricultural Resources Information System that included warehousing other major data outputs of BSWM. What we wanted is not just a web-accessible and Geographic Information Science (GIS)-based Soil Information System, but also an information system that could provide the varied data needs of local and international clientele.

The demand for soil resources information has also expanded in recent decades and we have to participate in several multi-agency and international collaborative consortia involving a variety of global issues pertaining to resources management within and outside the traditional agricultural arena. Soil science is traditionally taught in agricultural colleges and universities, and hence most of us have agricultural leanings and background. Soil data are mostly interpreted for agricultural purposes. But many of our clients now are in non-agricultural fields—architecture, civil works, forestry, and the various disciplines of botanical and life sciences, environmental science, natural resources management, rural development planning, policy and legislation, and other relevant branches of earth sciences. In fact, soil geography, with its socioeconomic dimension, is now emerging, for which soil survey, classification, and mapping should make a strong presence.

The Soils of the Philippines sums up all that we have been doing since the start of soil survey work in the Philippines from 1903 until the present. It is a homage to these men and women who have contributed to more than a century of soil survey work. It is a fitting tribute to BSWM's soil resources assessment activities on the occasion of her 62nd

Anniversary, as BSWM was re-established after the Second World War in 1951 and remains the sole nationally mandated authority on Philippine soils to this day. We believe this book also paves a positive future for soil survey and classification in the years and decades to come.

Quezon City, Philippines, December 2012 Rodelio Carating

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Alejandro Micosa, former chief of the Soil Survey Division (now retired), is credited with the consolidation of the history of soil survey from the time of the very first soil survey in 1903 to the time of his retirement during the second five year of the 15-year technical cooperation project with the Japan International Cooperation Agency (JICA). He also steered the Soil Survey Division to adopt the USDA Soil Taxonomy system of soil classification in the updating of the provincial soil maps. He is generally perceived as the last of the "hard core" classical soil surveyors to head the Soil Survey Division.

We are also greatly indebted to the now deceased Arturo Dayot, a national treasure when it comes to soil series mapping. Mr. Dayot is greatly responsible for much of the redefinition of the soil concepts and the establishment of new soil series. We greatly rely on voluminous unpublished documents he left behind for the "meat and substance" of this book. As these are unpublished compilations, we could not properly make the citations.

Noemi Pascual, Aerial Photo Interpretation Section of Soil Survey Division, collated the draft regional soil maps from the field survey team leaders and supervised the map finalization. Noemi also provided inputs to the Soils of the Lowlands chapter and controls the master list of soil series in the Philippines and the master file of the soil maps as well.

The co-author Clarita Bacatio completed the master list of the Soils of the Lowlands with the assistance of Oscar Costelo, Aerial Photo Interpretation Section of Soil Survey Division, who provided technical support in the inventory of the soil series and the taxonomic classification, and Gina Alberto who encoded the group's workshop outputs.

Luisito Costelo, Soil Survey and Interpretation Section completed the Soils of the Upland together with Berna Pastor, Aerial Photo Interpretation Section and Teresita Retamar of the Soil Survey and Interpretation Section. Raquel Rico Granil of ISRIS provided GIS and workshop data encoding support.

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The application of land evaluation through updating of the *Strategic Agriculture and Fisheries Development Zones* (SAFDZ) to represent the agricultural component of the Comprehensive Land Use Plan (CLUP) required of Local Government Units (LGUs) and its accompanying *Comprehensive Development Plan* (CDP) maybe new materials and there are no direct and published sources but certainly the framework was adapted based on unnumbered and undated Memorandum Circular (circa 2009) by the *Department of Interior and Local Government* (DILG) "Guide to Comprehensive Development Plan (CDP) Preparation for Local Government Units" (http://www.dilg.gov.ph/PDF_File/reports/DILG-Reports-2011712-1939d5d3d3.pdf, 126 pages, last accessed June 17, 2013). The participatory approach to SAFDZ mapping was adapted from "Participatory Approaches in Sustainable Land Management: Planning, Implementation, and Monitoring as Continuous Learning Processes, the Bhutan Experience" published by *SLMP-NSSC*, Department of Agriculture, Ministry of Agriculture and Forests, Royal Government of Bhutan, July 2011 (www.nssc.gov.bt/publication/files/pub9vl2131ol.pdf, 63 pages, last accessed June 17, 2013). Finally, the steps to identify and map SAFDZ was sourced from the unpublished PowerPoint lectures prepared by Mr. Elmer Borre, Chief, Agricultural Management and Evaluation Division, and his staff and Soil and Water Area Coordinator for Region 2, Mr. Bertolio Arellano, both of BSWM. We acknowledge the unmeasurable contributions of these sources for a section of this book that have yet no published reference materials.

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Contents

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AFMA	Agriculture and Fisheries Modernization Act
AFMP	Agriculture and Fisheries Modernization Plan
ARC	Agrarian Reform Community
BAS	Bureau of Agricultural Statistics
BFAR	Bureau of Fisheries and Aquatic Resources
BSWM	Bureau of Soils and Water Management
CAF	Census of Agriculture and Fisheries
CBFM	Community-Based Forest Management
CDP	Comprehensive Development Plan
CIS	Communal Irrigation Systems
CLUP	Comprehensive Land Use Plan
CSIRO	Commonwealth Scientific and Industrial Research Organization
DA	Department of Agriculture
DAR	Department of Agrarian Reform
DENR	Department of Environment and Natural Resources
DFIMDP	Diversified Farm Income and Market Development Project
DILG	Department of Interior and Local Government
DPSIR	Driving Forces-Pressures-State-Impacts-Responses
EC	Electrical Conductivity
ELA	Executive and Legislative Agenda
EMB	Environmental Management Bureau
ENRA	Environment and Natural Resources Accounting
ERDB	Ecosystems Research and Development Bureau
ESAFS	East and Southeast Asia Federation of Soil Science Societies
ESP	Exchangeable Sodium Percentage
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information System
GVM	Global Vegetation Monitoring
FAO	Food and Agriculture Organization of the United Nations
FMB	Forest Management Bureau
HLURB	Housing and Land Use Regulatory Board
IDP	Integrated Development Plan
IFOAM	International Federation of Organic Agriculture Movement
ISRIC	International Soil Reference and Information Centre
ISRIS	Integrated Soil Resources Information Service
ITTO	International Tropical Timber Organization
IUSS	International Union of Soil Science
JICA	Japan International Cooperation Agency
JRC	Joint Research Centre

LAC	Low Activity Clay
LADA	Land Degradation Assessment in Drylands Project
LC	Land Characteristics
LDC	Local Development Council
LGU	Local Government Unit
LQ	Land Qualities
LUR	Land Use Requirements
LUS	Land Use System
LUT	Land Utilization Type
MGB	Mines and Geosciences Bureau
MOA	Memorandum of Agreement
NAMRIA	National Mapping and Resource Information Authority
NIPAS	National Integrated Protected Areas System
NIA	National Irrigation Administration
NIS	National Irrigation Systems
NPAAAD	Network of Protected Areas for Agriculture and Agro-Industrial Development
NPV	Net Present Value
NSCB	National Statistics Coordination Board
OWA	One World Award
OCCP	Organic Certification Center of the Philippines
PAWB	Protected Areas and Wildlife Bureau
PCA	Philippine Coconut Authority
PHILCAT	Philippine Conservation Approaches and Technologies
PHILRICE	Philippine Rice Research Institute
PHILSIS	Philippine Soil Information System
RS	Remote Sensing
SAFDZ	Strategic Agriculture and Fisheries Development Zones
SAR	Sodium Adsorption Ratio
SEARSOLIN	Southeast Asia Rural Social Leadership Institute
SRA	Sugar Regulatory Administration
TLA	Timber License Agreement
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNSEEA	United Nations System of Integrated Economic and Environmental Accounting
UPLB	University of the Philippines Los Baños
USDA	United States Department of Agriculture
USLE	Universal Soil Loss Equation
WOCAT	World Conservation Approaches and Technologies
WTO	World Trade Organization

1 Introduction

Abstract
The introduction begins with a narrative of the history of soil survey and classification in the Philippines, from the very first conducted by Clarence Dorsey in 1903 and through the succeeding decades until the present, and the soil survey prospects in the immediate future. From the organization that studies the Philippine soils, we move on to the soil itself, to understand more about soils. We discuss the fundamentals of pedology and the description of the soil profile which will be the major structural content of the next three chapters. We then continue by applying these pedological concepts, specifically the factors of soil formation, given the Philippine geological setting. This provides an overview of the soils in the Philippines. We temporarily deviate from the technical discussions from the geological history of soils to a sidelight that we could glean from the names of the Philippine soils. Since the soils are named after places, some of these bear witness to the history of the Philippines. Contrary to the notions of many westerners, the country had culture and civilization centuries before the arrival of Spain. That before our colonization and westernization by Spain, we had an Islamic culture, and before the arrival of Islam to the Southeast Asian region, we had a Hindu culture as the rest of the region was. Finally, we return to the technical aspects of soil classification and nomenclature system, explaining how a soil is classified and named. Generally, this is part of the legend that accompanies soil survey maps and reports. A brief summary of the original soil series groupings is presented. This is a classic work and referred to every now and then even by younger crop of soil surveyors.

1.1 Historical Development of Soil Survey in the Philippines

1.1.1 The Beginning of Soil Survey in the Philippines

The first attempt to conduct soil survey in the country was done in the province of Batangas some time in 1903 by Mr. Clarence Wilbur Dorsey, an American soil scientist, whose "Soil conditions in the Philippines" was among those widely held (Alcasid 1992). This book was the first officially recorded attempt to provide soil science a role in the development of agriculture in the Philippines. This rare 1903 book was published as Bulletin Issue 3 by the then Bureau of Agriculture, consisting of 57 pages. Born in 1872, Dorsey is a Harvard University graduate with a background in Geology, followed by the practice of many years of relating soils to underlying geology (Helms et al. 2002 quoting Bonsteel and Harding 1942). He has done 15 works in 18 publications. Together with Means, Gardner, and Bonsteel, Dorsey had pioneered in soil surveys in Utah, Colorado, New Mexico, and the Connecticut Valley in the summer of 1899 (Lapham 1945).

It was not until 1921 that the Division of Soils and Fertilizers was organized under the Bureau of Science. Even then, most of the studies were confined to the chemistry of soils and fertilizer requirements of sugarcane areas. The most eminent of the Division heads was Dr. Angel S. Arguelles (1888–1952) who became chief of the division in 1923 (Philippine Heroes 2001). He pioneered the study of

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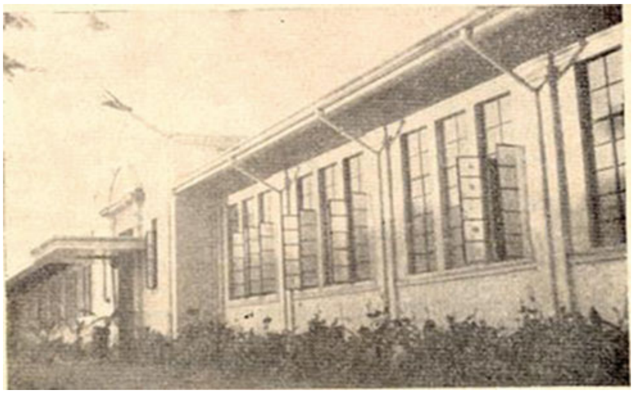


Fig. 1.1 The former soils office in Ermita, Manila when it was known then as the Division of Soils and Fertilizer under the Bureau of Science. This became later the Soils Laboratory until the Bureau moved to its present location in Diliman, Quezon City in the early 1990s. This old soils laboratory is currently occupied by the Court of Appeals

"The Soils of the Islands of Luzon" which appeared in the Philippine Journal of Science in 1914. He was promoted as assistant director of the Bureau of Science, and later became the first Filipino director of this Bureau as the Philippines was then an American colony. It was not only the Bureau of Soils that eventually emerged from this pre-war Bureau of Science, but also the Bureau of Mines, and the Bureau of Fisheries (Fig. 1.1).

1.1.2 From the 1930s Until the Outbreak of World War II

The actual inventory of soils in the country started in 1934 when the Soil Survey Committee was organized by the Secretary of Agriculture and Commerce. In 1936, the Bureau of Science reorganized the Division of Soils and Fertilizers into the Division of Soil Survey. In 1939, the National Assembly enacted Commonwealth Act 416 mandating agronomical soil survey to the Division of Soil Survey, expanding the division to five sections. This inventory was carried out in each and every province. Because of limited laboratory facilities and available technology during those periods, the reconnaissance type of soil survey was used. The reconnaissance soil survey in the country strictly followed the USDA system which was primarily based on the soil profile observations. Laboratory analyses at that time were mainly for soil fertility assessment. The profile observations recorded the key characteristics of the soil series, the key pedological unit used in mapping the soils of the province (Fig. 1.2).

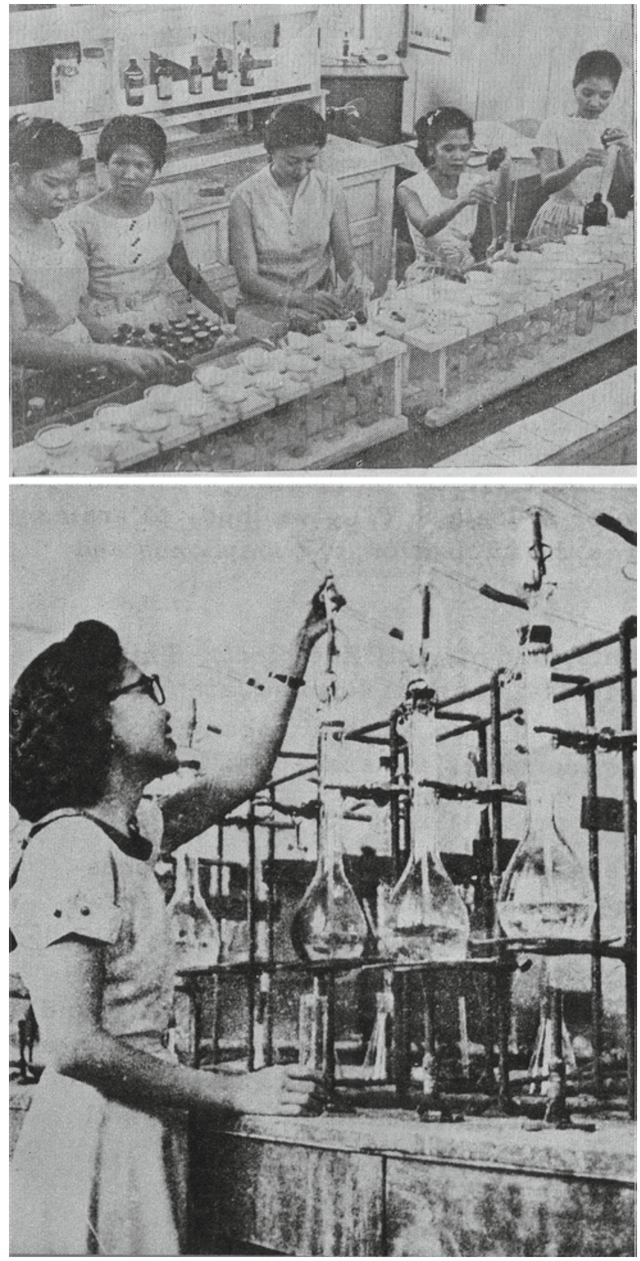


Fig. 1.2 Vintage photos of the old soils lab at the Orosa St., Ermita, Manila

1.1.3 From After the War Until the 1950s

Soil survey work was briefly interrupted by World War II. It was not until after the war in 1945 that the Soil Survey Division was reorganized. Unlike its pre-war activities, the focus of the activities during this time was conservation survey. The outputs served as the fundamental basis for laying the principles needed to undertake soil conservation work. In 1948, the Soil Survey Division was again

Fig. 1.3 Marcos M. Alicante was appointed as the very first Director of then Bureau of Soil Conservation and steers the Bureau into its first decade

Fig. 1.4 Members of soil survey team conduct auger boring for Bolaoen series in the 1951 soil survey and classification of Zambales province (Reproduced from Soil Survey Report of Zambales (1951))

reorganized into the Division of Soil Survey and Conservation with four sections to carry out its functions.

In June 5, 1951, the Congress of the Republic of the Philippines enacted Republic Act No. 622 organizing the Bureau of Soil Conservation consisting of five divisions. Dr. Marcos M. Alicante (Fig. 1.3) was named as the first Director. It is this date that the Bureau celebrates as its founding anniversary.

The first Bureau director was an experienced soil surveyor having conducted the soil survey of Bulacan in 1936, Batangas in 1938, Pampanga in 1939, Pangasinan and Tarlac in 1940, and Nueva Ecija in 1941 (sample soil survey team at work during the 1950's in Fig. 1.4). He also has a publication on Buenavista Estate Experiment Station in 1947 and on Soil Conservation and Our Republic in 1948, so soon after the devastation of the war. He obtained his Ph.D. degree in Soil Microbiology and was an active member of the New York Academy of Sciences.

1.1.4 Soil Surveys in the 1960s

Two directors served the Bureau during this decade—Ricardo T. Marfori (1960–1965) and Atanacio A. Simon (1966–1971). Director Marfori wrote a book "The Fertilizer Requirements of Rice in the Philippines" in 1969 and has published papers in the Journal of the Philippine Soil Science Society. He was considered a leading authority on the fertility of tropical soils. Director Simon was a soil surveyor and was involved in several soil survey and classification projects such as those of Batanes and Samar prior to being at the helm of the Bureau.

In 1964, the Bureau was renamed Bureau of Soils. Regional offices and provincial soils districts were created to bring the services closer to the farming communities and the Bureau became a major planning, policy making,

Fig. 1.5 A soil conservation regional office in the early 1960s before the Bureau of Soil Conservation was reorganized into Bureau of Soils with regional and district offices nation-wide

consultative, and advisory agency of the Department of Agriculture and Natural Resources (Fig. 1.5).

The reconnaissance soil surveys of the 75 provinces of the Philippines were completed sometime in the mid-1960s. In the entire survey activities, a total of 348 soil series were mapped and identified. The soil resources were further classified according to land use capabilities for agriculture, forestry, recreation, pasture, and wildlife refuge. There is lack of pedological descriptions and laboratory analyses of the representative pedons which made these early efforts rather difficult to link with the USDA Soil Taxonomy system of classification that the Bureau later on adopted. Nevertheless, being the only document for the Philippine soils, these studies are the most important source of soil information in the province and the only credible soil maps for use in the various agricultural development planning and studies.

Reconnaissance provincial soil survey activities continued during this decade. The reports were published in scales ranging from 1:75,000 (Cavite) to 1:250,000 in general and others at exploratory scale of 1:500,000 (Palawan). This variation in map publication scale is done to conform with the actual size and shape of the individual provinces, especially the island provinces. The soils were classified according to soil series and soil types/phases

1.1.5 Soil Surveys in the 1970s

Juan A. Mariano served as the Bureau director in the first half of the 1970s, from 1971 to 1976. Godofredo N. Alcasid, Jr. succeeded him and was the longest director serving the Bureau for 20 years, from 1976 until his retirement in 1996. Both directors had their roots in soil survey. Like his predecessors, Director Mariano has conducted several field soil surveys and authored various provincial soil survey reports prior to being assigned at the helm of the Bureau such as the soil surveys of Davao, and Ilocos Sur.

With Martial Law imposed upon the country, gloom dawned on the Bureau in September 24, 1972 when President Ferdinand E. Marcos issued Presidential Decree No. 1 reorganizing the Executive Branch, splitting the Department of Agriculture and Natural Resources into two departments and merging the Bureau of Soils with the Bureau of Plant Industry. Vigorous and active representations were made, with no less than the Mr. Godofredo N. Alcasid, not yet director at this time of merging, advocating for the retention of the Bureau of Soils as a distinct agency from the Bureau of Plant Industry. He was supported by the Soil Science Society of the Philippines. The gloom was replaced by joy in March 1973 when the two merged bureaus were again separated.

In 1972, from the meager laboratory data and based mainly on morphological descriptions, Mariano and Valmidiano prepared a schematic soil map of the Philippines at 1:1,600,000 scale using soil great groups to compose the map units. At about the same period, an FAO/UNDP-assisted soil survey and classification project was conducted using the Seventh Approximation to classify the soils.

The application of the USDA/SCS Soil Taxonomy to agriculture started in 1975 with the benchmark soils project which conducted tests on agro-technology transfer based on soil classification. The sites for experimentation were chosen to represent the distribution of two different soil families. However, there were inaccuracies in the initial classification, which demonstrated the low level of understanding of Soil Taxonomy even among specialists. Nevertheless, this project showed the predictability of crop responses to management of similar soils.

The decade of the 1970s was characterized by semi-detailed soil surveys in contrast to the reconnaissance soil surveys of the previous decades. Geomorphic mapping and soil classification were carried out at 1:50,000 scale and classified as soil series, great groups or subgroups.

Fig. 1.6 The decade of the 1970s was characterized by detailed soil surveys of four of the country's major irrigation projects, confined to alluvial, mostly rice lands

A number of soil series identified in past soil surveys were subdivided and new soil series were established as intergrades or extragrades of the former large map units. A detailed soil survey at 1:10,000 scale was carried out for irrigation development projects in 1975 through 1979 with assistance from the Food and Agriculture Organization (FAO). This marked a major milestone in the soil survey in the Philippines as the major lowland soil series were defined, properly documented, and adequately correlated. This also marked the first major attempt to use equivalent USDA Soil Taxonomy classification for each of the soil series. Subsequently, Soil Taxonomy was adopted as the official soil classification system in the Philippines.

The surveys were confined to the alluvial, flooded lands. This project covered four irrigation projects with a total area of about 152,000 ha. A total of 59 new soil series were identified. They are mostly found in Central Luzon (Fig. 1.6).

1.1.6 Soil Surveys in the 1980s

The 1980s and the 1990s were the decades of semi-detailed soil surveys with map scale of 1:50,000. About 20 provinces with 5,496,690 ha were surveyed (Fig. 1.7). But as we approached the middle of the 1980 decade, soil series classification could not be sustained because of lack of funds to support the required routine soil sample analyses. It became an exacting task to control and correlate the soil series identified in the field. The last province surveyed, classified, and reported to soil series level was Tarlac in 1986. In subsequent soil surveys, the soils were classified according to USDA *Soil Taxonomy* with soils classified at family level.

The Bureau's history mirrored the tumult that rocked the nation in the mid-1980s as President Corazon C. Aquino

Fig. 1.7 Field soil survey activities in the 1980s focused on the provincial soil surveys with the soils classified at family level of *Soil Taxonomy*

was swept into the presidency by the People Power Revolution. On January 30, 1987, President Aquino reorganized the Bureau of Soils into the Bureau of Soils and Water Management (BSWM) through Executive Order 116. The Bureau retained its function of soil resources survey, agricultural land resources evaluation, conservation, and research but its mandate was broadened to include the development and management of water resources through construction of small water impounding systems, the promotion of shallow tube wells, and other water resources management technologies to alleviate the impact of prolonged drought on standing crops. The expanded mandate included artificial rainmaking or conduct of cloud seeding sorties over areas suffering from seasonal drought.

Under this reorganization, BSWM ceased to be a line bureau and became a staff bureau of the Department of Agriculture. Its regional offices and provincial districts were integrated with other agricultural functions of the Department of Agriculture for a cohesive and coordinated delivery of services to the farmer clientele. Soil survey remained a solo mandate at the national level and the provincial soil district offices eventually lost touch with the central office for the technical capability to conduct soil mapping. Despite continuing efforts of the USDA and the Department of Science and Technology (DOST) through the Philippine Council for Agriculture, Forestry, and Natural Resources Research and Development (PCARRD) to equip local soil practitioners with the principles and fundamentals of *Soil Taxonomy* system of classification through series of workshops that extended up to the 1990s, soil mapping in the country was practically nil except those semi-detailed provincial soil map updating conducted by the Soil Survey Division.

In October 1988, the Republic of the Philippines through the Department of Agriculture entered into an agreement with the Government of Japan through the Japan International Cooperation Agency (JICA) for the establishment of the Soils Research and Development Center (SRDC). The groundbreaking ceremony for the Center's construction was made in 1989. In January 1990, BSWM moved from Sunvesco Bldg., in Taft Avenue where the technical and administrative staff were then holding office, and from Court of Appeals Building in Maria Orosa St., Ermita, Manila where the laboratories were, to its new home, the SRDC in Elliptical Road, Diliman, Quezon City (Fig. 1.8).

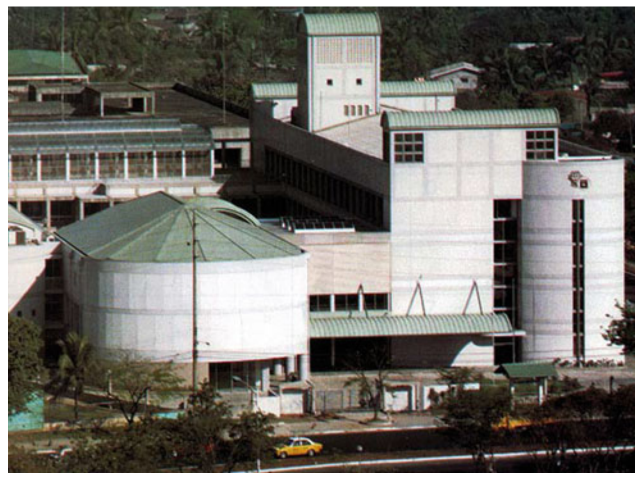


Fig. 1.8 Through JICA building and equipment grant, the Bureau of Soils and Water Management moved to its new home in Diliman, Quezon City in 1991. The administrative, technical, and laboratory services, formerly scattered in various buildings in Manila, were consolidated under one roof

1.1.7 Soil Surveys in the 1990s

At the national level, Republic Act 7160 known as the Local Government Code of the Philippines was enacted in 1991 by the Philippine legislature, empowering local governments through a system of decentralization with effective mechanisms to allocate powers, responsibilities, and resources from the central office to the local government. The devolution process stripped BSWM of its remaining hold on the regional and provincial soils offices, laboratories, staff, and on the farmer clientele as well, which before the devolution were under the jurisdiction of the regional offices of the Department of Agriculture. Only the regional soils laboratory remained with the Department of Agriculture. Budget remained a major constraint to effectively carry out this devolution process. The Laboratory Services Division asserted its supervisory capacity to look into the status of equipment and quality of analyses of former satellite soils laboratories; but even then, most of the soils laboratories have degenerated to qualitative soil analyses as its only service to the farmers. Worst, soils laboratories in other provinces were converted to other offices by the local government and its staff performed other functions. By this time, only the Soil Survey Division in the central office was capable of conducting soil resources mapping in the country. There was no understudy for retiring soil survey and classification experts to continue soil resources inventory work at the regional and provincial level. Soil survey function was not devolved for the simple reason there were no capable soil surveyors to conduct soil mapping activities and no local government funds were allocated for this purpose. The Local Government Code made BSWM as the *de-facto* sole nationally mandated authority on soil survey and classification.

The 1990s was the decade of the BSWM's two 5-year technical cooperation project with the JICA. The laboratory facilities of the JICA-funded SRDC made it possible to have more advanced analytical studies for soil mineralogy, soil biology, soil chemistry, and soil physics. These certainly improved the capability of BSWM to provide soil analytical data to different users and provide opportunities to participate effectively in the formulation of sustainable agricultural development program for the Philippines. The JICA presence at BSWM also ushered a computer-assisted map digitization and spatial analyses through the establishment of Geographic Information System (GIS) and Remote Sensing laboratories. These are very important developments in the advancement of soil science in the country. During the second phase of the technical cooperation, BSWM started to move from mainframe computing to desktop networking. The Local Area Network was established advancing the state of soil and water spatial and tabular data sharing within the various technical divisions.

In 1996, Director Godofredo N. Alcasid retired and he was succeeded by Director Rogelio N. Conception. Director Concepcion has also his roots in soil survey and was initially assigned in one of the soils district offices in Mindanao.

But the mid-1990s also marked the end to continuing updating of provincial soil maps at semi-detailed level (1:50,000 scale). While the demand for soil resources inventory as input to development planning was increasing, the government-appropriated budget for soil survey remained constant making it impossible to complete the provincial soil map updating with the escalating costs of practically everything. As a primary data producer, the Soil Survey Division could not compete with the other primary data generators such as those relating to census and statistics for budgetary increments commensurate to the increases in the cost of living.

In 1998, the Philippine legislature enacted Republic Act 8435, the Agriculture and Fisheries Modernization Act (AFMA). A major feature of this law is the delineation of Strategic Agriculture and Fisheries Development Zones (SAFDZ), the prime of the prime agricultural lands. The so-called prime agricultural areas consist of the Network of Protected Areas for Agriculture and Agro-Industrial Development (NPAAAD). The Soil Survey Division took this opportunity to reinvent itself and focus its soil survey activities from provincial to municipality level through cofinancing scheme with the sponsoring Local Government Unit (LGU). The law requires SAFDZ to be integrated into the municipality's Comprehensive Land Use Plan (CLUP). Soil resources inventory is an essential input to development planning, and a must as part of agricultural resources inventory. This becomes the soil survey thrust as the new millennium dawns. A Memorandum of Agreement (MOA) with the proponent LGU defines the role of each. The first decade of the new millennium continues with the municipal-level updating of soil resources.

1.1.8 The First Decade of the New Millennium (2000–2010)

A third 5-year technical cooperation project with JICA commenced the new millennium. In 2007, Director Rogelio N. Concepcion retired and Dr. Silvino Q. Tejada steered BSWM. The focus of this decade is on soil resources information technology networking and dissemination. The establishment of the Soil Museum is an important step in the collection of preserved soil profiles to correspond to the recognized soil series of the Philippines. The collection, however, is still very small (Fig. 1.9). With JICA technical cooperation project completed in 2005, the GIS and Remote Sensing facilities of BSWM were upgraded through a World Bank loan under the Diversified Farm Income and Market Development Project (DFIMDP) in 2008.

The first decade of the new millennium continues with the municipal-level updating of soil resources as a major component of SAFDZ. While the thrust will be most likely retained as the second decade of the new millennium comes, the Soil Survey Division braces for major changes.

Fig. 1.9 The Soil Museum provides an important link to the focus on soil resources information technology and networking and spatial database structure in the 1990s

In October 2004, President Gloria Macapagal-Arroyo issued Executive Order 366 instituting reforms in the bureaucracy through the rationalization of all offices under the Executive Department.

1.1.9 Prospects and Challenges for Soil Survey in the Second Decade of the New Millennium

As we enter into the second decade of the new millennium, Rationalization of the BSWM remains but a dream on paper. Six years had passed with several retirements of irreplaceable technical staff and there were no new hirings to serve as their understudy and fill up their vacated positions. As the Bureau awaits its fate in the Rationalization Plan, it is depleted of its soil survey experts who can describe soils, identify soil series in the field, and delineate soils in the map. With its key officials retired and no understudy for the remaining competent soil surveyors, BSWM awaits for the approval and implementation of its Rationalization Plan, how many years waiting yet, we have no idea. By this time, the Soil Survey Division conducts soil fertility mapping and scattered special soil investigations and soil mapping for selected LGU clients who need soil maps as part of their CLUP required by the national government. For several years now, there is no major provincial soil survey updating and mapping project similar in magnitude and scope to those of the early 1990s and the previous decades. But despite this deplorable circumstance, we remain optimistic about the future of soil survey in the Philippines.

Rationalization of government offices brings about a comprehensive review of the Bureau's mandates, missions, objectives, functions, programs, projects, activities, systems, and procedures. Functional and operational adjustments to improve service delivery and productivity threaten the very existence of Soil Survey Division under the Results-Based Management approach. It cannot just assert itself to be retained because it is older even than BSWM. The paradigm shift from government to governance emphasized the critical role of clients who are at the receiving end of public services. If Soil Survey Division is producing soil maps, how many purchase the soil maps every year? A tangible and measurable indicator of the soil map being used by clients has to be established and could spell the difference between being retained or being abolished. The government bureaucracy is now concerned with results rather than with processes and procedures. We cannot just say soil maps are essential planning tools because if only 150 people purchase those maps in a year, we might as well transfer that function to another agency with a resource mapping mandate also for efficiency of service. The Soil Survey Division needs to reorient and reinvent itself to the needs of clients or customers than to its concern which is production of soil maps if it were to survive as an organization producing primary data. It must expand its product output other than soil maps.

The BSWM rationalization proposal is to expand the Soil Survey Division to include developments in Soil Geography. Soil maps will just be one of its major outputs under the Pedology, Genesis, and Soil Classification Section. The Division will have to expand the scope of its researches and activities to be able to relate its soil mapping activities to other areas of concern such as sustainability of agricultural production, food security, land carrying capacity, soil aggradation, and degradation. The Division needs to look into the application of environmental sociology and economic theory to validate soil and water resources as natural capital for optimization of ecosystem services. It has to concern itself with current issues of climate change, land degradation, and carbon sequestration.

The Cartographic Operations Division is proposed to be merged with the Integrated Soil Resources Information Service (ISRIS) to become the Geomatics and Soil Information Technology Division. The move is toward digital cartography. While waiting for this merger, our vision is to come up with our first set of outputs—updating of our soils map with satellite imageries or ortho-image map as base map (Fig. 1.10).

1.1.10 The Future of Soil Survey in the Philippines

The original reconnaissance soil surveys may have been conducted in the decades following World War II, updated

Fig. 1.10 The Bureau is moving towards digital cartography and will be reissuing its maps. Its GIS and Remote Sensing facilities have emerged as indispensable tools in soil mapping

through semi-detailed soil surveys in the 1980s and 1990s, or not at all. But soils follow geological timescale, and in that sense, nonrenewable at human timescale. In fact, the value of these spatial data even increases through the years, especially if we consider the rate of urbanization. Many of our soil series have become "extinct", buried by urban and industrial development and land use changes. Several more have changed already their physical and chemical properties because of decades of human activities.

As the Soil Survey Division's soil mapping activities are the only source of soil information in the country, the application of GIS and Remote Sensing improves data reliability for predicting soil distribution especially in areas we were not able to update due to budgetary, landscape, accessibility, or peace and order constraints. By using these sophisticated technological tools, we make our "scientific guesses" more scientific. Updating soil maps include not only the review of the soil mapping unit boundaries and the tabular data therein, but also reissuing the map itself in view of changes in political boundaries with the splitting of provinces and the creation of new municipalities and provinces after the original surveys were completed.

The future of soil survey and classification in the Philippines is basically revisiting the established soil series for more detailed soil concept definition, updating of the physicochemical characterization, and more importantly, the harmonization of these national soil resources spatial and tabular data with that of the global system. But as we refine our soil maps to meet international soil survey and classification standards, and as we strive to meet the demand for high-resolution, site-specific soil attribute data, the greater challenge for us is to transfer these information to meet the needs of global environment and human well-being. Soil survey and classification has to metamorphose from a reductionist agricultural development planning tool perspective into a holistic and integrated approach to understand the complex and dynamic ecological and socioeconomic interactions, if it were to remain relevant. The future of soil survey and classification in the Philippines should consider relating soil mapping units to biogeochemical cycling and agricultural productivity, land degradation, climate change and carbon sequestration, biodiversity, waste management, changing demographic patterns, and a host of other topics that interlink our knowledge of soils with that of the atmosphere, the biosphere, the lithosphere, and the hydrosphere.

The soil is the foundation of the nation's wealth. Soil survey and classification remains the basis for rational resource utilization, and the key to sustainable development. The Soil Survey Division of the BSWM is poised to meet the emerging demands for the soil science discipline in the twenty-first century.

1.2 Understanding What Is Pedology

1.2.1 Giving the Soils a Second Look

Many are quite surprised one could have a science or a systematic and organized body of knowledge about soils. What is there to learn about soils? And what kind of work awaits one who studies soils?

But even the technical definition, in terms of its composition—the solid, liquid, and gaseous constituents, many soil scientists tend to ignore the soil's most important component. And thus, we are likely to miss the whole spectrum of the important roles that the soil plays in the ecosystem.

Textbooks generally define soil in terms of its composition—mineral materials and organic matter, water, and air. This is understandable because we primarily look at the soil as the medium for agricultural production. No wonder, we have an exploitative and non sustainable agricultural philosophy. But acknowledging its most important component—the diverse macro and microorganisms that are found in the soil—one would be able to appreciate the opposite of production which is decay and decomposition. The soil is not only the medium for agricultural production, it also plays a vital role in regulating atmospheric, hydrologic, and nutrient cycling.

We are the product of an educational system that has evolved through decades and centuries of human philosophical and ideological thinking. These evolving educational philosophies shaped the foundation of our thinking and our way of life; oftentimes, in extremes. The older generation of soil scientists was shaped by German rationalism and tended to compartmentalize. So we had the subdisciplines of soil science—soil chemistry, soil physics, soil biology, soil mineralogy, soil survey and classification, soil fertility, soil conservation and management, soil evaluation, and land use planning. This is the reductionist and isolated approach to the study of soils.

But today's educational philosophy tends to be systems in approach, multidisciplinary, holistic, and integrative. A look at the current organization of the International Union of Soil Sciences (IUSS) reflects this trend. It is no longer just soil fertility, it is already soil fertility and plant nutrition emphasizing the interface with botany, specifically plant physiology. It is no longer just soil conservation and management, it is already soil and water conservation. There is also a new subdiscipline that looks into the soil chemical, physical, and biological interfacial reactions. We have emergent subdisciplines like soil geography, pedometrics, paleopedology, and hydropedology. It is now recognized that a thematic science like soil science cannot stand alone but must take an interdisciplinary model to respond to the challenges of an equally complex society.

With this holistic approach to the study of soils, there is also the rise of environmental science, with graduates competing for jobs that would traditionally go to soils majors. This is significant considering the diminishing number of soil science major graduates. The older soil scientists tend to describe younger "environmental science" graduates going into soil science-related jobs as "raw" soil scientists, lacking depth in their understanding of soils. If this is the trend, it is therefore important that as the older generation of soil scientists are retiring, we consolidate our existing understanding of Philippine soils to guide the younger generation of soil scientists as well as the "raw" environmental science graduates. We need to know and understand what kind of soil resources we have in our country (Fig. 1.11).

Knowledge and understanding of the soil is a vital input to resource utilization and rural development planning and policy formulation. If we just look at soils as dirt, not only we will miss very important sustainable agricultural production principles, but more so, we will also overlook a very critical key to regulate atmospheric, hydrologic, and nutrient cycling. To quote John W. Doran and Timothy B. Parkin in *Defining and Assessing Soil Quality,*

> The thin layer of soil covering the earth's surface represents the difference between survival and extinction for most terrestrial life.

Fig. 1.11 The soil is more than just dirt. It is a universe by itself, teeming with macroscopic and microscopic life that provides vital key to nutrient, hydrologic, and atmospheric cycling

Fig. 1.12 The soil ped is the unit of soil structure

1.2.2 Pedology Fundamental Concepts

Try to get a soil sample with minimum disturbance as much as possible. This is the *soil ped*, a unit of soil structure, usually a block or a granule, formed by natural processes (in contrast to a soil clod which is formed artificially) and detached from the rest of the soil from natural lines of weakness (Fig. 1.12).

For those in the soil science field, soil is also referred to as the *pedon*. But a pedon is definitely not a handful of soil which is more of a consolidated soil ped, nor a spade of soil, nor a sack of soil. The pedon is the smallest three-dimensional unit or volume of a soil. It contains all the layers or the horizons of a particular soil. Theoretically, it would be the size of the canopy of a tree and would extend from the surface to the deepest roots, the shape is roughly hexagonal. But for purposes of scientific investigations, the *control section* of 150 cm depth is defined and a pit is dug just large enough to permit the study of individual horizons. The control section would have a lateral dimension of about 1.0–1.5 m

Fig. 1.13 We observe a two-dimensional soil profile through a purposive pit digging and assume this to be a representative of a three-dimensional basic unit of soil, the pedon

depending on the size of the person conducting the soil description. The pedon is defined as the basic unit of soil; but this is more of an abstraction or a theoretical concept than a reality. This is because in defining soil, it is supposed to be a three-dimensional body, occupying a volume in a soilscape. In practice, when we sample and describe the morphology of soils, we observe a one-dimensional soil profile, and assume this as a pedon. The most representative of the soilscape is called the Typical Pedon (Fig. 1.13).

A contiguous group of similar pedons is called the *polypedons*. While it is the pedon that is normally described by soil surveyors in the field, the polypedon is the unit of soil classification (Soil Survey Staff 1975). It is a taxonomic unit, homogeneous, and theoretically represents a single taxon concept. As a taxonomic unit, it is an abstract, because in reality we cannot really define the boundaries. What we have is a complex soilscape patterns because of the equally complex geology and ecology of the landscape we are mapping. The soil mapping unit as referred to in soil maps can be considered as the concrete equivalent of the polypedon, the cartographic representation of a complex soil pattern. It is concrete because it has arbitrary boundaries, a range of properties, normally based on statistical mode; but in addition, it has also a specific sample pedon called the Typifying Pedon. It should be clear to all those who are into soil survey and classification that the taxonomic unit as defined in the map legend is independent of its spatial manifestation, called the soil mapping unit. What we have actually is a landscape unit defined by a complex pattern of contrasting soils, dissected into its component elements (Hole and Campbell 1985) (Fig. 1.14).

Fig. 1.14 An alluvial fan in Barangay Blanco, Municipality of Balingasag, Province of Misamis Oriental. It is evident that there are several land uses which could impact soil properties despite its uniform origin. This alluvial fan as a soil mapping unit consists actually of a complex pattern of different soils. But the soil map unit is considered as a cartographic representation of the polypedon. Surveyors conduct pit diggings and auger borings to validate the boundaries, establish the taxonomic unit to characterize the polypedon as represented by the soil mapping unit

Pedology is the scientific study of soils, focusing primarily on the natural formation and development, soil system behavior in time, and soil distribution in space. Pedologists are concerned with the study of soils in space and time.

Soil morphology is the first major aspect of pedology and it studies soil features like color, texture, presence of roots, its agricultural workability such as consistency and friability. It is closely allied with *soil micromorphology* which examines soil samples under laboratory microscopes. Soils are studied under natural environment. A pit digging is done to expose different soil layers, called horizons, and one studies the differences between these horizons (Fig. 1.15). The *top soil* layer is called the A-horizon, the *subsoil* is called the B-horizon and the *substratum*, the unconsolidated mantle of weathered rock and soil material overlaying solid rock, is called the C-horizon also referred to as the *regolith*. The underlying consolidated rock is called the R horizon. The upper horizons consisting of the A- and B-horizons is called the *soil solum*. Part of the soil survey protocol is to conduct check auger borings to determine the extent of soil variability.

But a pedologist's job does not end with digging pits, auger borings, and describing soils. He further analyzes his data to study *soil genesis*, or the origin and formation of

Fig. 1.15 A pit is dug to enable soil surveyors to study and describe the morphology of the soil. Soil horizons are delineated and morphological features described and measured layer by layer

Fig. 1.16 Like any other science with a systematic body of knowledge, the study of soils begins with describing the morphology of a soil profile as the sum of the past and present soil forming processes. From the observable patterns, one proceeds to soil classification and mapping

the soil. There is such thing as time zero in soil formation and development. This is oftentimes a catastrophe like a volcanic eruption or a major geologic event that could bury the old soil or lift up and expose a new land mass. Soil is the product of the weathering of the parent material and is influenced by such other factors as climate, topography, organisms, and time. Soil horizons are formed by various processes that act on the soil. These processes include biocycling, water exchange such as precipitation and evapotranspiration and the consequent chemical reduction and oxidation, erosion and deposition, intersolum translocations and transformations, leaching, and weathering or the alteration of primary minerals into components that could be absorbed by plants. Eventually, soils carry imprints of the various processes that were active in the past and these could be important bases for understanding its properties and patterns as well as predicting the changes. Distinctive bioclimatic regimes and combinations of pedogenic and biogeochemical processes produce distinctive and observable morphological features of soils. The observed soil profile sums up the balance of past and present processes. Understanding the observable patterns, one could proceed to soil classification and mapping (Fig. 1.16).

Soil classification and mapping is one of the most difficult undertakings in pedology because the soil is a continuum. We cannot apply Linnean principles of classification which is used for classifying discrete objects. Vertically and horizontally, soils merge and what we have are imperceptible and arbitrarily defined boundaries. To be able to segregate the soil continuum into mapping units, it would be necessary to develop the soil-landscape model. Soil-landscapes are the products of soil forming factors acting on geological deposits over time; and they come up with unique soils and soilscapes. Soil classification and mapping is historically rooted in geology and uses Adansonian principles or reliance on greatest common factors. Traditional soil survey is focused on mapping soil morphological classes. In effect, we are quantifying soil evolution spatially. The most widespread approach is the famous Dokuchaev-Jenny-Gerasinov triad: factors → processes → features. This of course assumes a monogenetic soil evolution; we should recognize that in reality, soils are polygenetic (Fig. 1.17).

Fig. 1.17 Soil surveyors develop the landscape-soil relationship to be able to delineate soils in the map. Classical soil surveyors compute the area coverage using traditional tool like a planimeter. In today's post soil survey activities, computer-assisted GIS tools facilitate area computation. The use of satellite images also enhance landscape studies

Emerging soil survey technique is focused on mapping soil properties and developing the landscape—soil properties relationship. This is because the utility of soil maps has also expanded from purely agricultural to include environmental applications. The Information Technology revolution directly affects environmental sensing and measurement by producing sensors that are smaller, faster, energy efficient, wireless, and could be cleverly programmed. John Hempel, at the GlobalSoilMap.net Initial

Fig. 1.18 **a** and **b** Emerging technique in soil survey is rapid measurements in the field, although less precise is compensated by many sampling points. In the BSWM-ACIAR project for mapping of Cabulig watershed, two instruments were tested—gamma radiometrics (*left*) to provide information on soil parent material, and electromagnetic induction (*right*) to assess water and clay (*Photo credits* Anthony Ringrose, CSIRO Land and Water)

Meeting in New York, USA, in February 2009 stated, "Soil attributes are critical inputs for ecosystem services. We need to provide a consistent set of data that is geographically continuous, scalable, and which includes uncertainly estimates". A global consortium has been established and the Philippines through the BSWM is a member under the East Asia Node based at the Institute of Soil Science, Chinese Academy of Sciences, Nanjing, China. BSWM has an ongoing technical cooperation project with Australian government for watershed level soil mapping using rapid appraisal techniques (Fig. 1.18).

But for the rest of this book, the soil concept and soil maps are still based on the traditional soil series classes and morphological descriptions. Our soil classification system is still based on genetic principles rather than on quantifiable soil properties as differentiating criteria. The Philippines adopts the USDA Soil Taxonomy System of soil classification.

1.2.3 The Soil Profile

The Soil Survey Report describes the *soil profile* of a *Typical Pedon* that dominates the classified soil mapping unit. A soil profile is taken to mean the vertical exposure of the horizons of a soil individual (or the pedon, i.e., the soil body with profile features whose arrangements and combinations over a geographic area are unique) (Fig. 1.19). It consists of several layers or horizons named by using a combination of letters and numbers. The capital letters **O**, **L**, **A**, **E**, **B**, **C**, and **R** represent the *master horizon*s (Soil Survey Staff 2010). **O** is the top, organic layer of soil, made up mostly of leaf litter and humus or decomposed organic matter; **L** is the limnic horizon and includes both organic and mineral limnic materials that were either deposited in water or through the actions of the aquatic organisms or derived from underwater and floating aquatic plants and subsequently modified by aquatic animals. **A** is the designation for the topsoil, **E** is the eluviations (leaching) layer normally light in color, beneath the A-horizon, and above the B-horizon made mostly of sand and silt having lost most of its minerals and clay as the water percolates down the soil profile. **B** is for the subsoil, **C** is for the parent material, or the regolith. The hard or unweathered bedrocks are designated **R**. Granite, basalt, and sandstone are some examples.

The 2006 (Soil Survey Staff 2006) and 2010 editions of the Keys to Soil Taxonomy also include **M**-horizons as root-limiting subsoil layers consisting of nearly continuous, horizontally oriented, human-manufactured materials. Examples are geotextile liners, asphalt, concrete, rubber, and plastic. A **W** horizon indicates water layer within or beneath the soil.

Horizons dominated by one master horizon but having subordinate properties of another have combined letters such as **AB**, **BA**, or **AC**, the first letter being more dominant than the other. These are called transitional horizons. A single profile never has all the possible horizons. Most soils have an A- or two specific types of B-horizon, a C-horizon and one or two transitional horizons. An AB horizon has the characteristics of both the overlying A- and underlying B-horizons but looks more like an A-horizon than a B-horizon.

Horizons with two distinct recognizable properties of two kinds of master horizons are called combination horizons and separated by a virgule (/)—E/B, B/E, or B/C with the first symbol for the horizon with greater volume.

Lower case letters are used as suffixes to designate specific kinds of master horizons and layers. The letters and their meanings (based on the Soil Taxonomy 2011 and relevant to the Philippines) are: **a** (highly decomposed

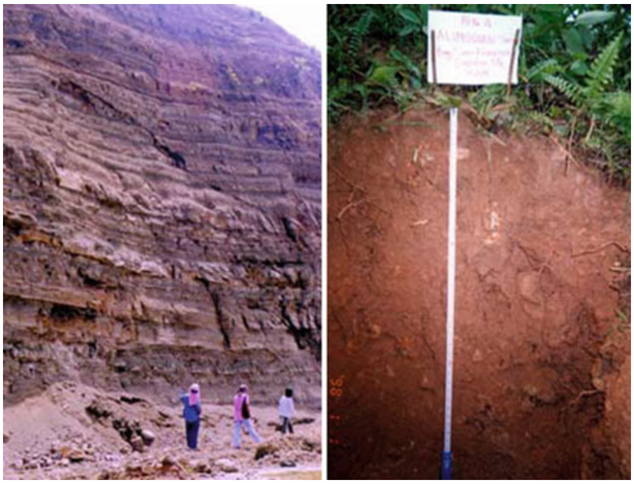


Fig. 1.19 **a** and **b** Two soil profiles of varying depth: (*left*) a soil profile with distinct horizons from a road cut; and (*right*) the soil profile of Alimodian series from a pit dug by soil surveyors. For purpose of scientific study, a control section is defined at 150 cm depth and suffices for horizonization and layer-by-layer morphological description. A soil profile is rarely described beyond the control section

Fig. 1.20 A gleyed soil profile of Maligaya series; the prolonged waterlogged reduced ferric oxide to ferrous oxide producing a typical *gley color* in the soil

organic material), **b** (buried genetic horizon), **c** (concretions or nodules), **co** (coprogenous earth), **d** (physical root restriction or other mechanically compacted zones), **di** (diatomaceous earth), **e** (organic material of intermediate decomposition), **g** (strong gleying), **h** (illuvial accumulation of organic matter), **i** (slightly decomposed organic material), **j** (accumulation of jarosite), **k** (accumulation of secondary carbonates), **kk** (engulfment of horizon by secondary carbonates), **m** (cementation or induration), **n** (accumulation of sodium), **o** (residual accumulation of sesquioxides), **p** (tillage or other disturbances), **q** (accumulation of silica), **r** (weathered or soft bedrock), **s** (illuvial accumulation of sesquioxides and organic matter, used with **B** if the color value or chroma at moist condition is 4 or more; also used with **h** if both the organic matter and sesquioxide components are significant and the color value and chroma moist is 3 or less), **ss** (presence of slickensides), **t** (accumulation of silicate clay), **u** (presence of human-manufactured materials or artifacts), **v** (plinthite), **w** (development of color structure), **x** (fragipan character), **y** (accumulation of gypsum), **yy** (dominance of horizon by gypsum), **z** (accumulation of salts more soluble than gypsum). Successive layers of the same horizon are assigned with subscript Arabic numerals (e.g. B_{t1}, B_{t2}, B_{t3}).

It can be seen that from the horizon nomenclature alone, one can understand a lot about the soils being described assuming one knows what those symbols mean. Let us take a look at four examples.

For instance, the symbol **g** when added in the master horizon description means the soil is gleyed and the soil is waterlogged or water saturated for an extended period of time. A soil profile described to have strong gley properties refers to soils that exhibit greenish-blue-gray soil color due to wetland conditions (Fig. 1.20). On exposure to air, the gley colors are changed to a mottled pattern of reddish, yellow, or orange patches. Gley soils are results of chemical reduction or absence of oxygen in the soil environment. Where drainage is poor because the water table is high, we have groundwater gley soils. On the other hand, where rainfall for example does not drain freely on the soil surface, we have surface water gleying. The reducing environment in the water saturated layer develops the mottled grayish blue or brown condition. Anaerobic microorganisms respire by using alternatives to oxygen as electron receptors. Thus, ferric oxide in the soil is reduced to ferrous oxide by the removal of oxygen. The reduced ferrous oxide produces the typical gley color in the soil. The presence of reddish or orange mottles in the horizon indicates the reoxidation of the ferrous salts in the soil matrix. The affected layer usually has a chroma of 2 or less and the soil is tested positive for redoximorphic field tests. If **g** is used with **B** (we have a Bg horizon), a pedogenic change is implied in addition to gleying condition. If there is no pedogenic change besides gleying, the horizon should be designated as Cg.

The symbol **t—**accumulation of silicate clay—is a significant mark of the soil's history. The symbol indicates accumulation of silicate clay that has been formed and subsequently translocated either within the horizon (formed in-place through pedogenesis) or moved into the horizon by the process of *illuviation* (defined as the deposition by

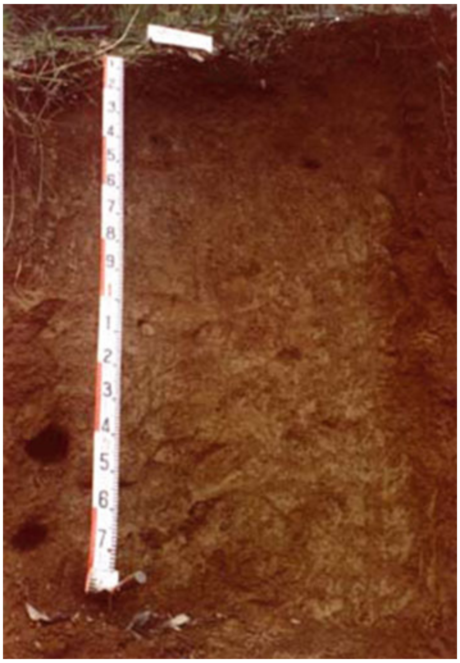


Fig. 1.21 An Oxisol soil profile; the presence of an argillic horizon or movement of clay into the lower layer, is a prerequisite for classifying Mollisols, Alfisols, Ultisols, and Oxisols. This can be confirmed by textural analysis in the laboratory

percolating water of clay or humus within a soil horizon), or both. At least some part of the horizon shows evidences of clay accumulation such as *coatings* on surfaces of peds or in pores or as bridges between mineral grains. Where we have a B-horizon identified by the illuvial accumulation of silicate clays, at least 7.5 cm thick except if the soil is sandy or sandy skeletal (it must then be 15 cm thick), and the percent total clay is more than the eluvial horizon (*eluviation* is the removal of soil materials from the surface soil horizon and their partial deposition in lower horizons) by at least 20 % more—we have a diagnostic subsurface horizon called the *argillic horizon*. Take note that the presence of **t** does not always indicate the presence of an argillic horizon. For a horizon to be defined as argillic, there are thickness criteria, percentage clay over the eluvial horizon criteria depending on the clay content of the eluvial and illuvial horizons, and ped coatings that must be met. A Bt and presence of an argillic horizon are diagnostic criteria for soil taxonomic classification (Fig. 1.21).

The symbol **ss**—which indicates the presence of *slickensides* certainly provides a unique attribute to a soil profile. Slickensides are subsoil structural features which develop as a result of two masses moving past each other commonly at angles of 20–60° above horizontal; polishing, and smoothing the surfaces due to the swelling of clay minerals and shear failure. Slickensides indicate the possible presence of other *vertic* characteristics such as wedge-shaped peds or parallel epiped structural aggregates, and surface cracks. The presence of slickensides is an indication of a vertic diagnostic horizon for soil taxonomic classification. This means that the soil shrinks when dry and swells when wet. Extensive swelling and shrinking upon wetting and drying result to *pedoturbation* or mixing of the soils and to minimal horizonation. These soils developed on alluvial materials in flat inland areas from weathered limestone or basalt rich in alkaline earth cations to produce *smectite* type of clays. These are considered among the fertile soils for agricultural production but because of their physical properties, they are mostly used in the Philippines for rice production.

The symbol **v** or presence of *plinthite* is another interesting feature in a soil profile making these soils one of the most colorful and visually exciting to see. This symbol indicates the presence of weakly cemented, iron-rich, humus-poor reddish material that forms platy, polygonal, or reticulate patterns, and hardens irreversibly to either "skeletic" or concretionary ironstone or to continuous ironstone hardpans (*petroplinthite*) when exposed to the atmosphere and to repeated wetting and drying. Plinthites form in perennially moist subsoil layers and involves (1) the accumulation of sesquioxides through the removal of silica and bases, and the accumulation of resistant minerals like sesquioxides, quartz, and kaolinite; and (2) the segregation of iron mottles by alternating reduction and oxidation. Usually, the hardening of plinthite is initiated by deforestation as this triggers erosion and the exposure of the plinthite to open air. The impenetrability of the hardened plinthite and the fluctuating water table restricts the use of these soils to livestock grazing and forestry. The major limitations are poor natural soil fertility, water logging in bottomlands, and drought on shallow soils. The plinthite limits the rooting zone to the extent that arable farming is not possible in these soils (Fig. 1.22).

We should also recognize that being in the "Pacific Ring of Fire", volcanic eruptions are a common phenomena in the Philippines. Lithologic discontinuities are not isolated occurrences for Philippine soils. Lithology is a geology term to refer to the gross physical character of a rock formation. The term has application in soils. In some soils, the C-horizon is a parent material unlike the parent material which formed the A- and B-horizons. The presence of the second parent material in soils is called a *lithologic discontinuity* (Fig. 1.23). Aside from volcanic eruptions, these might have been lakes or rivers in ancient times, now buried. Lithologic discontinuities are normally evidenced by abrupt textural contacts, contrasting sand sizes, the rock fragment in the soil is different than the underlying bedrock lithology, erratic or inverse distribution of rock fragments, soil color, and micromorphological features (for example, microscopic examination of the same primary mineral may show differences in color for the each soil layer).

Fig. 1.22 A soil profile characterized by presence of plinthite is amazingly *colorful* because of the *reddish color* that the concretionary ironstone imparts to the visual sense. But these soils are difficult to work with because of the limiting root zone

Fig. 1.23 Lipa soil series has portions characterized by lithologic discontinuity because of series of depositions coming from the eruptions of Taal Volcano

Depth-functions involving clay-free particle size data, especially for coarse soil fractions are considered the best indicators of discontinuity. The Keys to Soil Taxonomy (2011 edition) assigns Arabic numerals as prefixes to horizon designations (preceding the letters A, E, B, C, and R) to indicate discontinuities in mineral soils. These prefixes are distinct from the Arabic numerals that are used as suffixes denoting vertical subdivisions. Old soil survey reports traditionally used Roman numerals to precede the master horizon designation to indicate lithologic discontinuity. Soil survey report users should also understand that underlying contrasting materials are numbered consecutively and the third layer will be numbered as material 3 even if it is the same material as that of the first layer. The numbers indicate a change in materials, not change in the type of material. On the other hand, where two or more consecutive horizons were formed in the same material, the same prefix number is applied to all the designations in that material (e.g. Ap-E-Bt1-2Bt2-2Bt3-2BC).

1.2.4 The Soil Morphology: Description of Horizons

The soil color Because people would perceive and describe color differently, soil colors are described quantitatively by matching the color of a soil clod with a standard color chip in a special book of soil colors called the Munsell Color Chart (Fig. 1.24). Each color is characterized by its hue, value, and chroma. A symbol such as 10YR 4/3 is used to record these color characteristics. Because soil color is moisture dependent, the soil moisture at the time the color was recorded is usually stated.

Hue represents the special wavelength of the color. A hue of 10R represents pure red color. A hue of 10Y is for pure yellow color. In soils, a very common hue is 10YR which is exactly halfway between pure red and pure yellow. The common soil hues are 5YR (3 parts red and 1 part yellow) and 7.5YR (5 parts red and 3 parts yellow).

Value represents the amount of light reflected back to the eye and measured on a scale of 0–10, that is, from no reflection to complete reflection. Low numbers represent dark soil color as most of the incident light is absorbed. High numbers represent light colors as most of the light is reflected. Common values of soil colors are 3 and 4 representing 30 and 40 % of the light reflected. The value is shown in the color symbol as the numerator of the fraction that follows the hue.

Chroma represents the amount of dilution with white light. On a scale of 0–20, the chroma 20 represents pure color and 0 represents infinite dilution with white light. Chromas of soil colors range from 0 to 8, and commonly between 1 and 4. The lower chromas are black or gray colors, whereas the higher chromas are bright yellowish or reddish colors. The chroma is shown as the denominator of the fraction in the color symbol.

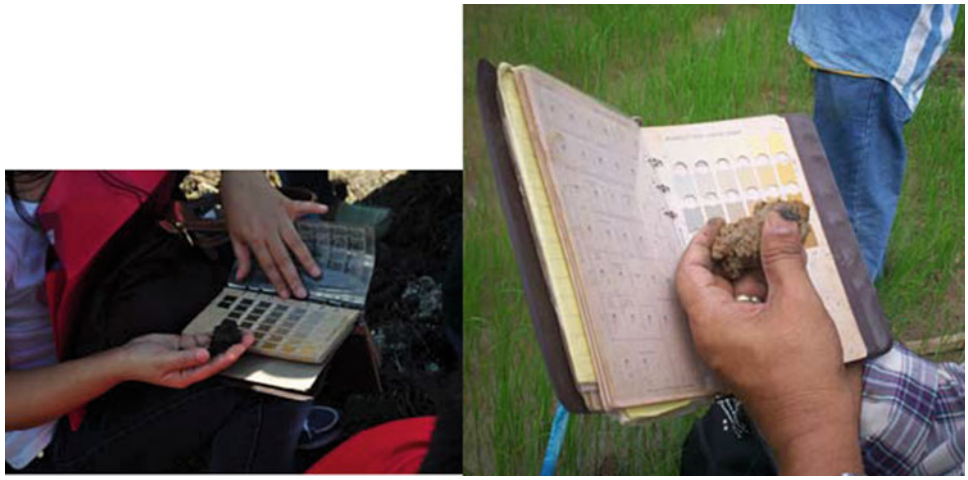


Fig. 1.24 A soil color Munsell chart is used to describe soil colors in the field

Fig. 1.25 Soil texture is obtained in the field using the feel method

The soil texture The soil texture is defined as the relative proportion of the various separates in a soil material. It refers to the distribution of particle sizes—*sand*, *silt*, and *clay*. Every soil contains a mixture of sand, silt, and clay. The analytical procedure which separates and determines the various percentage of the three particle sizes is called a *mechanical analysis*. A textural triangle is used after determining the percentages of sand, silt, and clay. The intersection point determines the textural class of the soil. Since the Philippines adopt the USDA Soil Taxonomy System of classification, the USDA textural triangle is likewise adopted. Sand is defined to measure from 2.0 to 0.05 mm and the size of silt is from 0.05 to 0.002 mm. Clay is smaller than 0.002 mm. Particles greater than 2 mm are called stones or gravels and not considered to be soil material.

In the field, soil texture is estimated by *feel method*. The soil is moistened and rubbed between the fingers and the thumb; and an estimate of the amount of the various particle sizes is made (Fig. 1.25). This requires quite a considerable skill and experience (Fig. 1.26) but the accuracy can be improved by frequent checks of the feel method with the results of the mechanical analysis (Fig. 1.27).

Mottles Some soils have spots of one color in a matrix of a different color. The spots are called mottles and the soil is said to be mottled. Some mottles appear to be splotches of reddish brown color in a gray matrix. Others appear as gray mottles in a brown matrix.

Mottling (Fig. 1.28) is caused by fluctuating water tables and is called a *redoximorphic* feature. When the water table is high, the soil is saturated and the iron oxide is reduced into mobile ferrous iron. The groundwater redistributes the iron throughout the soil profile. When the water table drops, oxygen begins to reenter the soil through the root channels and the large pores that are the first to drain. As the oxygen comes into contact with the moist soil containing the reduced iron, the iron quickly oxidizes to form an insoluble precipitate at the surface of the soil ped forming reddish brown spots. The longer the saturation period, the more pronounced is the reduction process, and the grayer the soil becomes. The gray colors do not form rapidly but result from many cycles of water saturation. This is not easily obliterated and serves almost as a permanent marker of the mean groundwater elevation to show that water table existed there for part of the year. The gray colors, however, do not indicate the duration of the anaerobic condition.

There are situations, however, when we have mottles that do not indicate wetness. These are the chemical weathering of rocks, relict mottling (the soil environment was wetter than it is now), and coatings on soil peds.

Soil structure The soil structure refers to the aggregation of individual grains of sand, silt, and clay into larger units

Fig. 1.26 Soil texture by feel method is not hit and miss proposition. Determining soil texture by feel method can be studied using soils with predetermined soil texture. One starts with mastering how loamy soils feel and imagine this as the center of the textural triangle; the soil becomes more clayey as we move to the upper corner; more sandy as we move to the lower left corner; and more silty as we move to the lower right corner of the textural triangle

Fig. 1.27 The field textural observation is usually confirmed in the laboratory using either Bouyoucos hydrometer method or the pipette method. The results are compared with the soil textural triangle for final textural classification

called peds. Plant roots, soil organic matter, and clay particles provide the physical and chemical binding agents. Soils that do not aggregate with naturally preserved boundaries are considered to be structureless. Two forms of structureless condition are recognized, they are: the single

Fig. 1.28 Soil profile of Sison series taken in Surigao City showing mottles of *reddish spots* resulting from alternate wetting and drying of the soil brought about by fluctuating water table

grain (particles are easily distinguishable) and the massive (individual particles adhere to each other but the mass lacks plane of weakness).

Structure creates large pores which favor movement of air and water into and through the soil. Even clayey soils can have good rates of infiltration and permeability if they have well developed and stable structure. Soil structures are described by shape, size, and grade (Fig. 1.29).

Soil consistency Soil consistency is commonly used to describe the feel of the soil and it includes soil properties such as friability, plasticity, stickiness, and resistance to compression and shear, all of which have obvious importance for cultivation operations. The sticky point indicates the moisture content at which the soil will begin to scour during cultivation (Fig. 1.30).

Cutans, nodules, and concretions A cutan is a modification of the texture, structure, or fabric at natural surfaces in soil material due to concentration of particular soil constituents or in situ modification of the plasma. In general, this is considered a microstructural feature and the detailed description is done in the laboratory. A 10x hand lens is normally used for field examinations, describing what could be actually seen such as color and thickness of the coating (Fig. 1.31).

Fig. 1.29 Soil structure refers to the natural aggregation of soil particles. Clay content and organic matter help bind the soil together into structural units or aggregates or peds

Fig. 1.30 Soil consistency is the strength soils resist fragmentation, deformation and rupture, usually described at either dry, moist, or wet moisture state. In the field this is usually measured in terms of stickiness (how the soil particles adhere to fingers after release of pressure) and plasticity (evaluation done by forming a 4 cm long wire of soil at a water content where maximum plasticity is expressed)

Fig. 1.31 A 10x hand lens is used for field examinations of cutans which is a microstructural feature

Concretions and nodules are local concentrations of soil materials. Color, hardness, size and relative abundance are usually reported in the soil survey report when observed. Quick field tests are done to determine the cementing agent. Effervescence in HCl indicates carbonate cementation while

Fig. 1.32 The first part of the pit protocol is horizonization, determining and measuring the horizon boundaries

effervescence in H_2O_2 indicates manganese oxides. Silica cementation is indicated in concentrations that may or may not effervesce in HCL but disintegrates after being placed in concentrated NaOH for several hours.

Horizon boundaries and continuity with the pedon Conventions have been developed to describe horizon boundaries. Two measurements are considered necessary, namely the *width* or the thickness of the boundary along the z (vertical) axis and the *topography* of the boundary within the x-y plane. The width of the boundary is usually described as abrupt, clear, gradual, or diffuse. The surface topography of a soil horizon is described as smooth, wavy, irregular, or broken (Fig. 1.32).

Field measurement Although **pH** is not a morphological feature, it is included in the horizon description, and taken at the time of field sampling using qualitative methods (Fig. 1.33). The pH values do not have precise significance but some generalizations such as nutrient status could be made for fertility and liming assessment purposes. The soil pH is normally validated in the laboratory using a more precise electrometric pH meter (Fig. 1.34). These laboratory values are reflected in the Chemical–Physical Data that accompanies soil morphological descriptions.

A penetrometer is used to determine *soil hardness* or compaction which relates to root growth and soil physical properties descriptive of tilth. Penetrometer readings from 8 to 22 mm would be considered normal. The millimeter readings are converted into pounds per square inch (psi), tons per square foot (tsf), or kilograms per square centimeter (kPa). Depending on soil hardness obtained during field surveys, the compaction rating can be developed and subsoiling recommended. As this parameter was introduced to the BSWM in the early 1990s as part of the technical cooperation with the JICA, soil surveyors often fail to convert the penetrometer reading to compaction value in the morphological description for the penetrometer reading to be usable. Compacted soils would present problems in

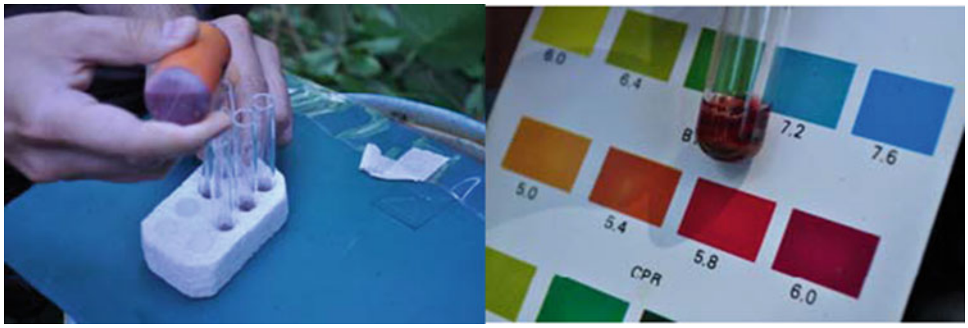


Fig. 1.33 **a** and **b** Soil sample is taken and put in the test tube and drops of CPR indicator are added (*left*) and the resulting solution is matched with the corresponding color chart (*right*) to determine the initial pH. The procedure is repeated using BTB if the soil color is greater than 6 and BCG if the soil pH is less than or equal to 5

Fig. 1.34 Field obtained pH value is further validated in the laboratory using more precise pH meter and presented as part of the chemical–physical laboratory analysis of the soil samples

terms of water percolation, poor seed germination and poor root growth and possible increase in fuel costs when breaking up hard soils during the tillage operations.

1.3 Factors of Soil Formation and Development

As an archipelago of 7,100 islands, the Philippines is blessed with natural diversity of soil resources reflecting the uniqueness of the Philippine geography, the influence of time, biodiversity, and climate, and the activities and endeavor of its people. What were once limestone areas were geologically uplifted in ancient times and formed part of the Cordillera mountain ranges in Luzon. The fertile valleys are now grown to vegetables serving the tables of those as far as Metro Manila. In many occasions, the farmers here are stunned to see seashells as they cultivate the soil. The Philippines also belongs to the Pacific Ring of Fire and it has many active volcanoes. The resulting volcanic ash soils are prized agricultural lands. Two decades ago, Mt. Pinatubo erupted and to date, it is still changing the landscape of Central Luzon.

1.3.1 The Soils That we Classify and Map

In the traditional concept, the soil is the natural medium for the growth of crops. Its importance lies in the fact that it supports plant life that gives us food, fibers, shelter, energy, and drugs. This is the first and most common function associated with soils, those relating to biomass production. In fact, scientific debates on whether a lahar-devastated area, for example, has already weathered to soil or not yet depends on whether the area could support or could not support yet, plant life.

Soil is generally defined to be the thin layer of the earth's surface and comprised of a mixture of mineral particles or disintegrated rocks, organic matter which is decayed plant and animal remains, water, and air which is mostly oxygen, carbon dioxide, and nitrogen in greatly varying proportions, and have developed layers produced through the action of climate, time, topography, and living organisms that include human beings.

The soil also abounds in life—both plants and animals, both macro and microscopic in size, both beneficial and pathogenic to humans. Bacteria, fungi, and actinomycetes by the millions are found in soils. There are rotifers, earthworms, insects, and some large animals that burrow and live in the soil. These organisms play important roles in nutrient cycling.

And thus, the soil is also recognized to play important roles relating to the environment. This includes storing, filtering, and transforming capacity and a key factor in regulating atmospheric, hydrological, and nutrient cycles. The soil is also a platform for human activity and hosts the infrastructure for housing, transport facilities, recreation, and industry.

In *Soil Taxonomy*, the upper limit of the soil is the boundary between soil and air, shallow water, live plants, or plant materials that have not began to decompose. Generally, where only water plants exist, it is no longer soil. Thus, for purpose of soil mapping—swamps and mangroves, active and former tidal flats (usually utilized as fishponds)

Fig. 1.35 Upper limit of soil definition—where we have only water plants thriving is no longer soil. Since mangroves grow deep rooted plants, mangrove areas are considered soils and classified as wetlands

Fig. 1.36 Lower limit of soil definition—for purpose of scientific study, the control section reaches down to 1.5 m since some soils can be very deep

are still considered soil. These are classified as wetland soils. Some of these coastal soils in the Philippines are acid-sulfate soils and drying them or using them for aquaculture may not turn out to be productive (Fig. 1.35).

The lower limit of the soil that separates it from the non-soil is rather difficult to define. In theory, where there is biological activity, it is still soil. The lower limit of biologic activity is the common rooting of native perennial plants; but in practice, this is difficult to discern and is often gradual. Hence, for purpose of soil classification and mapping, we define the arbitrary lower limit at 2 m. The control

Fig. 1.37 Buried soil—various lahar events are clearly identified in this Mount Pinatubo profile in Pampanga. The original soil (also Mount Pinatubo deposits from earlier eruptions some four centuries before) is the *brownish layer* at 70 cm. Only 50 cm is required for a soil to be considered buried for soil mapping purposes

section, the lower limit soil surveyors use for soil profile description, sampling and scientific investigations, is placed at 1.5 m. We rarely describe soils beyond this depth (Fig. 1.36).

Since the country is in the Pacific Ring of Fire, volcanic eruptions are significant occurrences that could have implications on soil mapping. *Soil Taxonomy* defines a buried soil as covered with a surface mantle of new soil material at 50 cm or more. At this depth of new soil material, mixing it with the old soils during the normal cultivation process would not be possible (Fig. 1.37).

1.3.2 Soils and the Geologic Parent Material

The Philippines has diverse geologic origins and is a mixture of numerous lithospheric blocks of different ages. These are known as terranes and may consist of slivers of oceanic crust, island arc, and continental materials. The geologic and tectonic evolution of the country resulted from the meetings and interactions among four major tectonic plates—the Continental Eurasian, the Indian–Australian, the Oceanic Pacific, and the Philippine Sea plates. In the early Cenozoic era some 65–60 million years ago, the Indian plate began to move on a collision with the Eurasian plate. The volcanic and ophiolitic terranes of eastern Philippines (Bicol, Leyte, and east Mindanao) known collectively as the proto-Philippine island arc formed from the subduction (Magdaraog 1998). These were the oldest components of the archipelago.

The archipelago began to take shape during the late Cretaceous period along the margin of southern China. It was then under water except for the Sierra Madre and other eastern Philippine volcanic chains. By the end of early Eocene period, the microcontinental terranes that would later become north Palawan, Mindoro and Zamboanga rimmed the margins of Southeastern Eurasia. As the proto-Philippine mobile belt broke off from the equatorial arc system and began its movement along the leading western edge of the Pacific plate, the Philippines was divided into three separate island arcs: the Luzon arc (whose remains are found in the Sierra Madre Mountains), the Halmehera arc (forming the east and Central Mindanao Cordilleras), both of which were Pacific plate in origin; and the third is the Sangihe arc (forming the Zamboanga peninsula and the Kudarat plateau in western Mindanao) which is floored by rocks of Eurasian margin affinity (Magdaraog 1998).

At the close of the Oligocene epoch, the Central Cordillera and other western volcanic islands began to form the western landscape of the country. Consequently the valleys were filled with sediments coming from the erosion of surrounding mountain ranges (Magdaraog 1998).

By 25–10 million years ago, during the Miocene epoch, the Borneo and Sulu block moved northeasterly and collided with the southwestern Philippines resulting in the formation of the Philippine Fault. Luzon rotated 40–50 degrees counterclockwise while Panay rotated 20 degrees clockwise. By late Miocene, the northen end of the Manila trench collided with Taiwan and the low-lying regions of Luzon emerged. The archipelago settled in its present position in the Plio-Pleistocene period, about 5–2 million years ago. Its basin expanded and developed into flatlands and rolling hills, accompanied by volcanic activities. The land mass expanded due to the fluctuations of the sea level. When the sea level was low, land bridges were exposed connecting Palawan-Borneo with central and western Indonesia to mainland Southeast Asia. This is believed to have provided the avenues which enabled the large animals and perhaps the early men to reach the Philippines. Hence, at the start of the Pleistocene, much of the Philippines had already evolved into approximately its present-day configuration (Magdaraog 1998).

The soil is developed from the weathering or decay of rocks. The hardest of rocks under the heat of the sun, the cold of the night, and the beating of the rain will crumble into pieces with time. Rocks, however, weather very slowly and may take thousands of years before they become soil. As they do, the soils that develop carry many of the characteristics of the original rock parent material. There is a saying that the child inherits many of the traits of the parents. This is also true with soils. Rocks rich in minerals will produce fertile soils for agricultural use.

Soils are made up of distinct layers called horizons and different horizons constitute a soil profile. At the lowest horizon is the parent material. This is usually the rock material where the soil originated. The most common parent material of Philippine soils is regolith or weathered mass rock largely Miocene or Pliocene-Pleistocene limestone, shale, wacke sometimes associated with basic to intermediate flows, pyroclastics (chiefly tuff or tuffites), or marine clastics. There are also transported parent materials. Those on bays and gulfs were marine deposits. There are also soils that originated from alluvial materials and lacustrine deposits. Crushed materials from tectonic plate materials also make up some parent materials (Magdaraog 1998).

There are soils that developed from igneous rocks; these rocks once in molten state inside the earth and forced upward to the surface, eventually cooled and solidified. The soils of Baguio City, the foothills of Bataan, the rolling lands around Mt. Kanlaon in Negros originated from andesite and basalt rocks. The striking characteristics of the soils produced from these rocks are the rolling to hilly relief, its brown to reddish brown color, friable and good drainage conditions. The soils of Negros Occidental which developed from the weathering of andesites and characterized by friable reddish brown soil classified as *La Castellana loam* (Fig. 1.38). The soils of what used to be the rice fields of Makati and Alabang, formerly part of Rizal province, as well as Imus and Tanza in Cavite and now concealed from agricultural use by urban development, originated from adobe, which is volcanic tuff, a kind of igneous rock which upon weathering gives rise to shallow, plastic, and sticky soils called *Guadalupe clay* (Plate 2C). These soils are gray in color, poor in drainage, and have slow permeability. These are among the best rice soils but unfortunately had to be sacrificed for urban expansion (Barrera 1967).

There are soils that developed from sedimentary rocks. In the sea are several kinds of animals covered with shells, the most important of which are mollusks and corals. Accumulation of the skeletal remains of these animals solidified into rocks, and these are called limestones. The soils in the foothills of Teresa in Rizal, Sibul in Bulacan, and those in the greater part of Cebu and Bohol are examples of soils derived from limestone. The soils are either black or red, shallow, good drainage, and fairly friable clay soils. An example is a black soil called *Faraon clay*. The soils are fairly productive and good for crops that require plenty of calcium (Barrera 1967) (Fig. 1.39).

Soils from both igneous and limestone materials formed in the uplands may be washed down by rain to the rivers and ultimately out into the sea where they accumulate layer by layer. Such series of deposits of soil materials took place

Fig. 1.38 Soil profile of La Castellana soil series that developed from igneous rock

Fig. 1.39 Soil profile of Faraon series, developed from sedimentary rocks. Limestone soils do not follow the substratum characterization and are classified according to soil color. Faraon soils belong to *black* or *dark colored* soils

thousands of years ago, later hardened due to pressure and turned into rocks called shale. Shale is a clastic sedimentary rock composed of mud, which is a mix of flakes of clay minerals and tiny fragments of other minerals like quartz and calcite. In La Union province, layers of shale rocks were pushed up from the bottom of the sea to become land during the process of mountain forming. The soil that eventually developed is called *Bauang clay*. Because the

Fig. 1.40 Soil profile of Tirik series derived from metamorphic rocks, taken from a road cut. It is quite difficult to get a good profile of soils of metamorphic origin because the soil is hard

rocks are fairly soft, they produce fairly good soils for agricultural use (Barrera 1967).

Igneous and sedimentary rocks, when subjected to long and strong pressure and high temperature, become modified so as to appear very solid, hard, and massive. Such rocks are called metamorphic. A metamorphosed limestone becomes marble; shale becomes slate; some igneous rocks become gneiss, quartzite, or schist. Because the rocks are very hard and weathering is very slow, the soils that eventually developed are shallow and poor. The natural vegetation that grows in these soils are sparse. Soils that developed from metamorphic rocks are generally not considered productive. An example is the *Malalag loam* in Palawan (Barrera 1967). There are very few soils in the Philippines that developed from metamorphic parent materials (Fig. 1.40).

1.3.3 Topography as a Factor of Soil Formation

Soils that formed directly from the rock below are termed primary or residual. The soils developed in-place. Such are the Philippine soils that we have in the mountains, hills, rolling lands, or in some fairly level areas. An example is *Tagaytay sandy loam* which was formed directly from the underlying volcanic tuff (Barrera 1967).

Rainfall may have washed the soil down to the stream, and deposited in some lower place to accumulate as plains. The soils that eventually developed are called secondary or transported soil. The soils in the Central Plain of Luzon, from Pangasinan down to Bulacan, the western part of Negros Occidental, the plains in Iloilo and Cotabato are examples of these soils.

But aside from rainfall, soils may be carried or transported to another place by gravity, water, snow, or wind.

Fig. 1.41 Umingan series is characterized by presence of stones and boulders. This Umingan soils in Misamis Oriental was formed from alluvial fan

Fig. 1.42 A flood plain in the Central Plain of Luzon

As a tropical country, we do not have snows in the Philippines, and thus, we do not have glacial soils. To a very limited extent, we have soils developed by wind erosion, or aeolian soils, as typified by the sand dunes along the coast of Ilocos Region. Our transported soils are primarily formed by water and gravity.

Colluvial soils are formed from the deposition of soil and weathered materials coming naturally down from upper regions by gravity. Such accumulation consists of a mixture of stones, gravel and silt, and forms a fan-shaped spread at the base of a hill or mountain. This kind of soil formation is found mostly in the hilly or mountainous regions. The area of such formation is not very large. *Maytalatala clay* are moderately deep, somewhat poorly to moderately well drained soils occupying nearly level to gently elevated alluvial fan terrace adjacent to foothills and mountains.

Alluvial soils are formed from the deposition by water such as rivers which carry large quantities of soil materials. The faster the river flows, the larger the size and quantities of soil materials carried. When the flow slows down, the coarser materials settle first and the finer ones settle farther down the stream. Very fine materials like clay remain in suspension for a long time before settling down. *Umingan silt loam* in the province of Pangasinan was developed from previous existing soil materials. The stones and the soil above it were carried by water and later deposited here (Barrera 1967) (Fig. 1.41).

Flood plains are bodies of land formed along the course of rivers (Fig. 1.42). Rivers meander or swing from one side to another. The speed of the water is faster on the outer curves of the bend than on the inner curves. For this reason, materials carried along by the river will be deposited at the inner curves. This deposition takes place on both sides of the river. The river may swing beyond its normal course, especially during floods and cut through previously formed alluvial deposits, creating terraces on both or either side of the river. River-terrace soils, and to some extent, the lake-terrace soils, are commonly used for agricultural production. *Luisita sandy loam, Angeles sandy loam,* and *La Paz sandy loam* are examples of river–terrace soils (Bareja 2010). *Looc silty clay loam* are moderately deep, poorly drained soils along the periphery of Laguna de Bay, in the first terrace position. *Pangil clay* are fine clayey, deep, poorly drained soils formed in recent lake-terrace alluvium slightly above the lakeshore marsh.

Delta is the continuation of the flood plain at the mouth of the river. The flow of the river is slowed down when it meets the sea. All soil particles then are deposited here, forming the plain or delta. Deltas become larger and larger as more soil particles are deposited annually. *Balongay clay* is found along the banks of the mouth of the Bicol River (estuarine plains) extending as much as 2 km inward. It should be remembered that damming a river for irrigation or hydropower would consequently reduce if not totally eliminate the clay and silt deposits arriving at the delta. Since deltas are dynamic landforms, soil losses from constant sea wave erosion could not be replaced by fresh deposits. Human activities such as dam constructions on major river systems do contribute significantly on soil formation and development.

Marine soils are accumulations of materials carried downstream by rivers into the sea or materials carried by the sea currents and deposited in quiet areas. There are few soils developed from this kind of formation in the Philippines. One example is Cavite City, including Sangley Point, the foremost tip of the peninsula. Sangley Point becomes longer over the years as a result of accumulation of sand carried by the undercurrent of the sea. *Bugko loamy sand*, soils on former tidal flats, is an example of soils derived from the accumulation of marine and alluvial materials (Fig. 1.43).

Fig. 1.43 *Landscape view* of Bugko series formed from the accumulation of marine and alluvial materials

Fig. 1.44 *Landscape* of Bantay series in Ilocos Sur characterized by Type 1 climate

1.3.4 Impact of Climate and Vegetation

The Philippines is characterized by four climatic types which range from distinct wet and dry season to even distribution of rainfall. Where the mountain soils are old and consequently acidic, those areas belonging to longer dry seasons are limited to the growing of acid-loving crops and slash-and-burn agriculture. Where the rains are evenly distributed throughout the year and where there are no typhoons, the same acidic soils are surprisingly utilized for plantation or commercial-type agriculture.

The Philippines can be classified into four types of climate according to Coronas:

Type 1—two pronounced seasons, dry from November to April and wet for the rest of the year. The maximum rainfall is from June to September All regions in the western part of the islands of Luzon, including Metro Manila, Mindoro Occidental, southern parts of Antique and Iloilo, northwestern part of Palawan, and the southern parts of Negros Oriental and Negros Occidental fall under Type 1 (Bareja 2010) (Fig. 1.44).

Fig. 1.45 *Landscape view* of Mayon series with Mayon volcano on the background showing the composite impacts of parent material, vegetation, and Type 2 climate in soil formation and development

Type 2—no dry season, with very pronounced maximum rain period from December to January. There is not a single dry month. The minimum monthly rainfall occurs during the period from March to May. These regions are along or very near the eastern coast—Catanduanes, Sorsogon, eastern part of Albay, eastern and northern parts of Camarines Norte and Sur, northeastern Samar, southern Leyte, and large portion of eastern Mindanao such as Surigao del Norte, Surigao del Sur, Agusan del Sur, and Misamis Occidental (Bareja 2010) (Fig. 1.45).

Type 3—the seasons are not very pronounced; maximum rain period, with short dry season lasting only from 1 to 3 months, either during the period from December to February or from March to May. Those in Type 3 climate are the northeastern part of Ilocos Norte, Kalinga-Apayao, Mountain Province, western part of Cagayan, Isabela, eastern part of Nueva Viscaya, Bulacan, eastern parts of Laguna and Bataangas, northern parts of Antique and Iloilo, most of eastern Palawan, Negros Occidental, Siquijor, Zamboanga del Sur, Basilan, Lanao del Sur, Bukidnon, Misamis Oriental, western part of Agusan del Sur, Lanao del Sur, and eastern part of Maguindanao (Bareja 2010) (Fig. 1.46).

Type 4—the rainfall is more or less evenly distributed throughout the year, and resembles Type 2 closely since there is no dry season. The areas of Type 4 include Batanes, northern Kalinga-Apayao, eastern Cagayan, Isabela, Quezon, western part of Bicol like southwest Camarines Norte, west of Camarines Sur, Albay, northern Cebu, Bohol, Zamboanga del Norte, Sultan Kudarat, South Cotabato, Davao del Norte, Davao Oriental, and eastern parts of Agusan del Norte and Agusan del Sur (Bareja 2010) (Fig. 1.47).

In the Philippines, the average annual air temperature at sea level is about 28 ˚C and the difference between the

Fig. 1.46 Luisiana-Tagburos soil complex and surrounding landscapes that developed in Narra, Palawan under Type 3 climate

Fig. 1.47 *Landscape view* of Adtuyon soil series in Bukidnon plateau, characterized by Type 4 climate or even distribution of rainfall throughout the year

highest and lowest averages about 8 ˚C. The average relative humidity is high, about 82 %. The prevailing wind from October to February is northeasterly (called *amihan*) which is easterly from March to May due to the Pacific trade winds, and it is southwesterly (called *habagat*) from June to September. The changes in the large-scale wind direction are due to the Asian monsoon, that is, the differential heating between the Asian mainland centered over the Tibetan plateau and the surrounding oceans.

Typhoons are very common in the Philippines. This affects the type of agricultural crops that farmers can grow. The typhoons that affect the country originate from the low pressure areas in the Pacific Ocean. They usually move westward and then veer to the northwest. On the average, the country more or less experiences about 19 typhoons a year.

In *Soil Taxonomy*, two soil classification parameters that have bearing on the climatic impact in soil development are

Fig. 1.48 Soils of mangrove forest are considered to be of peraquic soil moisture regime

considered—the soil moisture regimes, and the soil temperature regimes. It is important to define them here for proper interpretation of provincial semi-detailed Soil Taxonomy maps at family level.

Classes of soil moisture regimes applicable in the Philippines:

Aquic soil moisture regime Soils classified to have aquic soil moisture regime are under water most of the time and are said to be in chemically reduced condition. The soils are virtually free of dissolved oxygen because of water saturation. Where the aquic condition is all the time, caused by fluctuating water table but the ground water is always at or very close to the surface such as those soils in tidal marshes or we have landlocked depressions fed by perennial streams, the soils are considered to be in peraquic moisture regime (Fig. 1.48).

Udic soil moisture regime The soil is not dry in any part for as long as 90 cumulative days (3 months) in normal years. The udic moisture regime is common to the soils of humid climates that have well distributed rainfall. There is enough rain in summer such that the stored moisture in the soil and the rainfall equals or exceeds evapotranspiration.

Ustic soil moisture regime The concept is one of moisture that is limited but present when conditions are suitable for plant growth. It is not as wet as in udic, but certainly not dry as those found in arid conditions which does not exist in the Philippines. Where the mean annual soil temperature is 22 ˚C or higher, the soil is dry in some or all parts for 90 or more cumulative days in normal years. It is moist, however, in some part either for more than 180 cumulative days per year or for 90 or more consecutive days.

Classes of soil temperature regimes applicable to Philippine conditions:

Isothermic—the mean annual soil temperature is 15 ˚C or higher but lower than 22 ˚C. This is generally for many mountain and hillyland soils where the temperature is cooler.

Isohyperthermic—the mean annual soil temperature is 22 ˚C or higher. Most Philippine soils belong to this soil temperature regime.

Soil moisture and soil temperature regimes are normally specified at family level of soil classification, the category next higher than soil series. Maytalatala series, earlier mentioned as example of colluvial soil, belongs to fine clayey, montmorillonitic, *isohyperthermic* family of *Aquic* Eutropepts (based on the Keys to Soil Taxonomy, Second Edition, 1985). Succeeding revisions of *Soil Taxonomy* reclassify Eutropepts into Eutrudepts or Eutrustepts depending on climatic condition prevailing in the area, whether udic or ustic.

1.3.5 Anthropogenic Influences

Anthropogenic influences refer to soils disturbed from their natural setting because of human intervention. Man, or for that matter, human activities, do contribute to soil formation and development. Examples are urban landfills and reclamation areas. There are also areas cultivated for several decades under organic agriculture concept; or continually under puddled condition to the point that the original soil has been altered due to anthropogeomorphic processes.

There are still debates on the classification of anthropogenic soils. The underlying concept is to look at man as a natural part of the ecosystem (one of the biota factors) and man's activities as contributing to soil forming processes. However, in most cases, man's activities are destructive such that the soil is disturbed from its natural setting, and soil development is set back to or near to time zero. There are landscapes that cannot be mapped as simple as consociations.

As soil mapping units, there are very limited human altered and human transported soils in the Philippines. Currently, there are no urban soil series named and their differentiating characteristics defined. This is a possible new area of study under Philippine setting. In the international soil science scene, Anthrosols are proposed as soils that were formed or profoundly modified through human activities such as addition of organic materials or household wastes, irrigation or cultivation; but these soils are mostly for agricultural use and are not in urban setting (Fig. 1.49).

Fig. 1.49 A farmer sprays *Trichoderma harzianum* on his rice field to hasten in situ rice straw decomposition after harvest in lieu of traditional practice of burning; and thereby recycle back to the soil the biomass from previous rice harvest. Decades of such organic practice can bring about significant changes on the soil, a positive rather than negative example of anthropogenic influence on soil formation and development

1.4 The Soils and Philippine History

In the previous section, we discussed the geological history of the Philippines and traced the development and formation of Philippine soils. Do you know that we can also reconstruct the history of the Philippine civilization from the soils?

We recognize of course that this is a book on soils, and not a book on Philippine history. Like other dynamic social sciences, we further recognize various claims and counterclaims, and sometimes conflicting accounts of a historical event. The recounting of history is rather subjective, according to the view and perspective of the historian. This book is not to be taken as an authority on Philippine history but a sidelight and an insight on what else we could learn from Philippine soils.

Since the soils are named after the place where it was first described, a review of Philippine soils is like going through the pages of Philippine history, from as far back as before the coming of Islam to the Philippines when parts of the country were linked to Shri Vijaya and the Majapahit Empires and the Hindu culture dominated the land. The soil series were witnesses to the major and minor events of Philippine history.

1.4.1 Aborigines and the Waves of Early Migrants

For instance, we have the *Villar* series, residual soils developed from sandstone, named after barangay Villar in the municipality of Botolan, Zambales province. Botolan is the largest municipality in the province in terms of land area and known for its Aeta population, gray beaches, and the location of Mt. Pinatubo. Aetas are the aborigines of the Philippines, similar to pygmies of Africa—small stature, small frame, curly to kinky Afro-like textured hair, believed to have arrived in the country from the Asian mainland through land bridges some 30,000 years ago. They are nomadic, living in temporary shelters on isolated mountains,

Fig. 1.50 *Landscape view* of Mount Pinatubo-affected eruptions in June, 1991. The Aetas living in Mount Pinatubo footslopes were forced to live in relocation centers that altered their nomadic way of life for thousands of years

Fig. 1.51 Mount Kitangland in Bukidnon is home to several nonMoslem and nonChristian indigenous people such as the Talaandigs, Higaonons, and Bukidnons. Some soil series such as Dadiangas and Maramag bear imprint of the traditional names for the places where they moved about in ancient times

and had primitive communal type of organization. Their clothing is very simple, the women in bark cloths and the men in loin cloths. During the Spanish rule, attempts to settle them in reservations failed. Only the 1990 eruptions of Mount Pinatubo forced some of them to live in resettlement areas; but otherwise, the majority especially those in other islands, have a way of life that remained unchanged for thousands of years (Wikipedia 2011a) (Fig. 1.50).

When the land bridges disappeared as the ice glaciers thinned and the sea level rose, the next wave of migrants were skilled in seafaring and certainly more advanced in civilization. They were the Indonesians, coming from about 5,000–3,000 years ago. They were not nomadic as the Aetas but had tools and were engaged in farming and fishing in addition to hunting. They used materials like brass and wore clothings and had other body ornaments. They lived in houses built above the ground, with wooden frames and grass roofs. Eventually pushed to the mountains when the next migrants came in, they were unIslamized and un-Christianized peoples. But what is interesting from the point of view of soils series name is that we have significant lowland soil series that bear imprint of their heritage. *Dadiangas* series is on level to gently sloping volcanic pyroclastic residual terrace slightly to moderately dissected. Dadiangas, where this soil was named after, is presently called General Santos City and component city of South Cotabato province. But the old name Dadiangas was how the native B'laan tribe called this place, to refer to trees with thorns on trunks and stems that abundantly thrived here at that time (Wikipedia 2011b). *Maramag* series was first described in Maramag municipality, province of Bukidnon. These are red and acidic soils on gently sloping alluvial terraces. The name is a contracted form of Manobo term "Ag Ramag Ki Dini" which means "Let us eat our breakfast here", referring to Manobos stopping by the bank of Pulangi River to eat breakfast in flat stones every time they set out for battle against neighboring Maranaos, or just to take respite from travel, trekking, hunting, etc., (Wikipedia 2011c) (Fig. 1.51).

The next migrants were the Malays believed to have come from Java, Sumatra, Borneo, and the Malay Peninsula who also traveled in boats and with technology far more advanced than the Indonesians. They had pottery, weaving, jewelry, metal smelting, irrigation. They had advance navigational skills and conducted maritime trading with Asian neighbors like China, Japan, Siam, Vietnam, Indonesia, India, even as far as Greece and Persia. Influenced by the Hindu caste system, they had social structure composed of *maginoo* consisting of the ruling and the landed class, the *timawa* or the ruled class who shared the crops with the nobilities, the *maharlikas* or the warrior class equal in social rank with the timawas, and the *alipin* or the slaves who worked without a definite share of the harvest. They had a writing system derived from the Brahmic scripts of ancient India. Some of the natives, especially the chieftains, were proficient in other languages like Spanish, Latin, and foreign languages. In fact, it was claimed that the Philippines was an extension of if not heavily influenced by the vast Hindu and archipelagic Sumatra-based Shri Vijaya (seven to thirteenth centuries) and Java-based Majapahit (1293–1500) Empires. At its golden age, Shri Vijaya Empire's influence reached Manila by the tenth century and the Empire remained a sea power in the region until the thirteenth century. Shri Vijaya became a tributary to Khmer Empire and later on to the Sukothai Kingdom and finally succumbed to the Islamic intrusion. The last inscription mentioned Crown Prince Ananggavarman and was dated 1374 (Wikipedia 2011d). Majapahit Empire on the other hand, attained its peak in 1350–1389 during the

Fig. 1.52 Part of Candaba swamp in Central Plain of Luzon is utilized for the growing of rice when the monsoon rains come. The last wave of migrants, the Malays from Shri Vijaya and Majapahit Empires eventually occupy and dominate the lowlands pushing the earlier migrants to the mountains

reign of Hayam Wuruk. Its decline culminated when it succumbed to the rising power of the Malacca Sultanate in the mid fifteenth century and ultimately, Muslim forces emerged in the region (Wikipedia 2011e).

If the Philippines wants to reclaim its lost pre-Islamic culture and glory, it must revisit Sumatra and Java, Indonesia for remnants and traces of Shri Vijaya and Majapahit Empires, respectively, as Indonesia itself remains Islamized to these days (Fig. 1.52).

1.4.2 The Philippines Before the Islamization of Southeast Asia

Butuan series, formed from older alluvial terraces of the Agusan River and poorly drained (Fig. 1.53), was first identified around the vicinity of Butuan City, of what used to be the province of Agusan in Mindanao. This is a very old settlement and has established trading relations with the Kingdom of Champa (now southern Vietnam) and with the Shri Vijaya Empire of Sumatra (Wikipedia 2011f). It was described by the Chinese Imperial Court *Song Shih* document on March 17, 1001 AD as the Kingdom of Butuan, a small Hindu country with a Buddhist monarchy under Rajah Kiling (Wikipedia 2011g). The soil series was developed from older alluvial terraces along many sections of the Agusan River and very poorly drained.

Palo series was originally mapped in Palo, Leyte province in the Visayas, and a settlement as early as the tenth to thirteenth centuries as the Kingdom of Takuranga with its first ruler, King Guban. It was Miguel Lopez de Legazpi who coaslesced the various settlements and named the new confederation as Palo in 1550 (Wikipedia 2011h).

Jalajala series, deep and poorly drained soils on nearly level to gently sloping alluvial fan terrace (Fig. 1.54), was first described in Jalajala municipality, province of Rizal in the island of Luzon. A peninsula and a lakeshore town,

Fig. 1.53 *Landscape view* of Butuan series. Historically Butuan is one of the oldest settlements in the country. The 21 ct Golden Tara of Butuan found in 1917 by a Manobo woman in the bank of Wawa River now displayed in Chicago Field Museum of Natural History proves Butuan to be part of the cultural sphere in the archipelagic region that constitutes the Sri Vijaya Empire

Jalajala was in the heart of the ancient Kingdom of Bai and Mai (or Be'it and Ma'it) ruled by Gat Maitan nobilities in 1277 A. D (Wikipedia 2011i). "Gat" is honorific for nobilities, a short form for the local term for the titled which is *Pamagat*. Modern usage of the Tagalog word "pamagat" means "title".

The ancient Kingdom of Tondo is claimed to be the legendary Kingdom of Lusung (張燮, Cantonese: Lǖsòng Kók, 呂宋國) with what is now Tondo, Manila as the capital and the kingdom's extent reached up to what is now the Pampanga province—Betis, Lubao, and Macabebe and the coastal towns of Bulacan province in-between. Its more ancient name is Seludong. In Southern Chinese dialect, the character lǖ (呂) is added before a name to lessen its importance or value. The Sòng (宋) refers to the Song Empire (宋國). The name Lusong (呂宋國) therefore means "The Lesser Song Empire". Lusung was claimed to be a thalassocracy, a trading empire like Brunei and Malacca or the earlier Shri Vijaya and Majapahit empires of Java and Sumatra, and this kingdom was actively involved in the political and economic affairs of China's maritime sea route with its Macabebe fleet assisting the Sultanate of Atjeh's fleet retake from the Portuguese the control of the trade traffic in the Straits of Malacca in 1529; and Lusung warriors assisting the King of Siam to defend Ayuthaya in 1547 against the elephant army of the Burmese king (Los Indios Bravos' Mu quoting Meanggubie and Siula ding 2009). Expectedly, the soils of Betis and Lubao were classified in the reconnaissance soil maps as *Hydrosols* and developed as deltaic deposits from Guagua and Pampanga Rivers that emptied into Manila Bay. The soils of Tondo, although developed from alluvial deposits of a different river system, the Pasig River, would not differ significantly. Macabebe is on higher ground and the soils were formed from river levees with a soil series name, Quingua, that equally played

Fig. 1.54 A view of Laguna caldera from Jalajala, a kingdom ruled by the Gat Maitans in pre-Islamic Philippines (*Photo credit* Gubernatoria (2009) from Wikipedia: Wikimedia Commons)

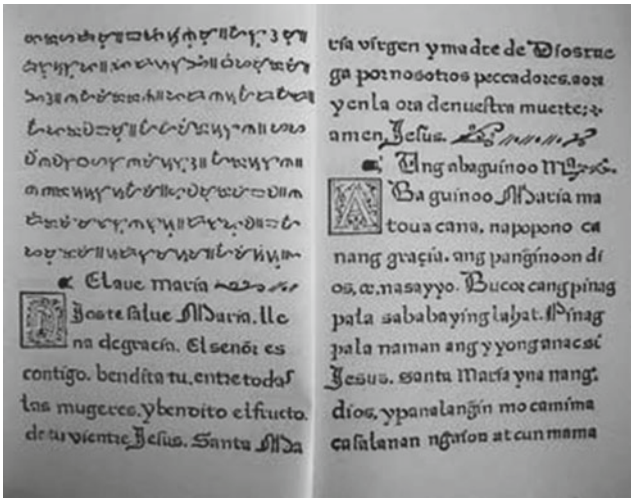
Fig. 1.55 Like other civilizations in other parts of the world, the ancient rajahnates of Namayan, Tondo, and Maynila that dominated Metro Manila before the arrival of Islam and the Spaniards in the Philippines were established on the banks of a river; Pasig River for these three rajahnates, here taken from Fort Santiago, where the former palace of Rajah Sulayman used to stand. When the archipelago was westernized by Spain, it lost its glorious pre-Spanish culture. And of its cultural remnants, most Filipinos are not aware of our authentic Asian cultural heritage, believing that they were remnants of Spanish rule

significant role in Philippine history. Lusung actually refers to a large wooden pylon used for pounding rice; and the Manila Bay got its name because it is shaped like the mouth of a *lusung*. Thus, Lusung referred to a body of water, the Manila Bay, but the Spaniards who conquered Lusung in 1571 mistakenly thought they conquered the whole island and thus Spanish geographers named the entire northernmost major island of the Philippine archipelago as Luzon (Los Indios Bravos' Mu quoting Meanggubie and Siula ding 2009). It was also anticipated with their divide-and-conquer philosophy that the Spaniards separated Tondo and carved out the province of Pampanga immediately after the conquest to weaken the original kingdom; and the ethno-linguistic difference between Tagalog and Kapampangan became pronounced in the centuries that followed. It is interesting that Tagalog was derived from *taga-ilog* (river dwellers) while Kapampangan was derived from *taga-pampang* (river bank dwellers). It was historically one kingdom with their cultural bonds tied to the river. Allusions to the pre-Spanish glory and might of the Kapampangan Kingdom could not be found in any historic records because Pampanga was carved out from what was the Lusung Empire or the Kingdom of Tondo for that matter after the Spanish conquest of 1571 (Fig. 1.55).

Romblon soil series sums up the Hindu civilization that dominated much of the Philippines before the Islamic wave that engulfed the Southeast Asian region. Romblon soils is a residual soil developed from the weathering of the underlying marble rocks for which the island province of Romblon is known for. Aetas, the aborigines of the Philippines, and according to tradition, came in through the land bridges that once connected the archipelago to the Asian mainland, were the first settlers of Romblon and still inhabit to these days the interior of the island. Then came the Malays during the golden period of the Hindu Kingdoms of Majapahit Empire based in Surabaya; then later on, by people coming from the Shri Vijayan Empire based in Palembang, Sumatra, Indonesia. The Romblon locals descended from this basic Malay stock with an admixture of other racial strains of later colonizers. This island of Romblon is an anthropologist's paradise with many unexplored ancient burial caves littered with countless broken potteries, gold tooth fillings, cosmetic refinements, and Visayan-Baybayin Script (Fig. 1.56) in stone murals that reflect the ancient glory of pre-Islam Philippines. But many of these priceless wall writings, evidence of pre-Spanish era literacy of the Filipinos, were destroyed by careless treasure hunters such that only heaps of stones remained. During the Spanish conquest, Martin de Goiti came here in 1569 and conquered every native village to establish Spanish settlements (Wikipedia 2011j).

1.4.3 The Coming of Islam in the Philippines

In 1380, Karim ul' Makdum and Shari'ful hashem Syed Abu Bakr, an Arab trader from Johore, arrived in Sulu from Malacca and established the Sultanate of Sulu. The Sulu Sultanate, the Johore Sultanate, the Brunei Sultanate, and the Malacca Sultanate came from the same clan arising from the intermarriages between Shri Vijayan royalties with the Arabs, Hindus, and the Chinese (Wikipedia 2011k). *Kaunayan* series was first mapped along the shorelines of Kaunayan, one of the barangays or villages of Patikul, Sulu.



Aue maría
Dios te salue Maria. lle-
na de gracia. El señor es
contigo. bendita tu entre todas
las mugeres. y bendito el fructo
de tu vientre Jesus. Santa Ma
ria virgen y madre de Dios rue
ga por nosotros peccadores. aora
y en la ora de nuestra muerte.
amen Jesus.
Ang abaguinoo Maria.
Aba guinoo Maria ma
toua cana, napopono ca
nang gracia. ang panginoon di
os, ca nasa yyo. Bucor cang pinag
pala sa babaying lahat. Pinag
pala naman ang yyong anac si
Jesus. santa Maria yna nang
dios, ypanalangin mo cami ma
casalanan ngayon at cun mama

Fig. 1.56 A photo of pages 8–9 of Doctrina Christiana Española y Tagala shows sample Baybayin scripts (*Photo source* Gubernatoria (2010) from Wikipedia: Wikimedia Commons). This is believed to have been printed in the Philippines in 1593. The ancient Filipino writing system, called *Baybayin* is most probably of ancient Sanskrit origin, rather than of Arabic origin and mistakenly referred to as Alibata by many. Islam came to the archipelago centuries later. As in Latin America, many of the ancient Filipino records were destroyed by the Spanish colonizers. Before the coming of the Spaniards, there was hardly an illiterate native but these ancient scripts were sadly abandoned in favor of Roman letters. The conquerors then kept the majority of the populace divided, illiterate, and ignorant. A subjugated nation with its glorious past destroyed, the nation is wanting in cultural identity, patriotic dignity and national pride

Fig. 1.57 The vast Cotabato Valley, here taken from Midsayap, North Cotabato as soil surveyors posed after pit digging to study the rice soils influenced by ejecta from Mount Matutum. This valley is one of the seats of Islamic culture in the Philippines. Islam reached the country in fourteenth century and by the time the Spaniards arrived in Manila in the island of Luzon a century later, it was governed by Islamic rajahs

This series is found adjacent to the beach over long narrow strips of level land.

In 1520, Shariff Mohammed Kabungsuwan of Johor arrived in Malabang, what is now Lanao del Sur and introduced Islam in Mindanao and he subsequently married Dayang Dayang Paramisuli of the Maguindanao ruling class. He established the Sultanate of Maguindanao with Cotabato valley as the sultanate's heartland (Wikipedia 2011l). *Malabang* series (Fig. 1.57) was first described in Malabang municipality where Shariff Kabungsuwan first arrived. Malabang black sandy loam is rather limited to agricultural use and best for pasture and forest. The parent material is basalt and volcanic ash from now extinct Buldung craters. The prominent features in Malabang are series of cold springs from the volcanic ash formation. Lanao del Sur where Malabang is located is now the seat of the Confederation of Maranao Sultanate consisting of four principalities and 16 royal houses.

Dagami series was first established in the municipality of Dagami, Leyte province (Fig. 1.58). Dagami series, similar to Palo series in features, represents the peaceful, rich, and colorful Islamic centuries in Philippine history that has now become more of legend and myth. Dagami, the ancient name of which was Dagilan, was the capital of the fusion of three sultanates when Sayambugan, the daughter of Sultan Diwaranda Mohammed of the sultanate of Dagaran, married Bantugan, the son of Sultan Maparanda of the sultanate of Bumbaran and conquered his challenger to Sayambugan, Sultan Mabanig of the sultanate of Kahagna who declared war on Bumbaran 2 days before their wedding. By 1478, some 200 years after the union of the three kingdoms by marriage and conquest, Dagilan's cultural and social life was enhanced by increased population and flourishing trade with Asia and Europe. Dagilan became Dagami in 1521 when the Spanish *conquistadores* could not pronounce "dinagami", the term used to describe a rice field after harvest as the name for this place (Wikipedia 2012a).

The *Boulevard* soil series was first described in Bangiad, municipality of Taytay, province of Rizal possibly along the highway and hence, the name of this soil series. These soils are located at the lowest catenal drainage of the lake, and the soils are dark gray or greenish gray clay. Taytay where this soil was first described, used to be part of the Kingdom of *Namayan* (also called Kingdom of Sapa, or Maysapan or Nasapan, circa 800–1571) that reached its peak in 1175 and dominated the upper portion of the Pasig River and the coast of Laguna de Bay (pronounced Bah-eh, referring to the settlement along the lake). The capital was Sapa, now known as Sta. Ana, a district of the city of Manila. It is the oldest of the three major kingdoms (the two others are the coastal or deltaic Kingdoms of *Tondo* on the north of the Pasig River and of *Maynila* on the south) that dominated what is now considered Metro Manila before the arrival of the Spanish colonizers (Wikipedia 2011m) (Fig. 1.59).

As to the Kingdom of Tondo, the earliest historical reference was the Laguna Copperplate Inscription (Fig. 1.60) written in ancient Javanese, dated Saka 822 or equivalent of

Fig. 1.58 The island of Leyte has been inhabited centuries before the coming of Spain, ruled by rajahs and later on by sultans when Islam came to the country. Now, its predominantly Christian population grow a variety of crops—rice, coconut, and banana in this *landscape view*. Still, the province is one of the most impoverished in the country

Fig. 1.59 A view of highly urbanized Taytay, Rizal and the far off Metro Manila up to Manila Bay taken from the foothills of Sierra Madre Mountains in San Mateo, Rizal. There is hardly any agricultural area in Metro Manila and as could be seen, even the foothills itself is not spared from the encroachment of urbanization and development considering the scenic views offered

900 A.D. The Ming Annals has also record of Tondo envoys coming to China in 1373 (Wikipedia 2011n). It is believed that Tondo, based on its Chinese calligraphy (東都, Cantonese: Tūngdū) is the eastern capital of the Majapahitan-influenced Seludong (or Saludong or Selurong; also referred to as the Kingdom of Lusung or Luzon) (Manila City Information 2008) with the western capital located somewhere in the estuarine of Pampanga province, probably Betis, said to be the richest, most populated, and most fortified throughout Lusung (Betis Parish Fiesta Committee 2009). Other historians alleged that the western capital was probably the Kingdom of Namayan because the Kingdom of Sapa (Sapa is Namayan's capital and known today as Sta. Ana, Manila) is said to be synonymous to the Kingdom of Selurung (Magnus Albertus 2010). Saludong is mentioned as one of the Majapahit realms in Canto 14 of the Nagarakretagama, the old Javanese eulogy to King Hayam Wuruk, written in 1365 (Wikipedia 2011o). The ruler of Tondo was perceived to be traditionally called Lakan (meaning, "Paramount Ruler") and this title is considered equivalent of Rajah (Wikipedia 2011p). By the fifteenth century, Sultan Bolkiah (Paduka Shri Baginda Rajah dan yang di Pertuan Bulkiah) also known as Nakhoda Ragam (the Singing Captain), the 5th Sultan of Brunei and ruling from 1485 to 1521, attacked the Kingdom of Tondo then ruled by Lakan Gambang who had no male heir, to break the monopoly in the China maritime trade. Despite previous failed efforts of China to subjugate the Kingdom of Tondo three times under Admiral Zheng Ho, Ragam succeeded because of the devastations brought about by Mount Pinatubo's eruptions. Ragam sealed the conquest through royal marriage by marrying Lakan Gambang's daughter and Regnant Queen upon Gambang's death, Dayang Kaylangitan (Wikipedia 2011n). Ragam is the same person as Gat Lontok who also became the Rajah of Namayan (Trismegistos 2011), although there are some historical citations that refer to Gat Lontok as the son of Ragam and his Sulu princess Dayang Lela Mechanai (Wikipedia 2011q). While allowing the Tondo ruler to retain his title and property, Ragam established a new dynasty in the neighboring Islamic Kingdom of Maynila where real political power resided to oversee the Chinese trade for Brunei's interest and to counter check Tondo (Wikipedia 2011r).

The Kingdom of Maynila under the Salalilan dynasty, was considered a Bruneian satellite. By the mid-sixteenth century, Maynila was governed by Muslim rajahs and had ties with Brunei, Sulu, and Ternate (in Indonesia, not Ternate, Cavite province) since Gat Lontok's brother, Gat Pandan, had six children and was the founder of Ternate and Moluccas. It is claimed that the Islamic Kingdom of Maynila was established in 1258 by Rajah Ahmad from Brunei after vanquishing Rajah Avirjirkaya of Maynila then a sureinty of Majapahit Empire (Rasul 1970).

But back to the kingdom of Tondo, it achieved its greatest power during the reign of Gat Lontok as it became the center of trade between China, Japan, Middle East, and the Malay kingdoms. The realm included possessions and subjugated kingdoms of Diloan in the Bicol peninsula, Diwata in the Batanes group of islands, Kumintang in what is now Batangas province, and Tawalisi in what is now Pangasinan province. There were also royal marriages through the Sultan of Sulu (where Ragam is known as Rajah Baginda) and the Rajah of Butuan to complete the security of the archipelago a century before the arrival of the Spaniards. The children of Gat Lontok and Dayang Kaylangitan were Dayang Panginoan who married Gat Balagtas

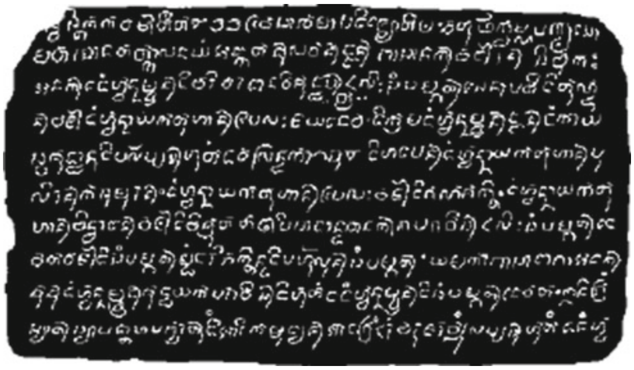


Fig. 1.60 The Laguna Copperplate Inscription circa 900 A.D. (*Photo source* Wikipedia: Wikimedia Commons). Because the Filipinos have lost much of their pre-Spanish heritage, historians like Antoon Postma and fellow Dutch Johann de Casparis had to rely on ancient Java writing script called Kavi to decipher the archeological findings like this copperplate with inscriptions earlier than Baybayin. Very few Filipinos are aware of their Javan and Sumatran cultural roots

Fig. 1.61 With the collapse of Shri Vijaya and Mapapahit empires, Islam supplanted Hindu culture in the country. Rajah Shri Lela (or Syrarirah or Salila) of the rajahnate of Maynila converted to Islam and became known as Rajah Sulayman I de Salila. By the time Miguel Lopez de Legazpi arrived in 1570, his teenage grandson Rajah Sulayman III ruled Manila together with his uncle, Rajah Matanda. Photo, Manila's Masjid Al-Dahab or the Golden Mosque was constructed in 1976 by then First Lady Imelda Marcos for the visit of Libya's President Muaamar al-Gaddafi but the visit was eventually canceled. Muslims are back in Manila (*Photo credit* Gonong (2011), Wikipedia: Wikimedia Commons)

of the Kingdom of Namayan, Rajah Salalila (the name is of Sanskrit origin, Syarirah or Shri Lela) but he converted to Islam and became known as Rajah Sulayman I de Salila of the Kingdom of Maynila (Fig. 1.61), Dayang Lahat who married Gat Timog, and Gat Kahiya (Wikipedia 2011s). With the Islamization of Southeast Asia and the demise of the Shri Vijaya (also called Shri Vishaya) and Majapahit Empires, the Hindu kingdoms in Java remained only in Blambangan on the eastern edge and in Pajajaran on the western part; and the Hindu communities retreated to the mountains and in the neighboring island of Bali. But the middle groups of Philippine islands retained its name—*Visayas*, reflecting its Malay population to have originated from the collapsing empires of Shri Vijaya and Majapahit.

Makato series was mapped in what was then Capiz province and belongs to a group of older alluvial soils with moderately developed profiles. But in 1956, Republic Act 1414 separated Aklan from Capiz province, and all those Makato series are found on the Aklan side, specifically in the municipalities of Makato where this soil was named after, Numancia, Lezo, Malinao, and Tangalan. Despite its more recent classification as a province, Aklan is considered to be the oldest province in the country. In the middle of the thirteenth century, ten Bornean datus of the Shri Vijayan Empire, together with their families, fled the oppressive rule of the Bornean king, Sultan Makatunao, in search of freedom, new lands, and better fortunes. A datu is a royal title for Malay people, roughly equated to the European dukes. They left Borneo on a flotilla of ships called "balangay" (Fig. 1.62), and hence the origin of barangay, the basic unit of Philippine political system. It was circa 1250 when they landed in Panay Island and purchased the lands from the Aetas, the aboriginal pygmies. The historic Barter of Panay involved a golden *salakot* (wide brimmed hat), a chain of some pure gold necklace, and other gifts given by the newcomers' leader, Datu Puti, to the Aeta king, Marikudo and his wife Maniwantiwang. As the Aetas moved to the hinterlands and mountains, the island was divided into three districts of Irong-irong under Datu Paiburong, Hantik under Datu Sumakwel, and Aklan under Datu Bangkaya. They were united against enemy attacks under the Confederation of Madyaas with Aklan as the confederation center. Datu Puti and the other datus moved on northward in search of new settlements. The Madyaas confederation fell under Spanish conquest in 1569 by Miguel Lopez de Legazpi and his grandson Juan de Salcedo. Legazpi parceled Aklan to his men under the *encomienda* sytem. In 1716, the old sovereign territory of Aklan became the Spanish politico-military province of Capiz and remained so for the next 240 years. Capiz was part of Aklan in pre-Spanish times (Wikipedia 2011t).

Where did the other datus and their families fleeing the Shri Vijayan Empire go? *Lipa* series are residual soils of volcanic tuff and was first mapped in Lipa City in the province of Batangas. Lipa as a settlement traces its origin from two of the ten datus of Borneo—these were the clans of Datu Dumangsil and Datu Balkasusa. Lipa was the center of worship of the Kingdom of the Tagalogs. *Taal* series was first described in the municipality of Taal, also in the province of Batangas. Taal is an old settlement that is traced also from the clan of Datu Dumangsil and from the clan of Datu Balensusa. Taal got its name from the presence of Taa-lan trees in what used to be called Taa-lan River but

Fig. 1.62 An excavated *balangay* boat in Butuan City and displayed at the Balangay Shrine managed by the National Museum (*Photo source* (Dennis Dolojan, 2012)http:lovemindanao.blogspot.kr, with permission). The balangay, an Austronesian word for "sailboat" played a key role in ancient migration and trade in Southeast Asia. Nine of these were discovered in 1976 in Butuan of which three were excavated dating back to 320, 990, and 1250 A.D. Since the ancient Filipinos came in balangays bearing a social unit, it became the smallest political unit in the country and ruled by a datu

Fig. 1.63 The soil profile of Taal series. Taal meant in Tagalog "indigenous" and the place is considered the center or origin of Tagalog dialect. The ancient name of Batangas Province where Taal is located is Kumintang. The people were forced to embrace western civilization with the Spanish colonization

now known as Pansipit River. Taal, in the Tagalog dialect, means "indigenous" and is considered the center or origin of the Tagalog dialect. In this Kingdom of the Tagalogs, Tanauan was the center of governance while Balayan, being near the sea, was the center of trade and commerce. The people developed flourishing trade with Chinese merchants; and thus they were Buddhist in religion but Indian in civilization. They were also trading with Japan and India. Datu Puti returned to Borneo later and divided the kingdom among the other datus—Dumangsil, Balkasusa, Paduhinog, Dumalogdog, Lubay, and Balensusa who was selected to be their leader. Upon Balensusa's demise, the kingdom was inherited by Datu Kumintang; and thus, the ancient name of Batangas province was Kumintang. The Kingdom of Kumintang was one of the progressive towns in the country when the Spaniards arrived. The people were forced to embrace western civilization by the Spanish colonization and Salcedo conquest of Batangas in 1572 (Wikipedia 2011u) (Fig. 1.63).

1.4.4 The Arrival of Spain in the Philippines

Philippine history makes a significant turn with the arrival of Ferdinand Magellan in 1521 who was searching for the Spice Islands (now known as Maluku Islands in Indonesia). *Malitbog* soil series was first described in the municipality of Malitbog, now province of Southern Leyte. This municipality when reorganized in 1893 under the provisions of the Maura Law, covered the island of Limasawa, which is now a separate municipality, and claimed to be the place where the first Catholic mass was held in the Philippines, on March 31, 1521 based on the chronicles of Antonio Pigafetta, the diarist of Ferdinand Magellan. Rajah Kulambu then ruled Limasawa and he was the brother of Rajah Siagu, the Rajah of Butuan. Magellan was killed in the Battle of Mactan on April 27, 1521 (Wikipedia 2011v) (Fig. 1.64). In 2007, Limasawa's historical title was being challenged by another place, the municipality of Bolinao, province of Pangasinan where *Bolinao* series was first described. It was argued that as early as 1324, Franciscan missionaries lead by an Italian priest named Odoric Mattiussi of Pordenone celebrated mass in Thalamasin claimed to be Santiago Island off the coast of Bolinao and baptized natives. This needs to be proven as Thalamasin from Odoric's narrative was somewhere between Java and Champa (now part of Vietnam) and near the South Sea (Wikipedia 2011w).

The Portuguese conquered Malacca in 1512 and became the masters of the lucrative East Asia trade. The Spanish rivals wanted a share but failing to establish a foothold, they gambled to turn their attention to the Kingdom of Lusung or the Kingdom of Tondo. In 1565, the Spanish expedition headed by Miguel Lopez de Legazpi made a foothold in Cebu then under a rajahnate founded by Shri Lumay or better known as Rajah Muda Lumaya, its first ruler, a minor but ambitious native prince from Sumatra, tracing his ancestry from the Chola dynasty. He was succeeded by Shri Bantug, then by Shri Hamabar (Rajah Humabon), and then by Shri Tupas when the rajahnate was dissolved by the forces of Legazpi in 1565 (Quirino 2010). Legazpi named

Fig. 1.64 Magellan's cross housed besides the Basilica Minore del Sto. Niño in Cebu City. The arrival of Ferdinand Magellan then searching for the westward route to the Spice Islands was a milestone in Philippine history, marking the arrival of western colonizers and bringing the concept of central government

the islands Philippines (Las Islas Filipinas) in honor of King Philip II of Spain, and this year was reckoned as the year when he became the first Spanish Governor General of the Philippines.

With the coming and colonization of the Philippines by Spaniards, *Mandawe* series comes to mind. Various textural types of Mandawe series were mapped not only in Cebu but also in the provinces of Masbate, Catanduanes, Bohol, Zamboanga del Norte, Leyte, and Negros Oriental. Mandawe series was first described in Mandawe City, Cebu (Fig. 1.65). As translated by Caso (1990), Antonio Pigafetta wrote about a settlement called Mandani with chieftain named Apo. The natives were forced into a town by the Spanish authorities, managed by the Jesuits in 1638 and by the Recollects a century later (Caso 1990). Today, Mandawe is one of the three urbanized cities of Cebu province and forms part of the Cebu Metropolitan area. Just across Mandawe City, and now connected by a bridge, is Mactan where Ferdinand Magellan met his death from the hands of Datu Lapulapu in 1521. Mactan was renamed Lapulapu City in 1961.

Kapalangan series was first described in barangay Kapalangan, Gapan City, Nueva Ecija just adjacent to the municipality of San Miguel, Bulacan where it was mapped. There is also another Kapalangan barangay equally adjacent to Bulacan but besides Calumpit municipality and it is in

Fig. 1.65 A *landscape view* of Mandawe City shoreline. Despite being one of the three urbanized cities that form the Cebu metropolitan area, mangrove forests have been preserved if not rehabilitated

Apalit, Pampanga province (Fig. 1.66). Kapalangan was derived from the word "palang" meaning machete or bolo believed to be owned by a nobility named Pangpalung of Gat Bonton ancestry. The Gat Bontons traced their lineage to Dayang Lahat, daughter of Gat Lontok and Dayang Kaylangitan and sister of Rajah Sulayman de Salila I of the Kingdom of Maynila who married Dayang Ysmeria and begat three children (Rodil 2009; Sales 2012)—Rajah Sulayman II, Lakan Banaw Dula (better known to most Filipinos as Lakan Dula. "Dula" means palace; Lakan Dula means Lord of the Palace) who was the ruler of the Kingdom of Tondo, and Rajah Mohammad "Ache el Viejo" (he was also known as Rajah Matanda, 1480–1572) who co-ruled the Kingdom of Maynila with Rajah Sulayman II's son, Rajah Sulayman III (Sulaiman bin Mahmud but better known as the Rajah Muda), who married a Bruneian princess, a daughter of Sultan Abdul Kahar Jalil ul-Alam of Sulu and bore him a son and a daughter (Henson 1955).

From their Spanish base in Panay, Legazpi sent Martin de Goiti to Maynila. When the Spaniards arrived in 1570, Lakan Dula, took this as an opportunity to be free from the shadow of the Kingdom of Maynila. Realizing the superiority of their civilization, Lakan Dula pledged his loyalty and cooperation with the Spaniards and took other lords and relatives of their vassals to render obedience to the King of Spain. He married his eldest son, Batang Dula, to the younger sister of Martin de Goiti to symbolize the alliance of the Kingdom of Tondo and Spain. In return, he and his descendants were granted by Legazpi various privileges like exemption from tribute and force labor (Rodil 2009). It would not be until 1594 when King Philip II of Spain signed a law giving the native royalties and nobilities the same respect and privileges they enjoyed before their Christian conversion, creating an elite ruling class called *Principalia* (Wikipedia 2011x).

Fig. 1.66 Kapalangan series was first described in Gapan, Nueva Ecija but Kapalangan in Apalit, Pampanga is far more famous because of Mount Arayat, the extinct stratovolcano that rises to 1,026 m and its historic association with Rajah Sulayman's cannon maker, Panday Pira (*Photo credit* (Ramon F. Velasquez, 2012) Wikipedia: Wikimedia Commons)

Fig. 1.67 The historic battle of Bangkusay is now human settlements as centuries of silt deposition created a delta and the sea has moved farther from the original shoreline. The new shoreline is itself a busy commercial port for domestic shipping lines and known as the Manila North Harbor (*Photo credit* (Matikas 0805, 2008) from Wikipedia: Wikimedia Commons)

1.4.5 The Spanish Colonial Rule in the Philippines

But back to 1570, Lakan Dula counted on the Rajah Muda's brashness and inexperience to handle the Spaniards. As the Rajah Muda expelled them forcefully, the Spaniards retaliated by bombing Maynila and then burning it to the ground. The next year, Miguel Lopez de Legazpi returned to Maynila from their Panay base with his entire force consisting of 27 vessels, 280 Spaniards, and 600 native allies to establish in Maynila the capital of the Spanish colony. The Rajah Muda, harnessing the tested and feared Macabebe fleet, faced the Spanish challenge. He had 40 warships and 200 warriors. But he was defeated during the Battle of Bangkusay on May 24, 1571 and his Macabebe fleet leader (unnamed in the Spanish records, just referred to as the Laxamana of Macabebe Armada while others refer to him as Tarik Soliman) died (Fig. 1.67). Legazpi established Maynila as the seat of the Spanish government on June 24, 1571 which would be the *de-facto* abolition date of the rajahnates of Maynila and of Tondo. It is this date that is annually celebrated as the foundation day of Manila to these days (Piedad-Pugay 2012; Wikipedia 2011y) (Fig. 1.68).

The Kingdom of Namayan which predated Tondo, and headed by Lakan Kalamayin at this time, is reckoned to have succumbed to Spanish rule in 1571. (From the marriage of Dayang Panginoan and Gat Balagtas of the Kingdom of Namayan, Lakan Takhan succeeded, then Lakan Laboy, and then Lakan Kalamayin when the Spaniards came.) The extinction of the Kingdom of Namayan was actually reckoned in Philippine history books when Lakan Kalamayin's son, Martin, was baptized a Catholic (PAOP-ADD 2012). But for Philippine history books, the two rajahnates of Tondo and Maynila still existed as resistance to Spanish colonization persisted.

Nevertheless, with the defeat in the Battle of Bangkusay, the three rulers—Rajah Matanda and his coruler/heir, Rajah Sulayman III, and Lakan Dula accepted Spanish rule and were converted to Christianity. Legazpi granted them with encomienda (trusteeship) of Maynila and Tondo but they actually disregarded the legitimacy of the Rajah Muda by installing the child Rajah Bago, the son of Rajah Sulayman III, as the new Maynila chieftain (Cerawiki 2011).

Legazpi died in 1572 and was succeeded by Guido de Lavezaris until 1575. A succession of Governor Generals followed. Rajah Matanda died in 1572 allegedly of poisoning by the Spaniards. He was survived by an only son, Ambrosio Mag-isa who had two daughters and two sons. Rajah Sulayman III (1558–1575), the last *ruling* Islamic Rajah of Maynila, claimed to be the 14th successor of Rajah Ahmad who wrestled the Majapahit (Hindu) Kingdom of Maynila from Rajah Avirjirkaya in 1258, a mere youth at 17 years old, was found dead in his cell in 1575 after he was implicated in the invasion of the Chinese pirate Lim Ah Hong by conspiring with Brunei forces to take advantage of the pirate's invasion of Manila the year before when he tried to repel the Spanish rule. Other sources mentioned that the Rajah Muda was killed in this second battle, dubbed as the First Battle of Manila Bay. He was survived by a daughter, Maria Laran and three nephews from unnamed brother—Gabriel Taumbasan, Jeronimo Bassil, and Agustin de Legazpi (Luciferous 2012). As in the case of Lakan Dula, only the eldest are allowed to use the western-introduced surnames to distinguish the heir apparent from the other princes following Chinese traditions. The Spanish-installed Rajah Bago was also executed in 1575 (Santiago 1990).


Fig. 1.68 From what used to be the palisade fort of Rajah Sulayman III that was destroyed by Martin de Goiti in 1570, the Spanish conquerors constructed Fort Santiago and built a walled city that became the capital of the newly colonized archipelago

Rajah Sulayman III's rajahnate, already under Spanish rule by this time and capital of the colony, was generally perceived to have been inherited by Lakan Dula's second son, and the next to the Crown Prince of the Kingdom of Tondo, Magat Salamat(1550–1589), who was in the end executed with seven others by the Spanish authorities after the Revolt of the Maharlikas, also known as the Revolt of the Lakans the preceding year. The rest of the conspirators were exiled to Mexico (Blair and Robertson 1909). The death of Magat Salamat in 1589 marked the formal end of the Islamic Kingdom of Maynila. Lakan Dula (December 16, 1503 to March 21, 1589) died the same year. The legendary Empire of Lusung, or the Majapahitan Kingdom of Seludong, or the Kingdom of Tondo as it was better known, formally ceased to exist. Lakan Dula is one of the most prolific of Luzon's ancient rulers and most of his descendants spread out to the provinces of Northern Samar, Pampanga, La Union, Marikina, Sorsogon, Quezon, Pangasinan, Quirino, Bulacan, Davao, Zamboanga, Panay Islands, Rizal, and Cebu. Aside from Magat Salamat, who became the nominal but not ruling Rajah of Maynila upon the demise of Rajah Sulayman III, and Batang Dula who was married to a sister of de Goiti, Lakan Dula's three other sons were Don Dionisio Capulong, the Datu of Candaba, Don Phelipe Salonga, the Datu of Pulu and among those exiled to Mexico, and Don Martin Lakandula who entered the Agustinian Order as lay brother in 1590. Lakan Dula had a daughter named Doña Maria Poloin who married Don Alonso Talabos (Dulay 2011). It is doubly historic that in the final overthrow of Spanish colonial rule in the Philippines in 1898, the founder of the Philippine revolutionary movement, Andres Bonifacio, came also from Tondo. By the way, Kapalangan series, our soil of interest, is also doubly memorable because it was in Kapalangan, Arayat in Pampanga where Panday Pira, Rajah Sulayman III's cannon maker, fled after the Battle of Bangkusay. He stayed there until summoned back to Maynila by Legazpi. Panday Pira died in 1576 but it was not until 1584 that a blacksmith from Mexico arrived (Wikipedia 2012b).

Under the Spanish colonial rule, the Philippines was governed by Spain from Mexico which was known then as the Viceroyalty of New Spain. The Viceroy governed the Philippines on behalf of the King of Spain. It was considered part of Spanish East Indies comprising of the Philippine islands, Marianas Islands, the Caroline Islands, Taiwan, and parts of Moluccas. As Spanish East Indies, the colonial rulers would refer to the native Filipinos as *indios* while they called themselves as either *peninsulares* for full-blooded Spaniards born in the Iberian Peninsula or *insulares* for full-blooded Spaniards born in the Philippines. *Basco* series, first described in Basco, Batanes, (Fig. 1.69) was named after the 44th Spanish Governor General José Basco y Vargas, the governor general from 1778 to 1787. He led the Philippines to freedom from the control of the Viceroyalty (Wikipedia 2012c).

The arrival of Spaniards in the Philippines ushered in the Manila-Acapulco Trade which started in 1565 when Andres de Urdaneta, sailing in convoy under Miguel Lopez de Legazpi, discovered a return route from Cebu to Mexico crossing the Pacific Ocean. Manila became the colonial entrepot in the Far East. The trade ended in 1865 after the Mexican War of Independence. The Manila-Acapulco Galleon trade flourished from the years 1571 to 1815 (Wikipedia 2012d). *Toran* series was first described in the municipality of Aparri, province of Cagayan. Aparri is a Japanese trading post as early as 1405 prior to the coming of the Spaniards and eventually was established as one of the major ports of the Galleon Trade in 1680 (Wikipedia 2012e). Toran soils are derived from alluvial deposits and occupy bottom lands along streams; and as such are regularly flooded soils.

But through the centuries, we also had unabated rebellions against continued Spanish rule in the Philippines. *Palapag* series, developed from alluvium from the surrounding upland soils, was first described from the municipality of Palapag, Northern Samar (Fig. 1.70). Palapag is known in Philippine history as the hometown of Juan Ponce Sumoroy, a Waray who led a rebellion against the Spaniards from 1649 to 1650 because of forcible conscription of workers from Ibabao region to work in the shipyards of Cavite province. A coconspirator was a grandson of Lakan

Fig. 1.69 *Landscape view* of Basco series, first described in Basco, Batanes. This soil series is named after the 44th Spanish Governor General, Jose Basco y Vargas, who is responsible for freeing the Philippines from the Viceroyalty of Spain, as Mexico was then called. Prior to this, Spain ruled the Philippines from Mexico

Fig. 1.70 In Samar, the hometown of Juan Sumoroy who lead a rebellion against Spaniards in 1649, the alluvial soils developed from surrounding uplands

Dula through a son that married the sister of de Goiti (Wikibooks 2012).

The Ilocos Region is proud of Diego Silang y Andaya who conspired with the British forces during the Seven Years War to overthrow Spanish rule in the Philippines. He was assassinated in 1763 but his wife Gabriela Silang took command of the revolt. She was forced to retreat to Abra where she was captured and hanged (Wikipedia 2012f). Abra province is where the soil series *Bituin* was first described. Developed from a variety of rocks—igneous, shale, and sandstone, this soil series occurs in gently sloping to strongly rolling relief. Meaning a star, Bituin actually refers to a big solid rock situated in the mountain hill of Licuan Baay and is considered a local attraction. Legend said that this tall star-shaped rock illuminates in the evening, and hence the name (Fig. 1.71).

Fig. 1.71 The soils of the provinces of Ilocos where Diego Silang and his wife Gabriela came from were noted for the growing of tobacco

There were many more revolts from as far as the north like the Cagayan Revolt of 1639 and as far south as the pacification campaigns against the Muslims in Mindanao. Except in Mindanao where the sultans succeeded in defending their territory, the revolts failed because the general populace sided with the colonial government. The Lakan Dula clan, which remained a major political power in the country, are said to be of two kinds—patriots and traitors. Most if not all of the revolts were prematurely discovered because of treacheries.

1.4.6 The Philippine Revolution and the American Rule

But before the final revolution that culminated with the first Philippine Republic, peaceful changes for the country were sought by the *Propaganda Movement* as a result of the Cavite Mutiny and the execution of three Filipino priests in 1872—Mariano Gomez, Jose Burgos, and Jacinto Zamora—on charges of subversion. Composed of Filipino intellectuals studying in Europe, the aim was to increase Spanish awareness on the needs of the Philippines as a colony of Spain. Foremost among the propagandists were Jose Rizal, Graciano Lopez Jaena who was the publisher of La Solidaridad, the movement's principal organ, Mariano Ponce, and Marcelo H. del Pilar. *Looc* series, first described in barangay Looc, municipality of Calamba where the Philippine national hero Jose Rizal was born, in the province of Laguna, is just like the very historic Boulevard series associated with the Kingdom of Namayan. These are soils at the lowest of the catenal drainage. But Looc soils are much younger than Boulevard series, having only an AC horizon (Fig. 1.72).

In 1892, Andres Bonifacio founded the *Kataas-taasan, Kagalang-galangang Katipunan ng mga Anak ng Bayan*

Fig. 1.72 The residence of Dr. Jose Rizal, the Philippine National Hero, in Calamba, Laguna. Prior to the revolution, intellectuals like Dr. Rizal launched the Propaganda Movement in Europe to seek an increased awareness by Spain on the needs of its colony, the Philippines

(or KKK which can be translated as The Highest and Most Honorable Society of the Children of the Nation). Its existence was revealed to the Spanish authorities when a member told his sister about their activities who then told it to the mother portress of the Mandaluyong Orphanage. Seven days after, on August 26, 1896, the revolution commenced with Bonifacio and his men tearing their *cedulas* (residence certificates) with patriotic shouts in what is known as the the Cry of Balintawak (as it was officially called from 1908 to 1963) (Wikipedia 2012g), also known today as the Cry of Pugad Lawin; the exact place remains disputed due to the double meaning of Balintawak which could refer to either a specific place or a much wider area (Wikipedia 2012h). *Novaliches* series, underlain by tuffaceous materials and occurring on lowlands, uplands, and hillylands, is a soil series name associated with Andres Bonifacio and his Katipunan movement. Balintawak is now an industrial barangay of District 2 of Quezon City, with Novaliches itself divided into several barangays, Novaliches Proper as the only remaining barangay that carried the Novaliches name. Even Balintawak is now known as barangay Apolonio Samson and the area of the disputed Cry of Balintawak is known today as barangay Unang Sigaw (first cry) (Fig. 1.73). It is believed that Novaliches got its name from the 75th Spanish Governor General, Manuel Pavia y Lacy, the first Marquis de Novaliches, who served as Governor General from February to October 1854 (Wikipilipinas 2011).

From Cavite Mutiny of 1872 which was believed to be the beginning of Filipino nationalism to the Propaganda Movement lead by Jose Rizal, to the Cry of Balintawak in 1896, events moved fast with the proclamation of independence and the establishment of Philippine Republic in 1898. A power struggle among the revolutionaries lead to the execution of Andres Bonifacio in May, 1897; and the revolutionary command shifted to Emilio Aguinaldo. Although the coastal soil *Patungan* series is now deleted from the list of established soil series in the Philippines, it is not necessarily deleted from the pages of Philippine history. This soil series was first described in barangay Patungan, municipality of Maragondon, Cavite province. Maragondon is very prominent in Philippine history because this is where the founder of the Philippine revolutionary movement Andres Bonifacio and his brother Procorpio were executed and buried in unmarked grave after he lost the presidency during the short-lived Philippine Republic (Wikipedia 2011z) (Fig. 1.74).

Sibul series is residual soils of limestone origin. Sibul series occurs on level to hilly land and can be expected to be found also on lowland areas (Fig. 1.75). Sibul, where this soil series was named after, is a barangay of the municipality of San Miguel, Bulacan which has the historic solutional cave known as Biak-na-bato (meaning Split Rock) that came to prominence during the revolution against Spain being the headquarter of the first Philippine Republic. Then Spanish Colonial Governor General in the Philippines, Fernando Primo de Rivera, signed a truce with the revolutionary government president Emilio Aguinaldo to end the Philippine Revolution in December 1897 (Wikipedia 2011aa). Aguinaldo and the revolutionary leadership went into a voluntary exile in Hongkong after receiving amnesty and monetary indemnity by the Spanish government. Aguinaldo returned to the Philippines with the other exiled revolutionaries in May, 1898 purportedly to assist the United States in the war against Spain. But he reassumed command of the Filipino rebel forces, and proclaimed a provisional republic after a month.

Capipisa series was first described in barangay Capipisa in the municipality of Tanza, Cavite province. This municipality is where Emilio Aguinaldo took his oath as the first president of the Philippine revolutionary government in June 1898. It is also the hometown of Felipe G. Calderon who drafted the first Philippine constitution (Wikipedia 2011ab).

Philippine history marches on with the outbreak of the Spanish–American War and the coming of the Americans to the Philippines. Spanish rule in the country officially ended when Spain ceded the Philippines to the United States of America under the 1898 Treaty of Paris signed in September, 1898. The Filipino–American War subsequently followed as the embryonic First Philippine Republic declared war against the United States in June, 1899. A soil series name stood out to represent the gallantry of the Filipinos to defend the nascent republic from another colonization of a western power. This is the *Quingua* series, one of the best soils in the Philippines for agriculture, and was first described in Quingua, Bulacan, a settlement that dated back as early as 1595 during the early years of Spanish colonization. This place was famous for the two-part *Battle*

Fig. 1.73 Balintawak, the disputed site where Bonifacio and his men tore their residence certificates to commence the revolution against Spanish rule is now called BarangayUnang Sigaw (shown *above*) and the rest of Balintawak is renamed Barangay Apolonio Samson. Younger generations would have difficulty finding Novaliches series, the soil that will always be associated with Andres Bonifacio and his revolutionary movement against Spanish colonial rule because the Novaliches is now divided into several barangays and renamed and also highly urbanized. This soil series is characterized by presence of volcanic tuff materials below the subsoil (*Photo credit* (Velasquez, 2012), Wikipedia: Wikimedia Commons)

Fig. 1.74 The memorial in Mount Nagpatong in Maragondon, Cavite where Andres Bonifacio, the *Katipunan Supremo,* and his brother were executed by rival faction who got the upper hand in the revolutionary movement and buried in unmarked grave

of Quingua, fought on April 23, 1899 during the Philippine–American War. The first part was a victory for the young Filipino general, Gregorio del Pilar over the American Cavalry led by Major J. Franklin Bell. During the second phase, Bell was reinforced by the 1st Nebraskan Infantry and routed the Filipinos who also managed to repel a cavalry charge that killed Colonel John M. Stotsenburg (Wikipedia 2011ac) (Fig. 1.76). Today, Quingua is known as Plaridel, Bulacan and highly urbanizing such that it is now included in Metro Manila's built-up area. Quingua soils is most likely a candidate for extinction because of encroachment of urbanization.

Matuya-tuya series was first described in Barangay Matuya-tuya, municipality of Torrijos, island province of

Fig. 1.75 Sibul series, soils of limestone origin, is associated with the historic solutional cave Biak-na-Bato where the revolutionary forces headed by Emilio Aguinaldo signed truce with the Spanish Governor General to end the revolution and for them to go into voluntary exile in Hongkong. The Sierra Madre mountain range forms the highlands not only of the municipality where Sibul is located, but of the whole province as well

Marinduque. Torrijos is very significant in Philippine history. It was here in Torrijos where the Battle of Pulang Lupa took place during the Philippine–American War on September 13, 1900 in which the Filipino forces under Colonel Maximo Abad routed the American forces under Captain Devereux Shields giving the Americans one of its worst defeats during the war (Wikipedia 2012i). "Pulang Lupa" meant red soil, but Matuya-tuya series is not red but grayish black to grayish brown due to poor internal and external drainage. This is a secondary soil formed from the deposition of washed-down sediments by gravitational and running water (Fig. 1.77).

What soil series best represents the American occupation of the Philippines and the ensuing commonwealth years? The nation's economy was mostly agriculture-based. Products included abaca, coconuts and coconut oil, and sugar. These were plantation crops. And those were economically stable years. But despite the revolution that threw the Spanish rule that transformed the natives who once cultivated the lands in freedom into mere tenants, and despite the initiatives on agrarian reforms to break up huge friar estates, peasants remained beholden to the landed lords. *Luisita* soil series best described the hacienda life. These are brownish gray soils characterized by the presence of sandy coarse materials in the lower subsoil (Fig. 1.78). This soil series was first described inside Hacienda Luisita in barangay San Miguel, Tarlac City, province of Tarlac. The hacienda has historic ties with former Philippine president Corazon Cojuanco Aquino and her son who also became Philippine president, Benigno Simeon Conjuangco Aquino III. The estate was named after Luisa Bru y Lassus, the wife of Don Antonio Lopez y Lopez, the first Marquez de Comillas, founder of Compania General de Tabacos de

Fig. 1.76 The commemorative monument of the Battle of Quingua, the old name of the municipality of Plaridel, Bulacan located at Agnaya, Plaridel (*Photo credit* Velasquez 2012, Wikipedia: Wikimedia Commons). Quingua soils are among the best for agriculture but with the rapid urbanization of Plaridel, this soil is going to be extinct, buried by urban development

Fig. 1.77 A *landscape view* of Marinduque which is one of those historic islands that gave the Filipinos a victory against the Americans during the Filipino–American War

Fig. 1.78 The soils of Tarlac is traditionally grown to sugarcane. But as Hacienda Luisita is now distributed to its farmers under the land reform program, farmers diversify to improve farm income. The hacienda life is symbolic of the years under the American colonial rule. The soils above are taken in Capas, Tarlac

Fig. 1.79 Palo soil series will always be associated not only with pre-Islamic Philippines as the kingdom of Takuranga but also with the liberation of the Philippines from Japanese occupation during the World War II. Palo is where Gen. MacArthur landed in October 1944 to start the military campaign to liberate the Philippines from the occupying Japanese Imperial forces (*Photo credit* (Orazunwa 2010), Wikipedia: Wikimedia Commons)

Filipinas, Sociedad Anonima (better known as the Tabacalera) where the hacienda was once part of their holdings conceived to take over the Philippine Tobacco Monopoly from the Spanish colonial government (Wikipedia 2012j).

1.4.7 The Second World War to the Present

Then we have the horrors of the Japanese invasion and the Greater East Asia Co-Prosperity Sphere. As we moved to the World War II, *Pilar* series, fine and sandy loam to silt loam soils, was first described in the municipality of Pilar, province of Bataan. It is in this municipality where the mammoth *Dambana ng Kagitingan* stands on the highest part of Mt. Samat, in barangay Diwa. This is a memorial shrine complex built to honor the gallantry of the Filipino and American soldiers who fought to defend the country from invading Japanese imperial forces during World War II. A memorial cross towered 92 m (302 ft) from the base, with an elevator and viewing gallery at the arm of the cross. *Palo* series once more reenters Philippine history as the site where General Douglas McArthur and flotilla of American soldiers returned to liberate the Philippines from the Japanese forces (Fig. 1.79).

Liberation from the Japanese invasion and the succeeding years of peace and development ushered urbanization and industrialization. *Marikina* series is classified as *Udorthentic Chromusterts* characterized by swelling

Fig. 1.80 Guadalupe series is very much like Novaliches series characterized by tuff, and both soil series being named after locations in Metro Manila are going extinct because of urbanization. *Photo* shows Guadalupe, Makati as a major Metro Manila road artery. Guadalupe as soil series is a symbol of the country's rapid urbanization after the war (*Photo credit* (Roque 2012), Wikipedia: Wikimedia Commons)

conditions during the rainy season and cracking during the dry season. It is obviously the best soils for the growing of rice but the worst for human settlements. The soil was first mapped in Marikina City, formerly part of Rizal but already part of Metropolitan Manila. This city is known as the Shoe Capital of the Philippines. As these soils are in highly urbanizing areas, most of these swelling–cracking soils must have been extinct by now, buried by urban development, a clear reflection of the state of use of Philippine soils. *Guadalupe* series, developed from tuff, is now at the heart of the skyscrapers of Makati City, a proud sign of Philippine economic development (Fig. 1.80). These two soil series, Marikina and Guadalupe, are ideal representatives of post-World War II Philippine condition.

But what soil series best represents the Philippines of the twenty-first century? A soil series that would sum up all that we have—a glorious coastal Lusung Empire that once was, an agricultural community desired and eventually enslaved by foreign powers, a witness to the courage of the Filipinos against colonial forces, liberated only to find itself enmeshed with its own political power struggle, economic initiatives that convert its best agricultural resources to residential and commercial, and industrial land uses, and now wrestles with forces of nature like floods that should have been blessings rather than an environmental problem because the silts carried by the flood renews the soil. Let us take a look at Obando soil series.

Obando series was first described in the municipality of Obando, Bulacan. Obando of course is a coastal town, certainly encompassed by what was the legendary and mighty Majapahit-influenced Lusung Empire. Obando is a religious pilgrimage site, where childless couples come for its religious fertility rites. With the continuous expansion of Metro Manila, this municipality is now an urbanized city and part of Metro Manila. Expectedly, Obando soil series (Fig. 1.81) as an important agricultural resource is threatened by extinction because of encroachment by urbanization. Expectedly also, being in flat and low-lying coastal plains as the area was formerly an estuary, the now commercial-residential-industrial-fishpond municipality is flood-prone. Obando is also struggling against river pollution brought about by the Tanza, Navotas dumpsite. There is also the Obando landfill that converts 44.4 ha of Salambao River into a garbage dump (Wikipedia 2011ad). Obando town got its name to honor Don Francisco de Obando y Solis Marquez, then Governor and Captain General of the Philippines who issued a decree in 1753 to separate this town from Polo. The Governor had an untimely death at the hands of the British during the Seven Years' War, and thus the honor of having the town named after him (Wikipedia 2011ad). Obando soil series is similar to Bugko but Obando is located at higher position and characterized by presence of marine shells. But the presence of marine shell fragments is not diagnostic for Obando because they occur below the control section. The morphology is also similar to Matimbo series but Obando is coarse textured (loamy) formed from nearly level, weakly developed beach ridge remnants on coastal plain landscapes over a substratum of fine sand and marine shells. Matimbo is fine textured (clayey) and occupies higher landscape position than Obando. Obando is classified as coarse loamy, mixed, isohyperthermic *Fluventic Eutropepts*. It is moderately well drained. These soils have been mapped also in Cavite, Leyte, Negros Occidental, Rizal, and Zamboanga del Sur totaling 16,885 ha in the reconnaissance soil surveys. It is interesting that in Bulacan, the semi-detailed soil survey of the province in 1987 decreased the area coverage of Obando series from 2,210 ha of Obando sandy loam to 593 ha of Obando loam. Hence, the effective national total for Obando series is now 15,268 ha. Obando soil series represents the sum total of the history of the Philippines from the beginning of its civilization to the present. Obando is the past, the present, and the future mirror of the status of Philippine soils, and of the Philippine society as well.

1.5 The Classification and Mapping of Philippine Soils

1.5.1 Basic Soil Classification and Soil Mapping Concepts

The soil is a continuum. However, the principles of soil classification enable us to organize our knowledge of the

Fig. 1.81 Obando series, the soil considered the representation of the past, the present, and the future of the Philippines. *Photos* show *landscape view* and soil profile of Obando series taken in Negros Occidental. The original Obando series in Bulacan is also on the way to extinction, buried by urban development

Fig. 1.82 Typical pedon of Camiguin series characterized by presence of big boulders of basalt and andesite as well as rock outcrops scattered in abundance on the surface soil. In classical soil survey, sampling is done purposively

natural phenomena and thereby allow us to understand the relationships among soils and to remember their properties.

In soil survey and classification, the concept of a *pedon* is introduced as a discrete object within the continuum. The pedon is defined as the smallest three-dimensional body of a soil which soil surveyors describe and sample. The pedon is normally described in terms of the morphology and physico-chemical characteristics of the soil profile. Since the sampling is purposive, a representative soil profile is presented in the soil survey report as the *Typical Pedon* to represent the soil mapping unit (Fig. 1.82).

The emphasis of soil classification is to define mappable classes. While it is the pedon that is described and sampled by the soil surveyors in the field, it is the *polypedon* that is classified and mapped and just as theoretical and as difficult to grasp and understand as the pedon. It has therefore a cartographic representation, the *soil mapping unit*, which can be considered as a discrete object. Given a geographic positioning system and a soil map, one can put one's left foot on one soil mapping unit and a right foot on adjacent soil mapping unit with a line in-between. But since we have already established that the soil is a continuum and in reality we could not really distinguish one soil body from another, the set of soil morphological data to characterize a soil mapping unit is normally presented in the soil survey report in a statistical mode format based on many sampled pedons as the *soil concept*, or referred to in other soil survey reports as the *central concept taxon* or the *soil taxonomic class* in soil survey text books and manuals, or the *soil genetic key* in the academe.

So in soil maps, we have tangible or discrete soil mapping units delineated, but the soil class given to name the soil mapping unit as presented in the map legend has a set of abstract and statistical mode format morphological properties referred to as the soil concept or its genetic key that differentiates it from other soil mapping classes (Fig. 1.83). A *Typical Pedon*, selected from among the purposively sampled pedons during the course of field survey work, is presented as a representative sample profile for the soil mapping unit.

Expectedly, there will be noncentral pedons or impurities that can be found in the area during the course of field survey. They still fall within the range and characteristics of the referenced soil series name, but are on the very edge of the allowed range. The *similar* inclusions are those pedons

Fig. 1.83 **a**, **b**, and **c** Three soil profiles of Lipa series. Despite differences in soil moisture (hence *color*) and interference by depositions of fresh ejecta coming from Taal Volcano, the central concept taxon or the genetic key distinctly distinguishes Lipa soil series from other soil series found in the country. The central concept of Lipa series is that it developed from volcanic tuff and underlain by tuffaceous rock

that fall outside the range in characteristics of the series, but are very similar to the reference series in terms of use and management. Maybe the color in the subsoil is slightly outside the range, or the texture of the underlying material is a loamy sand and the series only allows for sandy loam. These differences are slight, and in terms of use and management, they will behave the same (Soil Survey Staff 1993a).

Hence, the soil concept in our soil mapping units are not really that "pure" because of the map scale which limits the delineation of impurities that could be either similar or dissimilar soils. The mapped soils are generally *consociations* which allows 50 % purity and 50 % impurities (25 % similar soils and 25 % dissimilar soils). The Soil Survey Report discusses only the similar soils, and referred to in the report as the associated soils and their differentiae to the mapped soil series.

The *dissimilar* soils, however, are something different. They are expected inclusions in the map unit. They are in the landscape, but simply too small to separate as a distinct delineation. If the area is big enough for the map scale, it can be separated as another taxonomic unit. These inclusions behave differently than the named reference soils. However, the dissimilar soils are not identified nor discussed as inclusions to the mapped soil series in the Soil Survey Report (Soil Survey Staff 1993a).

Soil concepts can also be *complexes* or *associations*. Complexes and associations consist of two or more named dissimilar taxa or miscellaneous areas occurring in a known and definable pattern. The difference between the two is that the major components of a complex cannot be mapped separately at a scale of about 1:24,000. At this scale, an area of 0.4 cm^2 on the map represents an area of 2.3 ha on the ground. The named components of an association should be mappable at this scale, while unmappable in a complex. In either case, the major taxa components are sufficiently different in morphology or behavior that the map unit cannot be called a consociation (Soil Survey Staff 1993b).

It should be noted that the kind of map unit depends on the taxonomic or categorical level used to designate the components of the map unit—i.e. an association of great soil groups on one map may be called a complex of soil series on another map. In each delineations of either a complex or an association, the total amount of inclusions that are dissimilar to all of the major components does not exceed 15 % if limiting and 25 % if nonlimiting. *Nonlimiting inclusions* are inclusions of soils having less severe restrictions to use than the dominant soil of a map unit. They do not affect most predictions about the unit as a whole. *Limiting inclusions* have significantly more severe restrictions for use than the dominant soil or affects the feasibility of meeting management needs. A small amount in a map unit can greatly affect predictions. These are the most critical inclusions (Soil Survey Staff 1993b).

1.5.2 Soil Classification in the Philippines

The Philippines adopts the USDA *Soil Taxonomy* classification system. It is a six-hierarchical level of classification (Table 1.1). It should be noted that there are many soil classification systems in the world and *Soil Taxonomy* as developed by USDA is but just one of them.

Soil Taxonomy uses many word elements in its nomenclature to convey a common meaning in different classes. These cognate terms can be used to qualify subdivisions of taxa or phases of higher categories for general soil maps. An example is *aqu-* from "aqua", meaning water.

Table 1.1 The hierarchical system in *Soil Taxonomy*

Category	Differentiating characteristics
Order	Dominating processes that developed soil as indicated by major diagnostic horizons
Suborder	Control of current soil forming processes, emphasizing genetic homogeneity
Great group	Degree of expression of horizons according to similar kind, arrangement, and presence of diagnostic features
Subgroup	Blending of soil forming processes—intergrades or extragrades; where we have none, we have typic concept
Family	Internal features influencing soil—water relations that affect response to management
Series	Homogeneity of composition and morphology—kind and arrangement of horizons, color, texture, structure, consistence, etc.

Source McSweeney and Grunwald (1999)

Fig. 1.84 **a** and **b** At higher level of *Soil Taxonomy*, beach soil can be classified as *Typic Ustipsamment* while a lahar deposited area is classified as *Vitrandic Ustorthents*. The soil classification can be used to name the mapping units. At the lowest level of the hierarchical classification system is the soil series, usually named after the place where it was first described

The adjectival form "aquic" is used to identify subgroups of moderately wet soils in great groups of soils that are predominantly not wet. The structure of *Soil Taxonomy* is such that the cognate terms, also referred to in the Soil Taxonomy literatures as the formative elements, are carried as we move from one hierarchical level to the next; and hence, the names of taxa in the four highest categories of *Soil Taxonomy* (order, suborder, great group, subgroup) can be used to designate soil map units. The hierarchical or categorical level depends mainly on the scale of the maps, but more than one level can be used in one survey and on maps of the same scale.

As an example of soil mapping at subgroup level, we can cite soils of sandy profile, one is located in the beach and the other is weathered lahar derived from Mt. Pinatubo's eruptions. Both are young soils with no horizon development, both are sandy and have the same color, but they differ in origin and location—the first is deposited by sea waves and located along the seashores while the second is deposited by a volcano and located on a river terrace. The beach soil is mapped as *Typic Ustipsamments* while the lahar deposit is mapped as *Vitrandic Ustorthents*.

The subgroup level, presented as the first name in a bi-nomenclature system similar to plant and animal taxonomy, is differentiated in terms of blending of soil forming processes, the intergrades or the extragrades. The "Vitrandic" term which signifies high amount of volcanic glass clearly differentiates a volcanic deposition as against a sea wave deposition, which in this case is "Typic", meaning there is no intergrade nor extragrade to other soil orders.

The second name consists of formative elements for the great group, suborder, and order levels. The "Ust-" or the first syllable in the second name designates the great group classification and refers to the ustic soil temperature regime. The mid syllable or the suborder "-psamm-" is a formative element that means sandy while the "-orth-" formative element means the soil temperature is greater than 20 ˚C. The last syllable stands for the soil order and "-ent" is the formative element for Entisols. These two soil mapping units are young soils with no discernable profile development, and both soils fall under the order Entisols (Fig. 1.84).

1.5.3 Soil Mapping at Higher Levels of Soil Classification

Of the 12 soil orders in *Soil Taxonomy*, nine can be found in the Philippines (Table 1.2).

Three soil orders in *Soil Taxonomy* are not found in the country—Gelisols (permafrost soils), Aridisols (soils of the dry region), and Spodosols (soils with subsoil accumulations of humus and sesquioxides). It should be noted that considering advances of pedology in the Philippines, the presence of Spodosols in the country is now a subject of study. There are Spodosols in the Cordillera-Sierra Madre mountains with soil formation and development conditions

Table 1.2 Formative elements for the soil orders and their differentiating characteristics

Soil order	Formative element	Distinguishing characteristics
Entisols	-ent	Recently formed soils, no profile development
Inceptisols	-ept	"Embryonic soils", with few diagnostic features
Vertisols	-ert	Shrinking and swelling dark clay soils
Andisols	-and	Soils with andic properties
Mollisols	-oll	Grassland soils of steppes and prairies
Alfisols	-alf	High-base status soils with finer-textured subsoils
Ultisols	-ult	Low-base status soils with finer-textured subsoils
Oxisols	-ox	Low activity soils
Histosols	-ist	Organic soils

Source Buol et al. (2003)

similar to the Spodosols of Vietnam. The soil series we are yet to establish.

At higher level of soil classification, Soil Taxonomy Map of the Philippines at 1:2,000,000 scale is available and published in 1995. The soil mapping units are up to soil great groups. Earlier, in 1972, Mariano and Valmidiano published the soil map of the Philippines at 1:1,600,000 scale using soil great groups to compose the map units.

1.5.4 Soil Mapping at Lower Levels of Soil Classification

1.5.4.1 Soil Maps at Soil Family Level

Some provinces have been mapped at soil family level which highlights internal features influencing soil–water relations. At this categorical level, the practice in the Philippines is to name soils based on the following sequence: Broad textural class averaged over the control section—Mineralogy class—Soil temperature regime class—Soil subgroup—Soil great group—Slope—Erosion or Flooding class. Example: *Very fine, mixed, isohyperthermic, Typic Pellusterts, 3.0—8.0 % slope, no apparent erosion.* The map legend is presented as a fraction: the numerator consists of the symbols for Soil Order, Textural Class, Subgroup, and Great Group. The denominator consists of slope class and flooding/erosion class. The mineralogy class and the soil temperature regime are not included in the map legend.

The provinces with soil maps available at family level are Bulacan, Rizal, Laguna, Bataan, Nueva Ecija, Cavite, Negros Occidental, Davao Oriental, Bohol, Iloilo, and Aurora.

1.5.4.2 Soil Maps at Soil Series Level

Soil series and phases of soil series is the most common way of naming soil map units. Perhaps the most important function of the series category in *Soil Taxonomy* is interpretive uses. Soil series are commonly established because there is a need to recognize separate groups of soil properties because of different uses and management.

The process of establishing soil series or revising concepts of existing soil series requires a very systematic and uniform procedure. The distinctions between any one soil series and another must be large enough to be consistently recognized and differentiated in the field. Secondly, the characteristics used to differentiate series must be observable and measurable within the series control section. The soil series is the most narrowly defined and most homogenous taxon; and it most nearly meets the requirements for categorical detail demanded by the objectives of detailed soil resources assessments. Usually, the soil series is named after the geographical area where it was first described or where it is most prominent. Since many of the soil series have been established during the reconnaissance soil surveys of the 1930s, 1950s, and 1960s even before there was *Soil Taxonomy*, the future of soil survey activities in the Philippines would center on and involve validation and redefinition of the soil series concepts so that they can be properly placed in the higher hierarchical levels of *Soil Taxonomy*. We also need to update the attribute data as these were originally geared towards agronomic uses rather than towards taxonomic classification.

Based on the old system of classifying soils at soil series level, there are nine major groups of soil series in the Philippines and based on the physiography, parent materials, mode of formation, and the kind of soil profile. Although we are redefining and regrouping our soil series under semi-detailed or detailed soil surveys, we include in this chapter the original soil series key to enable the younger generation of pedologists to look into the thought pattern of those who originally described and named these soils in earlier reconnaissance soil surveys. This original soil series grouping is a classic work and referred to every now and then even by younger soil surveyors.

Soil Profile Group 1 These are soils formed on level to nearly level recent alluvial fans, flood plains, or other alluvial deposits subject to river flooding, having profiles underlain by unconsolidated materials. Most of the soils classified as Entisols belong to this group. The Group 1 soils could be further subgrouped into Class A and Class B.

Class A are soils with medium to coarse texture and are moderately well or extensively drained. The relief is generally nearly level to level. The soil series under these are Angeles, Bugko, Buguey, Dadiangas, Gasan, Guintabuan, Kaunayan, La Paz, Luisita, Magcalon, Malandag, Obando, Patungan, Pulupandan, Sinolan, Umingan.

Class B are soils on older alluvial fans or terraces with fine to very fine textures, poorly or somewhat poorly drained either because they have high water tables or an excess of water due to flat position. The relief is generally level to slightly sloping or gently undulating. The soil series under these are Balongay, Bay, Ligao, Macabare, and Pawing.

Soil Profile Group 2 These are soils formed on young alluvial fans and low terraces subject to seasonal flooding for short periods. They have formed slight or weakly developed profiles with slightly compact subsoil horizons. Most of the Inceptisols belong to this group. The Group 2 soils are further subgrouped into Class A, Class B, and Class I.

Class A are the coarse textured soils and extensively drained, relief is generally nearly level to level. The soil series are Banga, Bauyan, Pilar, San Manuel, Sara, and Sorsogon.

Class B have fine to very fine textures and poorly or somewhat poorly drained soils, relief is generally level to slightly sloping or gently undulating. The soil series belonging to this class are Bigaa, Candijay, Hernani, Indan, Malinao, Mandawe, Marikina, Maydolong, Mogpog, Sinapangan, Timaga.

Class I developed from the decomposition of organic deposits. The soils are very poorly drained, relief is generally level, and the water table is usually at or very near the surface. So far, only Dolongan series has been mapped under this class.

Soil Profile Group 3 These are soils formed on older alluvial fans, alluvial plains, or terraces above river flooding. Shallow flooding from tributary creeks and impeded local runoff may occur. They have moderately developed profiles, moderately dense subsoils underlain by unconsolidated materials. These are generally deep soils, and not underlain by claypans or hardpans. The soil series could be further subgrouped into Class A and Class B depending on texture and drainage characteristics.

The Class A or the coarse textured and well-drained soil series are Baluarte, Bantog, Calape, Donsol, Kitcharo, Legaspi, Lutayan, Palo, and Siaton.

The Class B or the fine textured and poorly drained soils are Aborlan, Babuyan, Bancal, Barcelona, Bascaran, Brookes, Busuanga, Cabahuan, Cabangan, Candaba, Dagani, Isabela, Kabacan, La Carlota, Libi, Libon, Maapag, Mabini, Mailag, Makatao, Maligaya, Mambajao, Manapla, Matina, Matuya-tuya, Mayan, Palapag, Pañganiran, Patnogan, Pila, Quingua, San Fernando, Sta. Filomena, Sta. Rita, Silay, Siliman, Tamontaka, Tingib, Victorias, and Zaragosa.

Soil Profile Group 4 These are soils formed on older plains, fans, or terraces having dense clay subsoils underlain by consolidated materials. They have no flooding hazards. These are claypan soils. As such, we only have Class B or fine textured and poorly drained soils under this profile group. The soil series under Class B are Bago and Cauayan series.

Soil Profile Group 5 These are soils on older plains, fans, or terraces having subsoil or lower subsoil layers generally underlain by consolidated materials. These soils have cemented rock-like hardpan horizons that do not soften with water. These layers may be tuff, high lime-shell, lime-iron, or iron cemented. We have only Class B and Class C under this profile group.

The Class B or finely textured and poorly drained soils are Cadiz and Calumpang.

The Class C soils are on older terraces or upland areas developed from the weathered products of volcanic ejecta or the soil development was influenced by successive volcanic eruptions. These soils have undulating to rolling and hilly relief. The soil series under this class are Guadalupe, Lipa, Maahas, Magallanes, Novaliches, Prensa, and San Fabian.

Soil Profile Group 6 These are soils on older terraces or upland areas having dense clay subsoil resting on moderately consolidated materials. The higher coastal terraces soils belong to this group. They can be further subgrouped into Class B, Class C, and Class K.

The Class B or finely textured and poorly drained soils has only one soil series so far—Kamandag.

The Class C or the volcano-influenced soils are Buenavista, Carmona, Ibaan, Pasil, and Taal.

The Class K are the soils of the upland areas developed from a mixture of two or more kinds of rocks such as igneous-sedimentary, igneous-metamorphic, sedimentary–metamorphic, etc. We have so far mapped Castilla soil series under this class.

Profile Group 7 These are soils on upland areas developed from hard igneous bed rock materials. These soils are formed from the underlying igneous rock and occupy rolling to steep topography. The soils are further subgrouped into Class C, Class D, Class J, and Class K.

The Class C or the volcano-influenced soils are Langkong, San Jose, Tagaytay, and Tupi.

The Class D are soils in upland areas developed from hard igneous bed rock materials. The igneous rock may be andesite or basaltic rocks. The relief is generally rolling to hilly or mountainous. The soil series belonging to this class are Adtuyon, Alaminos, Annam, Antipolo, Arayat, Baguio, Balanacan, Baliangao, Banto, Barotac, Basco, Bayho, Bulaoen, Buldun, Burgos, Calauaig, Camiguin, Cervantes, Coron, Dolores, Guimaras, Guimbalalon, Jasaan, Kidapawan, La Castellana, Legua, Libertad, Luisiana, Malitbog, Maranlig, Nupol, Paete, Parang, San Rafael, Sapian, Tacloban, Tagburos, Tagum, Tapul, and Tarug, Tigaon, Timbo, Tiptipon, Tugbok, and Zamboanguita.

The Class J are soils that developed from conglomerate and agglomerate rocks. The soil series are Boac, Uyugan, and Sabtang.

The Class K soils which developed from the mixture of two or more kinds of rocks are Casiguran, Guinabotan, Macolod, Malalag, Mauraro, Mayon, and Miral.

Soil Profile Group 8 These are soils in upland areas developed from consolidated sedimentary rocks. These are soils that have been formed from stratified residual materials such as limestone, sandstone, and shales. The topography is generally from rolling to steep. The soils could be further subgrouped into Class E, Class F, Class G, Class I, and Class K.

The Class E soils are on older terraces or upland areas that developed from shales. They have generally rolling and steep relief. The soil series are Alimodian, Bani, Bantay, Bauang, Cabantian, Carig, Catbalogan, Himayangan, Kudarangan, Maasin, Madunga, New Iloilo, Palombon, and Ubay.

The Class F are soils on older terraces or upland areas developed from weathered products of limestone. The relief is from rolling to steep mountainous. The soil series belonging to this class are Binañgonan, Bolinao, Faraon, Inabañga, Medellin, Sibul, and Lugo.

The Class G soils are on older terraces or upland areas developed from the weathered products of sandstone. The relief is generally rolling and steep. The soil series in this class are Aroman, Balut, Banhigan, Culis, Ilagan, Lourdes, Matulas, Quilada, San Juan, Tarlac, and Villar.

The Class I or the organic soils are Camansa and Mantalongan.

The Class K which developed from two or more kinds of rocks are Batuan, Bulusan, Caromatan, Cataingan, and Rugao.

Soil Profile Group 9 These are soils on upland areas developed on soft consolidated materials. These soils are generally formed on the marly or soft sandstone-like materials. The topography is generally from rolling to steep. We have only Class F or limestone soils under Group 9, the Sevilla series.

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2 The Soils of the Lowlands

Abstract
The lowland soils represent the heavy use of our land resources being easily accessible to the general populace. These are the flat areas located between the sea and the surrounding uplands, hills, and mountains. The alluvial flood plains, being dissected by a meandering river, are regularly visited by floods. Yet, great civilizations of East and West both of the past and of the present were built on river banks because of the agriculturally productive soils and the ease of navigation and transport even to the hinterlands. These are the best areas for agriculture since the farms are annually renewed by the silt that comes with the flood when the monsoon season comes. Ironically these days, because of the pressure of population increase and urban expansion, agriculture finds itself eased out as it competes with residential, commercial, industrial, and recreational land uses. As the farms give way to the residential subdivisions and industrial estates, the centuries-old traditional Filipino houses, slightly raised above grounds and standing on stilts, are abandoned in the quest for more living space. When the annual floods come, the social, economic, and environmental costs are staggering. We also greatly invest on flood protection infrastructures that address more the effects rather than the causes of floods. Understanding our lowland soil resources incorporates a holistic perspective in the development planning process. This chapter dissects the lowland soils into its geographic setting for land management purposes—(1) soils of the coastal areas, (2) soils of the river and lake terraces, and freshwater swamps, (3) soils of the narrow and broad alluvial valleys and flood plains, and (4) soils of the infilled localized valleys, collo-alluvial plains, and fan terraces. These soils are developed from alluvial deposits, with slopes ranging from 0 to 8 %, altitude of less than 100 m above sea level, and temperature of more than 25 °C. This chapter includes unpublished but recognized soil series through more recent mapping projects or past soil surveys with missing reports even in the archives.

2.1 The Soils of the Coastal Areas

As an archipelago of more than 71,000 islands, the Philippines has a very long coastline, about 36,289 km. The coastline is irregular, with several gulfs, bays, and islets. About 10 of the largest cities in the country are located along the coast, and if we include the Manila Bay area which is an important economic resource with many competing uses, we can say that about 60 % of the total population inhabits the coastal areas.

Coastal soils were formed by dynamic degradational and aggradational processes. Coastal sediments came from inland (called the littoral zone) and from the offshore zone and beyond. Thus, despite the continuing pounding of the coast by the waves and the resulting wave erosion, river sediment deposits are much more. Fluvial erosion is the chief sediment source that eventually became soil. Very few coastal soils in the Philippines, if ever there are, were formed from bedrock. The soils of the coastal plains are flat and low lying.

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Fig. 2.1 Beach sand is not considered true soil because it has undeveloped soil profile

Fig. 2.2 Coastal sand dunes along the coast of Paoay, Ilocos Norte

As an archipelago, coastal soils constitute economically important natural resource and they play an important role in food production and other human activities. Major limitations are seawater intrusions for agriculture, and the presence of acid sulfate soils for aquaculture. The coastal areas are also subjected to several hazards like flooding and storm surges during tropical cyclones and tsunamis during earthquakes. Despite these, changes have occurred in the country's shorelines due to reclamation projects, construction of ports, coastal roads, housing, and other urban development.

2.1.1 Beach Sand and Coastal Sand Dunes

Beach sand (Fig. 2.1) that line many of our shorelines is not considered true soil because it has undeveloped soil profile. In old Soil Survey Reports, *Patungan* series were mapped along the shores of Cavite for pale gray to almost white beaches with substratum of marine conglomerates and tuffaceous rocks (Alicante and Rosell 1938). This soil series was deleted from the list of established soil series in updated soil series maps owing to very small area coverage nowadays to meet the definition of a soil series owing to intrusion of urbanization. These soils are reclassified as Beach Sand. Beach sands are found along coastal margins, the accumulation of action of waves and currents. Without well-defined soil characteristics these are azonal in nature and consisted of single stratum of water-deposited sands. Beach sands generally occupy less than 1 % of the total land area of the country. But this is quite a preferred settlement site and with its nearly pure silica composition used in the manufacture of glass, beach sands are of far greater economic importance that its small percentage area implies.

In the Philippines, we also have *coastal sand dunes* along the coast of Ilocos Norte (Fig. 2.2), a rare example of aeolian deposits or wind-blown sediments accumulated and sheltered from wave and current actions. The Ilocos Norte Sand Dunes is unique in the country and stretches from the municipality of Currimao in the north and winds its way to La Paz, Laoag City, then to Suba, Paoay, and finally to Pasuquin in the south with a total of 135 sq km. Suba has the most extensive and continuous stretch.

2.1.2 Soils of the Active Tidal Flats

This is a stretch of land consisting of sandy or muddy sediments exposed at ebb tides. It could also include adjacent hinterlands and littoral waters stretching from the intertidal area. These are not actually flat but gently slope down towards the sea. These areas are flooded and drained with each rise and fall of the tide. Active tidal flats are either in their original or rehabilitated mangrove condition or developed as fishponds or salt beds. Muddy tidal flats usually show dendritic pattern with winding courses and point bars. Sandy tidal flats on the other hand, do not have well-defined banks and very few tributaries. Tidal flats are built up from clay-sized and fine silt-sized particles carried to the coast by rivers. These silt and clay particles flocculate upon meeting salty water and form larger aggregates to settle out as mud in quiet coastal waters. The mud is carried in by the incoming tide and deposited before the tide reverses.

Bongliw series is the most extensive soil of the active tidal flats. It was originally described in Barangay Bongliw, Laoang, Northern Samar in 1989. It is a fine, mixed, isohyperthermic *Typic Hydraquents.* The parent material is fluviomarine, and the soils are poorly drained. The cultivated top soil extends down to 20 cm and is gray clay loam with yellowish red mottlesand subangular blocky structure. The gleyed subsoil is greenish gray clay loam with dark

Fig. 2.3 An active tidal flat in natural state is often covered by mangrove or nipa forest

Fig. 2.4 A tidal swamp is continuously flooded by salty tidal water of mixed alluvial and marine deposits. The soils are classified based on discernable texture

yellowish brown mottles and reaches down to 120 cm. The gleyed substratum is dark bluish gray clay loam, has no mottles, and has many partially and highly decomposed plant remnants. About 47,265 ha of Bongliw series were mapped in Visayas (Fig. 2.3).

2.1.3 Saline Soils of the Estuaries and Tidal Swamps

An estuary is a transition zone subjected to both marine and river influences with seawater and freshwater inflows. Jara-Marini et al. (2009) described it as a partly enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea. With constant mixing of saline water and freshwater, the dominant environment is characterized by salinity, sulfate reduction, and autotrophic nutrients.

Saltwater and freshwater marshes or swamps are classified as *Hydrosols* in old soil survey reports and as *Hydraquents* when correlated to Soil Taxonomy in updated soil survey reports.

Tidal swamps, continuously flooded by salty tidal water of mixed alluvial and marine deposits and with discernable texture but have little or natural soils are classified and mapped either as *Clayey Tidal Swamp, Loamy Tidal Swamp,* or *Mucky Tidal Swamp*.

Soils developed on this landform are classified either as *Balongay* or *Sicaba* series. Soils of this landform are saline with the intrusion of seawater or capillary rise of saline water. They are sandy loam, loamy sand, to clay loam (Fig. 2.4).

Soils underlain by unweathered and weathered pure marine shells

Balongay series (Plate 1A), classified as *Typic Fluvaquents*, is an estuarine soil and was originally mapped on the northwestern part of Calabanga, Camarines Sur on the whole area of Cabusao town, along the Bicol River and facing San Miguel Bay. The relief is level to nearly level. The elevation is from 3 to 5 m above mean sea level. Most of the year, a major portion of the series is under water. The parent material is mixed of alluvial and marine deposits, usually mapped along the banks by the mouth of river (estuarine plains) extending as much as 2 km inward. The soils are influenced by intrusion of salty water during high tides when summer comes. During heavy rains and typhoon months, the area is affected by slight to moderate flooding. Balongay series is characterized by slightly weathered shells of uniform size in the substratum. The surface soil is dark brown, grayish brown to nearly black clay, sticky and plastic when wet, frible when dry; and with an average depth of 20 cm. If rolled and dried, the soils become hard and difficult to pulverize. When baked, the clay cracks. In the elevated or unsubmerged places, the average depth of the topsoil is about 15 cm, the surface soil is lighter in texture. The subsoil is light gray clay, loose, with highly weathered and uniformly sized marine shells embedded to indefinite depth. The soil drainage is very poor and the infiltration rate is slow to very slow. The water table is very shallow. During high tides, some portions of the series near the shore are covered by brackish water, sometimes converted to fishponds. The vegetation is mostly grass. Mangrove species grow in the swamps, especially near the mouth of rivers. Rice is grown on patches not inundated by brackish water. About 5,400 ha of Balongay clay were mapped in Camarines Sur (Lucas et al. 1965).

2.1.3.1 The Acid Sulfate Soils Underlain by Loamy Materials

The *Sicaba* tide water soil series was originally mapped in barangay Sicaba, Cadiz City, Negros Occidental. It belongs to coarse, loamy isohyperthermic *Haplic Sulfaquents*. These

Fig. 2.5 A beach ridge taken in Palawan, with the Saint Paul mountain dome visible behind where the famous underground river can be found

are poorly drained soils of fluvio-marine parent material. Sulfaquents have strong clay component, rich in organic matter from rotting wetland vegetation, and have high mineral content primarily iron. These tidal marsh soils are anaerobic and contain sulfur-reducing bacteria which turn the sulfates in the seawater into iron sulfide or pyrite and release sulfuric acid, creating the distinct smell of a saltwater marsh at low tide. The Sicaba soils are very acidic with a pH of 3.2. This is a typical acid sulfate soil in the Philippines. Incidentally, a major complaint of fishpond owners who grow prawns in these soils is stunted growth. The topsoil is about 30 cm deep, very dark gray sandy clay loam. A transitory AC horizon to 50 cm depth is observed, similar to the A horizon but has partially decomposed plant remnants. The substratum is dark gray sandy loam; and reaches to 120 cm (Alicante et al. 1951). This series covers 89,568 has for the whole country.

2.1.3.2 Soils of the Beach Ridges and Swales

Beach ridges are elongated, narrow mounds at the back of an active beach above the mean high tide and wave zone, roughly parallel to the waterline. As the coastal plain is uplifted, the changes are preserved as succession of alternate ridges and swales. A swale is a shallow trough between ridges on a beach running parallel to the coastline, and usually a swamp. Sandy beach ridges are former shorelines (Fig. 2.5).

The soils on beach ridges and swales can be classified either as *Bugko, Buguey, Laylay, Kaunayan*, or *Magsaysay* series. Soils developed from such recent coastal deposits are usually coarse textured with gray to grayish black color. These soils developed from accumulation of marine and alluvial materials.

Bugko and *Buguey* are similar soils; however, Buguey has deeper A horizon, extending almost near to the control section. Bugko also developed over sandy substratum and characterized by absence of marine shells while Buguey has similar sand stratum but with marine shells. *Laylay* has many stones and boulders in the lower C horizons. *Magsaysay* series would be similar to Laylay but has thinner topsoil. *Kaunayan* series has few coralline gravels within 25–45 cm that increases with depth, and underlain by substratum of white and friable sand. These soils of the beach ridges and swales are usually covered with coconuts, fruit trees, bananas, and grasses.

2.1.3.3 Soils Underlain by Structureless Sandy Materials, Absence of Marine Shells

Bugko series (Plate 1B) was originally identified at Barrio Bugko, municipality of Mondragon, Northern Samar and classified as *Typic Tropopsamments* in the older scientific literatures, but already updated to *Typic Ustipsamments*. The soil is derived from the accumulation of marine and alluvial materials such as those deposited by the Pacific Ocean and the nearby rivers. These are well-drained soils. Bugko is very similar to Obando series but they differ in physiographic position as well as in the absence of marine shells which are present in Obando soils. Bugko series is also found on the shorelines of Quezon province. About 19,219 ha of Bugo sand, loamy sand, and sandy loam were mapped in Samar and Quezon provinces. The plowed surface soil is dark grayish brown, dark brown to almost black loose and structureless fine sand to loamy sand or sandy loam, reaching to a depth from 20 to 30 cm. The C horizon (no B horizon) is light brown to light grayish brown or yellowish brown, loose and structureless fine sand or loamy fine sand. The lower C horizon is light yellowish brown to light brown sand, loose, and structureless, and has common manganese–iron concretions. The crops grown are coconut, sweet potato, and other root crops or tubers, peanut, vegetables, and some fruit trees (Simon et al. 1975).

2.1.3.4 Soils Underlain by Structureless Sandy Materials, Presence of Marine Shells

Buguey series (Plate 1B) was first mapped in Cagayan province and classified as mixed isohyperthermic *Typic Udipsamments*, formed from fluvio-marine sediments deposited by waves or from recent coast deposits of sandy materials from rivers and ocean. The place Buguey also has an old history, established in 1596 as a Dominican ecclesiastical mission, when the Philippines was colonized by Spain. The name was derived from the Ibanag word *bugay* which means "shipwreck." The distinguishing characteristic of this series is the presence of marine shells in the substratum. The soils are deep sandy textured, coarse, loose, and structureless. The relief is slightly undulating. The external drainage is good and the internal drainage is excessive. These were mapped in the provinces of Cagayan, Mindoro, and Quezon covering some 18,639 ha. The surface soil is brownish gray to dark brown, loose and structureless fine sandy loam; and the depth is from 10 to 30 cm. The C horizon (no B horizon) is dark brown in the upper and could be olive brown in the lower; sand depth could reach up to 150 cm; and few marine shells are observed in some places. These soils are covered by shrubs and the cultivated areas are planted with coconut, vegetables, and root crops (Dagdag et al. 1967).

2.1.3.5 Soils Underlain by Sandy Materials, with Stones and Gravels

Laylay series is named after Barangay Laylay, Boac, Marinduque. It is classified as mixed isohyperthermic *Typic Udipsamments*. This is a recent soil resulting from the accumulation of sandy materials from the sea. There are no coralline materials on the substratum but there are many embedded stones and boulders. The relief is almost level and almost sea level elevation. The soil is excessively drained. The soils are usually planted with coconut, or covered by shrubs and bushes. This soil series has been mapped besides Marinduque, also in Quezon and Romblon provinces covering some 10,175 ha. The surface soil extending from 20 to 30 cm is grayish brown, slightly compact, and structureless sandy loam. The substratum (no B horizon) reaches down from 80 to 100 cm and brown to grayish brown compact sandy loam to sand, with waterworn gravels and pebbles. The gravels and pebbles become more abundant in the lower portion of the horizon (Salazar et al. 1962).

2.1.3.6 Soils Underlain by Sandy Materials, with Corraline Gravels

Kaunayan series was first mapped along the shorelines of Kaunayan, one of the barangays or villages of Patikul, Sulu, classified as *Typic Udipsamments*. It consists of recent coastal deposits mostly due to wave action. This series is found adjacent to the beach over long narrow strips of level land. The water level is shallow, the external drainage is fair while the internal drainage is rapid. The sandy loam surface soil is brown, dark brown to almost black, reaching down from 20 to 25 cm. The subsoil is easily distinguished from the surface soil by marked differences in color and texture and consists of grayish brown to light grayish medium sand that could reach down to 45 cm in some areas. Coralline gravels are found in the horizon. The substratum consists of light gray to almost white medium sand. Some marine shells and coralline gravels and stones are found in this layer. Coconut thrives well on this series. The other crops grown are banana, lazones, citrus, and other permanent crops.

Fig. 2.6 A former tidal flat is not affected by ebbing currents and above tidal swamps

Bamboo and betel nuts also abound in this soil series. About 5,005 ha of Kaunayan sandy loam were mapped in Sulu province (Sindayen et al. 1965).

2.1.4 Soils of the Old or Former Tidal Flats

These were lands formed on the landward side of the coastline and unaffected by ebbing currents, the soils on broad flat low-lying deltaic plains adjacent to and above the tidal swamps. They were formerly active tidal flats but because of the dynamics of the wave action, continuing sand deposition, and infilling built up the land; and with time, eventual soil formation and development ensued. There is an old saying in Filipino that the sea reclaims what used to be its domain. Although these areas are no longer affected by the rise and fall of tides, these poorly drained soils are usually subject to seasonal flooding and affected by salty tidal water.

The soils of former tidal flats were developed from recent marine deposits (Fig. 2.6). They are heavy to medium-textured soils with dark gray to grayish black color. They are shallow to moderately deep soils. Soil pH ranges from 6.5 to 7.8. They are planted to salt-resistant varieties of paddy rice, others were developed into fishponds and built-up areas. The prominent soil series are *Maydolong*, *Libmanan*, *Hermani*, *Pulupandan*, *Gasan*, and *Obando*.

2.1.4.1 Soils Underlain by Clay Loam to Clay, Below is a Mix of Marine Sediments and Weathered Limestone Fragments

Maydolong series was initially mapped in Maydolong, Eastern Samar. These are poorly drained and ponded soils; and as such, generally planted to paddy rice. This soil series is characterized by slightly compact subsoil horizons. The soil is classified as fine, isohyperthermic *Aeric Endoaquents*. It is derived from mix of local alluvial deposits from higher surrounding areas and marine sediments. There are partially and highly weathered limestone fragments in the substratum. The soil is moderately shallow. The relief is nearly leel which rises just a few centimeters above mean sea level. It is under water part of the year. The common vegetation are *ticog* (*Fimbristylis globulosa, Retz., Kunth*) usually weaved into mats, hats, bags, and cushion; and *tikiw* (*Scirpus grossus*), a wild variety of seagrass family and utilized to produce container baskets, hampers with lids, bags, rugs, carpets, placemats, jars, and other decorative items. The cultivated areas are grown to rice and *galiang* (*Alocasia macrorrhiza,* L., Schott), a tuber. Most of the Maydolong series were mapped in Samar province covering 1,343 ha. The topsoil is grayish brown to very dark gray friable and granular silt loam to clay loam and could be from 15 to 30 cm thick. The substratum (no B horizon) is dark brown to very dark gray silty clay loam to clay. Below 75 cm or lower is very light brown fragmental and massive corals and highly weathered limestone fragments. These soils are also found on estuarine plains (Simon et al. 1975).

2.1.4.2 Soils Underlain by Muck with Partly Decomposed Organic Matter

Masantol series was named after the municipality of Masantol, Pampanga province and claimed to be the hometown of the father of Andres Bonifacio, the founder of the revolutionary movement against Spanish rule in the Philippines. The soil series, however, first appeared in the semi-detailed soil survey report of the nearby Bulacan province. This soil series consists of very poor to poorly drained soils on broad flat low lying deltaic plains adjacent to and above the tidal swamps. The soils were formed from the accumulation of mixed alluvial materials over a moderately deep organic matter deposit. In the representative profile, the surface soil about 20 cm thick is gray clay with yellowish red mottles. Below this and up to a depth of 96 cm is gray, dark gray, or very dark gray silty clay with mottles of dark brown or brown in the upper part and greenish gray in the lower part. The next layer to a depth of 230 cm is muck with partly decomposed plant materials with strong odor of hydrogen sulfide gas. A greenish gray silt loam mixed with decomposed organic matter underlain this layer. The series is subject to slight to severe flooding during wet season, normally 10–50 cm depth or more for a period of 6–8 months annually. It is also subjected to brackish water flooding during high tide periods. Most of the soils are grown to paddy rice when flood water subsides during the months of September to early part of November. Some areas are utilized for fishponds. This soil series is associated with the coarse loamy Dolongan soils. But Dolongan series has thinner mineral surface layer. Masantol series occurs on relatively low-lying alluvial terrace landscape and the depth to organic matter is deeper compared to that of Dolongan series. The soils are classified as *Typic Tropaquepts.* This soil series covers 3,532 ha in Bulacan province.

2.1.4.3 Soils Underlain by Clay, Developed from a Mix of Marine Sediments and Alluvial Materials

Libmanan series was first described in Libmanan, Camarines Sur. It is an old town dating back to 1574. Libmanan series is very fine mixed isohyperthermic *Aeric Endoaquepts*. The parent material is fluvio-marine, poorly drained, and this soil series is usually planted to paddy rice nonirrigated. The soil is rather deep, and the gleyed B horizon extends up to the control section. The surface soil is very dark gray clay that reaches down to 30 cm. The subsoil is grayish brown to light brownish gray clay with olive yellow mottles and extends down to 150 cm (Lucas et al. 1965).

2.1.4.4 Soils Underlain by Coralline Sand with Admixture of Silt, Clay, and Organic Matter

Hermani series was first described and delineated in the coastal municipality of Hermani, province of Eastern Samar. This series is classified as *Typic Epiaquept* and developed from local alluvium and marine deposits. The extent of soil formation from marine deposits can be seen in the substratum where the coralline materials, coralline limestone are found. The alluvial materials came from the surrounding areas and contributed to the formation of the upper layers of the soil profile. The surface soil is grayish brown to very dark gray, fine to coarse granular loam, the depth rating from 20 to 30 cm from the surface. The subsoil consists of an upper and a lower layer. The upper layer is yellowish brown to grayish brown, coarse granular to blocky silty clay loam; depth is 70 cm from the surface. The lower subsoil is brown, grayish brown to dark grayish brown and blocky silty clay; the lower boundary is 100 cm from the surface. The substratum is coralline sand with admixture of some silt, clay, and organic matter. It is loose and friable. The depth extends beyond 150 cm from the surface. Hernani loam covers 269 ha in Eastern Samar (Simon et al. 1975).

2.1.4.5 Soils Underlain by Almost Purely Marine Shells

Pulupandan series (Plate 1E) was first mapped in Pulupandan, a municipality of Negros Occidental. As this is an island province, the coastal town faces Panay Gulf and across is nearby Guimaras Island. It got its name from "pulo sang pandan", meaning isle of pandan. Pandan is an aromatic tropical plant (*Pandanus amaryllifolius*) and used widely in Southeast Asian cooking as a flavoring. There were wild forests of pandan during the early days before it became a busy seaport. Just like Obando and Matimbo, Pulupandan soils developed over sandy substrata mixed with white marine shells at depth from 100 to 150 cm. Puludandan series have darker surface soil, more marine shells in the substratum, and denser substratum than Obando series. The substratum is almost pure marine shells. These soils are excessively drained (Alicante et al. 1951). The soils are classified as *Typic Ustipsamments*. These soils have been mapped aside from Negros Occidental, in Misamic Occidental, Samar, and Zamboanga del Sur covering some 12,812 ha.

2.1.4.6 Soils Underlain by Coarse Sand, with Gravels and Stones, Absence of Corraline Materials

Gasan series was originally mapped in Gasan, Marinduque, classified as *Typic Udipsamments*. This coastal town has jurisdiction also over Tres Reyes the nativity, Gaspar, Melchor, and Baltazar. This is a tourist area, flocked during the Holy Week for the Moriones Festival when Christ Passion and Crucifixion is re-enacted. The municipality's name is derived from *gasang*, a type of coral once abundant around the town's shoreline. The soils of the Gasan series are recent water laid formed as a result of accumulation of sandy materials from the sea. The substratum is sand and gravel, and there are no coralline materials. The drainage ranges from good to excessive due to the loose consistency and coarse texture of the subsoil and the substratum. About 1,140 ha of Gasan loamy sand and Gasan clay loam were mapped in the province of Marinduque. The surface soil is grayish brown to pale brown structureless loamy sand to sandy loam, from 25 to 30 cm deep. The subsoil is pale brown to grayish brown loose, fine to medium sand with waterworn stones of varying sizes and shapes and reaches down to 90 cm. The substratum is grayish brown coarse sand with gravels and stones of varying sizes (Salazar et al. 1962).

2.1.4.7 Soils Underlain by Fine Sand, Presence of Marine Fragments Below the Control Section

Obando series (Fig. 1.81 and Plate 1E) was first described in the municipality of Obando, Bulacan. With the continuous expansion of Metro Manila, this municipality is now an urbanized city and part of Metro Manila. Expectedly, Obando soil series as an important agricultural resource is threatened by extinction because of encroachment by urbanization. Expectedly also, being in flat and low-lying coast plains as the area was formerly an estuary, the now commercial-residential-industrial-fishpond municipality is flood-prone. Obando town got its name to honor Don Francisco de Obando y Solis Marquez, then Governor and Captain General of the Philippines who issued a decree in 1753 to separate this town from Polo. The Governor had an untimely death at the hands of the British during the Seven Years' War, and thus the honor of having the town named after him (Wikipedia 2012a). Obando series is similar to Bugko but Obando is located at higher position and characterized by presence of marine shells. But the presence of marine shell fragments is not diagnostic for Obando because they occur below the control section. The Obandfo series is the result of the accumulation of sandy materials from the sea and nearby towns of Obando and Polo. It is characterized by brown fine sandy surface soil with depth ranging from 10 to 30 cm. Below the surface soil at a depth of about 80 cm is the subsoil of fine brown sand. Beneath the subsoil is gray mixed with marine shells (Alicante et al. 1939). The morphology is also similar to Matimbo series but Obando is coarse textured (loamy) formed from nearly level, weakly developed beach ridge remnants on coastal plain landscapes over a substratum of fine sand and marine shells. Matimbo is fine textured (clayey) and occupies higher landscape position than Obando (Soil Survey Division 1987a). Obando is classified as coarse loamy, mixed, isohyperthermic *Fluventic Eutrudepts*. It is moderately well drained. These soils have been mapped also in Cavite, Leyte, Negros Occidental, Rizal, and Zamboanga del Sur totaling 16,885 ha in the reconnaissance soil surveys. It is interesting that in Bulacan, the semi-detailed soil survey of the province in 1987 decreased the area coverage of Obando series from 2,210 ha of Obando sandy loam to 593 ha of Obando loam (Soil Survey Division 1987a). Hence, the effective national total for Obando series is now 15,268 ha.

2.2 The Soils of the River and Lake Terraces, and Freshwater Swamps

The physiography of the Philippine archipelago is rather diverse. Generally, on the larger islands, we have high mountain masses alternating with narrow structural or alluvial valleys. As affected by the monsoon, heavy rainfall is the dominant agent in soil formation, resulting in relatively faster and deep weathering of rock materials. Terraces form when the river's erosional capacity increases and cuts down through its flood plain. River valleys are subjected to alternating phases of aggradation and dissection, creating the terraces.

Small rills and gullies form small streams and eventually form rivers, carrying with it sediments that are eventually deposited along the path through the channels and valleys of the drainage basin, to the coasts, and to the sea. In the Philippines, most of the rivers are short, the consequent streams flow seasonally, and the channels are larger than what the usual flows deserve.

A lake terrace is composed of flat or gently sloping geomorphic surface called "tread" bounded on one side by a steeper and ascending slope called a "riser" or "scarp". A lake or lacustrine terrace is usually the former shoreline formed by erosion and accumulation of sediments, certainly much narrower compared to those formed in the coastal areas.

Marshes is a category of wetlands, partially or periodically submerged or where the water table is near or above the soil surface. A marsh is formed by a shallow depression and kept wet by streams or groundwater. A marsh is covered with nonwoody vegetation, while swamps are forested wetlands, wet only at certain times of the year, usually during the rainy season.

Let us first take a look at the river—and other water-related geomorphology of the major islands of the country to understand the upstream, midstream, and deltaic soils, as well as the soils of the broad alluvial plains that eventually developed.

2.2.1 The Major River Systems, Lakes, and Wetlands of Luzon

At the northern Luzon is the Cagayan Valley dominated by alluvial soils deposited by the *Cagayan River* and its various tributaries, mainly the *Chico*, the *Ilagan*, and the *Magat* rivers (Fig. 2.7). It is an extensive syncline approximately 1.3 million ha of deep and rich Tertiary and Quaternary alluvial deposits, mostly limestone sands and clays (Wernstedt and Spencer 1967). The Cagayan Valley is believed to be the northern extension of the Central Plain of Luzon, cut-off and displaced to the east by the uplift of the Caraballo Mountains formed in the early Miocene by the uplift and marginal faulting of the ancestral Cordillera Central. The Cagayan River head is on the south of the Caraballo Mountains and descends to the valley floor some 90 m above sea level some 225 km from the river mouth in Babuyan Channel. The river meanders northward eventually absorbing the major tributaries of Magat and Ilagan rivers in Ilagan City and of the Chico River between Tuguegarao and Aparri. The main stream and all its tributaries are heavily flooded during the monsoon seasons. Bruce (1981) reported that the Cagayan River Basin was once part of the sea that covered all but the highest parts of northern Luzon. Except for the Iligan River on the east of Cagayan, all the sizeable streams in the basin enter from the west, giving the valley an asymmetrical profile. It was further noted that throughout the lower surface of the basin, marine sediments extend to great depth and the younger strata of river alluvium limited to the uppermost layers.

Fig. 2.7 Night gives a dramatic view of Buntun Bridge of the Cagayan River. The river head is on the south of the Caraballo Mountains, descends to the valley floor and meanders northward absorbing major tributaries of Magat and Ilagan Rivers (*Photo credit* de Rivera (2007), Wikipedia:Wikimedia Commons)

The Cordillera Central has an unbroken north-south length reaching nearly 322 km with a maximum elevation approximately 2,700 m in the south and descends gradually to some 900 m in the northern coast of Luzon. There are three parallel subranges in the in the northwestern part of the Cordilleran System, and from west to east: the Malayan Range fronting the shores of the South China Sea leaving very limited development of plains along the Ilocos coast; the Central Range with the more important rivers like *Chico*, *Abra*, and *Agno* with headwaters on the slopes of Mount Data breaking through the Malayan Range to enter the sea; and the Polis Range in the east of Mount Pulog (2,929 m), the highest point on Luzon, and the second highest in the Philippines, that slopes gently eastward to Cagayan Valley (Wernstedt and Spencer 1967) (Fig. 2.8).

The Central Plain is somehow similar to Cagayan Valley and occupies an open-ended syncline oriented north-south, covering almost an equal area. There is an imperceptible topographic divide between Tarlac City and Mount Bangcay that separates the northward drainage of the lowlands by the *Tarlac* and Agno rivers from the southward drainage of the *Rio Grande de Pampanga* and its many tributaries. Most of the alluvial soils developed from Tertiary and Quaternary sediments, basically limestones, sands, and shales brought down from the surrounding highlands, or from marine sediments deposited during several periods of sea incursions (Wernstedt and Spencer 1967). Near the confluence of the Angat and Pampanga Rivers is the *Candaba Swamp* (Fig. 2.9).

Fig. 2.8 The Agno River in Pangasinan originates from the Cordillera mountain range and drains towards the South China Sea (*Photo credit* (Beltugade 2007), Wikipedia:Wikimedia Commons)

Fig. 2.9 The Candaba Swamp viewed from the Candaba Viaduct, the 5 km bridge in the North Luzon Expressway, one of the longest in the Philippines (*Photo credit* (Ramon F. Velasquez 2012), Wikipedia:Wikimedia Commons)

The large lake, *Laguna de Bay* separates the volcanic areas in the southwestern Luzon from the front ranges of the Eastern Cordilleras. Covering some 92,000 ha, it was believed to be an extension of the Manila Bay and separated on the north by a slight arching on the eastern shores. It was further believed that accumulation of volcanic debris during a violent eruption of Taal Volcano cut the southern opening to the sea (Wernstedt and Spencer 1967). *Pasig River* drains Laguna de Bay into Manila Bay, cutting through the Hagonoy Isthmus.

Southeastern Luzon is the Bicol Peninsula, actually several small peninsulas. Its main geographic feature is a long interior synclinal depression flanked by mountains and hills (Wernstedt and Spencer 1967). The *Bicol River* is the longest in southern Luzon which drains northward through the longitudinal depression and empties into San Miguel Bay.

Going now to the major Luzon islands, the largest area of lowlands in the island of Mindoro is on the northeast and eastern coasts. There are smaller lowlands in the southwest near the mouths of *Pandan* and *Ibod* rivers. *Lake Naujan* is one of the largest lakes in the country which is found on the eastern coastal plain. The eastern coast of this island province is generally low-lying, poorly drained, and bordered by marshes and swamps. The island of Palawan has very limited lowlands, mostly confined to the coasts and rarely extends for more than 8 km. The more principal lowlands are in the *Ilian*, *Barbacan*, and *Caramay* river valleys along the coasts of Panacan and Brook Point. The island of Marinduque has the west-flowing *Boac River* as the major drainage artery. The delta formed at its mouth is the provincial capital.

2.2.2 The Major River Systems, Lakes, and Wetlands of Visayas

This is an extensive group of large and small islands between Luzon and Mindanao and a geologic look shows that it structurally belongs to neither. It consists of raised blocks with intervening grabens (Wernstedt and Spencer 1967). Samar island is the largest, and the lowlands are restricted to narrow strips of coastal plains in the north, small river floodplains, and deltas. The eastern littoral is surrounded by series of small deltaic lowlands, isolated from each other by mountains. The *Ulug*, *Catubig*, *Palapag*, *Gandara*, and *Oras* rivers are the major streams, each building small alluvial plains on the lower river course. The next island, Leyte, has broad alluvium-filled Leyte Valley between the northeastern and central highlands and one of the largest contiguous lowland areas in the Visayas. *Subangdaku* is one of the largest and considered a braided river of several channels that divide and reunite to form an alluvial fan with wide floodplain. *Lake Danao* is on the southeast. Leyte has also the marshy plains of *Sab-a Basin* covering some 90,000 ha on the northeastern plain, draining east into Leyte Gulf and consisting of numerous small lakes and ponds and peat bogs.

The island of Bohol lies in the Camotes Sea midway between Leyte and Cebu. Bohol is drained by many short streams developing several small alluvial lowlands in the northern coast. The four major rivers are *Inabanga*, *Loboc*, *Abatan*, and *Ipil* (Fig. 2.10). The island of Cebu is in the geographical center of the Philippines and shares some structural and topographical elements with Bohol (Wernstedt and Spencer 1967). The interiors are highly dissected and the rivers are short and rapid flowing. The coastline is without

Fig. 2.10 A view of the reservoir of Malinao Dam in the municipality of Pilar, island province of Bohol. The dam is in the Wahig-Inabanga watershed and serves some 4,700 ha of ricelands

embayments and consists of series of alternating valleys and ridges. The Central Cebu river basins have a total area of 68,133 ha and have four major watersheds—Mananga, Lusaran-Combado, Coastal, and Kotkot. Negros is the fourth largest island in the Philippines. The main mountain range is on the eastern shores descending abruptly on the eastern side leaving little room for coastal plains except where infrequent rivers developed small isolated deltas or piedmont plains. On the western flanks of this central range are a number of high volcanic masses such as Mounts Silay, Mandalagan, and Kanlaon (2,465 m) which is the highest point in the Visayas (Wernstedt and Spencer 1967). Mt. Kanlaon is an important watershed area and on its slopes are the *Bago*, *Nahalin*, and *Ilog* river systems.

The island of Panay is the sixth largest island in the Philippines. A narrow strip of alluvial lowlands is wedged between the western highlands and the west coast. The northeastern hills divide surface drainage between the large Iloilo Basin to the south, and the short streams that flow northward into the Sibuyan Sea. The Iloilo Basin is a large depression filled with sands, clays, and conglomerates of Miocene and younger sediments, with the drainage system oriented toward the island of Guimaras and the Iloilo straits (Wernstedt and Spencer 1967). The rivers and streams of the basin built up a large delta at its mouth. The principal rivers are *Jalaud*, *Jaro*, and *Sibalum*.

2.2.3 The Major River Systems, Lakes, and Wetlands of Mindanao

Mindanao is the second largest island in the Philippines, with deep embayments, several large peninsulas, and extremely long coastline. The island has five major mountain systems of complex structural origins while others were formed by a

Fig. 2.11 The Wawa River in Agusan del Sur is one of the twelve tributaries on the eastern side of Agusan River. The other river tributaries are Gibong and Simulao also on the eastern side, Ojot, Pusilao, Kasilayan, Libang, Maasam, Adgawan, Cawayan, Umayam, and Ihaon Rivers on the western side. The Agusan River eventually empties into Butuan Bay

simple process of volcanism (Wernstedt and Spencer 1967). Mount Apo (2,954 m) is the highest peak in the Philippines, and found on the southern part of the central highlands.

The Davao-Agusan Trough is one of the largest lowland areas in the island. In the northern area is the *Agusan River* (Fig. 2.11), the largest and longest in the Philippines. It originates in the extreme southeastern corner of Mindanao and traverses some 290 km northward, emptying into Butuan Bay. The southern end of this valley is more elevated and better drained. The entire valley floor is covered to considerable depths by Tertiary and Quaternary sediments that include alluvial deposits of volcanic origin (Wernstedt and Spencer 1967). At the center of the valley is series of large freshwater lakes and marshes, the *Agusan Marsh*, and covers some 90,000 ha.

In the north central Mindanao is the Bukidnon-Lanao Plateau, at an elevation of about 610 m above sea level, built by successive basaltic lava flows, interbedded with ash, tuff, and sandstone materials. In the southwestern corner is *Lake Lanao*, the second largest lake in the Philippines, occupying nearly 35,000 ha probably formed by the damming action of lava flows that blocked its natural drainage or by the collapse of a large volcano forming the basin lake. *Agus River* drains Lake Lanao through the plateau escarpment of some 29 km. The basaltic lavas have weathered to clay loam soils and the plateau and the lower slopes of the mountains are arable.

The Cotabato Basin is broad, northwest-southeast trending intermontane structural depression in southern Mindanao. This depression was covered by sea as recently as Pleistocene (Wernstedt and Spencer 1967). It extends some 97 km eastward from the shores of Illana Bay to the

Fig. 2.12 From the airplane approaching the runway of Zamboanga City, a view of one river system that empties into the Moro Gulf

Fig. 2.13 A third level river terrace in Valencia City, Bukidnon utilized for rice production. Pulangi River winds through the Maapag Plain in Valencia City

southern boundary of the province of Bukidnon. A low drainage divide south of the large and shallow *Lake Buluan* separates the northward-flowing tributaries of the Rio Grande de Mindanao from the southeast flowing rivers of the Koronadal Valley.

The Koronadal and Allah valleys which are the southern extensions of the Cotabato lowlands, are two narrow plains flanked by moderately high mountain ranges. The well-drained valley floors are covered by deep deposits of marine and river alluvium. In the Koronadal valley, this has been further enriched by recent volcanic deposits from the nearby Mount Matutum. Koronadal slopes gently southeastward to Sarangani Bay while Allah Valley is drained to the north.

Much of the Cotabato lowlands is oriented toward the *Rio Grande de Mindanao*. The many tributaries include the *Pulangi* and *Maridagao* from the north, the *Allah* from the south, and the *Malabul*, *Dalapuan*, and *Alip* from the east. These are conjoined in the extensive freshwater swamplands of the *Libungan*, *Ebpanan*, and *Liguasan* marshes, the conglomerate of which is the largest in the country, covering an area of about 288,000 ha. This is a vast complex of rivers and tributaries, small freshwater lakes and ponds, and arable lands subjected to seasonal flooding. From these junctures, the low-gradient Rio Grande flows across a broad level plain through narrow-terraced inner valleys caused by the recent uplift near the river mouth and into Illana Bay. The Rio Grande appears to be aggrading its valley above its constriction with thick deposits of river alluvium.

In the Zamboanga Peninsula, the major drainage is oriented toward Moro Gulf. In other areas, we have only short consequent streams that drain the interior uplands. There few lowland areas. The northern highlands generally descend sharply to the coast. The southern coastline is deeply indented by the Sibuguey and Dumanquilas embayments. The peninsula is drained on the north by the *Lubungan*, *Dipolog*, and *Quipit* rivers. In the south, the main rivers are *Subuco*, *Pangasinan*, and *Sioco* which form a delta of mangrove forests, certainly economically exploited (Fig. 2.12).

2.2.4 Soils of the River Terraces, Interhill Miniplains, and Intermountain Valleys

River terraces are the elevated portion of the alluvial plain near to the river bank. The soils developed from recent alluvial deposits and subject to river flooding. The soil profile is generally underlain by unconsolidated materials. Bruce and Morris (1981) reported that for recent river terrace level 1 represents valley floor abandoned as the river cuts down to the new and lower base level. Level 2 would be similar but farther away from the river and at a higher elevation. Level 3 would also be similar but even farther away from the river and at an even higher elevation; usually has transition zone with alluvial plain landforms (Bruce and Morris 1981) (Fig. 2.13).

Interhill miniplains are narrow valley floors between hills or hillocks, common between hills or fringing the alluvial plains (Bruce and Morris 1981). These could have originated as valley bottoms in hillslope land subsystems or as drainage ways in river-cut plain land subsystems.

Intermountain river terrace is sometimes referred to as river terrace in intermountain (or intermontane) valleys (Fig. 2.14). The concept would be similar to interhill but instead of the valley floor in between hills, we have the valley between mountains.

As a generalization, soils are thin, skeletal in development, and patchy in occurrence. Where we have more gentle slopes, we have more developed soils due to alluvial filling.

Fig. 2.14 An intermountain valley in Valencia, Bukidnon is a narrow valley sandwiched by two mountains

2.2.4.1 Soils Underlain by a Layer of Gravels and Boulders

When the river terrace soil is underlain by gravels and boulders we have either *Peñaranda*, or *Gapan* series. This diagnostic criterion is shallower for Peñaranda, the gravelly loam subsoil is usually found within 50 cm. The Gapan series has similar gravels and boulders but found deeper, about 100 cm from the surface.

Peñaranda series (Plate 1E) is a recently established soil series, first described in Peñaranda, Nueva Ecija in 1971 as one of the outputs of the Peñaranda River Irrigation Project. Peñaranda was originally called Mapisong and was formerly part of Gapan, also in Nueva Ecija. It was organized into a municipality by Jose Maria Peñaranda, a Spanish engineer and thus, the municipality was named after him (Wikipedia 2012b). This place was once known for *ikmo* or piper betel. This leaf is used to wrap betel nut and lime and chewed, a practice still observed in many Southeast Asian countries and in the South Pacific Islands. Peñaranda series is classified as *Fluventic Eutrudepts*while some descriptions classify it as *Typic Eutrudepts*. These are well drained occuring in scattered areas associated with the confluence of mountain footslopes and broad plains. It has a sandy and gravelly subsoil. The A horizon is brown to dark brown friable loam, silt loam, or heavy fine sandy loam. The thickness ranges from 10 to 30 cm. The cambic B horizon is brown or dark brown or dark yellowish brown loam or light clay loam, light silty clay loam, and heavy silt loam with weak subangular blocky and moderate granular structure. The C horizon below 50–100 cm is stratified sandy skeletal texture including gravelly loam sand, and very gravelly sandy loams. Minor stratum of finer textures may occur. About 663 ha of Peñaranda loam were mapped in the province of Bulacan (Bureau of Soils 1973a). To understand the soil concept of Peñaranda series, and the associated soils Agustin, Gapan, and San Manuel, Peñaranda keys out as follows:

Soils with fine loamy subsoil textures (10–35 % clay, hues 7.5YR–10YR):

a. With subsoils thinner than 100 cm

1. Subsoils overlying gravelly sand	Peñaranda Series
2. Subsoils overlying sand	Agustin Series

b. With subsoils thicker than 100 cm

1. Subsoils overlying gravelly sand	Gapan Series
2. Subsoils overlying sand	San Manuel Series

Gapan series is also underlain by sand and gravel, similar to Peñaranda but it is not the thicker subsoil but the substratum that is gravelly sand. Gapan, of course, was originally mapped in the neighboring Gapan, Nueva Ecija. Established by the Spanish curates and officials in 1595, Gapan used to be part of neighboring Pampanga province. Gapan series is classified as fine loamy, mixed, isohyperthermic *Fluventic Eutrudepts,* and consist of thick well-drained soils on medium to high river terraces landscape position, normally above annual seasonal flooding. The topsoil is about 21 cm thick dark brown silt loam with few yellowish brown or dark brown silt loam mottled with few to common brown to dark brown or yellowish brown. The subsoil is dark brown silt loam that could reach down to 130 cm. The substratum is very dark grayish brown structureless gravelly sand or sandy loam. Below 150 cm is gravelly (Bureau of Soils 1973a). About 407 ha of Gapan series were mapped in the province of Bulacan. The Gapan series is closely associated with the slightly lower and thinner Peñaranda series and slightly higher and deeper San Manuel series.

2.2.4.2 Soils Underlain by Sand

The *Agustin* soil series is characterized by thinner subsoil, below which is a layer of sand. When the subsoil is thicker, this is classified as *San Manuel* series. When the soil profile is much younger characterized by absence of a B horizon, the soil belongs to *Barang* series. *Pangasinan* series is sandy soils accumulated from various sources through stream flow such as those found in swamps and mangrove areas (hydrosols), beach, and river terraces and flood plains.

Agustin series (Plate 1A) is established in 1971 as one of the outputs of the Peñaranda River Irrigation Project. This soil series is classified as fine loamy, moderately deep over sandy, nonacid, mixed isohyerthermic *Fluventic Eutrudepts*. The soils occur in scattered and relatively small areas along the Pampanga and other rivers in Central Luzon, 2–5 m above and adjacent to continental rivers, first and second bottom landscape position subject to annual flooding during typhoon months. The parent materials are recent and near recent alluvium from volcanic, graywacks, limestone, conglomerates, and metamorphic. This series is associated with Peñaranda, Gapan, and also with San Manuel on lower and moderately high river terraces and with Quingua series on the high terraces. The solum thickness ranges from 50 to 100 cm. The surface soil is brown, dark brown, or yellowish brown friable silt loam, loam, or light clay loam, 10–30 cm thick. A few fine or medium faint or distinct red mottles may be observed. The cambic B horizon is similar to A horizon in texture but with weak blocky structure and less organic matter content. The substratum below 50–100 cm is yellowish brown or brown stratified loamy fine sand, loamy very fine sand with minor strata of silt loam or sandy loam. Very few or no gray mottles can be seen beyond 100 cm (Bureau of Soils 1973a). This soil series is associated with San Manuel, Peñaranda, and Gapan series on the lower and on moderately high river terraces and with the Quinga series on the high terraces. Agustin series was first described Camba, Arayat, Pampanga but the soil series was named after the neighboring barangay San Agustin, Candaba municipality, also province of Pampanga. The Agustin series covers 112 ha in Pampanga.

San Manuel series profile (Plate 1F and Fig. A.10) has no band or layer of stones or gravels and the soil is characterized by *slightly compact* subsoil horizons. There is no band or layer of stones or gravels. The soil is underlain by sandy materials that start from 100 cm and deeper. The soil is also characterized by good drainage. San Manuel soils is classified as fine loamy, deep over sandy, nonacid, mixed, isohyperthermic *Typic Eutrudepts*. It has an A horizon that is brown or dark brown silt loam or loam 10–25 cm thick. The cambic B horizon is brown, light clay loam. The C horizon below 100–150 cm thick is stratified, dark brown to yellowish brown, dominantly sandy with thin fine loamy strata and few grayish mottles (Bureau of Soils 1973a). These soils are formed from weakly stratified alluvium and can be found on medium or river terrace landscape positions; or moderately high terraces adjacent to continental river channels and subject to seasonal flooding. Where the drainage is poor and there are evidences of redoximorphic features, we have Mogpog series. This soil series was first described in San Manuel municipality, province of Tarlac. This municipality was named after the late Don Manuel de Leon who sponsored its separation from Moncada in 1909. It was originally covered with dense forest, lakes, and creeks and wild animals roamed in the wilderness. This is the last town of Tarlac at the northernmost tip of the province. San Manuel series also occurs in broad alluvial plains and is also associated with Tagulod Series. Tagulod, is heavier in texture as compared to San Manuel. San Manuel has fine loamy textures in A to B horizon that goes coarser in lower B horizon. Both series have manganese concretions at 50 cm that increases with depth. About 1,080,726 ha of various textural types of San Manuel series were mapped in the provinces of Tarlac, Leyte, Ilocos Norte, Ilocos Sur, La Union, Pangasinan, Mindoro, Abra, Bataan, Cagayan, Cotabato, Ifugao, Isabela, Kalinga-Apayao, Leyte, Marinduque, Misamis Occidental, Misamis Oriental, Negros Occidental, Negros Oriental, Nueva Ecija, Nueva Vizcaya, Pangasinan, Quezon, Samar, Sulu, Zamboanga del Norte, Zamboanga del Sur, Bontoc, Bukidnon, Camarines Sur, Surigao, Agusan, Antique, Cotabato, Capiz-Aklan, Catanduanes, Palawan, and Davao (Fig. 2.15).

Fig. 2.15 Landscape view of San Manuel series grown to rice taken in Calayan, Cagayan

Barang series are classified as *Typic Ustifluvents*, moderately well drained. They occur on river terraces and with nearly level relief. The plowed topsoil is pale brown to grayish brown loamy sand; no mottles. The lower subsoil is brownish gray sand, no mottles, and extends down to about 40 cm. As an Entisol, there is no B horizon. The upper substratum is light yellowish brown loamy sand, the mid substratum becomes light brownish gray very fine sandy loam with brownish yellow mottles, and the lower substratum is brownish gray coarse sand, no mottles. These soils were first described in barangay Barang, municipality of Malasiqui, Pangasinan province. This soil series covers 300 ha in the province.

Pangasinan series (Plate 1E), classified as *Typic Ustifluvents* consists of soils found along the mouth and beds of the Agno, Calmay, and Bued Rivers. These are mostly sands accumulated from various sources through the agency of streams. Because of the similarity of origin and mode of formation, the different soils were placed under one series name and the types are as follows: (1) *Pangasinan hydrosols* which are under water during the greater part of the year, such as those found in swamps, nipa, and mangrove areas, fishponds, and saltbeds. The soils in salt beds are usually pale gray to brownish gray sand; the fishpond soils are a mixture of silt, sand, and a very small amount of clay; the soils in the nipa and mangrove areas are a mixture of organic matter, a small amount of clay, and a large quantity of silt and sand. (2) *Pangasinan beach sand* consists of sandy areas along the beach from San Fabian to Sual. The sand is usually greenish gray and fine in texture; there are many silt beds within this type. (3) *Pangasinan river sand* consists of sandy areas along the river flood plains and river beds. It is characterized by the presence of some gravels both in the surface and in the subsoil. It is greenish gray, mixed with whitish and brownish shades. A large portion of this type is located at the mouth of the Bued River and in eastern Pangasinan along the headwater of the Agno River. (4) *Pangasinan fine sand* consists of reddish brown fine sand along the elevated portions of the hydrosol areas. It is planted to rice during the rainy season and vegetables during the dry season. Areas reached by tidal water are converted into salt beds during the dry season and fishponds during the rainy season. A total of 13,781 ha of Pangasinan sand was mapped in Pangasinan province.

2.2.4.3 Soils Underlain by Loamy Materials

River terrace soils characterized by loamy substratum belongs to *Mandawe* series when pebbles are present. When there are no pebbles, the soil is classified either as *Zaragosa* series when vertic properties are exhibited or as *Mogpog* when none. These three soil series are characterized by poor drainage and there will be observable redoximorphic features.

Mandawe series developed from recent alluvium that is fine loamy depending on the surrounding parent materials. These are secondary soils of recent formation having almost flat topography. These soils are formed along some of the big rivers on both sides, from alluvial deposits consisting of series of layers of sand, silt, and clay which in some places reach to a depth of 1 m. There are no stones or boulders present on the surface. The surface drainage is fair but the internal drainage is rather poor owing to the fine structure and slight compactness of the soil in the substratum. These soils are classified as loamy, mixed isohyperthermic *Fluvaquentic Eutrudepts*. The topsoil, reaching down to a depth of 20 cm from the surface is light brown to dark brown clay loam to silt loam with good to poor coarse blocky structure; no stones nor boulders of any kind. The upper subsoil, extends down to 50 cm, and is dark brown to dark grayish brown clay loam with good coarse blocky structure. The lower subsoil extends down to 120 cm, and is yellowish brown, moderately coarse columnar and compact clay loam that becomes only slightly soft and compact when wet; no coarse skeleton. The substratum, extending down to the control section at 150 cm, is yellowish brown medium coarse granular clay loam with brown to dark brown mottlings. Some rounded pebbles are sometimes present in deep

Fig. 2.16 Landscape view of Zaragosa series grown to corn in Calayan, Cagayan

layer. Soil drainage is fair externally and poor internally (Barrera et al. 1954). Various textural types of Mandawe series, namely, silt loam, loam, sandy clay loam, clay loam, and clay were mapped not only in Cebu but also in the provinces of Masbate, Catanduanes, Bohol, Zamboanga del Norte, Leyte, and Negros Oriental covering some 60,996 ha (Fernandez and Jesus 1980). Mandawe series was first described in Mandawe City, Cebu. Today, it is one of the three urbanized cities of Cebu province and forms part of the Cebu Metropolitan area. Antonio Pigafetta wrote a settlement Mandani with chieftain named Apo Noan. The natives were forced into a town by the Spanish authorities, managed by the Jesuits in 1638 and by the Recollects a century later (Caso 1990). The crops that are grown in both upland and lowland are rice, corn, sugarcane, legumes, annual cash crops, coconut, root crops, and perennial trees.

Zaragosa series (Plate 1G) are classified as fine clayey, nonacid, mixed, isohyperthermic *Vertic Eutrudepts*. These are poorly drained soils in nearly level and low lying areas that become under water during the rainy season. These soils are formed in stratified fine clayey alluvium or low continental river terraces subject to seasonal flooding. The surface soil when used for paddy rice is gray to grayish brown, clay loam to light clay with puddle structure, and extends down to 40 cm; very sticky when wet. The subsoil that reaches down to 70 cm, and is dark gray and almost compact clay loam, mottled with dark brown and brownish gray color; breaking into columnar structure of big, sharp clods. The substratum, reaching to a depth of 100 cm, is yellowish brown to yellowish gray fine clay loam to sandy clay loam, clay or loamy fine sand (Alicante et al. 1941). This soil series is associated with Bantog, Bigaa, Candaba, and Malimba soils. They occur in small areas along rivers and creeks. This soil was first described in Zaragoza, Nueva Ecija, along the Rio Chico, Pampanga River. The native vegetation of this series consists of talahib, cogon, agingai, and buri palm. The cultivated areas grow rice. A total of 13,210 ha of Zaragoza clays were mapped in the provinces of Cagayan, Nueva Ecija, and Tarlac (Fig. 2.16).

Mogpog series was first described in Mogpog municipality, Marinduque province and classified as *Typic Eutrudepts*. Mogpog is famous for the large image of Our Lady of Peace and Good Voyage located in its main shipping port. It is said that the famous Moriones Festival originated from Mogpog. Mapped in the level areas, the drainage is poor. Mogpog has brown to reddish brown, fine granular clay loam to silt loam top soil that extends from about 20 to 25 cm. The subsoil is brown to yellowish brown slightly compact to compact clay loam with rust-like splotches, extending down to more than 100 cm. The substratum is yellowish brown, sandy clay loam to sandy loam with pale rust-like streaks. Concretions that produce black powdery mass are present. The greater part of the soil is cultivated to rice, corn, mongo, peanut, and coconut (Salazar et al. 1962). About 8,894 ha of Mogpog sandy loam, silt loam, and clay loam were mapped in the provinces of Marinduque, Romblon, and Mindoro provinces.

2.2.4.4 Very Deep Soils Characterized by Clayey Subsoils Extending to the Control Section

Bantog series (Plate 1A for soil profile and Fig. A.1 for soilscape view) is classified as fine clayey, montmorillonitic, isohyperthermic *Udorthentic Pellusterts* and consists of very thick, poorly drained very fine clayey soils formed on weakly stratified clayey alluvium in nearly level to broad slightly dissected low alluvial terraces landscape with or without seasonal flooding. The plowed surface layer is very dark gray clay with few reddish brown mottles. Below this layer down to a depth of less than 40 cm is dark gray clay with brown mottles and few small manganese concretions. The subsoil extends to a depth of 280 cm, dark grayish brown, grayish brown, gray or dark gray clay with pale olive, yellowish brown or brown mottles and manganese concretions. Common intersecting slickensides occur in the upper portion of this layer. The substratum is light olive gray clay with brownish yellow mottles and few manganese concretions (Alicante et al. 1941). About 142,812 ha of Bantog sandy loam, silt loam, clay loam, silty clay loam, silty clay, and clay were mapped in the provinces of Bulacan, Ilocos Norte, Ilocos Sur, Iloilo, Isabela, Leyte, Nueva Ecija, Nueva Vizcaya, Pampanga, and Sulu, Capiz-Aklan, Bohol, Mindoro, Misamis Occidental, Misamis Oriental, Surigao, and Zamboanga del Sur (Fernandez and Jesus 1980). This soil was originally described in barangay Bantog, the municipality of San Miguel in the province of Bulacan. Bantog town is highly urbanized nowadays symbolizing conversion of prime rice soils characterized by cracking properties into residential, commercial, industrial, and recreational uses. To understand the concept of Bantog series, this is how it keys out with the associated soils:

Soils with fine clayey subsoil textures (more than 60 % clay, hues 10YR–5YR)

a. With gray or dark gray Ag horizon

1. Ag horizon thinner than 50 cm	Bantog Series
2. Ag horizon thicker than 50 cm	—
i. Without brown substrata (Bb paleosoils)	Bigaa Series
ii. With brown substrata (Bb paleosoils)	Malimba Series

b. With very dark gray or black Ag horizon

1. Ag horizon thinner than 50 cm	—
2. Ag horizon thicker than 50 cm	Candaba Series

Malimba series is classified as fine clayey, montmorillonitic, isohyperthermic *Udorthentic Pellusterts*, very deep and poorly drained. These soils occur on slightly depressed terrace landscape positions near creeks and small streams in the slightly dissected Central Plain of Luzon, probably derived from higher lying soils formed from thin bedded tuff, moderately thick beds of limestone, some beds of conglomerate, greywacke, and volcanic ejecta. The slopes could be 0.0–1.0 % but could range to 5 % along stream banks. These soils have gray or dark gray, extremely hard, very sticky fine clay Ag horizon from 50 to 100 cm thick. The Bg horizon is grayish brown, very fine clay, very sticky and plastic with slickensides close enough to intersect. Very coarse prismatic structure forms annually with cracks more than 1 cm wide extending from 50 to 100 cm deep and remains open from 90 to 150 accumulative days during the year except when irrigated. Brown, dark brown or yellowish brown fine clayey Bb paleosols with few manganese-iron concretions and calcium carbonate nodules occur below 100–150 cm depth. The subsoil could extend down to 300 cm (Bureau of Soils 1973a). This soil series was first described in barangay Malimba, Gapan municipality, province of Nueva Ecija. Malimba is similar to Bantog, Bigaa, Tagulod, Candaba, and Zaragosa series. The Bantog and Bigaa soils have thinner Ag horizon and lack brown Bb horizon within 300 cm depth. The Tagulod soils have mottled brown and gray clay subsoils and somewhat coarser C horizon textures. The Zaragosa soils have distinctly stratified clay solum. Malimba series are of relatively small extent though scattered individual areas can be quite large. This soil series covers 1,547 ha in Pampanga. These occur in slightly dissected terrace landscapes near creeks and small rivers in the vicinity of Candaba Swamp. These soils were originally classified as Bantog series in the old

Fig. 2.17 A landscape view of Quingua series, one of the best soils for agriculture

Fig. 2.18 An aerial view of lakeshore landscape showing the Laguna de Bay (pronounced as Ba-i) shoreline along Binangonan, Rizal. Despite its flood-prone position making it one of the best soils for agriculture with annual silt renewal coming from the floods, the encroachment of urbanization is very evident. (*Photo credit* P199 2012, Wikipedia:Wikimedia Commons)

reconnaissance level soil surveys. It was one of the outputs of the Peñaranda River Irrigation Project in 1971.

2.2.5 Soils of the River Levees

This is a river's bank built up above the level of the rest of the floodplain. Rivers carry sediments depending on their speed. When a river floods over its bank, the water spreads out, slows down, and deposits its load of sediment. Over time, the river bank becomes elevated. Natural levees are a common feature of all meandering rivers.

Quingua series (Plate 1F and Fig. A.8) developed on elevated portions of the river terrace and characterized by the presence of well-developed B horizon (presence of argillic horizon). These soils are classified as clayey, non-acid, mixed, isohyperthermic *Typic Tropudalfs*. The soils are moderately thick brown friable clay loam A horizon and very deep brown clay Bt horizon. The C horizon is below 150 cm and is brown stratified sandy alluvial materials. The soils are formed on very gently undulating high river terrace above flood levels. They are well-drained soils (Alicante et al. 1939). Quingua series are almost similar to Tagulod, Peñaranda, and San Manuel soils. The Tagulod soils have gray mottles throughout the solum. The San Manuel soils have fine loamy textures and occur on moderately high terrance landscape positions subject to flooding. The Quingua soils are formed on slightly dissected high river terraces and levees above flood levels. The Quingua soils are usually planted to diversified crops and sometime developed as built-up areas. A total of 373,693 ha of various types Quingua series (sand, sandy loam, silt loam, loam, sandy clay loam, clay loam, silty clay loam, silty clay, and clay) were mapped in the provinces of Nueva Ecija, Bulacan, Cavite, Isabela, Laguna, Mindoro, Rizal, Agusan, Cagayan, Camarines Sur, Kalinga-Apayao, Mindoro, Misamis Occidental, Pampanga, Quezon, Zambales, Sulu, Palawan, Samar, Zamboanga del Norte, and Bontoc (Fernandez and Jesus 1980). The Quingua series was first described in Quingua, Bulacan, a settlement that dated back as early as 1595 during the early years of Spanish colonization. But this place is currently known as Plaridel, Bulacan. It was famous for the two-part Battle of Quingua, fought on April 23, 1899 during the Philippine–American War. The first part was a victory for the young Filipino general, Gregorio del Pilar over the American Cavalry led by Major J. Franklin Bell. During the second phase, Bell was reinforced by the 1st Nebraskan Infantry and routed the Filipinos who also managed to repel a cavalry charge that killed Colonel John M. Stotsenburg (Wikipedia 2012c). Today, Plaridel, Bulacan is highly urbanizing and now included in Metro Manila's built-up area (Fig. 2.17).

2.2.6 Soils of the Lake Terraces and Lacustrine Plains

These are soils with parent materials originating from lake or lacustrine deposits. During an interval of stationary water level, a line of low cliffs is cut and in front of this is a narrow shelf, partly cut and partly built. These are the lake terraces, formed by wave actions during the fluctuations of the lake water. Materials are usually lakeshore deposits and minor deltaic sandy deposits on a layer of fine sediments (Fig. 2.18).

2.2.6.1 Soils at the Lowest Catenal Drainage

Soils along lake fringes and marshy areas and those on the *lowest* of the catenal drainage can be classified as *Looc*, *Boulevard*, or *Bay* Series.

Looc has only an AC profile, no B horizon development and the subsoil consists of fine loamy deposits or sands or loamy sands. It contains silty materials, decaying humus, and some shells. These soils occur originally along the periphery of Laguna de Bay in the first terrace position and subject to seasonal flooding. It belongs to fine clayey, calcareous, mixed *Typic Psammaquents* (Soil Survey Division 1987b). Looc is a lakeshore barangay or village of Calamba City, Laguna, the birthplace of the Philippine national hero, Dr. Jose Rizal. About 1,130 ha of Looc soils were mapped in the province of Laguna.

Boulevard series has a cambic Bg horizon or gleyed clay, poorly to very poorly drained, occurring on level to nearly level narrow lake terrace of the lacustrine landscape. The A horizon is not more than 30 cm thick. The cambic Bg horizon extends down 50–100 cm thick, and are gray, light gray, to dark gray or greenish gray with distinct clear yellowish brown, strong brown, red, or yellowish red mottles. The substratum is greenish gray or dark greenish gray clay, silty clay, or clay loam and with decomposed plant remains and lacustrine shells (Soil Survey Division 1989a). Boulevard soils are somewhat similar to Fluvaquents. Both soils have decomposed remains and lacustrine shells derived from lacustrine deposits. Their main difference is in physiographic position. Fluvaquents appear on freshwater marshes and have undeveloped B horizons. They also have lighter texture in the substratum compared to Boulevard series. Boulevard soils belong to fine, mixed, isohyperthermic *Aeric Endoaquepts* and first described in Bangiad, Taytay, Rizal. This soil series must have been originally described along the highway and hence, the name. A total of 1,508 ha of have mapped in the province of Rizal. But many of these areas have been urbanized since the last soil survey. Incidentally, Taytay where this soil was first described, used to be part of the Kingdom of Namayan (also called Kingdom of Sapa, or Maysapan or Nasapan) that reached its peak in 1175 and dominated the upper portion of the Pasig River and the coast of Laguna de Bay (Wikipedia 2012d).

Bay (pronounced as *ba-i*) series is characterized by vertic properties and classified as fine clayey, mixed, isophyperthermic *Typic Pelluderts*. The surface horizon is dark gray to very dark gray and very dark grayish brown clay of more than 30 cm thick. The cambic Bg horizon has thin patchy continuous slickensides along ped paces extending into the lower B horizons. The substratum is coarse sand to sandy clay loam, and below the substratum is hard tuff (Soil Survey Division 1989a). The old soil survey report of Laguna estimates 1,477 ha of Bay clay. The updated soil survey is around 5,175 ha. Quezon Province has about 1,792 ha of Bay loam. For Bay clay loam, Palawan has 2,900 ha, Samar has 1,343 ha, and Rizal province in the old soil survey report has 2,525 ha. The updated soil survey of Rizal did not mention this series, obviously reclassified into other soil series. To understand the Bay soil series concept, we should see how it keys out with the other soil series in older landscapes:

Poorly drained clayey soils on minor alluvial landscape underlain by volcanic tuff:

If shallow	Canlalay Series
If moderately deep	Dita Series
If deep	Calumpang Series
If very deep and underlain by *unconsolidated* materials	Bay Series

Bay is a municipality of Laguna and the Spaniards pronounced it as "Bah-ee" while the natives refer to it as "Baheh". This lead to the misconception that it was named after Laguna de Bay. Tagalog, spoken in the area, has "baybay" to refer to shore. But there is another legend that Bay was derived from the first letters of Datu Pangil's three daughters—Maria Basilisa, Maria Angela, and Maria Elena or *Bae* which became Bay over a period of time. Datu Pangil ruled this thriving community in 1571 when then 18-year old Spanish Capitan Juan de Salcedo landed with Augustinian missionaries Alfonso de Alvarado and Diego Espinar to claim these territories for Spain (Wikipedia 2012e).

2.2.6.2 Soils at the Middle of the Catenal Drainage

Soils at the middle of the catenal drainage is classified as *Pangil* series if characterized by clay substratum and poorly drained, mixed with decomposed plant materials, and deep. *Ramain* series has substratum of decomposed plants mixed with clay but shallower compared to Pangil series. When we have a similar clay substratum but well drained, the soil belongs to *Rugnan* series.

Pangil series is classified as very fine mixed isohyperthermic *Typic Endoaquepts*. The topsoil is dark greenish gray, extends to no more than 20 cm. The Bwg horizon is mottled that could extend down to 100 cm. Continuous thick slickensides are observed on the lower horizons. The substratum of Pangil is gleyed clay and poorly drained, characterized by common to many partially and highly decomposed plant remains (Soil Survey Division 1987b). Pangil is a municipality of Laguna province and founded in 1579 by two Franciscan missionaries. There are three versions as to the origin of the place' name—pangil could refer to the fang of wild boars, presumably hunted here in the early days, or could refer to the first native inhabitants of the place, called *Pangilagans,* or could refer to the first pre-Spanish chieftain named Datu Paguil. A total of 2,557 ha of Pangil clay were mapped in Laguna province.

Ramain was first described in the municipality of Ramain, Lanao del Sur and classified as *Aeric Endoaquepts*. It is developed from local alluvium and found on nearly level relief. It is imperfectly drained due to the high water table condition which could be attributed to its proximity to the lake. The gleyed topsoil, about 15 cm in depth, is dark reddish gray silty loam with sharp reddish brown mottles. The gleyed upper subsoil, reaching down to 30 cm, is dark gray silty clay to clay with many coarse prominent and sharp yellowish red mottles and many small soft spherical carbon-black concretions. The gleyed lower subsoil, 42 cm in depth, is dark gray clay with common coarse prominent and sharp yellowish red mottles. The upper substratum, reaching down to 65 cm, is dark reddish brown slightly decomposed plant debris mixed with clay, with the plant debris dominating. The gleyed lower substratum, reaching down to the control section at 150 cm, is dark gray silty clay to clay mixed with slightly decomposed plant debris. This soil series covers 10,709 ha in Lanao provinces.

Rugnan series (sometimes reported as Rugunan series) was first mapped in what was then Lanao Province, the seat of the Sultanate of Lanao, eventually divided into Lanao del Norte and Lanao del Sur under Republic Act 2228 in 1959. Rugnan, where this soil series is named after, is now one of the barangays of the municipality of Bubong, Lanao del Sur. Rugnan is also the name of one of the big rivers in the province that drains neighboring mountain systems. The soils of this series occurs on level to nearly level topography. This soil series is classified as *Typic Hapludults*. These soils are moderately well drained. The top soil, reaching down to 20 cm, is brown to strong brown loamy sand. The subsoil extends down to 80 cm, brown clay loam to clay. The substratum is reddish brown clay. The area coverage is 3,569 ha in Lanao provinces.

2.2.6.3 Soils at the Highest of the Catenal Drainage

Soils on the highest of the catenal drainage (elevated terrace) is *Baybay* series. This soil is classified as *Typic Endoaquerts*. The top soil is rather shallow, about 12 cm, gray, massive structure. The Bwg subsoil extends down to 140 cm, dark gray clay to silty clay as we go down the profile, with mottles. Continuous thick slickensides are observed deeper down the profile. The substratum is greenish gray or very dark gray clay, with mottles and thick continuous slickensides. Presence of some decomposing humic materials are observed (Soil Survey Division 1987b). These soils were first observed in Baybay, Siniloan, Laguna. “Baybay” is a general term to refer to lakeshore towns along Laguna de Bay. About 838 ha of Baybay soils were mapped in Laguna province.

2.2.7 Nonsaline Soils of the Freshwater Swamps and Marshes

Freshwater marshes or swamps correlated to Soil Taxonomy in updated soil survey reports are classified as *Fluvaquents* (Fig. 2.19). Soils of freshwater marsh are usually classified either as *Pawing* with sandy substratum and poor drainage, *Palo* which has similar sandy substratum but better drained than Pawing, or *Candaba* series, which is a Vertisol or dominating presence of expanding-shrinking clays. The soils developed from recent alluvial deposition of freshwater. They are clayey to coarse texturedV soils with dark grayish brown, brown to dark gray soils. They are very poorly drained soils submerged during most part of the year.

Fig. 2.19 Marshes adjacent to a river is hardly noticeable having been economically utilized for rice production in this view in the Zamboanga peninsula coming from Zamboanga City going to Dapitan. Swamps and marshes are wetlands differentiated by presence of woody plants in the former and none in the latter

2.2.7.1 Soils Underlain by Sandy Materials

Where the landscape position is a depression establishing a condition of temporary swamp, we have *Pawing* series, classified as *Fluventic Eutrudents*. Pawing is one of the barangays that constitutes Palo, Leyte. The soil is of recent deposit as evidenced by immature development of the soil profile and the short meanders of rivers. Its elevation is just a few meters above mean sea level. But despite its being on level relief, it has many wide depressions in many places that water collects in them, thus establishing a temporary swamp. The water table is very shallow, ranging from 10 to 50 cm. Although the substratum is loose sand, the drainage is not facilitated because of the high water table and because of its landscape position. The surface soil, reaching down to a depth of 15 cm from the surface, is dark brown to reddish brown fine sandy loam, structureless, very loose when wet. The substratum (no B horizon), reaching down to the control section at 150 cm, is gray coarse sand, structureless, very loose, and always wet (Barrera et al. 1954b). Vegetation consists mostly of talahib (*Saccharum spontaneum,* Linn.), tambo (*Phragmites vulgaris,* Linn.), ticog (*Fimbristylis globulosa*, Retz., Kunth.), and balanggot (*Typha capensis,* Rohrb). About 5,431 ha of Pawing sandy loam was mapped in Leyte.

Palo series belongs to *Typic Epiaquepts* and was originally mapped in Leyte, one of historically rich municipalities of the province. The settlement is traced to as early as tenth to thirteenth century as the Kingdom of Takuranga, the first name of Palo under King Guban, its first king. Its second name was Kingdom of Kaluugan under King Pitik. In 1550, Don Miguel Lopez de Legazpi coalesced the various settlements (to include Kasangitan, Binangalan, Kasuguran, Bunga, and Guindapunan) and named the new confederation as Palo. Palo became a town in 1768. It was the site where Gen. Douglas MacArthur returned to the Philippines to reclaim the country from the Japanese forces in 1944 (Wikipedia 2012f). About 61,260 ha of Palo clay loam was mapped what was then Leyte province, and eventually politically subdivided into Leyte (also known as Northern Leyte) and Southern Leyte. Palo series is almost like Pawing soils but Palo series is slightly better drained. The elevation ranges from sea level to 91 m; the rise from the coast to the interior is gradual. Although there are several rivers and creeks that traverse and drain this soil series, there are also several pockets of depressed areas where runoff water collects and produces a condition of intermittent swamps like those found in Pawing soils. Palo soils were developed from recent alluvial deposits. No stone or rock of any size could be found on the surface nor on the substratum. The surface soil is brown clay loam, extending down to 25 cm; with poor granular structure; slightly friable when dry and moderately friable when wet. The subsoil is light reddish brown clay that could reach as far down as 45 cm; poor fine granular structure, slightly compact but otherwise, also friable like the surface soil. The upper substratum is reddish gray mottled with brown sandy loam with poor coarse granular structure and at times, structureless; extends down to 100 cm. The lower substratum is gray structureless sand, very friable, and loose either wet or dry; reaches down to the control section at 150 cm. The lower substratum is mostly wet or waterlogged (Barrera et al. 1954).

2.2.7.2 Soils Underlain by Clay

Candaba series (Plate 1C for soil profile and Fig. A.4 for soilscape view) belongs to fine clayey, montmorillonitic, isohyperthermic *Udic Pellusterts* and the soil was originally mapped in the Candaba Swamp, Pampanga. Two sample profiles are presented—one of dark brown and another of yellow brown to show that soil color may change but the definition of a soil series in terms of similarity of the arrangement of the soil profile, physical property, and pedogenesis is undeniable in these two sample profiles. This swamp encompasses about 32,000 ha and composed of freshwater ponds, swamps and marshes surrounded by seasonally flooded grasslands. The entire area becomes submerged in water during the rainy season but dries out during the months from November to April and converted to farmlands. The Candaba Swamp acts as natural flood retention basin during the rainy season and holds the overflow from five smaller rivers of Maasim, San Miguel, Garlang, Bulu, and Peñaranda before draining into the larger Pampanga River. About 15,487 ha of Candaba series were delineated in Pampanga province, mostly along the borders of the Candaba Swamp. The Candaba soil series concept was updated in 1971 as one of the outputs of the Peñaranda River Irrigation Project. Part of the Bantog series in the Reconnaissance Soil Survey of Nueva Ecija is reclassified as Candaba Series. The Ag horizon ranges from 50 to 100 cm thick, very dark gray, very sticky and very plastic fine clay with brown and red mottles. The Bg horizon is deep, gray or olive, very stick and very plastic fine clay. Common slickensides occur throughout the solum. The Cg horizon is similar to the Bg horizon except for having slightly more heterogenous texture and lack of blocky structure. These soils occur on broad flat landscapes adjacent to the marshes. The soils are poorly drained (Bureau of Soils 1973a).

2.2.8 Organic Soils (Peatlands)

Organic soils are classified as Histosols in *Soil Taxonomy* the soils are further classified according to the degree of decomposition of the organic materials as Fibrists, Saprists, or Hemists.

There are several sites in the Philippines where we have substantial area of peatlands, and among these are the Agusan Marsh and the Leyte Sab-a Basin. Peats are also found in Liguasan Marsh in Mindanao, and in Dolongan in Basey, Western Samar. There are certainly many other peatland areas. Since 1994, the Philippines is signatory to the Convention on Wetlands, commonly known as the Ramsar Convention. The Protected Areas and Wildlife Bureau (PAWB) is designated administrative authority and is conducting resource assessment and resource management studies in the area since by definition, peatlands are considered part of wetlands. The multisectoral Protected Area Management Board (PAMB) has jurisdiction over peatlands within the National Integrated Protected System (NIPAS) and would be responsible for conservation issues. PAWB in coordination with BSWM is surveying these peatlands for soil classification and mapping.

The Agusan Marsh covers some 110,000 ha of which about 44,000 ha are declared protected areas and considered one of the most ecologically significant wetland ecosystems in the Philippines. It soaks up the rainwater coming from the mountains, rivers, creeks, and streams of Agusan del Norte, Agusan del Sur, and Campostela provinces and protect the downstream towns and Butuan City from floods. It drains in the north via the Agusan River into the Butuan Bay. It is a wildlife sanctuary of awesome natural beauty.

The soils of the Agusan Marsh is named as *Caimpugan* peat. Caimpugan peat is classified as a "dome" peat consisting of a tall peat swamp forest on shallower peat and a stunted peat swamp forest on deep peat at the center of dome (Philippine Sustainable Development Network Undated). There are some literature descriptions of Caimpugat peat as being ombrotrophic (literally means "cloud-fed") referring to soil or vegetation which receive all their water and nutrients from precipitation, rather than from streams or springs (Van Alibo and Lasco 2011). Such environments are further described as hydrologically isolated from the surrounding landscape since the rain is acidic and very low in nutrients; and as such, these are home to organisms tolerant of acidic, low-nutrient environments. The vegetation of ombrotrophic peatlands is described as bog, dominated by *Sphagnum* mosses. Very limited soil survey has been conducted in the area due to the prevailing peace and order situation (Wikipedia 2012g).

Liguasan marsh complex in Cotabato provinces in Mindanao actually consists of three adjoining marshy basins, with different water regimes. Liguasan Marsh in upper Cotabato lies at the confluence of the Pulangi, Maganoy, Buluan, and Allah Rivers while Libungan is in mid Cotabato and lies at the confluence of the Libungan and Mindanao Rivers (ASEAN Regional Centre for Biodiversity Conservation 2009). Ebpanan Marsh is in lower Cotabato drained by Mindanao and Tamontaka Rivers. The three Cotabato marshes cover about 288,000 ha (UNESCO World Heritage Center 2012) and considered the largest in the Philippines, serving as natural filters and flood control for the plains of Cotabato. This Liguasan marsh complex is in the news recently because of siltation and proliferation of water hyacinths reflecting breakdown of their natural ecological functions. The old reconnaissance soil survey report classifies the soils as *Hydrosols* covering 76,875 ha (Mojica et al. 1963). These are soils submerged throughout the year or greater part of it, not yet delineated due to difficulty in setting soil boundaries below the surface of water. The reconnaissance report further states that these marshes are of little value save as a source of game, fish, and shells. Crocodiles are hunted for its hide. The eggs are used as food by the natives. In some cases where the water is shallow to allow cultivation, lowland rice is grown. More detailed soil surveys are yet to be conducted in the area.

Tinambulan peat is found on the southwest shore of Lake Buluan. A great deal of partly decomposed plant materials is mixed with the peat. The vegetation is predominantly marsh grass with some bancal trees (*Nauclea orientalis,* Linn.). Owing to its low position, the soil being barely above the level of the water, areas are drained to be cultivated. These areas are easily flooded with a slight rise in the level of the lake. Lowland rice is planted. The soil is very dark brown or black when moist. On drying, it becomes brown, very light, and spongy. From the surface until the control section at 150 cm, the soil is very uniform. There is no means to determine what lies beneath the control section but it is safe to assume that the soil is much deeper and of the same material (Mojica et al. 1963). Tinambulan peat covers 2,275 ha. This peat soil is named after sitio Tinambulan on the southwest shore of the lake at the time of the survey. Today, Tinambulan is a barangay of the municipality of Mangudadatu, province of Maguindanao.

The Sab-a Basin is a west-east elongated basin close to the north coast of Leyte and separated by a metamorphic ridge with a total area of approximately 90,000 ha (Society for the Conservation of Philippine Wetlands 2012). The peat forest constitutes some 3,088 ha of which about 1,740 ha or 44 % have been reclaimed for agriculture (Sustainable Management of Peatland Forests in Southeast Asia 2011). The remaining unutilized peatland in the eastern half of the basin are small remnant areas of swamp forest and sedge/grass peat swamp. Two smaller peat basins in Daguitan consisting of 210 ha and in Kapiwaran of 430 ha have been converted to agriculture. The water supply comes from several springs, small rivers, and aquifers at the edge of the basin and rainfall. There are several traversing waterways most of which drain east into the Leyte Gulf.

The Sab-a Basin and Dolongan Peatlands are classified as *Dolongan* series. *Dolongan* series was first mapped in Dolongan, a barangay of the municipality of Basey, Samar. It is classified as *Typic Tropohemists*. The soil originated from organic materials and fine soil materials from the higher surrounding areas; and underlain by silt loam mixed with decomposed organic matter. Dolongan has a thin mineral layer (less than 50 cm thick) and an organic layer. This is poorly drained soils. The surface soil extends down from 5 to 30 cm deep, dark brown, very dark gray, to black friable loam with plenty of organic matter. The subsoil is organic material (O horizon), dark brown, dark grayish brown, dark reddish brown that could be dark red as we move down the profile, loose and friable loam with highly decomposed and intermediately decomposed organic materials, and reaches down from 30 to 70 cm, or even 90 cm in some areas. The substratum is dark brown to dark grayish brown loose and structureless muck. Some undecomposed wood fragments and coarse fibers were observed in some areas. About 3,357 ha of Dolongan series were mapped in Samar (Barrera et al. 1954).

2.3 Soils of the Narrow and Broad Alluvial Valleys and Flood Plains

Wernstedt and Spencer (1967) mentioned that it is probably that the Philippine archipelago existed since the beginning of Tertiary. During and subsequent to the Tertiary, there have been several periods of widespread subsidence and subsequent uplift; and deep layers of sediments, which include limestone, conglomerate, carbonaceous silt, and even coal were deposited over wide areas in downwarped or synclinal areas in the presence of relatively quiet waters as evidenced by lack of sorting of the materials. Tertiary sedimentary rocks underlie about 55 % of the country's total land area. In general, these sediments form foothill and lowland landscapes. Many of the plains including the Central Plain and Cagayan Valley in Luzon and many other smaller coastal and riverine lowlands on several islands are covered with deep Quaternary depositions.

The soils that developed from alluvium are the economically important soils in the Philippines. Found generally on lowland areas, a wide variety of soils eventually developed. Four types of alluvial materials constitute most of the parent materials—shale, limestone, recent unconsolidated alluvial deposits, and the older unconsolidated alluvial deposits. Being in the Ring of Fire, and with active volcanic activities, volcanic materials do serve as an important parent material for many soils.

Fig. 2.20 A narrow or minor alluvial plain. As against a narrow mini plain, Filipino soil surveyors differentiate the two in terms of valley width. The narrow or minor alluvial plain is usually more than 50 m in width but the narrow mini plain is less than 50 m. There are certain soil series specific to minor alluvial plains and to narrow mini plain

2.3.1 Soils of the Narrow Alluvial Flood Plains: The Poorly Drained Soils Characterized by the Presence of Redoximorphic Features

These soils occur on valleys of less than 500 m width (Fig. 2.20). Some of these slowly sank as the river bottoms became filled with successive layers of sediments and broad valley plains were formed where before the sloping sides of deep valleys were. The poorly drained soils and characterized by presence of redoximorphic features are as follows.

2.3.1.1 Soils Underlain by Clay, with Weathered Tuffaceous Fragments; Heavy Cracking Soil (Vertisol)

Baras series, named after the municipality of Baras, province of Rizal, is classified as very fine, montmorillonitic, isohyperthermic *Udorthentic Pelluterts*. The typical pedon was described in Lagundi, Morong, Rizal. The soils are deep, poorly drained, found on level to nearly level very gently sloping (0–5 % slopes) minor alluvial plain. The Ag horizon is dark gray to gray clay (hues 10YR to 5Y) with no more than 40 cm thick. The Bg horizon is composed predominantly of gray, dark gray, light gray to olive gray clay with distinct brown and olive mottles. The Cg horizon below 110–150 cm from the surface is olive gray, olive and play olive clay with distinct clear gray and light yellowish brown mottles. Few soft and hard iron and manganese concretions are present. Calcium carbonate nodules and weathered tuffaceous fragments are also observed and increased with depth. Cracking of the surface with a width of 2–3 cm to a depth of 50–1 m was common during the dry season. About 1,506 ha of Baras clay was mapped in Rizal province. Baras series is associated with Jalajala. Both occur on minor alluvial plains and are derived from alluvial deposits. Baras have finer texture in all horizons than Jalajala. Baras also has much deeper sola. Pinagbuhatan series is also associated with Baras series and asides from occurring on the same landscape position, they have the same taxonomic classification. But Pinagbuhatan is shallower.

Pinagbuhatan series was named after barangay Pinagbuhatan in what was then Pasig, the capital of Rizal province. Pasig City has been ceded from the province in 1975 and is now part of highly urbanized Metropolitan Manila. It became a city in 1994. The typical profile for this soil series was described in barangay Ususan, Taguig, then a part of Rizal. Taguig was also ceded from Rizal to be part of Metropolitan Manila and became a city in 1998. Pinagbuhatan series is one of those extinct soils encroached by urbanization but owing to its shrinking-swelling properties, is best for paddy rice production. This soil series is classified as very fine, mixed, isohyperthermic *Udorthentic Pellusterts*. The soils are moderately deep to deep poorly drained soils on nearly level to gently sloping (0–5 % slope) minor alluvial plain. The Ag horizon is no more than 30 cm thick, gray to dark gray clay with distinct yellowish red, dark yellowish brown, and strong brown mottles, firm when moist, sticky, and plastic when wet. The Bg horizon is 80–150 cm deep, gray to very dark gray, olive gray, light olive gray clay with distinct yellowish brown to dark yellowish brown, olive brown mottles, firm when moist, plastic or very plastic, and sticky or very sticky when wet. Few thin slickensides are found especially in the lower Bg horizon. The C horizon is gray, very dark gray, light olive gray, pale olive gray with light to dark yellowish brown or olive brown mottles. Few small weathered tuff fragments are sometimes observed. A total of 5,491 ha of Pinagbuhatan series was mapped in Rizal province. Pinagbuhatan series is quite similar to Baras and Binangonan series. The three soil series were classified as Udorthentic Pellusterts and found on alluvial landscapes. But Baras has darker and deeper solum than Pinagbuhatan. Baras has also calcium carbonate nodules. Binangonan soils contain calcium carbonate nodules in the profile and occur on narrow mini plain landscape position. Pinagbuhatan series lacks calcium carbonate nodules.

2.3.1.2 Soils Underlain by Coarse Granular Clay to Silty Clay, with Mottles

Matina series (Plate 1E) consists of deep, somewhat poorly drained soils of very fine, mixed, isohyperthermic *Aeric Epiaquepts* on level to nearly level overflow basin of alluvial plains. These are secondary soils derived from recent alluvium washed mainly from uplands underlain by limestone and shale. The relief is nearly level to level, and the elevation varies from a few meters to about 25 cm. The external drainage is slow, but the internal drainage is fair. The water table is shallow in some places. These soils are subjected to seasonal flooding. The surface layer ranges from 15 to 34 cm thick, very dark grayish gray to black clay loam to clay with strong brown mottles. The subsoil reaches down from 80 to 125 cm from the surface, light grayish brown to dark grayish brown clay, silty clay loam, clay loam, and silty clay with strong brown mottles. The substratum reaches down to 170 cm, grayish brown, yellowish brown, to light yellowish brown clay to silty clay, with occasional silty clay loam and strong brown to gray mottles; fine to coarse granular structure (Mariano et al. 1953). Originally described in Matina, Davao City, a total of 17,222 ha of Matina series were mapped in Davao, Surigao, Lanao, and Misamis Oriental provinces. Corn and coconut are the dominant crops but abaca, upland rice, and vegetables are also grown.

2.3.1.3 Soils Underlain by Structureless Clay to Silty Clay, with Weathered Shale and Mottles; Has Vertic Properties

Toran series (Plate 1G) is classified as very fine mixed isohyperthermic *Vertic Endoaquepts*. This soil series is derived from alluvial deposits, occupying the bottom lands along streams, and regularly flooded. The top soil is gray to dark gray to pale brown clay to silty clay; with reddish brown mottles; granular; extending down to 40 cm. The subsoil is light yellowish brown to light gray clay; with yellowish brown mottles; granular; with small soft black manganese concretions and reaches down to 130 cm. The substratum is light gray to very dark brown clay loam, clay to silty clay; with yellowish mottles; structureless; with some concretions; with weathered shaled materials in some places; and could extend down to 190 cm (Dagdag et al. 1967). Lowland rice is the principal crop. Fruit trees are grown in more elevated portions. Toran, where this soil was first described, is a barangay of Aparri municipality, Cagayan province. Aparri is a Japanese trading post as early as 1405, prior to the coming of the Spaniards; and was eventually established as one of the major ports of the Galleon Trade in 1680. This Galleon Trade is also known as the Manila–Acapulco Galleon Trade, inaugurated in 1565 when Andres de Urdaneta, sailing in convoy under Miguel Lopez de Legazpi, discovered a return route from Cebu to Mexico (then known as New Spain) crossing the Pacific Ocean. It ended in 1815 after the Mexican War of Independence. A total of 37,126 ha of Toran loam and silty clay were mapped in the provinces of Cagayan and Kalinga-Apayao.

2.3.1.4 Soils Underlain by Plastic Clay, with Mottles; Has Vertic Properties

Glan series is classified as *Vertic Epiaqualfs* and formed from recent alluvial deposits in level to nearly level decantation basin. The top soil is dark gray clay loam; compact, sticky and plastic when wet but hard when dry, and extends down to a depth of 20 cm. The subsoil is grayish brown to dark grayish brown compact sticky clay and changes to greenish gray as we go down the profile that could reach down to 90 cm; very hard when dry. The substratum, extending to the control section at 150 cm, is greenish gray to yellowish gray very sticky and plastic clay with orange mottles that appear at 120 cm depth. The color becomes more gray as depth increases (Mojica et al. 1963). Glan clay loam covers 1,875 ha in what was originally Cotabato provinces which has now become North and South Cotabato, Sultan Kudarat, Maguindanao, Shariff Kabunsuan, and Sarangani. Glan is currently a municipality of Sarangani Province.

2.3.1.5 Soils Underlain by Plastic Clay, with Weathered Gravels and Mottles; Heavy Cracking Soil (Vertisol)

Pili series (Fig. 5.6 and Plate 1E) are very fine mixed isohyperthermic *Typic Epiaquerts*. This soil series has a wide range of colors and textures. The very fine soil materials of volcanic origin and the presence of organic matter gives the black color to some soils of the series. The surface soil is brown, dark brown, very dark gray to black loam, clay loam to clay. Few black small and soft gravels are found on the surface. It could extend down to 30 cm. The subsoil is light brown, grayish brown, gray to reddish brown, soft, plastic, waxy, and compact clay to clay loam, extending down to

60 cm. The substratum is moderate brown to strong brown, loose, and plastic clay. White mottles and weathered gravels are present (Lucas et al. 1965). The external and internal drainage are poor. This soil series was first described in Pili, Camarines Sur. About 69,573 ha of Pili loam, clay loam, and clay were mapped in Camarines Sur covering the fertile valley of the province west of Mount Isarog and Mount Iriga. Except in the slightly elevated areas, Pili soils is flooded and renewed by the Bicol River every year, depositing fine volcanic materials and organic matter from the surrounding highlands, hills, and mountains. Rice is the principal crop. Upland rice and corn, coconuts, fruit trees like jackfruits, citrus, and banana are also grown.

2.3.1.6 Soils Underlain by Clay, with Limestone Gravels; Has Vertic Properties

Panganiran series is classified as *Vertic Endoaquepts* and developed from stream deposited materials washed down from the surrounding hills and uplands of limestone origin. This series occupies narrow coastal plains and the area is not very extensive, level to nearly level. External drainage is fair while internal drainage is poor owing to the fine texture of the soil. The surface soil is very dark gray to black, medium blocky to columnar clay, extending down from 35 to 40 cm. The surface soil is free from coarse skeleton. The upper subsoil is grayish brown and speckled dark gray, orange, or yellowish brown clay; columnar in structure; also free from coarse skeleton. The depth reaches down from 60 to 70 cm. The lower subsoil is similar to the upper layer but of heavier and denser material reaching down to 95–100 cm. Below until the control section at 150 cm is the substratum, very dark gray to gray, gravelly clay and the gravels are limestones (Aristorenas et al. 1965). The soils are usually planted to diversified crops like banana, coconut, rice, sugarcane, corn, sweet potato, vegetables, and other annual crops. This soil series was first mapped in Panganiran when it was but still a sitio of Malidong, then a barrio of the municipality of Guinobatan, province of Albay. Panganiran is now a barangay of the neighboring municipality of Pioduran. Panganiran is a Muslim word and meant the land of "no return" or the land of the setting sun. A total of 4,386 ha of Panganiran series were mapped in the provinces of Albay, Masbate, and Sorsogon.

2.3.1.7 Soils Underlain by Loam, Sandy Loam, Gravelly Clay, Sandy Clay or Weathered Tuffaceous Fragments

Cupang series was named after barangay Cupang, municipality of Antipolo, Rizal province. But the typical pedon was taken in Santa Cecilia Village, Las Piñas, then a municipality of Rizal province. In 1976, it became part of Metropolitan Manila and was made city in 1997. Cupang series belongs to fine, mixed, and isohyperthermic *Vertic Tropaquepts.* These soils are moderately deep, poorly drained occurring on nearly level (0–2 % slope) minor alluvial plains. The Ag horizon is 20–30 cm thick, dark gray, very dark gray clay with distinct clear dark brown, very dark brown, strong, and dark grayish brown mottles. The structure is subangular blocky, firm when moist, and sticky and plastic when wet. The cambic Bg horizon is gray, ark gray, very dark gray, and olive gray clay with olive, olive gray, or olive brown mottles. The structure is angular to subangular blocky, firm when moist, and sticky and plastic when wet. Few thin discontinuous slickensides are present in the lower Bg horizon. Few small weathered tuffaceous fragments are present with increasing depth. The C horizon 64–130 cm deep and is loam, sandy loam, gravelly clay, sandy clay, or weathered tuffaceous fragment. About 1,843 ha of Cupang clay was mapped in Rizal province. Cupang series is associated with the deeper somewhat poorly drained Jalajala series. Both soils occur on minor alluvial plain and are classified as Vertic Tropaquepts. The substratum of Cupang is stratified coarse loamy and clay but Jalajala is fine to very fine clayey throughout the horizon. Jalajala is also deeper than Cupang but the latter contains higher clay content than the former. Cupang is also somewhat similar to Philcomsat series but Cupang is darker. Philcomsat has also calcium carbonate nodules.

2.3.1.8 Soils Underlain by Silt Loam to Fine Sandy Loam Materials

Catubig series is classified as fine, mixed, isohyperthermic *Typic Epiaquepts*. Catubig is an inland municipality of the province of Northern Samar. This soil was developed from alluvial deposits washed down from the higher surrounding areas. The relief is level to undulating. Drainage is fair to poor. It has a shallow water table, ranging from one to 1.5 m from the surface. Rice is the principal crop grown. The other crops are corn, sweet potato, coconut, banana, sugarcane, *gabi,* and vegetables. The surface soils is yellowish brown to grayish brown (moist), light yellowish brown to light grayish brown (dry) mottled loam; moderately loose when moist and slightly friable when dry; granular in structure, extending down to 25 cm. The upper subsoil is light brown, brown to grayish brown silty clay loam with plenty of iron concretions; coarse granular structure, with depth reaching to 50 cm. The lower subsoil is light brown to reddish brown silty clay loam with lesser iron concretions but larger in size than those in the above layers, easily crushed between the thumb and forefinger, reaching to 90 cm. The substratum below is silt loam to fine sandy loam, without concretions (Simon et al. 1975). A total of 22,292 ha of Catubig loam and clay loam were mapped in what was originally Samar province, later on politically subdivided into Northern Samar, Eastern Samar, and Samar (formerly Western Samar) provinces.

2.3.1.9 Soils Underlain by Gravelly Clay Loam to Sandy Clay

Busuanga series was first described in Busuanga Island which is a member of the Calamian Group of Islands between Mindoro and mainland Palawan. Busuanga is also the name of the municipality that covers the western third of the island. This soil series occurs on valleys with surrounding low hills from where the soil parent material originated. The land is level like those of San Manuel or Babuyan soils. Busuanga soils is brown to light brown while Babuyan soils is light gray. The drainage is poor. The surface soil, reaching down to 20 cm from the surface, is grayish brown to almost black and dark gray loam, silt loam to clay loam; fairly friable and slightly compact with fine granular structure; gravels maybe found in some instances. The subsoil, reaching a depth of 50 cm from the surface, is dark brown to grayish brown loam to clay loam; fine granular structure. The substratum that reaches down to the control section at 150 cm, is gray to light brown gravelly clay loam to sandy clay; with brown mottling; slightly compact; coarse granular structure (Barrera et al. 1960). This soil series is classified as *Typic Eutrudepts* and Busuanga loam covers 6,650 ha in Palawan province.

2.3.1.10 Soils Underlain by Coarse Sand, with White and Brown Mottles

Malinao series is a coastal lowland soils classified as *Aeric Epiaquepts* and developed from alluvial materials from the surrounding uplands transported and deposited through volcanic action and water. This soil series developed from alluvial materials from the surrounding uplands and transported and deposited through volcanic action and water. The surface soil is grayish brown, yellowish brown friable fine sandy loam with red streaks and orange splotches, reaching down from 15 to 20 cm. The upper subsoil is light gray, brownish gray to grayish brown friable fine to medium granular silt loam, extending down from 45 to 50 cm from the surface. The mid-subsoil is reddish brown, light grayish brown to yellowish brown granular to massive silt loam with numerous red streaks and some gravels are present. It extends down from 70 to 75 cm. The lower subsoil is grayish brown, structureless to fine granular very friable sandy loam with red splotches and reddish streaks. Some gravels are present. It reaches down from 95 to 100 cm. The substratum is very dark gray to gray, medium to coarse sand with white and brown specks. The drainage is poor (Aristorenas et al. 1965). The surface soil of this series is lighter in color than that of the Legaspi series and is further differentiated by the presence of reddish streaks and orange splotches. About 3,580 ha of Malinao sandy loam were mapped in the province of Albay. This soil series was named after Mount Malinao in Albay with an estimated altitude of 1,584 m above sea level, a dormant volcano with the active Mount Mayon on its southwest. Malinao is also a municipality in the Albay and founded between 1600 and 1616.

2.3.2 Soils of the Narrow Alluvial Flood Plains: The Well-Drained Soils

2.3.2.1 Soils Underlain by Clay to Silty Clay Loam

Mayan series belongs to fine, loamy, isohyperthermic *Fluventic Eutrudepts,* developed from local alluvium. The relief is level to gently undulating. These soils are moderately deep, moderately well-drained soils on narrow alluvial plains or valleys. The topsoil, reaching down to 40 cm in depth from the surface, is reddish brown clay loam; coarse granular to block structure; strongly plastic when wet, hard and brittle when dry; no coarse skeleton. The subsoil, extending down to 80 cm from the surface, is brown to reddish brown clay; columnar to cloddy structure; very plastic and sticky when wet, hard when dry; no coarse skeleton. The substratum that reaches down to the control section at 150 cm and even below is light reddish brown to light yellowish brown clay; columnar in structure; plastic and sticky when wet, hard when dry; no coarse skeleton (Simon and de Jesus 1974). This soil series was first mapped in Mayan, a barangay of Itbayat, Batanes. About 213 ha of Mayan clay loam, mainly in Batanes were mapped, occupying small areas, mostly on depressions or sinks. The crops grown are sweet potato and other tubers like yams, garlic, onion, banana, coconut, and fruit trees. This soil series is well drained and the water that accumulates on the surface during flash-floods does not stay long.

2.3.2.2 Soils Underlain by Massive Loam to Silt Loam, Below is Coarse Sand

Irosin series is classified as *Typic Epiaquolls* developed from recent alluvial deposits. The surface soil is dark brown, dark grayish brown, to brownish gray structureless to fine granular silt loam to sandy loam reaching down from 20 to 35 cm. The upper subsoil is light brown, gray to reddish gray structureless and loose medium to coarse sandy loam and extending down to a depth from 45 to 60 cm. The lower subsoil is grayish brown, grayish black to light brown structureless very porous and loose gravelly sand, reaching down from 145 to 160 cm. The substratum is light brown to grayish white friable and massive loam to silt loam. Below is grayish black to gray structureless coarse sand with white specks. The drainage is good (Aristorenas et al. 1963). A total of 3,030 ha of Irosin sandy loam and Irosin silt loam were mapped in the province of Sorsogon. This soil series was first mapped in the municipality of Irosin, province of Sorsogon. The town name was believed to have originated from the local dialetct "iros", meaning to cut-off a part and probably to describe the gush of floodwaters eroding riverbanks and cutting through the lands to form another river route.

2.3.2.3 Soils Underlain by Coarse Sand, with Stones and Gravels

Dadiangas series is on level to gently sloping volcanic pyroclastic residual terrace slightly to moderately dissected; and classified as *Typic Eutrustepts*. The top soil is dark gray, structureless loamy sand to sandy loam that extends down to 25 cm or more. The subsoil is gray, loose, and structureless, coarse sand with gravels. The substratum is gray, coarse sand with stones and gravels (Mojica et al. 1963). Dadiangas, where this soil was named after, is presently called General Santos City and component city of South Cotabato province. The new name was after General Paulino Santos who lead the relocation of 62 first batch of Christian settlers from Luzon to the shores of Sarangani Bay aboard the steam ship "Basilan" of Compania Maritima in 1939 (Wikipedia 2011). Thousands more from Luzon and the Visayas subsequently migrated making *GenSan City* one of the most populous urban center of the country. But the old name Dadiangas was how the native B'laan tribe called this place, to refer to trees with thorns on trunks and stems that abundantly thrived here at that time. A total of 37,500 ha have been mapped in the east bank of Allah River between Kolambug and Sipaka extending to the west of Sapali to Selken and Lampuko, and in western Koronadal Valley.

2.3.2.4 Soils Underlain by Friable Sandy Loam, with Few Gravels; Has Vertic Properties

Buayan series (Plate 1B) is very fine isohyperthermic *Vertic Epiaqualfs*, developed from recent alluvial deposits, and first described in what was then Cotabato province before it was divided into North Cotabato, Maguindanao, Sultan Kudarat, South Cotabato, and Sarangani provinces. This municipality of Buayan facing Sarangani Bay is now called General Santos City, a component city of South Cotabato. This city was formerly known as the municipality of Buayan but Buayan nowadays refers to one of the barangays or villages that constitutes the city. General Santos City was its third name, and before it became Buayan municipality, this place was known as Dadiangas, the name of another lowland soil series and should not be confused with Buayan series. The Buayan series consists of secondary soils developed from alluvium deposited by the Buayan River. Despite its moderately heavy subsoil, water easily percolates. The surface soil of Buayan series is dark gray, slightly compact friable clay loam; and could extend down from 25 to 45 cm. The subsoil is very light gray to brownish gray, coarse granular, loose, silty clay loam, reaching down from 80 to 95 cm. The substratum is very light gray, slightly compact, very friable sandy loam with few gravels, with depth ranging from 135 to 148 cm (Mojica et al. 1963). Below this is a layer of waterworn gravels and other sizes of stones with coarse sand between 15 and 20 cm thick. About 7,500 ha of Buayan clay loam were mapped in what was then Cotabato province. Rice is usually grown.

2.3.3 Soils of the Broad Alluvial Plains: The Poorly Drained Soils and Characterized by Presence of Redoximorphic Features

Soils developed from recent alluvial deposits are of mixed parent materials. They are of different soil taxonomic classifications, ranging from very young Inceptisols to mature and cracking Vertisols. They vary in color and in texture, ranging from coarse to fine textured. These soils are the most extensive area for agriculture. There are several soil series in this landform and we therefore group the soil series according to their drainage conditions. The first we discuss are soils with poor drainage and characterized by presence of redoximorphic features.

2.3.3.1 Soils Underlain by Buried a Horizon of Clayey Materials

Colgante series (*Corgante* in the updated soil survey report of Bulacan, 1987; and would thus appear as such in almost all literature citations) covered some 537 ha in Bulacan province and classified as *Aeric Epiaquepts*. The soils are deep, somewhat poorly drained silty clay loam to clay loam becoming clay as we go down the profile. The soil is associated with the somewhat poorly drained Tagulod and the very poorly drained San Fernando series. Colgante differs from the two series by having buried A horizon below 100–150 cm depth. Colgante occurs in moderately low broad flat alluvial plain, Tagulod in nearly level low alluvial terraces above backswamps, and San Fernando soils occur in depressions (Soil Survey Division 1987a). Colgante series was first described in barangay Colgante, municipality of Apalit, province of Pampanga. This soil series is principally grown to rice.

2.3.3.2 Soils Underlain by Clayey Materials, Adjacent to Marshes and Swamps

Recognizing *Timaga* series over the *Tagulod* series is rather tricky since both were developed adjacent to marshes and swamps. Timaga series was first described in the Cotabato Basin, a broad northwest-southeast trending intermontane structural depression in southern Mindanao. This depression was covered by the sea as recently as Pleistocene (Wernstedt and Spencer 1978). Tagulod series was first described in the Central Plain of Luzon, on the southward drainage by the Rio Grande de Pampanga with Tertiary

(65.5–1.8 million years ago) and Quaternary (1.8 million years ago to the present) sediments consisting of limestones, sands, and shales. It is interesting that Smith (1913) thinks that the Central Plain was probably the site of an ancient sea and even cited Adams (1910) to have drawn a hypothetical map of the Tertiary geography of the Central Plains. Pleistocene is an epoch of Quaternary. It is logical that although both soils are the same in physiographic position, alluvial in formation, clayey in substratum, and with presence of redoximorphic features, Timaga would be geologically younger. The mineralogy of the two soil series will be an important factor to distinguish one from the other which can be a subject of future studies. For now, Timaga would not have a B horizon as against Tagulod which has quite discernable development.

Timaga series, classified as *Typic Ustipsamments* are poorly drained soils developed from recent alluvial deposits. The surface soil is dark gray to almost black friable clay loam that reaches down from 15 to 20 cm in depth. The upper subsoil is grayish brown silty clay loam that extends down from 20 to 60 cm from the surface. The lower subsoil is brown to grayish brown clay reaching a depth from 60 to 100 cm. The substratum is grayish brown clay loam (Mojica et al. 1963). About 62,500 ha of Timaga clay loam were mapped in what was then the province of Cotabato, occupying the level land south of Dulawan between Dansalan and Talayan Rivers and east of the Sapakab-Tacurong road to the Liguasan Marsh.

Tagulod series (Plate 1G) are deep, somewhat poorly drained soils formed on weakly stratified clayey alluvium in very broad to nearly level slightly dissected alluvial terraces and classified as clayey, nonacid, mixed, isohyperthermic *Typic Endoaquepts* intergrade with high base saturation These soils are formed from weakly stratified fine clayey alluvium in very broad slightly dissected low continental terraces. Except in some areas, these soils are subject to seasonal river or stream overflow or runoff accumulation. The base saturation is more than 60 % in the control section. The surface layer, about 10 cm thick, is brown clay with common yellowish brown mottles but could be dark gray, gray, or light gray when used for paddy rice. Below this layer to a depth of 26 cm is light brownish gray clay commonly mottled with strong brown. The upper subsoil that extends to 60 cm depth is gray clay commonly mottled with yellowish brown and accompanied by slickensides. The lower subsoil to a depth of 150 cm is pale brown or brownish yellow clay with common brownish yellow and few brownish gray mottles and few manganese concretions (Soil Survey Division 1987a). Tagulod series is associated with the lower lying and poorly drained Bantog, Bigaa and Malimba soils and the well-drained Quingua soils of the upper river terraces. These soils cover about 21,706.3 ha in Bulacan province, formerly classified as Bantog in the old reconnaissance soil surveys. Tagulod where this soil series is named, is a barangay of Candaba, Pampanga and currently partly urbanized.

2.3.3.3 Soils Underlain by Clay with Brick-Red Mottles

Tamontaka series classified as *Typic Endoaquepts* are poorly drained soils developed from alluvial deposits. This soil series is located on low physiographic position and poorly drained. A considerable portion of the area is under water at certain periods of the year. The surface soil is very dark brown to almost black clay with brick-red mottling. In waterlogged areas, partly decomposed leaves and stems of aquatic plants are present. The depth extends down from 20 to 4 cm. The subsoil is brown, brownish gray to yellowish gray clay with orange or brick-red mottles, and extends down from 45 to 90 cm from the surface. The substratum is light brownish gray, brownish gray to pale brown clay with brick-red mottling. White sand grains are present in some cases appearing as white spots or mottling (Mojica et al. 1963). These soils are used mainly for rice production. In the elevated portions, other crops like vegetables and coconuts are grown. About 30,625 Tamontaka clay were mapped in what was then Cotabato province. Tamontaka these days refer to six barangays (Tamontaka I, II, III, IV, V, and VI) comprising Cotabato City.

2.3.3.4 Soils Underlain by Clay with Yellow Mottles

Butuan series (Plate 1B for soil profile and Fig. A.3 for soilscape), classified as *Typic Epiaquepts,* was first identified around the vicinity of Butuan City, of what used to be the province of Agusan. Butuan City eventually became the capital of Agusan del Norte when Agusan was divided into two provinces in 1967 but Butuan City was separated from the province as a highly urbanized city in 2000; and Cabadbaran City became the new provincial capital. However, many of the provincial government offices including the Provincial Capitol are still located in Butuan City. This is a very old settlement and has established trading relations with the Kingdom of Champa (now southern Vietnam) and the Srivijaya Empire of Sumatra; which by the eleventh century, is known as the Kingdom of Butuan (Wikipedia 2012h). The soil series was developed from older alluvial terraces along many sections of the Agusan River and very poorly drained. The alluvial deposits were deposited mostly on the low-lying poorly drained places along the river although slightly elevated areas are also covered by this soil series. The surface soil, reaching down to 40 cm is dark brown loam with red streaks; fine granular structure; slightly sticky and plastic. The subsoil, reaching down to 90 cm from the surface, isolive gray clay with dark red mottlintgs; granular; very sticky and plastic; concretions are present and most abundant at the lower part of th horizon. The substratum extends down to the control section at 150 cm, and is olive gray clay with yellow mottlins; sticky and plastic; no concretions (Mojica et al. 1967). A total of 74,010 ha of Butuan loam were mapped in what was then Agusan province.

2.3.3.5 Soils Underlain by Clay, with Orange Mottles and Gravels

Cabahuan series are young secondary soils classified as *Aeric Endoaquepts*. This is an alluvial soil formed from the deposition of running water. This soil series closely resembles Isabela soil series in the color of the surface soil, relief, and drainage conditions. But unlike Isabela, the subsoil and substratum of the Cabahuan series contains some coarse skeleton and yellowish in color. The Isabela series has no coarse skeleton in the subsoil and has grayish black and pale gray to yellowish gray subsoil and substratum. The surface soil of Cabahuan series extends down to 40 cm and black massive (structureless) clay; sticky and plastic when wet; hard, compact, and cracks when dry. The subsoil reaches down to 90 cm and also black, massive heavy clay with gravels; very sticky and plastic when wet, hard, and compact when dry; permeability is very slow. The substratum is grayish black, pale gray to yellowish gray compact clay with orange splotches and whitish specks, and presence of gravels. This soil series is almost entirely cultivated to lowland rice and corn. Coconuts are also grown in small areas (Salazar et al. 1962). About 803 ha of Cabahuan soils were mapped in the island province of Marinduque. This soil series was first described in Cabahuan, Boac, Marinduque.

2.3.3.6 Soils Underlain by Clay with Olive Brown Mottles; Heavy Cracking Soil (Vertisol)

Bigaa series (Plate 1B for soil profile and Fig. A.2 for soilscape view) are classified as *Aeric Endoaquerts* and consist of deep, poorly drained soils formed on weakly stratified very fine clayey alluvium on broad, nearly level slightly dissected alluvial terraces slightly above the main river flood plains and on broad depressed areas subject to seasonal flooding. The plowed surface soil is about 22 cm thick, dark greenish gray clay with strong brown mottles. The gleyed A horizon continues to a depth of 59 cm, very dark gray clay with few olive and olive brown mottles. The subsoil is about 70 cm thick, olive gray clay with few olive brown, and very dark gray mottles and manganese concretions. The substratum goes down to a depth of 150 cm and very dark gray clay with olive brown mottles. Surface cracks 3–5 cm wide to a depth of about 0.5 m (Salazar et al. 1962). The Bigaa soils are associated with the slightly higher lying Bantog series but Bigaa soils have thicker Ag horizons and darker in color than Bantog. Bigaa series is named after Bigaa municipality, now named as Balagtas in the province of Bulacan. This new town name was after the great Filipino poet, Francisco Balagtas (1788–1862), and author of the classic "Florante and Laura". A total of 89,971 ha of Bigaa series were mapped in the provinces of Bulacan, Samar, Quezon, Abra, La Union, Pampanga, Cagayan, and Isabela (Fernandez and Jesus 1980).

2.3.3.7 Soils Underlain by Clay with Manganese Concretions

Tingib series are poorly drained and ponded, and classified as *Typic Epiaqualfs*. This is a secondary soil developed from local alluvium brought down by water from the higher surrounding areas. It occurs on nearly level or flat relief slightly above sea level. The water table is commonly at or near the surface during most part of the year. The surface soil is light grayish brown to light gray clay loam with reddish brown streaks, with depth ranging from 20 to 30 cm. The upper subsoil is light gray clay, with reddish brown streaks that become light brownish gray when mashed, and with some black manganese concretions, extending down from 30 to 45 cm. The lower subsoil is light yellowish brown to grayish brown clay, mottled, with manganese concretions as those found in the upper layer. The depth is from 55 to 70 cm from the surface. The substratum is light yellowish brown to light grayish brown clay, with manganese concretions with size ranging from a coarse sand to as big as a corn kernel; less massive than the above layer (Simon et al. 1975). Tingib differs from Bigaa because the concretions in Tingib are manganese while those in Bigaa are iron. Bigaa is also better drained than Tingib. Tingib series also differs from Catubig series in that Catubig has fewer and smaller concretions. Lowland rice is the principal crop grown; coconuts, banana, fruit trees, and vegetables are also grown. About 10,206 ha of Tingib clay were mapped in the province of Samar. Tingib, where this soil was first identified, is a barangay in the municipality of Basey, province of Samar.

2.3.3.8 Soils Underlain by Clay; with Vertic Properties

San Fernando series (Plate 1F for soil profile and Fig. A.9 for soilscape view) is fine, mixed, isohyperthermic *Vertic Endoaquepts* developed from recent alluvial deposits. The soils of this series were developed from stream-deposited materials washed down from the surrounding hills and uplands of limestone origin. The area is level to nearly level. External drainage is fair while internal drainage is poor. The surface soil is pale gray, brownish gray, dark gray to black clay loam to clay with reddish brown streaks; hard and compact when dry, sticky, and plastic when wet. The depth is from 20 to 25 cm. The upper subsoil is dark brown to nearly black, stiff, hard and waxy heavy clay; very sticky when wet. The depth reaches down from 35 to 450 cm. The lower subsoil is dray grayish brown, sticky clay with black mottles, and reaches down to 100 cm. The substratum is gray, sticky and plastic clay (Yñiguez et al. 1956). About 28,231 ha of San Fernando sandy loam, clay loam, silty clay, and clay were mapped in the provinces of Pampanga, Ilocos Norte, and Cagayan. In Pampanga province, a drainage canal leading to the Pampanga swamps passes through the soil series. Being in low areas, the drainage is very poor and subject to flooding during the rainy season. This was first described in San Fernando City, Pampanga, founded in 1754 and carved out from the neighboring towns of Bacolor and Mexico with Don Vidal de Arrozal as the first gobernadorcillo (Wikipedia 2012i).

2.3.3.9 Soils Underlain by Clay Mixed with Decomposing Plant Materials

Soils with redomixmorphic features: Both *Cagugubngan* and *Sugodsuron* series would have a clay substratum but mixed with decomposing plant materials. Cagugubngan series has shallower topsoil compared to Sugodsuron.

Closely associated with Bigaa and Tagulod soil series is *Cagugubngan* series which has an aquic soil moisture regime and classified as *Aeric Endoaquepts*. These are poorly drained soils, moderately deep to deep, and subject to slight seasonal runoff flooding during the rainy season. The gleyed surface soil, 15 cm thick, is dark gray, dark grayish brown, or grayish brown clay, clay loam to silty clay loam with few to common fine and medium distinct yellowish brown, strong brown, and prominent yellowish red mottles. The cambic and gleyed subsoil reaches down to the control section at 150 cm or more, mottled grayish brown, brown, yellowish brown, dark yellowish brown, and light gray clay, massive at the lower horizon. The gleyed substratum is gray, dark gray, dark greenish gray or greenish gray clay with partially decomposed plant remnants. Cagugubngan, where this soil series was first described, is in Catubig, Northern Samar. This soil series covers 4,805 ha in Samar provinces.

Sugodsuron series is classified as *Typic Endoaquepts* poorly drained soils formed on low parts of the alluvial plains. The gleyed topsoil reaches to about 20–25 cm, gray, greenish gray, bluish gray, grayish brown, and dark grayish brown clay to heavy clay with common fine and distinct yellowish brown and strong brown mottles. Soil structure is massive to weak and moderate angular to subangular blocky. The cambic gleyed subsoil with chroma of two or less, from 100 to 150 cm in depth, is gray, light gray, bluish gray, dark greenish gray, or greenish gray heavy clay with few to common fine and medium distinct strong brown, brown, to dark yellowish brown, brownish yellow, and reddish mottles. Structure ranges from moderate medium and fine blocky to massive, with slight or no evidence of clay translocation. The gleyed substratum is gray, dark gray, greenish gray clay to heavy clay with common fine and medium yellowish brown, dark yellowish brown, strong brown, and yellowish red mottles that gradually change to faint olive brown as depth increases. Partly decomposed plant remnants are observed in this layer. This was first observed in Northern Samar. This soil series covers 6,105 ha in the Samar provinces.

2.3.3.10 Soils Underlain by Massive Clay with Brown Mottlings

Babuyan series is classified as fine clayey, mixed, isohyperthermic *Aeric Epiaquepts*. These are poorly drained soils, derived from recent alluvial deposits. This was first described in barangay Babuyan, Puerto Princesa City, province of Palawan. The surface soil is brown to light brown, gray, light yellowish gray silty clay loam to slightly compact coarse blocky clay. Red mottles are sometimes present. The depth reaches down from 15 to 25 cm. The subsoil is light gray to light yellowish brown, loose, friable to coarse blocky clay, slightly compact when wet and hard when dry. The substratum is light gray, massive clay with brown mottling, soft when wet, hard, and compact when dry (Barrera et al. 1960). About 13,550 ha of Babuyan silty clay and clay were delineated in the island province Palawan. The province of Palawan is a the submarine ridge that rose from the deep waters of South China Sea and Sulu Sea, forming a connecting links in the great structural arc that extends from Mindoro to Borneo. Babuyan series were mapped in Puerto Princesa near the center of the island, a narrow lowland overlooking Honda Bay that breaks the continuity of the central mountains of Palawan. The mineralogy of the alluvial materials of Babuyan soils would be richer in metavolcanics and would be dominated by quartz, feldspars, amphiboles, and also pyroxenes.

2.3.3.11 Soils Underlain by Massive Clay, Below is Hard Tuff; Heavy Cracking Soil (Vertisol)

Mahipon series is classified as clayey, montomorillonitic, isohyperthermic *Entic Chromusterts*. These soils contain many (50–90 %) manganese-iron concretions. When used for paddy rice, the Ag horizon is grayish brown slightly concretionary clay loam with brown mottles, about 10–15 cm in depth. The Bcgn horizon, 60–110 cm in depth, is mottled gray and brown very concretionary clay with slickensides. Prismatic structural cracks form annually extending more than 50 cm deep and 1 cm wide and remain open more than 150 cumulative days during the year except when irrigated. The Cg horizon is mottled gray and brown very concretionary clay or clay loam with massive structure and slickensides. The shallow soils could reach down to 63 cm only while deep soils could reach down to 250 cm. Below is hard tuff. These soils are formed in weakly stratified unconsolidated concretionary fine clayey materials on dissected fan terrace landscape and piedmont footslopes (Bureau of Soils 1973a). About 825 ha of what were previously mapped as Prensa series in reconnaissance soil survey of Bulacan were delineated as Mahipon series during the updating and semi-detailed soil survey of the province. Mahipon was established in 1971 as one of the outputs of the Peñaranda River Irrigation Project in 1971. Mahipon is associated with Awayan and Prensa in similar landscapes and with the lower lying Kapalangan soils in the local alluvial valleys. It was first described in barangay Mahipon, Gapan City, Nueva Ecija.

2.3.3.12 Soils Underlain by Clay, with Partially and Highly Weathered Tuff

Canlalay series belongs to very fine clayey, mixed, shallow, isohyperthermic *Lithic Endoaquepts*. These soils are poorly drained on level to nearly level slopes on minor alluvial plain landscapes. The surface soil ranges from 15 to 25 cm thick, very dark gray clay with common fine prominent sharp strong brown mottles. The subsurface horizon ranges from 25 to 50 cm thick, gray, very dark gray, and very dark grayish brown clay with few to common medium distinct clear dark yellowish brown mottles. There are soft yellowish brown, brownish yellow, and light olive brown volcanic tuff fragments. The substratum is grayish brown to yellowish brown clay with many (about 50 %) highly and partially weathered brownish yellow and light olive brown volcanic tuff fragments (Soil Survey Division 1987b). About 1,967 ha of Canlalay series were mapped in the province of Laguna. This series was first described in barangay Canlalay, Biñan City, Laguna province. Biñan City has become a suburban residential community of Metro Manila and the location of some of the largest industrial estates and processing zones. It was founded by Captain Juan de Salcedo by the end of June 1571, a month after Miguel Lopez de Legazpi established Manila. Prior to becoming a city in 2007, Biñan is the richest municipality in the country based on its annual and gross income Wikipedia (2012j).

2.3.3.13 Soils Underlain by Clay, with Brown Mottles, Weathered Tuff Fragments, and Vertic Properties

Coralan series (Plate 1C and Fig. 5.24) belongs to very fine clayey, mixed, isohyperthermic *Vertic Endoaquepts*, vey deep, poorly drained soils, developed in the level to nearly level slopes on minor alluvial plain landscapes from the weathering of reworked materials or interbedded tuff materials forming as part of the old lake alluvial deposits of Laguna de Bay. There are few to common small strongly weathered tuff fragments and the occasional occurrence of few small soft iron and manganese concretions in the Ag and Bg horizons. The surface and subsurface horizons extend to a depth of 150 cm are generally deep fine clayey soils with grayish brown mottles. This soil series is associated with Calumpang series; they are both deep, poorly drained soils planted to paddy rice. Coralan is fine clayey, poorly drained soils with cracking type clays that have chromas of less than two (Soil Survey Division 1987b). The Calumpang soils is *Aeric Endoaquepts* and has better drained solum, with matrix chromas greater than two. Coralan is a newly established soil series and 1,887.08 ha were mapped in Laguna province. It was originally described in barangay Coralan, municipality of Sta. Maria, province of Laguna.

2.3.3.14 Soils Underlain by Clay, with Mottles, and Many Partially and Highly Weathered Tuff Fragments, Below is Hard Tuff Rocks

Dita series is classified as very fine clayey, montmorillonitic, isohyperthermic *Typic Endoaquepts*. These soils are moderately deep, poorly drained soils occurring on level to nearly level minor alluvial plains. They developed from mixed alluvium derived from weathered volcanic ejecta, pyroclastics, and old outwash materials from higher lying uplands. The surface soil is not more than 25 cm thick, dark greenish gray, dark gray to very dark gray, or dark grayish brown clay. The subsurface horizon extends down from 50 to 100 cm thick, greenish gray, dark grayish brown, very dark grayish brown, or dark grayish brown clay with few small manganese concretions and few to common partially and highly weathered volcanic tuff fragments. The substratum is dark yellowish brown, dark grayish brown or very dark gray clay with mottles and many partially and highly weathered volcanic tuff fragments. Below is hard tuff rocks (Soil Survey Division 1987b). Dita is associated with Canlalay and Bay series. They all occur on minor alluvial plains but differ in soil depth. Canlalay and Dita are shallower and classified as Endoaquepts while Bay is deeper and classified as Pelluderts. Dita soils was originally described in barangay Dita, Sta. Rosa City, province of Laguna. About 6,926 ha of Dita Series were mapped in the province of Laguna. Sta. Rosa City has evolved into an industrial, recreational, and residential estate. It is possible that this soil series is becoming extinct due to urban encroachment.

Pulong Buhangin was first described in Barangay Pulong Buhangin, the largest in the municipality of Santa Maria, province of Bulacan. Classified as *Aeric Tropaquepts*, this soil series consist of gently sloping to undulating moderately deep somewhat poorly drained soils that occur on dissected piedmont tuffaceous footslopes. The surface layer (Apg) of a representative profile is 30 cm thick, light brownish gray, and grayish brown clay loam to clay with dark yellowish brown mottles and very soft and hard manganese and iron concretions. The subsoil that reaches to a depth of 30–66 cm is grayish brown clay with few yellowish brown mottles and few iron and manganese concretions. The substratum that reaches down to a depth of 100 cm is light gray clay with few to common manganese concretions and strongly weathered tuffaceous rock fragments. The substratum is underlain by hard consolidated tuffaceous bedrock. This soil series covers some 6,207 ha in Bulacan province.

2.3.3.15 Soils Underlain by Clay, Below is Consolidated Tuffaceous Bedrock

Batia series is classified as fine, mixed *Aquic Tropudalfs* and consists of deep poorly drained fine clayey soils on nearly level to undulating dissected tuffaceous piedmont footslopes. The surface soil is pale brown clay loam with yellowish brown mottles, extending down to about 20 cm. The subsoil extending down to 115 cm is gray or light gray clay with few to common yellowish brown or light olive gray mottles and few manganese concretions. Patchy slickensides and few calcium carbonate nodules occur in the lower subsoil. Few subangular gravels are also present. The substratum reaching to a depth of 125 cm is gray clay with common pale yellow mottles and few manganese concretions underlain by consolidated tuffaceous bedrock (Soil Survey Division 1987a). A total of 13,136.3 ha of Batia series were mapped in Bulacan province, mainly in Pandi, Sta. Maria, Marilao, Meycauayan, and Valenzuela municipalities. Additional 144 ha of Batia clay was mapped in Rizal province. This was first described in barangay Batia, municipality of Bocaue, Bulacan province.

2.3.3.16 Soils Underlain by Clay, Below is Consolidated Tuffaceous Bedrock, and with Vertic Properties

Bago series (Plate 1A) is classified as *Vertic Argiudolls* and generally covers the soils of the rolling or gently undulating uplands and small valley floors. The undulating uplands have excessive external drainage and where the water collects on the valley floors, the drainage condition is very poor. The water remains stagnant for some time. The internal drainage is poor. Pendleton, who surveyed this place in 1925, thinks this soil was once a coastal swamp covered with brackish water but it rose to its present position when the whole western plain of Negros was elevated as a result of volcanic action. The surface soil ranges from fine sandy loam, loam to clay. In all cases, the soils thus formed is gray, with plenty of grayish brown spherical concretions. The subsoil is grayish to almost bluish gray clay with some concretions. The substratum is light bluish gray clay and sometimes mottled with brown. The substratum is sometimes found over a hard light gray layer of volcanic tuff (Alicante et al. 1951). A total of 119,096 ha of Bago series were mapped in the provinces of Negros Occidental, Isabela, Cagayan, Ifugao, and Nueva Vizcaya (Fernandez et al. 1980). This soil was first described in Bago City, Negros Occidental. This settlement was established when the Spanish Miguel Lopez de Legazpi allotted this area as encomienda to a Spaniard named Juan Gutierrez in 1571. It was named after a large tree called "bago" while some other historical versions claimed it was named after a shrub "bago–bago" that grew luxuriantly by the river banks (Wikipedia 2012k).

2.3.3.17 Soils Underlain by Clay, with Tuff Materials at Subsoil Increasing as We go Down the Profile; Heavy Cracking Soil (Vertisol)

Marikina series (Plate 1D) is classified as fine, mixed, isohyperthermic family of *Udorthentic Chromusterts*. These soils are deep, somewhat poorly drained on level to nearly level alluvial plains. The surface soil does not exceed 30 cm thick, gray, light gray to greenish gray clay with mottles. The cambic B horizon is yellowish brown, dark yellowish brown, dark brown or grayish brown clay, with few thin continuous and discontinuous slickensides, few soft iron-manganese concretions, and highly weathered tuffaceous fragments increasing with depth. The substratum below, less than 100 cm in depth, is dark yellowish brown or yellowish brown clay. This soil is associated with Pinagbuhatan series. Both are derived from alluvial deposits and occur on level to nearly level minor alluvial plains. Marikina is somewhat poorly drained or has lighter color (high chroma) while Pinagbuhatan is poorly drained and darker in the B horizon (low chroma). Marikina soils also have lower cation exchange capacity and base saturation percentage compared to Pinagbuhatan series (Soil Survey Division 1989a). A total of 3,166 ha of Marikina series have been mapped in Rizal province. As these are in highly urbanizing areas, most of these soils must have been extinct by now, buried by urban development. The soil was first mapped in Marikina City, formerly part of Rizal but already part of Metropolitan Manila. This city is known as the Shoe Capital of the Philippines. Briefly, it served as the capital of the Province of Manila, during the short-lived period 1898–1899 Philippine Republic when the revolution against Spain broke out. The Americans eventually took possession of the Philippines after the Spanish-American War.

2.3.3.18 Soils Underlain by Clay to Silty Clay, with Partly Decayed Plant Tissues

Dauin series, classified as *Typic Hapludands*, are poorly drained soils developed from volcanic deposits. It is a small soil formation and low-level alluvial deposit over a once marshland. Expectedly, the drainage condition is rather poor. The alluvium is water laid and originated from the upland areas. Below the alluvial deposit is partially decayed organic matter presumed to be the marsh before. There is no stone or other rocks found in this soil series. The water table is about a meter or less in depth from the surface. The surface soil is about 40 cm in depth, black clay; coarse granular; sticky and plastic when wet and hard and slightly compact when dry. The subsoil extends down to 70 cm, bluish black to dark grayish black clay to clay loam; coarse granular structure; soft, sticky, and plastic when wet and hard when dry. The substratum reaches down to the control section at 150 cm, and is dark gray to almost black clay to silty clay; soft when wet; friable when dry; presence of partly decayed plant tissues (Barrera and Jose 1960). A total of 880 ha of Dauin sandy loam and Dauin clay were mapped in Negros Oriental province. Dauin is a coastal municipality facing Siquijor Island and known as an excellent scuba diving site. The area is generally used for lowland rice.

2.3.3.19 Soils Underlain by Silty Clay, with Mottles and Slightly Weathered Rock Fragments

Kalayakan series, classified as *Typic Eutropepts*, was first described in the municipality of San Miguel, Bulacan. This soil series consist of shallow, moderately drained clayey soils on moderately dissected undulating to slightly rolling sedimentary (shale/sandstone) piedmont landscapes. The surface layer is 12 cm thick, dark grayish brown clay with few yellowish brown mottles. The subsoil that reaches down to a depth of 38 cm is very dark brown or very dark yellowish brown clay with few brownishy yellow and yellowish brown mottles and slightly weathering rock fragments. The substratum below to a depth of 100 cm is dark brown or very dark gray silty clay mottled with strong brown, yellowish brown, or very dark gray color. Slightly weathered rock fragments are common in this layer. The soils have very limited extent, 1,005 ha in the province of Bulacan. This soil series is associated with the lower lying deeper Awayan series and the concretionary Mahipon soils on upper piedmont slopes.

2.3.3.20 Soils Underlain by Gravelly Clay to Clay Loam

Indan series, classified as *Typic Eutrudepts,* are soils from recent alluvial deposits covering 6,363 ha in the province of Camarines Norte. This soil series occurs on level areas at elevation between 3 and 6 m above mean sea level. The clay surface soil is light brown to grayish brown with brown streaks. It is waxy and hard when dry. The average depth of the surface soil is 20 cm. The subsoil is grayish brown to very light gray clay loam with reddish brown mottles. This subsoil is compact and the permeability is slow. Some highly weathered concretions are found embedded in this layer. The average depth of the subsoil is 70 cm from the surface. The substratum, reaching down to the control section at 150 cm is light gray to gray, soft gravelly clay to clay loam. The lower portions are poorly drained (Lucas et al. 1966). Rice is the main crop. Corn, sugarcane, root crops, mongo, cowpea, coconut, and fruit trees are also grown. This soil was first mapped in what was then known as the municipality of Indan in the province of Camarines Norte, established as a town as early as 1581 by the Franciscan Fathers. But Indan was not its first name, rather it was Tacboan. Indan was later renamed as Vinzons for which it is currently known in honor of Wenceslao Q. Vinzons, a former governor of the province and the youngest delegate to the Philippine Constitutional Convention of 1935 (Wikipedia 2012l). Indan series developed from alluvial deposits of flanking mountains and hills with the Labo River draining westward. Mt. Labo is a high andesitic stratovolcano surrounded by numerous andesitic and dacitic satellite lava domes, rising some 1,544 m above sea level. The rock type is predominantly hornblende-biotite andesite to dacite.

2.3.3.21 Soils Underlain by Silt Loam to Clay Loam; Heavy Cracking Soil (Vertisol)

Maligaya series (Plate 1D for soil profile and Fig. A.6 for soilscape view) are classified as *Ustic Epiaquerts*. This soil series was developed from alluvial deposits. It has a moderately developed soil profile with moderately dense subsoil underlain by unconsolidated materials. Generally, Maligaya series is found on nearly level to slightly sloping or gently undulating, occurring near mostly near the foot of sloping areas where rain water from the higher areas drain in it. However, the soils could be drained easily because of its relief. The internal drainage is rather slow because of its compact subsoil. A typical profile description is as follows: The surface soil is brown to dark brown, slightly friable and fine granular silt loam, with some brick-red streaks. The subsoil is heavier in texture but lighter in color than the surface soil. The structure of the subsoil is sometimes cloddy and columnar. In some areas, concretions are present. The substratum consists of light brown, slightly compact silt loam to clay loam (Alicante et al. 1941). Rice is the most important crop in this series. Corn, sugarcane, tobacco, vegetables, banana, and citrus trees are also grown. About 57,282 ha of various types of Maligaya Series were mapped in the provinces of Nueva Ecija, Abra, Laguna, La Union, Nueva Vizcaya, Zamboanga del Norte, Zamboanga del Sur, Capiz, and Aklan provinces (Fernandez and Jesus 1980). This soil was first described in barangay Maligaya, Science City of Muñoz, Nueva Ecija.

2.3.3.22 Soils Underlain by Sandy Clay to Clay

Mabini series is classified as *Typic Endoaquepts* and poorly drained soils developed from old alluvial deposits. This soil series is of older alluvial formation. The soils were derived from soil materials transported from adjacent higher areas and deposited on the lower areas. The land is generally on the lower level areas. Some sections, however, are slightly undulating with slopes not exceeding 3 %. Drainage is poor. The native vegetation consists of cogon, and sporadic growth of binayuyo trees. Some portions are utilized for pasture. Coconut is the principal crop. The depth of the surface soil is around 10–15 cm, gray to light brown sandy clay loam; coarse granular and slightly compact. The upper subsoil could reach down to 100 cm and is light brown to yellowish brown coarse granular and slightly compact sandy clay. The lower subsoil extends to 120 cm and light brown to yellowish brown coarse granular and slightly compact sandy clay. The substratum is light yellowish brown compact sandy clay to clay Sindayen et al. (1970). About 2,011 ha of Mabini sandy clay loam were mapped in Misamis Occidental. This soil was first described in barangay Mabini, municipality of Baliangao, province of Misamis Occidental.

2.3.3.23 Soils Underlain by Clay Loam with Orange Mottlings

Makato and *Kabacan* series have concretions in the subsoil, above the substratum. Both developed in alluvial plains, have orange mottlings, and have clayey substratum also with concretions. Makato, Aklan, where this soil was first described, is on the northwest of almost triangular-shaped Panay Island in the Visayas, but east of the high, rugged mountain system of basic porphyritic basalt and tuff that parallel its western coastline. McCabe et al. (1982) showed that this northwestern tip of Panay, also called the Palawan metamorphic terrane, could have collided with the remainder of the island between late Oligocene and middle Miocene (both are Tertiary epochs), subduction continuing north and south of the collision zone along the Manila and Negros trenches (McCabe et al. 1982). Makato soils would have been on the side of the Miocene thrusting in the mélange terrane oriented parallel to the suture. Kabacan soils, being part of the Cotabato basin would have developed from alluvial materials of Pleistocene or younger. So even though both would be on the same physiographic position, both have clayey substratum, both have concretions in the subsoil and substratum, and both have redoximorphic features or presence of orange mottlings, Makato is therefore expected to have a more developed or deeper B profile or a discernable B1 and B2 compared to Kabacan. The mineralogy of these two soil series is also expected to be different owing to differences in sources of alluvial materials.

Makato series is classified as fine, mixed, isohyperthermic *Aquic Eutrodepts* and belongs to a group of older alluvial soils with moderately developed profiles. The presence of concretions in its profile makes this series different from Maligaya, Sta. Rita, and Buang soils while the absence of gravels in its profile makes it different from the Sara series. Makato is also characterized by orange hue of its lower horizons. The relief is from level to very slightly undulating, the internal drainage is poor. The surface soil, extending down from 20 to 25 cm, is brown to light brown medium coarse granular clay, some concretions and reddish orange streaks are present. The upper subsoil, reaching down to a depth of 40 cm from the surface, is brown to grayish brown medium granular clay loam with orange mottling and concretions. The lower subsoil extends down to 60 cm, is grayish brown clay to clay loam. The substratum, extending down to the control section at 150 cm, is gray clay loam with dark orange mottling, which tend to impart orange color to this layer (Calimbas et al. 1962). About 6,375 ha of Makato clay was mapped in what was then Capiz province. But in 1956, Republic Act 1414 separated Aklan from Capiz province, and all those Makato series are found on the Aklan side, specifically in the municipalities of Makato where this soil was named after, Numancia, Lezo, Malinao, and Tangalan. Despite its more recent classification as a province, Aklan is considered to be the oldest province in the country. Its written history begins in the middle of the thirteenth century when ten Bornean datus, together with their families, fled the oppressive rule of the Bornean king, Sultan Makatunao, in search of freedom, new lands, and better fortunes. It was circa 1250 when they landed in Panay Island and purchased the lands from the Aetas, the aboriginal pygmies. The historic Barter of Panay involved a golden *salakot* (wide brimmed hat), a chain of some pure gold necklace, and other gifts given by the newcomers' leader, Datu Puti, to the Aeta king, Marikudo and his wife Maniwantiwang. As the Aetas moved to the hinterlands and mountains, the island was divided into three districts of Irong-irong under Datu Paiburong, Hantik under Datu Sumakwel, and Aklan under Datu Bangkaya; united against enemy attacks under the Confederation of Madyaas. Aklan was the confederation center. Datu Puti and the other datus moved on northward in search of new settlements (Wikipedia 2012m). The confederation fell under Spanish conquest in 1569 by Miguel Lopez de Legazpi and his grandson Juan de Salcedo. Legazpi parceled Aklan to his men under the encomienda system. In 1716, the old sovereign territory of Aklan became the Spanish politico-military province of Capiz and remained so for the next 240 years. Capiz was part of Aklan in pre-Spanish times (Wikipedia 2012n).

Kabacan series (Plate 1D), classified as *Typic Hapludepts,* occurs on level to gently sloping alluvial plains and derived from alluvial deposits. These are poorly drained soils and subject to regular flooding. The surface soil is clay loam to clay; brown, dark brown, dark gray to almost black, extending down to a depth from 20 to 25 cm. The subsoil, 60–80 cm in depth, is brown, reddish brown, brownish gray or yellowish gray, slightly compact plastic clay loam to clay with orange mottling; concretions are present. The substratum, reaching from 80 to 150 cm, is brown, reddish brown, or brownish gray plastic and gritty clay loam with orange mottles. Sometimes the mottlings appear to become the dominant color giving a rich orange color to the soil. Because of the level relief, this soil series is grown mostly to rice (Mojica et al. 1963). A total of 68,907 ha of Kabacan clay loam and clay were mapped in Cotabato, Misamis Occidental, and Zamboanga del Sur provinces. This soil was first described in Kabacan, Cotabato dominating the area along the Pulangi River roughly from Kabacan on the east embracing Pagalungan, Pikit, Balatican, Silik, and Peidu Pulangi; and Midsayap going south along the highway to the Kudarangan Hills.

2.3.3.24 Soils Underlain by Clay Loam, with Mottles, and with Fine Highly Weathered Rock Fragments

Dumbal series is clayey, moderately deep and somewhat poorly drained soils derived from mixed alluvial deposits coming from the surrounding highlands. Classified as *Aquic* Hapludalfs, these soils are found on level to nearly level of the alluvial landscapes, with slopes ranging from 0 to 3 %. The soils are usually grayish with mottles of yellowish brown. The solum thickness ranges 60–100 cm. The soil reaction is from slightly acidic to neutral. The base saturation by ammonium acetate is greater than 35 % and the cation exchange capacity is moderate while the organic matter content is low. Available phosphorus is low to medium and exchangeable potassium is deficient. The surface horizon, 15–25 cm thick is dominantly greenish to grayish loam. The clay content ranges from 25 to 35 %. The consistency when wet is sticky and plastic and firm when moist but slightly hard when dry. The subsoil ranges from 60 to 100 cm in depth, from gray to dark gray yellowish brown clay loam. The consistency when wet is sticky and plastic and firm when moist but slightly hard when dry. The clay content ranges from 30 to 40 %. The substratum below 100 cm thick is yellowish brown, brownish yellow with light gray mottles. Consistency when wet is sticky and plastic to slightly plastic and firm when moist but slightly hard when dry. Rainfed rice is the main crop planted and associated with corn. A total of 2,438 ha of Dumbal silt loam was mapped in Zamboanga del Sur, mostly in Pagadian City. In the soil survey of the municipality of Tungawan, Zamboanga Sibugay conducted in 2004, about 512 ha of Dumbal clay loam was mapped.

2.3.3.25 Soils Underlain by Clay Loam, with Mottles, Weathered Basaltic Gravels and Highly Weathered Tuff

Maytalatala series belongs to fine clayey, montmorillonitic, isohyperthermic family of *Aquic Eutrudepts*, moderately deep to deep, imperfectly drained soils occupying nearly level to gently elevated alluvial fan terrace landscape adjacent to foothills and mountains. The soils are formed from reworked or interbedded tuff materials and other products from the weathering of basalts and andesites. The surface soils ranges from 30 to 50 cm thick, and is dark grayish brown, brown to dark brown clay with occasional yellowish brown and dark yellowish brown mottles. The subsurface horizon, extending down to 100 cm, is brown to dark brown, dark yellowish brown clay loam to clay with mottles and few iron and manganese concretions. The substratum extends down from to 150 cm in depth, mottled clay loam and consists of fine and medium weathered basaltic gravels and many strongly weathered tuff fragments (Soil Survey Division 1987b). Maytalatala series is associated with Calumpang series. Maytalatala is deep to moderately deep imperfectly drained soils while Calumpang is very deep poorly drained soils. Both soils have shrinking and swelling properties but Maytalatala is classified as Aquic Eutrudepts while Calumpang is classified as Aeric Endoaquepts. Maytalatala was first mapped in Maytalatala barangay, municipality of Mabitac, Laguna province. A total of 1,227 ha of Maytalatala clay were mapped in Laguna province.

2.3.3.26 Soils Underlain by Clay Loam to Clay with Some Amount of Sandy Materials and Highly Weatherd Tuff

Calumpang series (Plate 1C) are classified as very fine mixed isohyperthermic *Aeric Endoaquepts*. These are alluvial soils developed from the accumulation of fine sediments brought downstream and deposited in shallow areas. The topography is generally level. These poorly drained soils have surface soil that extends down from 15 to 40 cm depth, brownish gray to dark gray hard compact clay, clay loam, silt loam, to sandy loam with dark reddish brown mottles. The gleyed subsoil can reach as deep as 140 cm, dark gray to very dark brown clay loam to clay. The substratum is mottled grayish brown and yellowish brown clay loam to clay with some amount of sandy materials and highly weathered tuff (Alicante et al. 1938). This soil series was first described in the alluvial areas along Calumpang River in the southeastern Batangas City, flowing towards Batangas Bay in the province of Batangas. This was one of the oldest soil series in the country, established by Dorsey in 1903. Calumpang soils is usually associated with Coralan series but it has better drainage condition than the latter. These soils are traditionally grown to sugarcane and lowland rice. Calumpang sandy loam, silt loam, clay loam, silty clay loam, and clay were mapped in the provinces of Bukidnon, Batangas, Laguna, Mindoro covering 25,067 ha.

2.3.3.27 Soils Underlain by Sandy Clay Loam to Sand and Plant Remains

Lutayan series is classified as *Typic Endoaquepts*. This soil series was first identified in 1939 when the defunct National Land Settlement Administration had the Koronadal Valley soil surveyed in detail. Found in the vicinity of Lake Buluan, the soil had its origin from a mixture of alluvium from the hills and from the plant remains of the vegetation around the lake. Nearer the lake, the plant remains are more evident than from those soils farther away. Very close to the lake, the soil takes on the characteristics of the Tinambulan peat. The surface soil is dark brown, gray to almost black very friable and loose sandy loam, reaching to a depth from 10 to 20 cm. It is underlain by a slight, compact grayish brown clay loam to clay, plastic and sticky, extending down from 30 to 35 cm. The substratum is light gray sandy clay loam to light gray sand. The soils are fair to poorly drained (Mojica et al. 1963). A total of 19,375 ha of Lutayan sandy loam were mapped in what was then Cotabato province. The municipality of Lutayan, where this soil was first described, currently belongs to the province of Sultan Kudarat. It used to be a secluded barrio of Buluan, Cotabato in the southern part of Koronadal, Cotabato (now South Cotabato), and was quite progressive before the World War II. It was made a municipality in 1967 and became part of the newly created province of Sultan Kudarat in 1973.

2.3.3.28 Soils Underlain by Sandy Loam to Sandy Clay Loam with Gravels

Palapag series, classified as *Typic Epiaqualfs,* developed from alluvium from the surrounding upland soils. It is deep, fertile but poorly drained. The relief is level to undulating. The surface soil is from 10 to 25 cm deep, brown to grayish brown clay loam to silty clay loam, and some tiny limestone granules. The subsoil is compoased of two layers, both silty clay loam with iron concretions and gravels of varying sizes, increasing with depth. The upper subsoil reaches down from 30 to 35 cm, grayish brown to brown coarse granular mottled silty clay loam, and with iron concretions. The lower subsoil reaches down from 55 to 70 cm, light brown coarse granular to blocky silty clay loam, with iron concretions and gravels. The substratum below 70 cm is light brown sandy loam to sandy clay loam with gravels similar to that of the above layer (Simon et al. 1975). Rice is the principal crop grown. The other crops are coconut, sweet potato, corn, cassava, abaca, and yam. This soil was first described from the municipality of Palapag, Northern Samar. Palapag is known in Philippine history as the hometown of Agustin Sumoroy, a Waray who led a rebellion against the Spaniards from 1649 to 1650 because of forcible conscription of workers from Ibabao region to work in the shipyards of Cavite province. About 3,223 ha of Palapag clay loam were mapped in Samar provinces.

2.3.3.29 Soils Underlain by Sandy Loam to Sandy Clay Loam with Few Strongly Weathered Soft Tuff Fragments

Bagumbayan series was first described in barangay Bagumbayan, municipality of Santa Cruz, province of Laguna. This soil series belongs to fine loamy, slightly acid, mixed, isohyperthermic *Fluvaquentic Eutropepts*. These soils are deep to very deep, imperfectly drained soils occurring on nearly level to level (0.2–2.0 %) slopes on minor alluvial landscape. The soils are generally brown, brown to dark brown, very dark brown in color and have clay to clay loam texture underlying sandy loam or sandy clay loam parent materials at a depth of almost 90–120 cm depth. The A horizon is not more than 35 cm thick overlying cambic B horizon, brown to dark brown to dark grayish brown or dark yellowish brown clay to clay loam and sandy clay loam, with friable to slightly firm when moist consistency. The cambic B horizon is similar to the A horizon except for having grayish brown, brownish, or yellowish brown mottles and for having weak to moderate angular and subangular blocky structure. The C horizon below 100 cm deep and reaches down to 300 cm from the surface is predominantly dark grayish brown sandy loam or stratified fine to coarse loamy and fine clayey materials with grayish brown, yellowish brown, pale brown, and greenish gray mottles, and with few strongly weathered soft tuff fragments. Below the C horizon is highly weathered tuff. About 1,088 ha of Bagumbayan series were mapped in the province of Laguna. Bagumbayan is associated with Calumpang, Quingua, San Francisco, and San Manuel soils. These all are found on minor alluvial plain landscape developed from mixed alluvium consisting of weathered and reworked interbedded tuff materials. Solum thickness of San Manuel and Quingua series ranged from 100 to 120 cm. Calumpang and San Francisco series are moderately deep to deep soils with solum thickness ranging from 80 to 200 cm and 50 to 100 cm, respectively. The Bagumbayan soils have solum depth from 70 to 150 cm and characterized by the presence of strongly weathered tuff fragments in the B horizon extending to the substratum.

2.3.3.30 Soils Underlain by Silty Clay to Silt Loam; Heavy Cracking Soil (Vertisol)

Both *Sta. Rita* and *Libon* series are underlain by silt loam substratum, occurs on almost the same physiographic position, developed on alluvial materials. But Sta. Rita series is geologically older and is a heavy cracking soil, or a Vertisol. Libon would be affected by eruptions of Mayon

Volcano and geologically younger to develop even a pronounced soil profile.

Sta. Rita series (Plate 1G) is classified as *Typic Epiaquerts.* This soil series developed from recent alluvial deposit of fine soil materials from the surrounding uplands. Drainage is generally poor because of topography and the heaviness and compactness of the surface soil and the subsoil. There are no stones in the solum. It has black to dark brown clay surface soil that extends down from 20 to 25 cm; with moderate coarse granular structure; highly plastic and soft when wet; shrinks and cracks when dry. The subsoil is also clay with lighter shade than the surface soil and could reach down to 70 cm. The upper substratum that reaches down to 97 cm is brown to light silty clay; slightly compact with good medium granular structure. The deposition of silty clay is uniform. The lower substratum reaches down to the control section at 150 cm, and is light brown silt loam; soft and friable; good fine granular structure (Alicante et al. 1947). Rice is the principal crop raised on this soil. This is rotated with corn, mungo, and other legumes. This soil series was first described in barangay Sta. Rita, municipality of Oton, province of Iloilo in Panay Island. A total of 117,758 ha of Sta. Rita sandy loam, clay loam, and clay were mapped in the provinces of Iloilo, Antique, Cagayan, Isabela, and Capiz–Aklan (Fernandez and Jesus 1980).

2.3.3.31 Soils Underlain by Silt Loam

Libon series (Plate 1D) is a deep alluvial soil occupying the lowland and nearly level areas of the towns of Libon, Polangui, Oas, and Ligao in the province of Albay. At times, it is inundated by the streams that flow through it towards Lake Bato. The external drainage is poor; the internal drainage is fair. Only one soil type, Libon silty clay was mapped in the province of Albay covering 11,240 ha. The surface soil, reaching down to 40 cm, is silty clay; brown, grayish brown to dark dray; coarse columnar to blocky structure, free from coarse skeleton. Reddish brown and orange brown streaks are found at the lower portion. The upper subsoil, extending down to 90 cm, is clay; grayish brown to brownish black, massive; free from coarse skeleton. The lower subsoil is silt loam to silty clay loam; light brown, grayish brown to gray; coarse granular to blocky structure. The substratum starting from 140 and below is loam to silt loam; brown to grayish brown; columnar to blocky structure (Aristorenas et al. 1965). This soil series is principally planted to lowland rice. The other crops grown are corn, cassava, sweet potato, coconut, banana, vegetables, peanut, and some fruit trees. This soil series is classified as *Typic Eutrudepts.*

2.3.3.32 Soils Underlain by Structureless Silt Loam Below Which is a Hard Pan

The soil series falling under this kind of substratum would only have redoximorphic features because the hard pan below would impede water percolation. *Silay* series (Plate 1G), as the name implies, is an important soil resource of Negros Occidental province principally grown to sugarcane. This soil series is classified as *Aquic Hapludalfs.* This soil series was first described by Pendleton in 1925 in his soil survey of the Silay-Saravia area and it occupies practically the greater part of the northwestern plain of the province. There are numerous creeks and rivers traversing this soil that aids in draining. However, internal drainage or percolation is impeded by the hard soil layer, locally called “bakias”, beneath the surface. Sugarcane growers build drainage canals at regular intervals but for the growing of lowland rice, this soil series is well suited as the hard compact soil layer keeps the water for a long time. This soil series is water laid. The hard compact layer below the subsoil is attributed to cementing agent like silicates. There are neither rock outcrops nor any rock underneath the surface. The hard compact gray layer is the principal characteristic that makes Silay series different from the other alluvial soils. Bantog series for instance has brown and softer substratum; Palo series substratum is loose and coarse sand. The surface soil of Silay series extends down to 15 cm, gray to dark grayish brown sandy loam with excellent granular structure. The subsoil is grayish brown to gray silt loam, structureless and massive and reaches down to 30 cm. The substratum is brown to grayish brown silt loam, with mottling of dark brown, structureless and massive, very hard and compact when either dry or wet. Farther down the 3-m depth is a layer of dark gray clay (Alicante et al. 1951). A total of 83,136 ha of Silay loamy sand, sandy loam, loam, and clay were mapped in the provinces of Negros Occidental, Zamboanga del Norte, Sorsogon, and Samar (Fernandez and Jesus 1980). Silay City, where this soil series was first described, is called the “Paris of Negros” due to its large collection of perfectly preserved heritage houses. More than 30 of these houses have been declared as historical landmarks making Silay a museum city next to Vigan, Ilocos Sur. Silay was derived from the name of a tree that grew abundantly in the area, called the kansilay tree. It was first settled in 1565 under the name “Carobcob” which means “to scratch” in the local dialect of Kinaray-a. It was granted a status of *encomienda* in

January 25, 1571 through Cristobal Nunez-Paroja, one of the 17 soldiers of Miguel Lopez de Legaspi (Wikipedia 2013).

2.3.3.33 Soils Underlain by Stratified Sand

La Paz series is classified as sandy, mixed, isohyperthermic *Typic Tropaquents*, poorly and somewhat poorly drained. These soils have moderately thick gray fine sandy loam Ag horizons that could extend down to 30 cm and very deep gray stratified sand Cg horizon that could extend down to 300 cm. These soils are formed in broad flats and slightly depressed landscapes; also from very deep stratified fine sandy alluvial material on weakly dissected continental terraces above the main river floodplains (Alicante et al. 1940a). The La Paz soils are associated with Ramos, Angeles, Luisita, and Dadiangas series. The Ramos soils have fine sandy loam textures in the control section and occupy slightly higher landscape positions. The Angeles and Dadiangas soils have coarser sand textures with gravel and occupy higher better drained landscapes. The Luisita soils contain concretions and gravels below 100 cm depth. About 76,552 ha of La Paz sand and fine sand were mapped in the provinces of Tarlac, Pampanga, Bataan, Pangasinan and Zambales. La Paz was first described in the municipality of La Paz, province of Tarlac. The origin of the town is told in a legend whereby an old town by the bank of the Chico River was devastated when the river overflowed its bank during a storm and a great flood swept the entire town. The inhabitants resettled to a higher ground which prospered in time. Towards the end of the nineteenth century, the town was reorganized again into a more centrally located site and renamed by Francisco Macabulos and Captain Mariano Ignacio in honor of its patron saint, Nuestra Senora de La Paz y Buen Viaje. Macabulos was considered a Filipino patriot who led revolutionary forces against Spain in 1986, notably in the Battle of Dagupan (Wikipedia 2012o).

2.3.3.34 Soils Underlain by Structureless Medium to Coarse Sand

Donsol series (Plate 1C) is classified as *Aquic Eutrudepts* and developed from alluvium washed down from calcareous upland by rivers, and partly by depositions from the sea. The soil is fairly to poorly drained. The relief is nearly level, the elevation is from sea level to 15 m. The areas covered by this soil series are traversed by streams and narrow creeks which serve as natural drainage and also used for irrigation purposes. The flat relief and the presence of high water table, however, make both internal and external drainage rather slow. The surface soil is reddish brown to dark brown, slightly compact, cloddy sandy clay, with depth reaching down from 20 to 25 cm. The upper subsoil reaches down to 40 cm, and is black, grayish black to grayish brown, sandy clay; speckled brown and orange brown; massive to coarse columnar; slightly compact; and like the surface soil, free from coarse skeleton. The lower subsoil reaches down to 130 cm, and is orange brown to yellowish brown sandy clay; splotched with dark brown and black; coarse granular; moderately compact. The substratum extends down to the control section at 150 cm, medium to coarse sand, ash gray to yellowish gray, structureless; no stones (Aristorenas et al. 1963). This soil series is generally grown to rice. A total of 2,040 ha of Donsol sandy clay were delineated in the province of Sorsogon. Donsol is a municipality of Sorsogon, a popular tourist destination for whale shark viewing.

2.3.3.35 Soils Underlain by Structureless Coarse Sand

Ligao series were developed from alluvial deposits and first described in Ligao, Albay. The relief is level to nearly level, external drainage is good but the internal drainage is poor due to the compact gravelly layer in the subsoil. Shallow bank streams traverse the area. The elevation ranges from 67 to 79 m above sea level. These soils are classified as *Typic Eutrudepts* and the area coverage is 3,450 ha of Ligao loam mapped only in the province of Albay. The surface soil extends down to 10 cm, loam; grayish brown, light gray to dark gray; structureless to fine granular, mellow and friable; free from coarse skeleton. The upper subsoil reaches down to 15 cm, gravelly sandy loam; reddish orange, yellowish brown to dark brown; massive, compact and impervious; orange concretions present with increase and become coarser with depth. The mid-subsoil reaches down to 45 cm, silt loam; light brown to grayish brown with gray and black mottling; structureless; crumbly and compact when dry. The lower subsoil is compact gravelly fine sandy loam to loam; brown reddish brown to grayish brown; structureless; concretions present. The substratum is medium and coarse sand; light gray to dark gray or black; structureless, loose and porous (Aristorenas et al. 1965). Lowland rice is the main crop. Sweet potato, cassava, peanut, and vegetables are also planted.

2.3.3.36 Soils Underlain by Sand that Becomes Sandy Loam as We Go Down the Profile

Ramos series (Plate 1F and Fig. 5.22c) is classified as *Aquic Eutrudepts*. The surface soil reaches down to 20 cm, and light gray to gray or grayish brown silt loam. The subsurface soil is grayish brown to dark gray sandy loam and extends down to 90 cm. The substratum is light brownish gray, light gray to gray, to grayish brown sand that becomes fine sandy loam as we go down the profile. This soil series covers 4,500 ha in Tarlac. Ramos series was first described in the municipality of Ramos, Tarlac located above the city of Tarlac and Mount Bangcay which separated the northward drainage of the lowlands from the southward drainage of the large open-ended synclinorium Central Plain of Luzon, of Tertiary and Quaternary sediments. Generally not affected by the violent eruptions of Mount Pinatubo, Ramos series is composed largely of alluvial materials, rarely any pyroclastics. The Ramos alluvials would be typically limestones, sandstones, and shales and the mineralogy would be expected to be mix of calcite, quartz, feldspar, kaolinite, montmorillonite, and illite.

2.3.4 Soils of the Broad Alluvial Plains: The Well-Drained Soils

2.3.4.1 Soils Underlain by Gravelly Clay

Dalican series was first identified in what was then Dalican, Cotabato. Today, Dalican is a barangay of the municipality of Datu Odin Sinsuat, province of Maguindanao. This soil series occupies the area along the Talayan and Dalican Rivers. It is one of the more elevated portions of the Cotabato Plain. Because it is more elevated than most areas in the Cotabato Plain having a level to slightly sloping relief, drainage is not much of a problem. The more elevated portions are lighter in color, usually brown or dark brown and planted to coconuts, corn, vegetables, fruit trees, bananas, and other crops. The lower areas are predominantly dark gray, sometimes black and planted to lowland rice. A profile description of the type is as follows: the surface soil, 0–20 cm in depth is dark gray or nearly black when moist, gray to light gray when dry granular clay loam. The upper subsoil, extending down to 70 cm, is brown to dark brown clay; columnar; plastic and sticky when moist, hard and brownish gray when dry. The lower subsoil reaches down to 110 cm, brownish gray to gray sandy clay; columnar; sticky but crumbles easily when dry. Sand grains are coarse. The upper substratum reaches down to the control section at 150 cm, is very light gray to white, with a very light tinge of yellow; gravelly clay; structureless and crumbles very easily when dry. The lower substratum with depth reaching down to 158 cm, is dark gray silty clay; structureless (Mojica et al. 1963). This soil series is classified as *Typic Epiaquepts*. About 13,750 ha of Dalican clay loam were mapped in Cotabato provinces.

2.3.4.2 Soils Underlain with Clay and Tuffaceous Materials

Halayhayin series has clayey substratum with few to common tuffaceous fragments in the lower portion. *San Francisco* series has also clay substratum and tuffaceous fragments; but in addition, it has an argillic horizon, being an Alfisol, or geologically older.

Halayhayin series is classified as fine clayey, strongly acid, mixed, isohyperthermic *Typic Eutrudepts*. These soils are very deep, moderately well-drained, occurring on level to nearly level slopes on minor alluvial plains. They are derived from alluvial materials mainly volcanic tuff. The surface horizon ranges from 20 to 50 cm thick, brown to dark grayish brown or dark grayish brown clay with yellowish brown mottles. The cambic B horizon ranges from 120 to 200 cm thick is dark yellowish brown, yellowish brown, and gray clay with brownish yellow or yellowish red mottles. The substratum is reaches down from 200 to 250 cm, gray, light gray, or dark gray clay with yellowish brown and pale olive mottles. Few to common tuffaceous fragments are found in the central or lower portion of the substratum (Soil Survey Division 1987b). Halayhayin series is associated with Quingua soils but Halayhayin has highly weathered tuffaceous materials in the lower C horizon and classified as Eutropept. Quingua is classified as Tropudalf. About 581.72 ha of Halayhayin soils were mapped in Laguna province. This soil was first described in Halayhayin, Siniloan, Laguna.

San Francisco series are moderately well-drained clay loam soils with argillic B horizons and mainly used for coconuts.There is no substratum of stones and gravels. Below the regolith of weathered tuff fragments are hard tuff materials. These soils are probably derived from mixed alluvium of reworked or interbedded tuff materials and outwash plain materials underlain by consolidated tuff materials. The surface horizon is 30–50 cm thick, dark grayish brown, dark brown, brown to dark brown and yellowish brown clay loam, clays, or silty clay loam. The argillic B horizon ranges from 50 to 100 cm thick, grayish brown, dark brown, dark yellowish brown and yellowish brown clay loam with dark grayish brown, brownish yellow and yellowish brown mottles. The substratum ranges from 80 to 150 cm, dark brown, dark yellowish brown, dark grayish brown clay with yellowish brown and dark yellowish red mottles (Soil Survey Division 1987b). This soil is closely associated with Dita Series but the latter has fine soil texture and poorly drained, thus, usually under irrigated paddy rice. It was first described in barangay San Francisco, municipality of Victoria, Laguna province and classified as *Typic Tropudalfs.* About 4,952 ha of San Francisco clay loam were mapped in Laguna province.

2.3.4.3 Soils Underlain by Hard Consolidated Tuffaceous Sandstone Bedrock

Maysan series was first described in barangay Maysan, Valenzuela City and consists of very gently sloping to gently undulating shallow moderately drained soils that formed on degraded tuffaceous sandstone piedmont footslopes. This soil series is classified as fine, mixed, isohyperthermic *Lithic Troporthents*. The soils are shallow, poorly to poorly drained. The surface layer is 30 cm thick, dark gray clay with many strong brown mottles. Common small manganese and iron concretions occur in the lower part of this layer.

Underlying this layer is consolidated tuffaceous bedrock extending to several meters depth from the surface. This soil series covers 2,818 ha in the province of Bulacan. Additional 248 ha of Maysan clay was mapped in Rizal province. The Maysan soils are associated with the deeper Pulong Buhangin and Batia series of similar landscape position.

2.3.4.4 Soils Underlain by Sandy Clay

Sorsogon series is classified as *Aquic Eutrudepts* and developed from recent alluvial deposits. The surface soil is dark brown, grayish brown to brown, fine granular to columnar silty clay loam to sandy loam with reddish yellow and yellowish brown mottles. Few gravels are sometimes present. The depth reaches down from 20 to 35 cm. The subsoil is grayish brown to pinkish gray, structureless, compact sandy clay loam with brown to strong brown mottles. The depth is 40–55 cm. The upper subsoil is strong brown to grayish brown, structureless, porous and very friable sandy loam to loamy sand with gray mottling and fine red streaks. Depth is 70–85 cm. The lower subsoil is grayish brown to light brown fine sandy loam to silt loam reaching down to depth from 115 to 130 cm. The substratum is grayish black to black, medium to coarse columnar sandy clay. The drainage is fair to good (Aristorenas et al. 1963). A total of 6,512 ha of Sorsogon series were mapped in the provinces of Sorsogon and Masbate. It was first delineated in the municipality (now city) of Sorsogon, the capital of Sorsogon province. Sorsogon is the southernmost peninsula of Luzon, and composed entirely of volcanic mountains with Mount Bulusan (about 1,558 m) dominating. The soil mineralogy of Sorsogon series would be generally andesitic.

2.3.4.5 Soils Underlain by Sandy Clay, with Orange and Gray Mottles

Baluarte series, classified as *Typic Epiaquepts,* are fairly drained soils developed from recent alluvial deposits. The soil is of secondary origin with slightly undulating to flat relief. The surface drainage is slow and impeded, the internal drainage is fair. The surface soil is brown to dark brown friable loam, from 35 to 40 cm depth. The subsoil is yellowish brown to dark brown columnar, compact, sticky clay, extending down from 65 to 85 cm from the surface. The substratum is brown to dark brown columnar, friable sandy clay with mottles of gray and orange (Bureau of Soil Conservation 1952). On absence of stones, coupled with a level relief and medium-textured surface soil makes the land adapted to a variety of crops. The soils are planted to rice, corn, sugarcane, sweet potato, cassava, vegetables, banana, fruit trees, and coconut. This soil series is similar to Sinapangan but the substratum is heavier in Baluarte. About 401 ha of Baluarte clay loam were mapped in the island province of Bohol. Baluarte, where this soil series was first delineated, is a barangay of the municipality of Buenavista. Despite the karst topopgraphy for which Bohol is well known, Wernstedt and Spencer (1967) clarified that this island consists of rock materials with sharp distinction between the north and south. Baluarte series was first described and mapped in the northern part of the island, and is developed from deeply weathered volcanic materials. According to the Bureau of Mines, the Ubay volcanics, where the alluvial parent materials must have come from, appear to be Paleocene and constituted the eastern to northern Bohol. This was accreted by the ultramafic Cretaceous Boctol Serpentinite and intruded by Paleocene Talibon Diorite (Mines and Geosciences Bureau 2012).

2.3.4.6 Soils Underlain by Clay Loam

Kitcharao series was first identified in the Barangay Kitcharao, Jabonga municipality, province of Agusan. Today, this is a municipality consisting of 11 barangays. The soils were derived from recent alluvial deposits. The solum is about 85–95 cm deep. It is highly permeable. The relief is level to gently undulating, with good external and internal drainage. This soil has two types—the Kitcharao clay loam which has surface soil of dusky red to brown and columnar structure and the Kitcharao silt loam, dusky red to dark brown; massive. The upper subsoil is clay loam for the both soil types, and the lower subsoil is loose and granular and with gravels and concretions. The substratum is clay loam, dark reddish granular, and free from coarse skeletons. The upper boundary of the substratum lies from 85 to 95 cm from the surface (Mojica et al. 1967). Kitcharao clay loam and silt loam covers 5,625 ha in Agusan province and is classified as *Typic Eutrudepts.* Rice is the primary crop. These soils are also grown to fruit trees, textile crops (abaca and ramie), corn, root crops, tobacco, banana, and coconut.

2.3.4.7 Soils Underlain by Clay Loam, with Red Mottles and Concretions

Sara series is classified as *Aquic Eutrudepts*. It covers level to gently rolling alluvial plains. The elevation is from sea level to 76 m. The surface soil is moderately loose and friable brown to reddish brown sandy loam to nearly compact clay loam. Concretions and gravels are found in the surface layer that reaches down to 15 cm. The upper subsoil goes down to 30 cm and is yellowish brown to reddish brown silt loam with concretions and gravels. The lower subsoil reaches down to 80 cm and brown to gray silt loam with red streaks and some concretions. The substratum is grayish brown to reddish brown compact clay loam. The drainage is fair to adequate (Alicante et al. 1947). About 32,523 ha of Sara sandy loam and clay loam were mapped in the provinces of Iloilo and Capiz-Aklan, in the Island of Panay. This soil series was first described in the municipality of Sara, province of Iloilo.

2.3.4.8 Soils Underlain by Gravelly Clay Loam

Candijay series, classified as *Typic Eutrudepts,* are well-drained soils developed from recent alluvial deposits. It occupies lands between hills and along streams. The surface soil is dark brown to almost black, fine granular clay. Few gravels are present and the depth reaches down from 35 to 55 cm. The subsoil is dark brown, brownish gray to light reddish brown slightly gritty silty clay, extending down from 80 to 90 cm from the surface. The substratum is dark gray gravelly clay loam (Bureau of Soil Conservation 1952). A total of 1,307 ha of Candijay clay were mapped in the island province of Bohol. This soil was first described in the municipality of Candijay, province of Bohol, a coastal municipality facing Cogtong Bay. The alluvial materials from which Candijay soils developed could be sourced from three geomorphic surfaces, the Sierra Billones limestone surface of white tuffacious-calcareous siltstone and shale, the Jagna andesite surface, and the Quaternary alluvium surface composed of gravels, sands, and silts in the alluvial plains and coastal areas. Several river systems traverse the plains draining into Cogtong Bay, the coasts of which are lined up by mangrove forests.

2.3.4.9 Soils Underlain by Slightly Gravelly or Stony Clay Loam, Clay, or Silty Clay, with Mottles

Anao-aon series (Plate 1A) is classified as fine loamy, vermiculitic *Fluventic Eutrudepts*. These soils occur on nearly level to level upper flats of the recent river flood plain and not affected by seasonal flooding. The surface layer 12–25 cm thick is dark brown, dark grayish brown or grayish brown clay, silty clay loam or clay loam. The subsoil extends down to 100 cm is brown to dark brown, dark yellowish brown, or grayish brown clay, silty clay loam, or clay loam. Few subangular gravels are observed. The substratum is dark yellowish brown or yellowish brown slightly gravelly or stony clay loam, clay, or silty clay with mottles. About 9,275 ha of Anao-aon silty clay loam were mapped in Surigao provinces. This soil series was first mapped in what is now the province of Surigao del Norte. Anao-aon is the former name of what is now the Municipality of San Francisco. The name is based on the story of two lovers, Anao, the handsome strong hunter, who fell in love with Aon, then the most beautiful and daughter of a powerful datu who ruled the barangay and objected to the love affair. The lovers were found dead and the place was named in their memory. It became a pueblo upon the abolition of the encomienda system. The Philippine Senate changed the name to San Francisco in 1971 in honor of its patron saint, Saint Francis Xavier (Surigao del Norte 2012). Anao-aon series developed in the eastern coast of Mindanao or what is called the Pacific Cordillera region. Wernstedt and Spencer (1967) described the source of alluvial materials from where Anao-aon developed as high and rugged mountain zone paralleled offshore by deep waters of the Philippine Trough (Wernstedt and Spencer 1967). This Eastern Cordillera extends for some 402 km from Bilar Point in Surigao southward to Cape San Agustin in Davao and continues the structures on the island of Pilillo off eastern Luzon and continued through the island of Leyte into Mindanao. The higher portions of the partially submerged Pacific Cordillera reappear off the northeastern coast of Mindanao as the islands of Dinagat, Siargao, Bucas Grande, and the numerous surrounding smaller islands. The core is composed of a complex igneous and metamorphic basement complex, consisting mainly of serpentines, peridoties, and gabbros. The limited lowland areas in the eastern Mindanao are limited to narrow, discontinuous strip of lowland along the east coast and small floodplains and deltas. For the Anao-aon soil series, the Anao-aon River is the major river system that carries the alluvial sediments.

2.3.4.10 Soils Underlain by Clay Loam, with Gravels

Mambutay series was first identified in the barrio of Mambutay, municipality of Esperanza, Agusan province. Esperanza is now a municipality of Agusan del Sur. The soils of this series were developed from older alluvial terraces and classified as *Aeric Epiaquepts*. The solum is fairly deep, about 80 cm, and slowly permeable. The surface soil is dark reddish brown to brown sandy loam. The surface soil is from 15 to 20 cm deep. The subsoil is yellowish red clay loam sticky and plastic when wet, hard when dry and there are concretions on the lower part of the horizon. The lower boundary is about 80 cm from the surface. The substratum is yellowish red clay loam but contains no concretions. In this layer, gravels are usually present. Gravels also appear in overlying layers as short narrow bands or lines (Mojica et al. 1967). The common groups grown are rice, corn, vegetables, banana, and coconut. About 15,369 ha of Mambutay sandy loam were mapped in what was then Agusan province. Mambutay is closely associated with Butuan series as both soils adjoin freshwater swamps; but Butuan soils are waterlogged than Mambutay soils. The Mambutay series is on slightly higher elevation and is fairly drained externally but poorly drained internally.

2.3.4.11 Soils Underlain by Clay Loam to Clay, with Mottles, Some Limestone Materials

Piris series, classified as *Typivc Hapludalfs* is derived from recent alluvial deposits washed down from adjacent uplands. The relief is nearly level to slightly undulating. The drainage is from fair to good. This soil series is characterized by the presence of particles of limestone materials in the subsoil and in the substratum. The surface soil is very pale brown clay loam, platy structure that reached down to 35 cm. The subsoil is dark gray clay loam with some reddish brown streaks and mottles, platy structure and with some particles of limestone materials. The substratum is light brownish gray clay loam to clay, also with numerous particles of limestone materials (Renales et al. 1975). Rice and coconut are commonly grown. Piris clay loam is mapped in Quezon province covering 2,150 ha. Piris, where this soil was first described, is the former name of the municipality of Buenavista when it was then still part of the municipality of Guinyagan, province of Quezon.

2.3.4.12 Soils Underlain by Sandy Clay Loam to Sandy Loam

Siaton series are well-drained soils developed from recent alluvial deposits, occupying narrow coastal areas with undulating slopes, and is classified as *Typic Eutrupepts*. It is slightly elevated inland and forms high bluff from the shorelines. The soil is well-drained. The surface soil is brown, dark grayish brown to very dark brown, very friable, loose, structureless sandy loam, from 20 to 35 cm deep. The upper subsoil is light brown to grayish brown sandy clay, reaching down from 50 to 60 cm. The lower subsoil is light brown clay loam to sandy loam, with some weathered fragments of dark brown rocks, and reaching down from 80 to 90 cm from the surface. The substratum below is grayish brown to light brown, structureless, loose to slightly compact sandy clay loam to sandy loam (Barrera and Jose 1960). This soil is extensively grown to corn, rice, coconut ad banana. About 4,600 ha of Siaton sandy loam were mapped in Negros Oriental province. This soil was first described in the municipality of Siaton, province of Negros Oriental. Siaton was noted for Lake Balanan, formed after a tectonic earthquake in 1925 caused a landslide and dammed the Balanan River forming a natural water reservoir some 25 ha and 285 m above sea level.

2.3.4.13 Soils Underlain by Silty Clay Loam, Below is Band of Waterworn Gravels and Stones

Baler series, classified as *Typic Eutrudepts,* occupies a major portion of the level areas of what used to be a sub-province of Quezon but since 1979, is already the province of Aurora—Baler, San Luis, Maria Aurora, Dipaculao, and Casiguran, comprising about 10,990 ha of Baler silty clay loam. This soil series is of recent alluvial deposits washed down by water from the adjoining uplands. The relief is nearly level, the drainage condition is good. Baler soils differ slightly from Quingua series in the color of the surface soil. The former has very pale brown surface soil while the latter has brown to yellowish brown surface soil. Baler series is similar to Umingan in the presence of waterworn gravels and stones below the subsoil. The topsoil is very pale brown silty clay loam and reaches down to 30 cm. The upper subsoil extends down to 70 cm and is dark yellowish brown silty clay loam with numerous reddish brown streaks while the lower subsoil is dark brown silt loam with reddish brown streaks extending down to 100 cm. The substratum is strong brown silty clay loam. Beneath 150 cm is a band of waterworn gravels and stones, 50 cm thick, underlain by a compact heavy clay (Renales et al. 1975). The major portion of this soil is grown to rice. Some patches are devoted to coconut, root crops, citrus, banana, and vegetables. This soil series was first described in the municipality of Baler, the political and economic center of the province of Aurora.

2.3.4.14 Soils Underlain by Brown Compact but Friable Sandy Loam

Libi series was first mapped in what is now Libi (also known as Liby), South Cotabato and classified as *Typic Eutrudepts*. The series occupies the level to undulating areas in the vicinity of the Lun Rivers, the Big Lun and the Small Lun east of Sarangani Bay in Southern Koronadal Valley. Covered chiefly by secondary growth forest and small patches of cogon the area consists largely of abandoned kaingin. Small patches of cleared land are found where rice, corn, and vegetables are grown. Coconut trees to supply the needs of the natives have been planted. The land slopes gradually from the hills to the sea. The soil is of the finer texture along the shore but becomes coarser near the hills. It is loam to sandy loam 3.5 km from the shore near the foot of the hills. Similarly, the soil is loam to sandy along the streams. Depositions along the banks of creek exhibit unmistakable characteristics of the San Manuel soils. Similar depositions are evident to within 250 m from the creeks. This is also characterized by a textured surface soil which is loam to sandy loam, different from the clay surface soil near the shore. A typical profile of Libi loam has the following characteristics: The surface soil, with depth of 15 cm from the surface is dark gray, slightly plastic, slightly compact loam; hard when dry. The upper subsoil, reaching down to 25 cm is grayish brown silt loam, very slightly sticky, plastic, and slightly compact; hard when dry. The lower subsoil that reaches down to 90 cm, is pale brown, slightly sticky and plastic silt loam, compact; becomes more compact as the depth increases. The substratum, extending down to the control section at 150 cm, is brown, compact, hard, but friable, sandy loam. This material, on exposure, easily crumbles (Mojica et al. 1963). The extent of areal coverage is 1,416 ha in Cotabato provinces.

2.3.4.15 Soils Underlain by Grayish Brown or Gray Slightly Compact Sandy Loam to Coarse Sandy Loam

Pilar series, classified as *Typic Hapludepts,* have surface soils extending down to 25 cm, grayish brown to light brown, medium to coarse granular and friable very fine sandy loam to silt loam. The drainage is good. The surface soil, with a depth reaching down to 25 cm from the surface, is grayish brown to light brown medium to coarse granular, friable very fine sandy loam to silt loam. The upper subsoil, extending down to 51 cm, is darker in color than the surface soil and slightly more compact than the above horizon; fine to medium blocky structure. The lower subsoil, extending down to 80 cm, is yellowish brown to light brown or brown fine granular and friable sandy loam. The substratum, extending down to the control section at 150 cm, is grayish brown or gray slightly compact sandy loam to coarse sandy loam (Alicante et al. 1949). The greater part of this series is devoted to the growing of lowland rice and corn. Before the Word War II, sugarcane was an important crop grown but is not that widely grown now. Peanuts, mongo, cowpeas, and vegetables are also raised in this soil series. About 8,972 ha of Pilar silt loam and sandy loam were mapped in the province of Bataan. This soil was first described in the municipality of Pilar, province of Bataan. It is in this municipality where the mammoth Dambana ng Kagitingan stands on the highest part of Mt. Samat, in barangay Diwa. This is a memorial shrine complex built to honor the gallantry of the Filipino and American soldiers who fought during World War II. A memorial cross towered 92 m (302 ft) from the base, with an elevator and viewing gallery at the arm of the cross. The alluvial Pilar soil series developed from the deposits heavily dominated by sediments coming from the adjacent Mount Samat and neighboring mountain ranges of high, rugged peaks with considerable Quaternary volcanism evident in this southern portion of Bataan Peninsula. The basement complex materials consisted of basic, coarse-grained rocks and volcanics, including andesites, diorites, and gabbros.

2.3.4.16 Soils Underlain by Sandy Loam, Sandy Clay Loam, and Sands

Bancal series are found in level to slightly undulating areas, formed from older alluvial deposits, having a moderately developed profile and generally deep soil. The topographic feature is level to slightly undulating. The soil is well drained. The surface soil is light brown, brown to strong brown slightly porous and friable to slightly compact clay that extends down from 20 to 25 cm. The upper subsoil is brown, dark brown to almost black compact clay loam to clay and reaches down to 55 cm. The lower subsoil is the same as the upper layer with light brown color, and with dark red and grayish brown streaks and reaches down to 80 cm. The substratum is light gray to medium gray, gritty, slightly compact and friable sandy loam, sandy clay loam, to sandy (Alicante et al. 1951). Rice is the principal crop. The other crops grown are corn, sugarcane, peanuts, sweet potato, cassava, vegetables, and mango. A total of 32,234 ha of Bancal soils were mapped in the provinces of Lanao, Zamboanga del Sur, and Zambales. But current estimates is about 10,500 ha due to Mt. Pinabuto lahar burying the rest of the original soils. This soil series originated in barangay Bancal, municipality of Botolan, Zambales province. This soil series is classified as *Typic Eutrustepts.*

2.3.4.17 Soils Underlain by Structureless Coarse Sand, with Dark Brown and Rusty Mottles

Macabare series are *Aeric Epiaquepts* mapped along coastal plains. This soil series developed from recent alluvial deposits brought down by rivers from the surrounding uplands. The elevation is from sea level to about 15 m. These soils are fairly well drained. The surface soil is brownish gray, brown to reddish brown sandy clay loam with orange mottling; soft and slightly plastic when wet and mellow to crumbly when dry; free from coarse skeleton. It extends down from 25 to 30 cm from the surface. The subsoil is light brown to brownish gray sandy loam with brown and black mottles; friable and slightly compact; few gravels are present in this layer. The depth reaches down from 75 to 80 cm. The substratum is light brown to grayish brown structureless, loose, and very friable coarse and medium sand with some gravels and with chocolate and rusty brown mottles. The substratum extends down to the control section at 150 cm from the surface. Below is a layer of light gray coarse and medium sand (Aristorenas et al. 1963). Most of the areas are cultivated to rice and corn. About 5,020 ha of Macabare sandy loam, sandy clay loam, and clay loam in the provinces of Sorsogon, Sulu, and Masbate were delineated. The soil series is named after barangay Macabare, municipality of Barcelona, province of Sorsogon.

2.3.4.18 Soils Underlain by Grayish Brown or Gray Very Loose Coarse Sand with Gravels

Banga series is classified as *Typic Ustifluvents.* Banga soils were first described in Banga municipality in what is now the province of South Cotabato. This name was derived from *buanga*, how the natives called the palm tree that grew abundantly in the area during the presettlement period. When first mapped, it occupies the grater portion of the Allah Valley along the Banga and Allah Rivers extending from over 15 km south of Banga to as far as Maganuy on the north. This soil series is well drained. It has dark brown to brown surface soil, structureless, slightly compact, sandy loam that extends down from 5 to 10 cm. The upper subsoil is brown to medium brown, loose and structureless sand, reaching down to 60 cm. The lower subsoil is brown, structureless, loose coarse sand that reaches down to 120 cm. The substratum is grayish brown or gray, very loose, coarse sand with gravels (Mojica et al. 1963). The soil is generally cultivated and grown to a number of crops. Rice and corn are the main crops. Mongo, beans, vegetables, cassava, sweet potato, banana, and fruit trees are also grown. About 93,750 ha of Banga series were mapped in what was then the province of Cotabato. Eventually, the province was divided into North Cotabato, South Cotabato, Maguindanao, Sultan Kudarat, and Sarangani provinces.

2.3.4.19 Soils Underlain by Coarse Brown Sand with Gravels

Malandag series (Plate 1D) was first described in Malandag Plains between Buayan River and the hills adjacent to Nupol at the foot of Mt. Matutum, about a thousand ha generally undulating with patches of rolling relief near the hills on the west and along the streams. Tinagacan River cuts the plain in two, running almost midway between Buayan River and the hills on the west. Along the streams and the more elevated areas second growth trees cover the land. The lower areas are in grass. Patches of cultivated areas planted to abaca and coffee are found in the higher areas while rice and corn are the principal cultivated crops in the lower portions. Today, Malandag is a barangay of Malungon municipality, province of Sarangani, bounded on the west by the municipality of Tupi, South Cotabato, forming the footslopes on the eastern side of Mount Matutum. Classified as *Typic Eutrudepts*, the soil is very dark brown to almost black when moist, turns dark brown or medium brown when dry. At a meter or more below the surface is brown coarse sand and gravel waterworn pebbles and rocks. A description of the profile is as follows: the surface soil, 0–15 cm in depth, is very dark brown to almost black, friable and granular, loose fine sandy loam. The upper subsoil, from 15 to 50 cm in depth is dark brown, coarse granular, sandy loam, slightly compact; sand grains are coarser than layer above. The lower subsoil, from 50 to 100 m in depth, is brown, coarse sandy clay loam; slightly sticky and plastic; coarse granular structure. The substratum that reaches down to the control section is coarse brown sand with gravels (Mojica et al. 1963). A total of 1,250 ha of Malandag sandy loam were mapped in Cotabato in what is now part of Sarangani province. The extent of various types of Malandag series was updated in 2006 and the new total for Sarangani province is 3,581 ha.

2.3.4.20 Soils Underlain by Coarse Sand, with Gravels and Tuffaceous Concretions

Luisita series are characterized by brownish gray, pale gray, and ash gray relatively deep surface soil (40–50 cm) and classified as *Typic Endoaquepts*. The lower portion of the subsoil and the substratum have presence of coarse sandy materials with concretions and gravels that extend down to the control section (150 cm). This soil series is closely associated with Angeles and La Paz. Angeles Series has sandstones and gravels in the subsoil but in the case of Luisita Series, tuffaceous concretions and gravels could be found only in the lower portion of the subsoil. La Paz has no B horizon and characterized only by an AC profile, and has fine to medium sand throughout (no concretions and gravels). This soil series was first described inside Hacienda Luisita in barangay San Miguel, Tarlac City, province of Tarlac. The hacienda has historic ties with former Philippine president Corazon Cojuanco Aquino and her son who also became Philippine president, Benigno Simeon Conjuangco Aquino III. The estate was named after Luisa Bru y Lassus, the wife of Don Antonio Lopez y Lopez, the first Marquez de Comillas, founder of Compania General de Tabacos de Filipinas, Sociedad Anonima (better known as the Tabacalera) where the hacienda was once part of their holdings conceived to take over the Philippine Tobacco Monopoly from the Spanish colonial government. About 51,056 ha of Luisita sand and Luisiata sandy loam were mapped in Tarlac.

2.3.4.21 Soils Underlain by Coarse Sand, with Red-Coated Gravels

Calape series are well-drained soils formed from recent alluvial deposits. It is classified as *Typic Eutrudepts.* The drainage is fair to good. The surface soil is brown, dark brown to brownish gray cloddy friable clay loam with red and gray mottles and extends down from 65 to 75 cm. The upper subsoil is reddish brown to brownish gray friable silty clay, reaching down from 85 to 130 cm. The lower subsoil is brown to pale brown cloddy sandy clay with gray, black, and orange specks. The depth is 140–175 cm from the surface. The substratum below is a mixture of red-coated gravels and sand (Bureau of Soil Conservation 1952). Calape clay loam covers some 5,237 ha in Bohol province. It was first mapped in the municipality of Calape, province-island of Bohol, along the western coast, facing the island of Cebu. The name is derived from a type of rattan, "kapi" or "kalapi".

2.3.4.22 Soils Underlain by Coarse Sand and Silicious Materials

Polillo series, classified as *Typic Eutrudepts,* is an established soil series in the coastal plains of Polillo Islands, province of Quezon where this was first described, occupying some 2,867 ha of Polillo sandy clay loam, mainly in Polillo and Burdeos towns. Polillo soils is derived from recent alluvial deposits brought down from the uplands. The relief is nearly level to level, the drainage conditions are good. The surface soil is light yellowish brown sandy clay loam. The subsoil is yellowish brown silicious sandy loam mixed with particles of white sandy materials. The substratum is very pale brown coarse sand mixed with bigger particles of silicious materials (Renales et al. 1975). The Polillo Islands where this soil series was named after is home to one of the rarest reptiles on earth, the Butaan lizard, a highly endangered relative of the Komodo Dragon. The Chinese origin of the name *Pu Li Lu* which means "beautiful island with plenty of food" reflects on the long trade relations existing between the native inhabitants the islands and the Chinese merchants before the Spanish conquest (Polillo and Quezon Homepage 2012).

2.3.4.23 Soils Underlain by Coarse Sandstone

Angeles series are on nearly level to gently undulating landscape, and formed from recent alluvial deposits. The topsoil is pale brownish gray, ash gray to whitish gray, loose, and structureless fine sand to coarse sand, extending down to a depth of 30 cm. The subsoil is brownish gray, brown to light reddish brown, medium sand with sandstone and gravels for the first 50 cm; becomes pale gray to nearly white sand with reddish brown gravels until 95 cm, The subsoil becomes further gray, structureless, coarse to medium sand with small amount of sand resembling silica down to 110 cm. The substratum is grayish white coarse sandstone (Yñiguez et al. 1956). Angeles series was first described in Angeles City, Pampanga. The city name was derived from *El Pueblo de Angeles* in honor of its patron saint, *Los Angeles de los Custodios* and its founder, Don Angel Pantaleon de Miranda who staked out a new settlement in 1796, naming it as Culiat. It became a separate municipality in 1829 and took on its current name (Wikipedia 2012p). About 111,142 ha of Angeles Series were mapped in Pampanga, Tarlac, and Zambales provinces but current estimates place it at 17,800 ha. The decrease in area is attributed to the fresh deposition of Mt. Pinatubo lahar. This soil series is classified as *Typic Ustipsamments*.

2.4 Soils of the Infilled and Localized Valleys, Narrow Miniplains, Collo-Alluvial Plains, and Fan Terraces

Most of the lowland soils in the Philippines were developed from fluvial deposition. Rivers deposited materials along their course, but mainly in valley bottoms where the gradients are low or where gradients suddenly change or where channel flow diverges. Erosion from the adjacent uplands and highlands during monsoon rains and the consequent deposition during flood events comes almost like an annual cycle. Alluviation takes place and refers to massive deposition that affects much of the river system. Scour and erosion generally takes place in the upstream channels while fill and deposition dominate the downstream channels. The soils that developed are generally referred to as the alluvial soils.

2.4.1 Infilled, Localized Valleys, and Narrow Miniplains: The Poorly and Moderately Drained Soils and Characterized by Presence of Redoximorphic Features

These are confined valleys and its variants; and the river dynamics infills the valley floor with fluvio-custrine deposits resulting in characteristic soil patterns. They are level to nearly level slopes in between hills. Soils of this landform were developed from recent alluvium of the surrounding elevated areas (Fig. 2.21).

Fig. 2.21 An infilled and localized valley in Misamis Oriental as surveyors scout for possible sampling site

Some surveyors when delineating soil series are confused with the difference between minor alluvial plains and the narrow miniplains. These are generally differentiated by the width of the valley floor. The narrow miniplains have valley floors extending up to 50 m only. Beyond 50 m but still small enough that it could not be classified as a broad alluvial plain, the landform is referred to as the minor alluvial plain. The narrow miniplains are also so-called because they usually terminate with the lake or the river.

2.4.1.1 Soils Underlain by Fine Loam, with Highly Decomposed Plant Residues and Lacustrine Shells

Bulubog series is also poorly drained and very similar to Pangil Series, with the same textural class underlained by fine loamy, and associated with many highly decomposed plant residues and lacustrine shells (Soil Survey Division 1987b). They have the same taxonomic classification as fine clayey, mixed, isohyperthermic *Typic Endoaquepts* but differ in physiographic position. Pangil occurs in lake terrace landscape while Bulubog is on concave closed basin landscape. This Bulubog series was first described in barangay Perez, municipality of Calauan, Laguna province. Bulubog must have been originally described elsewhere as a tentative soil series but reappeared more extensively in Calauan, Laguna, where about 202.51 ha were delineated. This soil series is shallow to moderately deep poorly drained soils occurring on concave closed basin landscape. The Apg horizon is very dark gray, gray, dark grayish brown clay loam with dark gray and grayish brown mottles. The subsurface horizon is gray, dark gray, greenish gray to dark greenish gray clay loam, with brownish and grayish mottles. Few highly decomposed plant remains and lacustrine shells are observed. The substratum is greenish gray, dark greenish gray, dark gray clay loam to loam with highly decomposed plant remnants and lacustrine shell deposits.

2.4.1.2 Soils Underlain by Massive Sandy Clay, with Gravels

Mambajao series was first described in the municipality of Mambajao, the capital municipality of Camiguin Island, which used to be a sub-province of Misamis Oriental but is now an island province. The Battle of Camiguin in 1945 is an important annal in the liberation of the Philippines from the Japanese Imperial Army during the terminal phase of the Second World War. The soils of Mambajao developed from recent alluvium washed down from hilly areas of andesite and volcanic formation. The relief is level to sloping and moderately undulating with slopes ranging from 0 to 6 %. The elevation from mean sea level is about 152 m. The sloping area is well drained but the level portion has slow internal and external drainage. The surface soil reaches down to a depth of 30 cm, brown, light brown to strong brown moderately compact clay; soft and friable when moist, sticky and plastic when wet, hard and compact when dry; columnar to fine granular structure. The upper subsoil extends down to 65 cm from the surface, brown to light brown to reddish brown and moderately compact clay; moderately sticky and plastic when wet, soft and friable when moist, and brittle when dry; columnar structure. The lower subsoil extends down to 95 cm, and is gravelly clay with few stones, brown to reddish brown. The substratum that reaches down to the control section at 150 cm, is brown to yellowish brown sandy clay with grayish black mottling and few sandstone gravels; compact and massive in structure (Lopez et al. 1954). The soil is generally grown to coconut and abaca. The other crops are fruit trees, rice, peanut, corn, tubers, and banana. This soil series is classified as *Typic Hapludults* and Mambajao clay covers 23,877 ha in Misamis Oriental.

2.4.1.3 Soils Underlain by Massive Clay Loam; Heavy Cracking Soil (Vertisol)

Dagami series was first established in the municipality of Dagami, Leyte province. Dagami is rich and colorful in ancient Philippine history. Dagami, the ancient name of which was Dagilan, was the capital of the fusion of three sultanates when Sayambugan, the daughter of Sultan Diwaranda Mohammed of the sultanate of Dagaran, married Bantugan, the son of Sultan Maparanda of the sultanate of Bumbaran and conquered his challenger to Sayambugan, Sultan Mabanig of the sultanate of Kahagna who declared war on Bumbaran 2 days before their wedding. By 1478, some two hundred years after the union of the three kingdoms by marriage and conquest, Dagilan's cultural and social life was enhanced by increased population and flourishing trade with Asia and Europe. Dagilan became Dagami in 1521 when the Spanish *conquistadores* could not pronounce "dinagami", the term used to describe a rice field after harvest as the name for this place (Wikipedia 2012q). The external features of Dagami soil series are similar to the Palo and Umingan. This soil series has also a level topography and fair drainage. The external drainage is quite slow because of the gradual slope of the area. The heavy texture of the soil impedes the internal drainage. Dagami soils have dark brown surface soil which ranges in depth from 20 to 25 cm. It has fine granular structure with a slightly sticky consistency. The subsoil is dark brown to reddish brown medium granular clay loam that reaches to a depth of 50 cm from the surface. Some gravels of andesites with rough angular faces are present. The lower substratum has much deeper color than the subsoil. It has a clay cloam texture with a brick-red to light red color and massive structure. The color is influenced by the adjacent uplands which are reddish brown to red soils (Barrera et al. 1954). This soil series is classified as *Aeric Epiaquerts.* Dagami clay loam covers 1,757 ha in Leyte provinces.

2.4.1.4 Soils Underlain by Clay, with Calcium Carbonate Nodules; Heavy Cracking Soil (Vertisol)

Binangonan series was named after the lakeshore municipality of Binangonan, Rizal but the typical pedon for this soil series was first described more inland near Pantay Buhangin road, barangay Dalig, in the municipality of Teresa, Rizal province. The Binangonan series belongs to very fine, montmorillonitic, isohyperthermic *Udorthentic Pellusterts.* These soils are deep, poorly drained found at level to gently level (0–5 % slope) narrow mini plain of the alluvial landscape. These soils developed from alluvium of volcanic and limestone origin. The Ag horizon is not more than 40 cm thick, gray, dark gray clay with prominent sharp red, strong brown, yellowish brown mottles, firm when moist and sticky and plastic when wet. Few iron concretions and calcium carbonate nodules are present. The underlying Bg horizon reaches down from 100 to 150 cm, and is dark gray, light gray to gray, or olive gray clay with dark yellowish brown, grayish brown, olive gray or gray mottles, very firm when moist, very sticky and very plastic when wet. Slickensides are present in the lower horizon. Coarse to medium calcium carbonate nodules are observed, increasing with depth. The Cg horizon or the substratum is olive gray, light gray to gray, or olive clay, with olive mottles. Iron and manganese concretions are present, also coarse to medium calcium carbonate nodules occur abundantly. About 1,340 ha of Binangonan clay were mapped in Rizal. Binangonan soil series is associated with Teresa series, and both are classified as Udorthentic Pellusterts. But the B horizon of

Binangonan series has common to many tuffaceous fragments coated with iron-manganese concretions. Binangonan is also similar to Baras series but they differ on physiographic position with Binangonan at narrow mini plain while Baras occurs on minor alluvial plain (Soil Survey Division 1989b).

Teresa series is named after the municipality of Teresa, Rizal. The soil is classified as very fine, montmorillonitic, isohyperthermic *Udorthentic Pellusterts.* These soils are moderately deep to deep, poorly drained soils on nearly level to gently sloping (0–5 % slopes) narrow mini plain of the alluvial landscape. The soils developed mainly from alluvium derived from weathered tuffaceous materials, and perhaps from biochemically deposited weathered products of limestone, basalts, andesites, and conglomerates from adjacent hills and mountains fringing the area. The A horizon that extends as far down to 40 cm, is gray to very dark gray clay with distinct clear yellowish red, strong brown or reddish brown mottles, firm when moist and plastic when wet. The cambic Bg horizon, reaching down from 60 to 150 cm from the surface, is gray to very dark gray clay with strong brown or reddish brown mottles. Few iron-manganese concretions are sometimes observed. Few to common strongly weathered tuffaceous fragments coated with iron–manganese concretions are present at depth between 40 and 148 cm. Few calcium carbonate nodules also occur. Thin patchy slickensides are observed increasing with depth. The Cg horizon is olive gray, dark gray clay and mottled with gray, yellowish brown or light yellowish brown with few iron-manganese concretions and highly weathered tuffaceous fragments. Few small and medium calcium carbonate nodules sometimes occur. About 887 ha of Teresa clay was mapped in Rizal province. Teresa series is similar to Baras and Binangonan soils, all classified as Udorthenic Pellusterts. Binangonan series becomes heavier in texture as depth increases. Teresa series has thinner solum and lower clay content compared to both Binangonan and Baras. Teresa and Binangonan are found on similar landscape position at narrow miniplain of the alluvial landscape (Soil Survey Division 1989b).

2.4.1.5 Soils Underlain by Silty Clay to Clay, with Calcium Carbonate Nodules and Partially Weathered Rock Fragments, with Vertic Properties

Philcomsat series is obviously named after the soils describing the land property of the Philippine Communications Satellite Station at the foot of the Sierra Madre Mountains in barangay Pinugay, municipality of Baras, Rizal province. Soil surveyors who described the morphology and took the soil samples mistook Pinugay to be part of Antipolo, and this is reflected in the soil survey report. This soil series is classified as very fine, mixed, isohyperthermic *Vertic Tropaquepts.* The soils are moderately deep to deep, somewhat poorly drained, found on nearly level to slightly sloping (2–5 % slopes) narrow mini plain of the alluvial landscape. The A horizon 13–33 cm thick is brown to dark brown, light yellowish brown, dark yellowish brown, or dark grayish brown silty clay to clay with distinct strong brown, yellowish red, grayish brown or brown to dark brown mottles with moderate to strong angular blocky structure, firm to slightly firm when moist, sticky and plastic when wet. The cambic B horizon 60–130 cm deep is dark grayish brown, brown to dark brown, gray to dark gray or olive gray clay and increasing in clay content with depth. Mottles are yellowish brown, brown to dark brown or grayish brown. Structure is moderate to strong angular to subangular blocky; consistence is slightly firm to firm when moist, sticky and plastic when wet. Few discontinuous slickensides occur increasing with depth. Fe iron-manganese concretions and highly weathered rock fragments probably shales, are present. The Cg horizon is gray clay with distinct grayish brown, yellowish brown, or bluish yellow mottles. Few to common partially and highly weathered rock fragments occur. Few calcium carbonate nodules and iron-manganese concretions are observed. About 1,870 ha of Philcomsat series was mapped in Rizal province. This soil series is somewhat similar to Jalajala since they are both Vertic Tropaquepts but they occur on different physiographic position. Jalajala is on an alluvial fan terrace while Philcomsat is on a narrow miniplain landscape. Philcomsat is also associated with the poorly drained Cupang series which is found on a minor alluvial landscape. However, Philcomsat contains calcium carbonate nodules in the lower horizon (Soil Survey Division 1989b).

2.4.2 Infilled and Localized Valleys and Narrow Miniplains: The Well-Drained Soils

2.4.2.1 Soils Underlain by Clay

Binidayan series is one of the newly established soil series in Lanao del Sur province, first described in Binidayan municipality. This soil series is classified as *Typic Hapludults.* It is a residual soil developed from basalts and andesites. The relief is undulating to strongly rolling and the surface soil is excessive and the internal drainage is moderate. Binidayan sandy loam is found immediately south of Lanao Lake embracing the municipalities of Ganasi Binidayan, Bayang, Lumbatan, Maui, Tatarikan, Pualas, Tubaran and part of Malabang. The top soil is dark reddish brown loam with weak fine crumb structure, and reaching down to 15 cm. The subsoil is dark reddish brown clay loam with subangular blocky structure, and extends down to 70 cm. The substratum is reddish brown clay that extends down to the control section at 150 cm. Binidayan sandy loam covers 44,976 ha in Lanao provinces.

2.4.2.2 Soils Underlain by Sand

Umingan series (Plate 1G and Fig. B.11) is moderately well-drained deep soils with a distinct substratum of river washed stones and gravels with thickness ranging from 10 to 15 cm. The soil series is classified as *Fluventic Eutrupepts*. The surface soil varies in color from pale gray to dark gray or grayish brown to dark brown. The subsoil is usually silt loam. The lower subsoil has a distinct layer of river washed stones and gravels. The substratum is dark brown sand to coarse sand. This is the distinguishing characteristic of this soil—below the gravelly and stony later is a stone-free soil layer (Alicante et al. 1940b). This soil was first described in Umingan, Pangasinan located on the foot of the Caraballo Mountains. Aside from the province of Pangasinan, Umingan Series is extensively mapped in the provinces of Nueva Ecija, Albay, Antique, Benguet, Capiz, Aklan, Ilocos Norte, Ilocos Sur, Iloilo, Kalinga, Apayao, Leyte, Quezon, Marinduque, Batanes, Mindoro, Misamis Oriental, Samar, Cagayan, Zamboanga del Sur, Agusan, Antique, La Union, Leyte, and Negros Occidental with total area of about 207,161 ha (Fernandez and Jesus 1980).

Magcalon series has also a substratum of river washed stones and gravels similar to Umingan. Whereas Umingan is characterized by subsoil of silt loam, the subsoil of Magcalon is fine sand, notably dark grayish brown to black in color. Underlaying this horizon is a layer of light brown sand with gravels and stones. The layer of stone accumulation varies in depth from 35 to 150 cm. In some sections, there are two layers of stones separated by a layer of sand. This soil series was first mapped in barangay Magcalon, municipality of San Jose, province of Antique. This soil series is classified as *Typic Ustipsamments*. The relief is nearly level to gently undulating. The external and internal drainage are good to excellent. The cultivated portions are planted to coconuts, rice, corn, sugarcane, root crops, fruit trees, mongo, banana, and vegetables. A typical profile has the surface soil reaching down to 25 cm, sandy loam; grayish brown to brown when dry, dark grayish brown when wet; granular; loose and very friable. The subsoil extends down to 45 cm from the surface; fine sand; dark grayish brown when dry, almost black when wet; loose and friable. The substratum reaches down to 75 cm, layer of mixed sand, gravels, pebbles, and stones; the sand is light brown with reddish mottling. Below, until the control section at 150 cm is light grayish brown sand; loose and structureless. Magcalon sandy loam covers 4,018 ha, mapped in Antique province (Calimbas et al. 1963).

2.4.3 Soils of the Collo-Alluvial Plains and Fan Terraces: The Poorly Drained Soils and Characterized by Presence of Redoximorphic Features

Collovium materials refer to unconsolidated mass of rock debris at the base of a clip or a slope, deposited by surface wash. Alluvial materials are unconsolidated, stratified deposits laid down by running water, sometimes applied only to fine sediments (silt and clay) but more generally used to include sands and gravels, too. Alluvial fans are formed by the sudden change in river gradients at the junction of the mountains and the alluvial plains This induces deposition of the sediment load of the streams and rivers as they spread slowly upon entering the relatively level alluvial plain. The terrain ranges from almost level to undulating.

2.4.3.1 Soils Underlain by Stratified Concretionary Clay; with Vertic Properties

Kapalangan series are poorly drained, olive gray to grayish brown medium to fine medium-textured soils and characterized by soft and hard iron and manganese concretions within the 50 cm profile. The soils are classified as fine clayey, nonacid, mixed, isohyperthermic *Vertic Endoaquepts*. The Ag horizon is gray clay with yellowish red mottles. The cambic Bgcn horizon is deep, weakly stratified grayish brown concretionary clay. The Cgcn horizon is stratified grayish brown concretionary clay (Bureau of Soils 1973a). These soils are formed from stratified fine clayey local valley alluvium in dissected concretionary fan terraces in the western foothills of the Sierra Madre Mountains. They can also be found in narrow local valley alluvial positions. About 842 ha of Kapalangan soils were mapped in Bulacan province as part of the Peñaranda River Irrigation Project, delineated from what were Prensa series in the old reconnaissance soil survey. The soils are associated with Awayan, Prensa, and Mahipon series in adjacent upland positions and with the slightly lower lying Bantog soils. Kapalangan series was first described in barangay Kapalangan, Gapan City, Nueva Ecija just adjacent to San Miguel, Bulacan province where this soil was mapped. There is also another Kapalangan barangay equally adjacent to Bulacan but besides Calumpit municipality, and it is a barangay of Apalit, Pampanga province. Kapalangan was derived from the word "palang" meaning machete or bolo believed to be owned by a nobility named Pangpalung of Gatbonton ancestry (Camiling et al. 2012). The Gatbontons traced their lineage to Dayang Lahad, daughter of Rajah Sulayman de Salila I (Dulay 2012). Her brother was the famous Lakan Dula (1503–1589, the name literally means

Lord of the Palace), the ruler of the Kingdom of Tondo, who together with another brother, Rajah "Ache el Viejo" Matanda, also known as Rajah Sulayman II (1480–1572) and their nephew Rajah Sulayman III (1558–1575) ruler and heir of the precolonial Kingdom of Maynila, respectively, played significant roles in resisting the Spanish conquest of their kingdoms along the Pasig River delta in the early 1570's. Rajah Sulayman III and Lakan Dula were eventually succeeded by Lakan Dula's son, Magat Salamat, until the rajahnate's abolition. To understand the Kapalangan series concept, this is how it keys out with the associated soils:

Soils with clayey subsoil textures (35–60 % clay, hues 10YR–2.5YR)

a. With grayish brown subsoils
   1. Subsoils with slight evidence of stratification
      i. Subsoils with Mn-Fe concretions
         Kapalangan Series
      ii. Subsoils without concretions
         Zaragosa Series
   2. Subsoils without stratification
      i. Subsoils with Mn-Fe concretions
         – With 3–15 % Mn-Fe concretions
           Awayan Series
         – With 15–50 % Mn-Fe concretions
           Prensa Series
         – With 50–90 % Mn-Fe concretions
           Mahipon Series
      ii. Subsoils without Mn-Fe concretions
         –
b. With brown subsoils
   1. Subsoils with stratification
      –
   2. Subsoils without stratification
      Quingua Series

2.4.3.2 Soils Underlain by Slightly Concretionary Massive Clay; Heavy Cracking Soil (Vertisol)

Awayan series (Plate 1A) consists of nearly level to gently undulating somewhat poorly drained soils formed from weakly stratified unconsolidated slightly concretionary fine clayey materials on dissected fan terraces. These soils are classified as fine clayey, montmorillonitic, isohyperthermic *Entic Chromusterts*. The surface layer could extend to more than 20 cm thick, and when use for paddy rice, the Ag horizon is grayish brown light clay loam with brown mottles and few spherical manganese-iron concretions. The subsoil reaches as down as 150 cm, and is mottled gray and brown slightly concretionary clay with slickensides. Cracks form annually 50–100 cm deep and more than 1.0 cm wide and remain open more than 150 accumulative days during the year except when irrigated. The substratum below could reach to a depth of 300 cm and is grayish brown slightly concretionary clay with gray mottles, massive in structure, and with slickensides (Bureau of Soils 1973a). This soil series covers 26,803 ha in Bulacan province. Awayan soils is associated with the more concretionary Prensa and Mahipon soils of similar landscape position and with the slightly lower lying slightly concretionary Kapalangan soils in local alluvial valleys. This soil was first described in Awayan, Nueva Ecija. Established during the Peñaranda River Irrigation Project, they were included in the Prensa Series in the old reconnaissance level soil surveys.

2.4.3.3 Soils Underlain by Massive Clay; Heavy Cracking Soil (Vertisol)

Prensa series (Fig. A.7 for soilscape view) belongs to clayey, montmorillonitic, isohyperthermic *Entic Chromusterts*. These soils contain common (15–50 %) manganese-iron concretions. When used for paddy rice, the Ag horizon is grayish brown, slightly concretionary clay loam with brown mottles. The Bcgn horizon is mottled gray and brown concretionary clay with slickensides. Prismatic structural cracks form annually more than 50 cm deep and 1 cm wide and remain open more than 150 accumulative days during the year, except where irrigated. The Cg horizon is grayish brown clay with gray mottles, massive structure and slickensides (Bureau of Soils 1973a). These soils are formed on weakly stratified unconsolidated concretionary fine clayey materials on dissected fan terrace landscape and dissected piedmont footslope landscape position between mountain footslopes and broad low plains. The parent materials are derived from volcanic ejecta, limestone, metamorphic, greywacke, and conglomerates. These soils are associated with Awayan and Mahipon series in similar landscapes and with Kapalangan series in local valley alluvial positions. A total of 3,158 ha of Prensa soils were mapped in the updated soil survey of the province of Bulacan, much smaller than in the old reconnaissance survey which is 27,480 ha. It was one of those soil series updated during the 1971 Peñaranda River Irrigation Project. The updated soil survey of Rizal province deleted Prensa clay loam which originally covered 2,090 ha. Hence, the updated coverage of Prensa series in the provinces of Bulacan, Pampanga, and Nueva Ecija is around 40,368 ha, down from original 64,623 ha because of the redefinition of the soil series. Prensa was derived from Prenza, a barangay of the municipality of Marilao municipality, Bulacan province where it was first described in 1937. Marilao is also a fast developing urban community evolving from a conservative agricultural town. The 1971 redefined soil series has a typifying pedon described in San Roque, Gapan, Nueva Ecija some 5 m south of the San Roque to Kapalangan Road.

2.4.3.4 Soils Underlain by Clay Loam, Silty Clay Loam, Sandy Clay Loam or Clay, with Weathered Tuff Fragments; with Vertic Properties

Jalajala series belongs to the soil family of fine, mixed, isohyperthermic *Vertic Endoaquepts*. These are moderately deep to deep, poorly to somewhat poorly drained soils on nearly level to gently sloping alluvial fan terraces landscape. The soils have light brownish gray, light gray to dark gray silty clay or clay with brownish or reddish mottles. The cambic Bg horizons, 80–150 cm from the surface are predominantly gray, dark gray, olive gray, light gray to gray clay loam, silty clay or clay with iron-manganese concretions and weathered tuffaceous fragments. The C horizons are yellowish brown, brown to dark brown, grayish brown clay loam, silty clay loam, sandy clay loam, or clay with common to many weathered tuff fragments (Soil Survey Division 1989a). The soils are formed from mixed colluvial and alluvial materials derived from weathered tuffaceous materials and lake alluvial deposits. This soil is associated with Baras Series. But Baras soils occur on minor alluvial plains while Jalajala series are found on collo-alluvial fan terraces footslopes. Baras soils contain lesser tuffaceous fragments in the B horizon and substratum compared to Jalajala. Baras soils also have higher percentage of clay in the profile. This was originally mapped in Jalajala series was first described in Jalajala municipality in the province of Rizal. It is a peninsula and a lakeshore town in Laguna de Bay. It was in the heart of the ancient Kingdom of Bai and Mai (or Be'it and Ma'it) ruled by the Gat Maitan nobilities of 1277 AD (Wikipedia 2012r); and thus a source of many remarkable items of historic and archeological values. A total of 2,866 ha of this soil series were mapped in the province of Rizal. It should be noted that the semi-detailed soil survey of Rizal has additional 3,940 ha of Burgos series that is similar to Jalajala but well drained, originally named after barangay Burgos in the municipality of Montalban, Rizal province. Burgos series is already an established highland soil series name classified as an Ultisol, first described in the municipality of Burgos, La Union. This must have been overlooked in the preparation of the Rizal soil survey final report. Rather than rename Burgos series, the Soil Correlator at Soil Survey Division decided to merge this lowland Burgos series with Jalajala since they have similar substratum characteristics. The revised extent of Jalajala series is thus, 6,806 ha.

2.4.3.5 Soils Underlain by Massive Clay

Bascaran series are poorly drained soils of recent alluvial deposits in collo-alluvial terraces, the drainage depending upon the distance from the coastlines. In some places, the water table is shallow being only 10 cm, or even less below the surface. In some other cases, the area has a half-bogged condition. The solum is generally deep. The top soil that reaches as far down to 40 cm is brownish gray, grayish brown to light reddish brown clay, with gravels. The subsoil is grayish brown to dark brown coarse columnar heavy silty clay to clay with brick-red streaks and gray specks. Weathered yellowish orange gravels are sparsely embedded in the layer that reaches down to 65 cm. The substratum is yellowish brown, grayish brown to brownish gray, massive clay (Aristorenas et al. 1965). This soil is principally used for the cultivation of lowland rice. These soils were first described in what is now urbanizing barangay Bascaran, municipality of Daraga, Albay province and classified as *Aeric Epiaquepts*. Aside from the province of Albay, Bascaran sandy loam and clay were mapped also in Sorsogon province totaling some 9,550 ha.

2.4.3.6 Soils Underlain by Deep and Massive Clay; Heavy Cracking Soil (Vertisol)

Padapada series is classified as clayey, montmorillonitic isohyperthermic *Udorthentic Pellusterts* and poorly drained. These soils have dark gray to gray, sticky and plastic hard clay Ag horizon 20–50 cm thick, with brownish mottles. The cambic Bg horizon is grayish brown, clay, very sticky and plastic with slickensides close enough to intersect, extending down to 100 cm and have little or no evidence of clay illuviation. The Cg horizon is very deep, gray with massive structure. Cracks from annually more than 1 cm wide, extend 50–100 cm deep, and remain open 90–150 cumulative days during the year except when irrigated (Bureau of Soils 1973b). The Padapada soils are formed from weakly stratified continental clayey alluvium in very broad slightly dissected low alluvial terrace landscapes slightly above the main river flooding. Any flooding that occurs is due more to low base levels and lack of dissection or blocked drainage outlets rather than to large river overflow. The source from which the parent materials were derived are the Sierra Madre mountains which include such formations as greywacke, metamorphic, limestone, conglomerates, tuff, volcanic, etc. This soil series was established in 1972 as one of the outputs of the Guimba Soil Survey and Land Classification Project. The similar soil series are Bantog, Bigaa, Malimba, Tagulod, and Candaba. Bantog soils have fine clayey texture, the Bigaa soils have fine clayey textures and thicker Ag horizons ranging from 50 to 100 cm. The Malimba soils have fine clayey texture, thicker Ag horizon, and brown Bb horizon below 100–150 cm depth. The Tagulod soils have mottled brown colors, imperfectly drained, and occupy somewhat higher position. The Candaba soils have grayer colors, black or very dark gray Ag horizon 50–100 cm thick, and occur in very poorly drained landscape position. In the drainage catena, the position is Quingua-Tagulod-Padapada. These soils are extensive in the alluvial terraces in the Central

Plain of Luzon in the vicinities of Guimba, Cabanatuan, and Peñaranda. This soil series covers 36,250 ha in the provinces of Tarlac. It was first established in barangay Marikit, municipality of Guimba, province of Nueva Ecija. But Padapada is a barangay of Gerona municipality, in the neighboring province of Tarlac where this soil series must have been first described.

2.4.3.7 Soils Underlain by Massive Clay to Silty Clay; with Lithologic Discontinuity; with Vertic Properties

Isabela series (Plate 1C for soil profile and Fig. A.5 for soilscape view) was first mapped in Isabela municipality, province of Negros Occidental. These soils are formed from older alluvial deposits laid on fans or fan terraces and classified as fine, montmorillonitic, isohyperthermic *Vertic Hapludolls*. The solum is almost a meter depth. The surface soil is dark gray to almost black, coarse granular heavy clay to sandy loam extending down to as deep as 35 cm. The subsoil is coarse granular heavy clay, dark gray to very dark gray when wet and gray when dry turning to yellowish gray light brown to yellowish brown as it extends down to as deep as 60 cm. The substratum extending to more than 100 cm is yellowish brown, structureless clay to silty clay. Lithologic discontinuity is observed in some profiles (Alicante et al. 1951). The soil is poorly drained. Isabela differs from other soil series of alluvial formation. It is different from Bantog Series in the color of the surface soil; Bantog could be dark brown with dark brown to light brown subsoils. The Isabela series are distinctly black. It is similar to Matina series but they differ in the color of the subsoil; the Matina subsoils are gray to dark grayish brown. Isabela series is also similar to Medillin clay of Cebu but the substratum of Medillin has weathered limestone gravels. A total of 69,816 ha of various textural types of Isabela Series have been mapped in Negros Occidental, Agusan, Lanao provinces, Cagayan, Kalinga-Apayao, Zamboanga del Norte, and Zamboanga del Sur.

2.4.3.8 Soils Underlain by Compact Clay

Brooke's series (Plate 1B) occupies narrow coastal plain. The land is level to very slightly undulating. The nature of the fine textured soils in the profile makes internal drainage very poor. There are no rocks either as outcrops or in the lower layers of the profile. The top soil has light brown, dark gray to almost black coarse clay to clay loam that goes down to as deep as 20 cm from the surface. The subsoil is light brown to yellowish brown coarse granular to massive clay and could extend down to 70 cm. The substratum is light brown clay; compact and hard when dry, sticky and plastic when wet (Barrera et al. 1960). Upland rice is usually planted. This soil series was first described in Brooke's Point, Palawan and classified as *Typic Kanhapludalfs*. A total of 52,967 ha of Brooke's clay, clay loam, and loam were mapped in the provinces of Palawan and Nueva Vizcaya.

2.4.3.9 Soils Underlain by Sandy Clay, with Gravels

The *Patnongon* series is found on older alluvial fans or alluvial plains and has a moderately developed soil profile. This soil series is associated with Sta. Rita series but they differ in color and texture of their subsoil and substratum. Patnongon series gravels and stones are found in the subsoil and substratum but none are found in the Sta. Rita series. The relief is moderately rolling. The external drainage is fair but the internal drainage is poor. The surface soil reaches down to 20 cm from the surface, light brown clay loam; with dark brown mottles; granular structure; compact and hard when dry, sticky when wet. The upper subsoil extends down to 45 cm, light brown to brown clay; moderately coarse granular structure; gravels and stones are present occasionally. The lower subsoil extends down to 70 cm, brown sandy clay; with reddish mottles; coarse granular structure. The substratum reaches down to the control section at 150 cm, is light brown to light grayish brown sandy clay with some gravels; light brown to light grayish brown; coarse granular structure (Calimbas et al. 1963). The main crop grown to these soils is lowland rice. Corn, banana, coconut, vegetables, and some fruit trees are secondary crops. These soils are classified as clayey skeletal *Aquic Eutrudepts*. It was first described in Patnongon, Antique. This is an old town formally founded in 1762 when the first gobernadorcillo, Don Pedro Tucoy, was appointed. But this town was settled long before the arrival of the Spaniards by Maghats, a little bit more cultured than the Aetas, the aborigines of the Philippines. Patnongon sandy clay loam covers about 4,807 ha in Antique province.

2.4.3.10 Soils Underlain by Clay Loam to Clay, with Dark Brown Mottles

Catanauan series is fairly drained and classified as fine, loamy, mixed, isohyperthermic *Fluventic Eutrudepts* that occurs on level to nearly level fan terraces and derived from collo-alluvium materials. Drainage conditions are poor. The relief is nearly level. The topsoil is gleyed, greenish gray clay loam with sharp brownish yellow mottles and could extend down to 20 cm. The subsoil is very deep, reaching to the control section (150 cm), yellowish brown clay loam in the upper subsoil turning to brown silty clay in the lower horizon. The substratum is yellowish brown clay loam to clay, with plenty of dark brown streaks; sticky and plastic (Renales et al. 1975). The soil is used mostly for paddy rice. This soil series was first described in Catanauan municipality, of what was then sub-province of Quezon but now province of Aurora. This town was first recorded in the map of Father Pedro Murillo in 1734. Even as early as 1685, there was this petition of Bishop Andres Gonzales of Nueva Caceres, Naga City requesting the King of Spain to assign the Pueblo of Catanauan to the Recollect Order showing even earlier establishment. The name Catanauan literally means "to see each other" and refers to the two small stone forts or artillery watch towers constructed against frequent Moro raids that enabled the fort guards to see each other (Wikipedia 2012s). About 6,451 ha of Catanauan series was mapped in Quezon province.

2.4.3.11 Soils Underlain by Sandy Loam, Clay Loam to Clay, Unconsolidated Materials Below

Cabangan series is secondary soil developed from older alluvial materials deposited on fans or terraces and classified as *Aquic Eutrudepts*. The solum is of average depth, the grades from silty clay to sandy clay. Unconsolidated materials of shale, sandstone, and some limestone are found underneath this series. External drainage is fair to good while internal drainage is poor. The relief is level to gently sloping. The topsoil extends down to 25 cm, pale brown, brown to grayish brown, loose to slightly compact clay loam to sandy loam with numerous reddish to yellowish red streaks. The upper subsoil is pale brown to light brown, slightly compact heavy but friable clay loam, extending down to a depth of 55 cm. The lower subsoil is brown to grayish brown, clay loam, reaching down to 70 cm. The substratum is brown to dark brown sandy loam, sandy clay loam to clay (Alicante et al. 1951). The crops grown are lowland rice, corn, sweet potato and other root crops, vegetables, and coconut. A total of 129,965 ha of Cabangan sandy loam, clay loam, and clay were mapped in Agusan, Zambales and Davao provinces (Fernandez and Jesus 1980). This soil was first described in Cabangan municipality, province of Zambales.

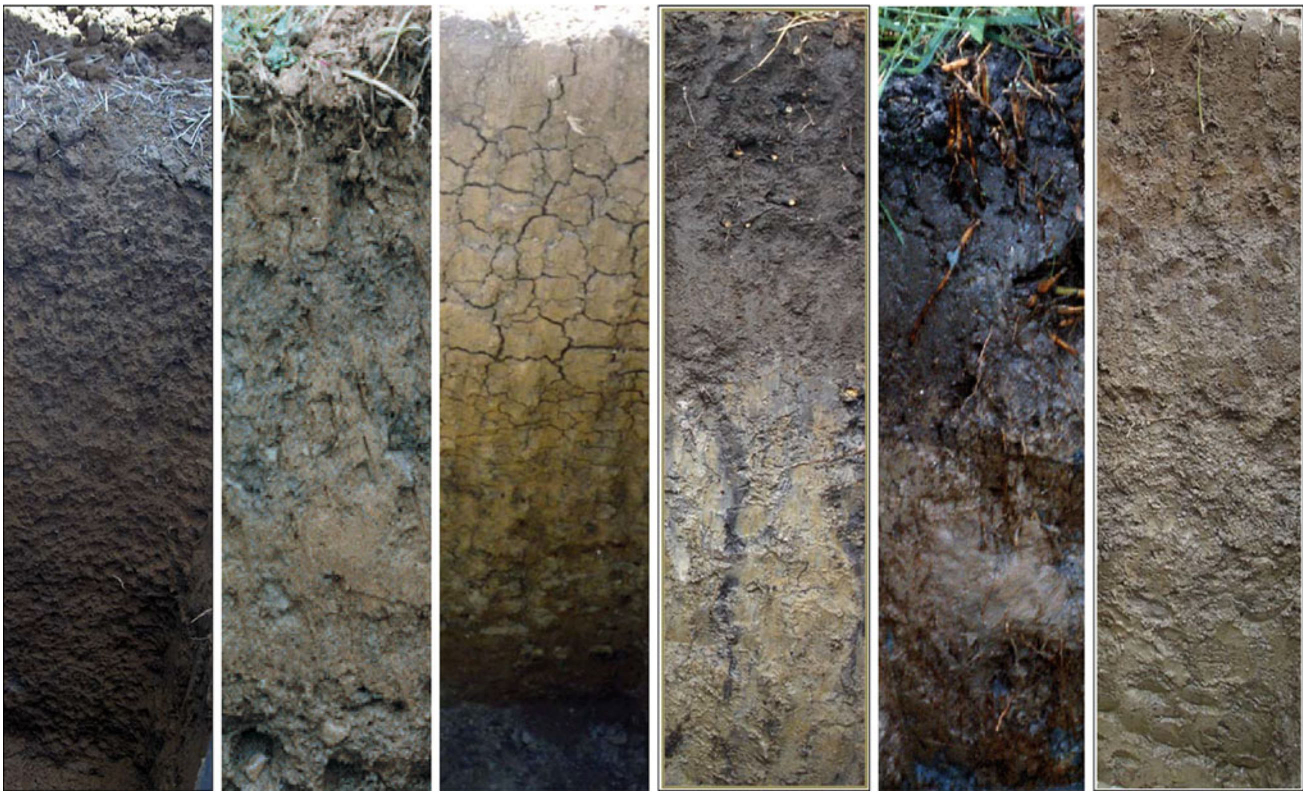
2.4.3.12 Soils Underlain by Waterworn Gravels Mixed with Little Clay

Matuya-tuya series was first described in Barangay Matuya-tuya, municipality of Torrijos, island province of Marinduque. Torrijos is very significant in Philippine history. It was here in Torrijos where the Battle of Pulang Lupa took place during the Philippine-American War on September 13, 1900 in which the Filipino forces under Colonel Maximo Abad routed the American forces under Devereux Shields giving the Americans one of its worst defeats during the war (Wikipedia 2012t). "Pulang Lupa" meant red soil, but Matuya-tuya series is not red but grayish black to grayish brown due to poor internal and external drainage. This is a secondary soil formed from the deposition of washed-down sediments by gravitational and running water. The relief is level to very slightly undulating with poor drainage conditions. Lowland rice is the principal crop grown. This soil series is classified as *Aquic Eutrudepts* and only one soil type, Matuya-tuya clay loam was mapped covering 373 ha in Marinduque. The surface soil extends down to 30 cm from the surface, grayish black to grayish brown, fine, granular, compact clay loam; sticky, plastic when wet, slightly hard when dry; poor internal drainage; no mottling, no concretions. The upper subsoil reaches down to 80 cm, and grayish brown compact clay which is sticky and plastic when wet; internal drainage is poor; mottled with reddish specks. The lower subsoil extends down to 130 cm, reddish brown, hard, compact clay with concretions which when crushed produce a brown powdery mass; poor internal drainage; mottled by orange color. The substratum is yellowish brown, waterworn gravels mixed with little clay (Salazar et al. 1962). Rice is generally grown in these soils.

2.4.4 Soils of the Collo-Alluvial Plains and Fan Terraces: The Well-Drained Soils

2.4.4.1 Soils Underlain by Structureless Loamy Materials

Legaspi series is formed from recent alluvial deposits brought down through the water action from the surrounding uplands, especially from the slopes of Mayon Volcano. These soils are classified as *Aeric Epiaquepts*. The areas occupied by Legaspi series are narrow and irregular, mostly coastal and embracing half of the northeastern, eastern, and southern slopes of Mayon Volcano. The surface soil is very dark brown, grayish brown, to very dark gray fine sandy loam to sandy clay loam, and extends down from 15 to as far as 50 cm. The subsoil is brownish red, brown, to yellowish brown silty clay with mottling and could extend up to 95 cm. The substratum is grayish brown, light gray to dusky red structureless, loose and friable sandy loam to medium sand. The drainage is from fair to good (Aristorenas et al. 1965). About 12,480 ha of this series have been mapped in the province of Albay. Legaspi series was first described in Legazpi City, the capital of the province of Albay; and noted for the world-famous beauty of Mayon Volcano. The city was founded by ancient settlers of Barangay Sawangan under the rulership of Gat Ibal. Sawangan was a corruption of Sabal, signifying natural wharf formed by the sea. This city was built on what were originally mangrove swamps. The settlers were eventually converted to Christianity by the Franciscan friars as early as 1587.

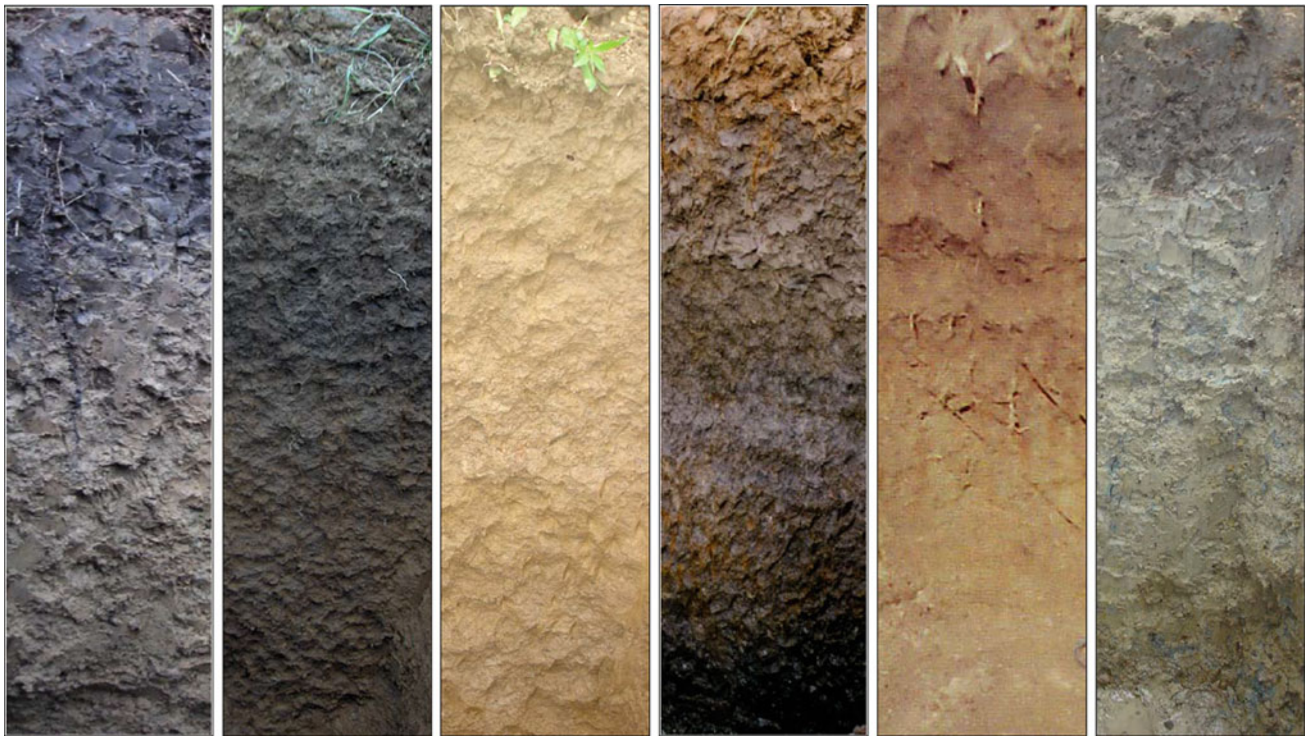


AGUSTIN *(Fluventic Eutrudepts)* **ANAO-AON** *(Fluventic Eutrudepts)* **AWAYAN** *(Entic Chromusterts)* **BAGO** *(Vertic Argiudolls)* **BALONGAY** *(Typic Fluvaquents)* **BANTOG** *(Udorthentic Pellusterts)*

Plate 1A Soil profiles of Agustin, Anao-aon, Awayan, Bago, Balongay, and Bantog series (*Photo credits* BSWM and UPLB)

BIGAA *(Aeric Endoaquerts)* **BROOKE'S** *(Typic Kanhapludalfs)* **BUAYAN** *(Vertic Epiaqualfs)* **BUGKO** *(Typic Ustipsamments)* **BUGUEY** *(Typic Udipsamments)* **BUTUAN** *(Typic Epiauepts)*

Plate 1B Soil profiles of Bigaa, Brooke's, Buayan, Bugko, Buguey, and Butuan series (*Photo credits* BSWM and UPLB)

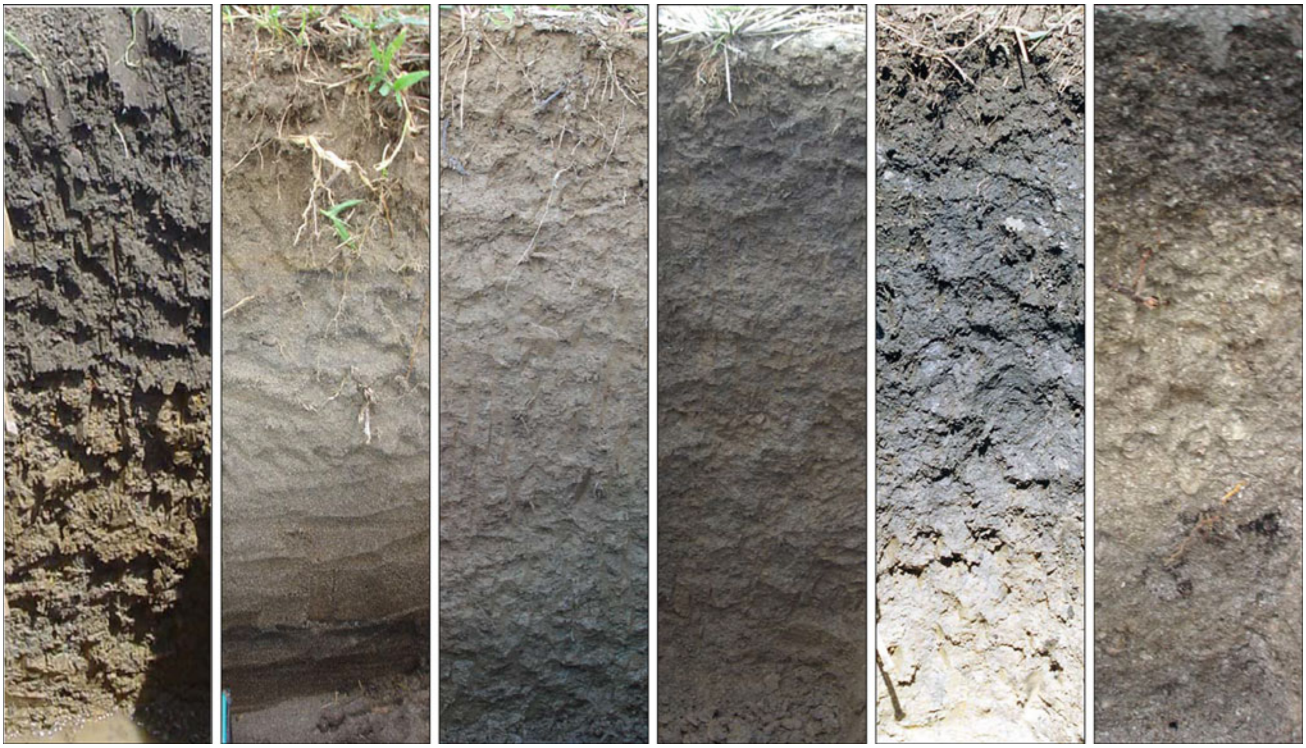


CALUMPANG *(Aeric Endoaquepts)* | **CANDABA (1)** *(Udic Pellusterts)* | **CANDABA (2)** *(Udic Pellusterts)* | **CORALAN** *(Vertic Endoaquepts)* | **DONSOL** *(Aquic Eutrudepts)* | **ISABELA** *(Vertic Hapludolls)*

Plate 1C Soil profiles of Calumpang, Candaba (moist), Candaba (dry), Coralan, Donsol, and Isabela series (*Photo credits* BSWM and UPLB)

KABACAN *(Typic Hapludepts)* | **LIBON** *(Typic Eutrudepts)* | **MAAPAG** *(Typic Endoaquepts)* | **MALANDAG** *(Typic Eutrudepts)* | **MALIGAYA** *(Ustic Epiaquerts)* | **MARIKINA** *(Udorthentic Chromusterts)*

Plate 1D Soil profiles of Kabacan, Libon, Maapag, Malandag, Maligaya, and Marikina series (*Photo credits* BSWM and UPLB)



MATINA *(Aeric Epiauepts)* | **OBANDO** *(Fluventic Eutrudepts)* | **PANGASINAN** *(Typic Ustifluvents)* | **PEÑARANDA** *(Fluventic Eutrudepts)* | **PILI** *(Typic Epiaquerts)* | **PULUPANDAN** *(Typic Ustipsamments)*

Plate 1E Soil profiles of Matina, Obando, Pangasinan, Peñaranda, Pili, Pulupandan series (*Photo credits* BSWM and UPLB)

QUINGUA (1) *(Typic Tropudalfs)* | **QUINGUA (2)** *(Typic Tropudalfs)* | **RAMOS** *(Aquic Eutrudepts)* | **SAN FERNANDO** *(Vertic Endoaquepts)* | **SAN MANUEL (1)** *(Typic Eutrudepts)* | **SAN MANUEL (2)** *(Typic Eutrudepts)*

Plate 1F Soil profiles of Quingua, Ramos, San Fernando, San Manuel series (*Photo credits* BSWM and UPLB)

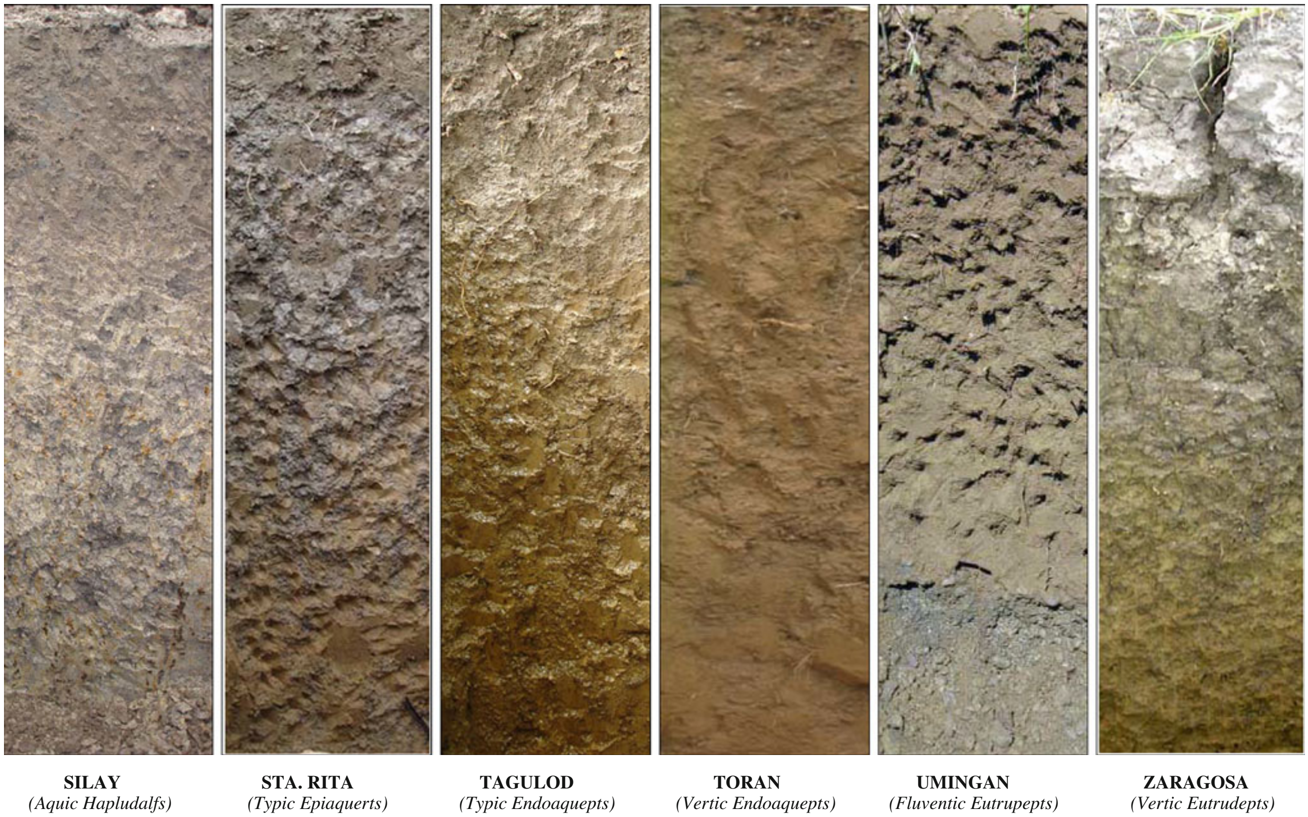


Plate 1G Soil profiles of Silay, Sta. Rita, Tagulod, Toran, Umingan, and Zaragosa series (*Photo credits* BSWM and UPLB)

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3 The Soils of the Uplands

Abstract
The upland soils have elevation of more than 100 m but less than 500 m above sea level. The topography is nearly level and undulating with slopes ranging from 8 to 18 %. The temperature regime is 22.5–25 °C. The soils of this pedoecological zone were developed from different physiographic and different soil parent materials and generally used for the growing of upland crops, tree crops, and agroforest trees with portion devoted to the cultivation of paddy rice, especially on areas with recent alluvium deposited from upland or hilly land through runoff siltation. The alluvial soils developed from sediments deposited at deltas by a river system necessarily begin from the sediment supply zone at the surrounding hills and mountains. In Chap. 2, we discussed about soils that developed at deposition sites. It is inevitable that the same lowland soil series would occur at midstream and possibly upstream valleys. The upland soils developed from alluvial deposits would follow the concept of sediment continuity. Some of the soil series found in the lowland soils would also be observed on the midstream and upstream valleys, but maybe the drainage characteristics, being located at higher elevation, would have improved. But we also expect additional alluvial soil series at the sediment transfer zone not necessarily found at the lowlands (the sediment deposition zone). In addition to alluvial soils, the upland soils developed in situ are further grouped according to their parent materials—igneous, sedimentary, and metamorphic rocks. Tuff materials can also be classified as igneous rock, consisting of consolidated volcanic ash ejected during volcanic eruptions. We have separated the tuff-derived soils from the rest of the soils of igneous parent materials since the archipelago belongs to the Ring of Fire and these soils generate special interest from local researchers; plus the fact that a great portion of Metropolitan Manila is underlain by tuff and these soils are becoming extinct because of urban development. As in lowland soils, we have included unpublished but recognized soil series, more recently established. We also follow the usual delineation between the poorly drained soils which are characterized by presence of redoximorphic features and the well-drained soils.

3.1 Alluvial Soils at Midstream and Upstream River Valleys

Where does the lowland soil ends and the upland soil begins?

By definition, lowland soils are developed from alluvial, collo-alluvial, marine, and lacustrine deposits with slopes ranging from 0 to 8 %, temperature of more than 25 °C and altitude of less than 100 m above sea level. They are the most important soils and widely used for agriculture specifically rice, the staple food of most Filipinos. These are located in various landforms of coastal and alluvial landscapes.

The soils of the warm–cool upland have elevation of more than 100 m but less than 500 m above sea level. Generally, the topography is nearly leveled and undulating with slope ranging from 8 to 18 % and have soil temperature

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regime of 22.5–25 °C. The soils of this pedoecological zone were developed from different physiographic and different soil parent materials and generally used to upland crops, tree crops and agroforest trees with portion devoted to the cultivation of paddy rice, especially on areas with recent alluvium deposited from upland or hilly through runoff siltation.

The alluvial soils developed from sediments deposited at deltas by a river system necessarily begin from the sediment supply zone at the surrounding hills and mountains. In Chap. 2, we have discussed about various soils that developed at deposition sites. Obviously, as we study fluvial sediment transport and morphology, it is inevitable that the same lowland soil series would occur at midstream and possibly upstream valleys. Rainwater flows down the slopes and come together to form stream flow, and in the process and with time develop various landforms along the way. The major river processes are erosion, transportation, and sedimentation. When flood flows from the mountain to the plains, sediments are deposited along the way according to size.

The upland soils developed from alluvial deposits would follow the concept of sediment continuity. Hence, the soil series found in the lowland soils would also be observed on the midstream and upstream valleys. But in addition, at the sediment transfer zone, the river redistributes sediments that derived from upstream as well as bank and bed erosion. These sediments vary from cobble and gravel-sized material in the upper reaches to silt, clay, and alluvium in the lower reaches. Hence, we could expect additional alluvial soil series at sediment transfer zone not necessarily found at the sediment deposition zone.

3.1.1 The Poorly Drained Soils, Characterized by Presence of Redoximorphic Features

Three soil series are underlain by massive clay but they can be easily distinguished from each other. *Bascaran* series has gravelly topsoil. *Manapla* series has iron concretions and riverwash stones on the surface and the massive substratum clay are whitish. *Barcelona* series is characterized by absence of neither stones nor concretions on the surface soil. We also have additionally four upland soil series of alluvial origin which are poorly drained, three of which have massive clay loam for substratum. *Aborlan* series has massive clay loam for a substratum but this is an Oxisol and characterized by high soil acidity. Both *Cadiz* and *Candijay* are underlain by massive clay loam with gravels: But Cadiz gravels are reddish or lava flow called "igang" in the local dialect while those of Candijay are slate gravels. *Victorias* is underlain by massive fine sandy loam, sandy loam, to sandy clay and would appear similar to Cadiz but there are no concretions on the substratum of Victorias series.

3.1.1.1 Soils Underlain by Massive Clay

Bascaran series are classified as fine mixed isohyperthernic *Aquic Eutrudepts* developed from recent alluvial deposits and also found on level to gently sloping areas including collo-alluvial terraces. This soil was first mapped in Bascaran, now considered as an urban barangay of the municipality of Daraga, province of Albay. The surface soil is brownish gray, grayish brown to light reddish brown clay with light gray, reddish brown, and gray splotches. Gravels are present. Depth is 35–40 cm. The upper subsoil is grayish brown to dark brown coarse columnar heavy silty clay to clay with brick-red streaks and gray specks. Weathered yellowish orange gravels are sparsely embedded in the layer. Depth is 60–65 cm. The lower subsoil is brownish gray to light gray, very coarse columnar cheesy clay with red splotches. Yellowish orange gravels are numerous. The depth is 110–115 cm. The substratum is yellowish brown, grayish brown to brownish gray massive clay, plastic and sticky when wet; brittle and hard when dry. The internal drainage is poor (Aristorenas et al. 1965). The uncultivated areas are under grass cover. The cultivated areas are grown to lowland rice, corn, coconuts, bananas, vegetables, and fruit trees. The area coverage is about 9,550 ha of Bascaran sandy loam, sandy clay, and clay mapped in Albay and Sorsogon provinces.

Barcelona series (Plate 2B) is quite a unique Philippine soil series name since the original Barcelona is located in Spain. But Barcelona series was first mapped and described at Barcelona, in the tobacco municipality of Tubao, La Union. The soils of Barcelona series consist of brown, dark brown to dark grayish brown, granular, sticky to plastic surface soils underlain by yellowish brown to grayish brown granular clay loam subsoil. The substratum is dark gray to almost black clay. The general topography is undulating to gently rolling. In small areas, however, where rice and corn are planted, the land is almost level. Surface drainage is good but the internal drainage is poor to fair. The soil materials came from the hills and mountains containing shales and sandstones. The 15–30 cm surface layer of Barcelona series is brown, dark brown to dark grayish brown, slightly compact, granular clay which is friable when wet and hard when dry. It cracks into big clods during the dry season. The subsoil is grayish brown, granular clay loam. At a depth of 65–85 cm from the surface, this grades into a material of lighter color which continues down to 100 cm where the soil becomes dark gray to almost black clay. Concretions are abundant in the lower subsoil. The substratum that reaches down to the control section at 150 cm is dark gray to almost black shale-like material, massive, soft, cheesy clay; can be broken with the hands into angular lumps with glistening fracture planes. On drying, becomes dark gray, hard and brittle. No concretions in this horizon (Alicante et al. 1950). This soil series is classified as *Aeric Epiaquepts*, and only one soil type, Barcelona clay, was mapped in the provinces of La Union, Cagayan, and Kalinga-Apayao covering 6,815 ha.

3.1.1.2 Soil is Underlain by White Clay

Manapla series (Plate 2D and Fig. 5.10) are *Typic Hapludults* derived from old alluvial deposits on sloping to rolling residual terraces. This soil series was first described in the municipality of Manapla, province of Negros Occidental. The surface soil is dark brown to grayish brown loam, clay loam to silt loam, reaching down from 15 to 25 cm. The surface soil is further characterized by the presence of iron concretions and riverwash stones. These stones are not as numerous and as big as those of the Guimbalaon nor of the La Castellana soil series where Manapla soils are closely associated. The upper subsoil is dark brown to grayish brown clay loam, with gravels present, and reaches down from 30 to 50 cm. The lower subsoil is yellowish brown massive clay, with red mottles, with presence of highly weathered gravels, and the depth is from 55 to 60 cm. The substratum is white clay with ripples of dark red. The drainage is poor (Alicante et al. 1951a). The cultivated areas are basically grown to sugarcane, rice, corn, coconuts. This series covers about 6,589 ha of Manapla loam in the province of Negros Occidental, and another 883 ha in the same province are complexed with Bago series.

3.1.1.3 Soils Underlain by Massive Clay Loam

Aborlan series, classified as *Aquic Eutrudox* and developed from recent alluvial deposits. These are poorly drained soils found also on nearly level to undulating collu-alluvial terraces. The surface soil is shallow, 20–25 cm deep, is pale brown to light gray loam. An important characteristic of the surface soil is its high acidity. The subsoil, 25–55 cm in depth, is light yellowish brown loam, hard and compact in both wet or dry condition. There are no coarse skeletons observed and these soils are non-calcareous. The substratum is strong brown to moderate reddish brown clay loam, hard and massive, no coarse skeleton and non-calcareous (Barrera et al. 1960). A total of 8,800 ha of Aborlan loam were mapped in Palawan province. This soil series was first delineated in the municipality of Aborlan, Palawan. Aborlan series may appear very similar to Silay series but the compact substratum of Silay is white to gray while that of Aborlan is dark brown.

3.1.1.4 Soils Underlain by Massive (Structureless) Gravelly Clay Loam

Cadiz series (Plate 2B) was first mapped in Cadiz, Negros Occidental. Cadiz soil is similar to Victorias soil, occupying also the same geographical position and developed from older deposits. Cadiz series has an undulating to almost flat topography. External and internal drainage condition is reported to be fair but mottling of reddish brown to dark red are also reported and the hard subsoil does impede internal This thick layer of almost compacted, reddish gravel or lava flow, called locally "igang" beneath the surface or subsoil layer, differentiates this series from Victorias. The Cadiz soil is more elevated than the Silay series. Its elevation ranges from just a few to 55 m above mean sea level. The surface soil, reaching down to a depth of 15 cm, is brown to light brown when wet, grayish brown when dry; gravelly loam; good coarse granular structure; gravels and concretions are present. The upper subsoil extending down to 25 m from the surface, is brown to yellowish brown when wet, brown to light brown when dry; clay loam; poor coarse granular; concretions are present. The lower subsoil reaching down to 80 cm is dark yellowish brown when wet, yellowish brown when dry; poor coarse granular; gravels (*igang*) are present. The substratum is dark yellowish brown when wet, yellowish brown when dry; clay; structureless; gravels are present. Further boring becomes difficult because of gravels (Alicante 1951a). This soil series is classified as *Typic Eutrudepts* and Cadiz loam gravelly phase covers an area of 2,138 ha in Negros Occidental (Fig. 3.1).

Fig. 3.1 Landscape view where Cadiz series occurs in Negros Occidental

3.1.1.5 Soils Underlain by Gravelly Clay Loam

Candijay series is classified as *Typic Eudrudepts*. The soil series was first observed in Candijay, Bohol occupying the bottom lands between hills and along streams on the Candijay-Ubay Road. It is typical dark heavy soil mainly used for rice production. Drainage is from fair to poor. The soils of this series are characterized by dark brown to almost black fine clay with small amount of gravels present in the surface soil. This A horizon is from 35 to 55 cm deep. The subsoil, ranging in depth from 55 to 85 cm from the surface, is dark brown silty clay underlain by slate gray gravelly clay loam substratum which extends down to 100 cm (Bureau of Soil Conservation 1952). A total of 1,307 ha of Candijay series were mapped in the island province of Bohol.

3.1.1.6 Soils Underlain by Massive (Compacted) Fine Sandy Loam

Victorias series (Plate 2F) was first described in Negros Occidental and classified as *Typic Hapludults*. This series is characterized by a gently rolling topography. In areas where creeks are far apart from each other the land is almost flat, but where the land is crossed by many creeks, a rolling topography results. Drainage is mostly external and quite excessive. For this reason, this soil type is seriously eroded. Internal drainage is impeded due to the presence of a layer of clay soil below surface. The soil of this series had been developed from older alluvial deposits. The parent material consists of almost compacted fine sandy loam. The area is slightly elevated over the alluvial plains such as those of the Silay and the swampy areas of Hydrosols. Its elevation ranges from 24 to 43 m above sea level. There are no stones or boulders on the surface but concretions are quite numerous. Concretions are rounded or oval and dark brown. Some are hard but some can be crushed with the fingers, revealing a black powdery mass. A typical profile has the following characteristics: the surface soil with depth extending down to 15 cm from the surface is grayish brown to brown when wet and grayish brown when dry; clay loam; good medium granular; slightly friable to sticky when wet and friable when dry; with concretions. The subsoil is from 30 to 40 cm deep and consists of grayish brown clay to clay loam; poor coarse granular structure that tends to become compact or massive on drying; concretions like those on the surface soils are present. The substratum is light gray with ripples of reddish brown when wet or dry; structureless and massive; compact and hard either wet or dry. The rippled color may indicate the nature of its deposition during the early part of the formation (Alicante 1951a). The greater part of this series is under cultivation to crops. This soil is non-calcareaous and highly acidic. Victorias clay loam covers around 1,590 ha in Negros Occidental (Fig. 3.2).

Fig. 3.2 Landscape view where Victorias series occurs in Negros Occidental

3.1.1.7 Soils Underlain by Gravelly Sandy Clay

Langa soil series, classified as fine silty, mixed, nonacid, isothermic *Typic Fluvaquent* was first described in Ifugao province but there is no clear identification of the exact place. Subsequent soil survey placed the typical pedon at Bucos, Banaue, Ifugao (Raymundo et al. 1989). This soil series occurs about at elevation of 1,000 m above mean sea level, and the surrounding physiography is dome or volcanic cone in mountains or in deeply dissected plateaus. The Apg1 horizon that reaches down to 17 cm is dark olive gray (5Y 3/2) moist, silty clay; massive; soft, sticky, plastic; slightly acid; clear smooth boundary. The Apg2 horizon reaches down to 29 cm, and is dark gray (5Y 4/1) moist, clay loam; moderate coarse angular blocky structure; loose, sticky, plastic; many fine roots; many fine tubular pores; medium acid; clear smooth boundary. The BAg horizon reaches down to 29 cm, olive gray (5Y 4/2) moist, clay loam; weak medium subangular blocky parting to weak fine to medium granular structure; sticky, plastic; medium acid; clear smooth boundary; presence of many small soft irregular and platy probably silt stone rock fragments were observed. The Bg1 horizon extends down to 74 cm, olive gray (5Y 4/2) moist, clay loam; weak, medium subangular blocky parting to weak medium granular structure; sticky, plastic; few fine roots; many very fine to fine tubular pores; strongly acid; diffuse smooth boundary; presence of common small soft irregular and platy stone observed. The Bg2 horizon reaches down to 112 cm, very dark grayish brown (2.5Y 3/2) moist, fine sandy clay loam; massive parting to weak medium subangular blocky; sticky, plastic; medium acid; abrupt smooth boundary; presence of few small irregular and platy probably clay stones were observed. The CR layer reached down to 130 cm; dark greenish gray (5BG 4/1), moist, gravelly sand clay; massive parting to weak medium subangular blocky; sticky, plastic; strongly acid; abrupt smooth boundary; presence of few small irregular and platy probably clay stones were observed. Langa clay loam was mapped in Ifugao province covering 26,287 ha.

3.1.2 The Well-Drained Soils and Characterized by Absence of Redoximorphic Features

3.1.2.1 Soils Underlain by Clay Materials with Highly Weathered Basaltic and Andesitic Fragments

Sala series is classified as fine, clayey, mixed, isohyperthermic *Oxic Dystrudepts*. These soils are deep to very deep, well drained, and occur on level to nearly level narrow mini-plain landscape. They are formed from colluvium-alluvium materials. The surface soil is brown to dark brown,

Fig. 3.3 Profile of Sala series

Fig. 3.4 Soil profile of Sariaya series in Quezon Province

yellowish red and dark reddish brown clay with depth reaching from 15 to 30 cm. The cambic B horizon is predominantly brown to dark brown, strong brown clay with yellowish brown, brownish yellow, yellowish red, reddish yellow mottles. There are few to common weathered basalts and andesites in the subsurface horizon that reaches down from 100 to 150 cm. The substratum extends down to 180 cm, and is strong brown, brown to dark brown clay with brownish yellow and reddish yellow mottles. There are also highly weathered basaltic and andesitic fragments (Soil Survey Division 1987a). This soil is associated with Luisiana series but Sala occupies slightly lower footslopes elevation with slopes ranging from 2.0 to 5.0 % with materials that are colluvial-alluvial in nature. Luisiana soils occupy areas with moderate relief with slope relief ranging from 5 to 25 %. The excess surface runoff from Luisiana series is received and drained in the mini-plain landscape occupied by Sala series. This soil series is mainly devoted to coconut, tree crops intercropped with pineapple and some diversified crops. About 1,338 ha of Sala series were mapped in the province of Laguna. This soil series was first mapped in barangay Sala, municipality of Cabuyao, Laguna province. This is a highly urbanized barangay (Fig. 3.3).

3.1.2.2 Soils Underlain by Silty Clay Loam

Nabago series is classified as fine, mixed, hyperthermic *Fluvaquentic Eutrudepts* formed on nearly level to gently sloping high parts of alluvial terraces. These are deep and moderately well-drained soils. The soils are very dark gray, very dark grayish brown and dark brown friable to firm clay loam, clay, silty clayloam and silty clay A horizons that are between 25 and 50 cm thick with few faint to distinct brown mottles. The cambic B horizon is brown slightly firm to firm clay loam, clay, silty clay loam and silty clay with distinct brown and gray mottles reaching down to the control section. The C horizon past 150 cm is mottled yellowish brown and pale brown silty clay loam with few spherical manganese concretions. The soil was first described in the province of Bukidnon. Nabago soils are yet to be established as a soil series, and were first described in barangay Nabago, Valencia City, Bukidnon.

3.1.2.3 Soils Underlain by Silt Loam

Sariaya series is classified as loamy, mixed, isohyperthermic *Cumulic Hapludolls* derived from collo-alluvial parent materials which includes accumulated sand, stones, and gravels. The distinctive characteristic of these soils is the presence of boulders on the surface and cobblestones embedded in the profile. The topsoil that extends to 20 cm is black loam. The subsoil is very dark to dark grayish brown loam to silt loam, turning to dark yellowish brown as it extends down the profile that could reach to more than 100 cm. The subsoil is yellowish brown silt loam with mottles (Mojica et al. 1963). The external and internal drainage are good. Sariaya sandy loam is mapped in Quezon province, covering 5,256 ha. This place is known for beaches, resorts, heritage houses, and hiking sites. The famous Mount Banahaw is located on the north (Fig. 3.4).

3.1.2.4 Soils Underlain by Clay Loam

Sta. Filomena series (Plate 2F) was first described in barangay Busilac, municipality of Bayombong, which is the capital of the province of Nueva Vizcaya and classified as *Typic Eutrudepts*. It is interesting to note that there is no place in Busilac that is named Sta. Filomena nor Philomena. Where this soil series got its name is a subject of conjecture. The neighboring province of Isabela has barangay Sta.

Filomena in the municipality of San Mariano but too far away from Bayombong. The basic soil concept of this series is that this soil developed from older alluvial forms or terraces, with the soil materials originating from places of higher elevation and brought down by streams and runoff to their present location. Gravels and smooth rounded pebbles would be found throughout the profile. In Bayombong where this was first described, this soil series was formed from older calcareous deposits but in Sulu where more extensive areas were mapped, the parent materials were alluvium. The relief of this series is undulating, rolling, and sometimes, hilly. The external drainage is good and the internal drainage is fair. The surface soil, about 30–35 cm deep, is grayish black clay loam; coarse granular in structure; slightly sticky when wet; has slow permeability; few rounded gravels are present, and in some places, boulders. The subsoil, reaching down to 75 cm from the surface, is grayish brown to reddish brown clay; compact and slight plastic and sticky, thus internal drainage is poor; the lower part is of heavier clay, reddish brown to yellowish brown. The substratum ranges from grayish to dark brown to light brown clay loam to compact coarse granular clay; gravels and pebbles which were water laid and some weathered rocks are present (Dagdag et al. 1963). The cultivated areas are planted to rice, sugarcane millet, cassava, corn, and sweet potato. Fruit trees are also grown such as coconut, citrus, jackfruit, lanzones, durian, mango, marang, and mangosteen. A total of 1,550 ha of Sta. Filomena clay loam were mapped in Nueva Vizcaya and Sulu provinces.

3.1.2.5 Soils Underlain by Gravelly Clay Loam

Managok series is classified as fine, mixed, isohyperthermic *Aquic Tropudalfs.* These soils are deep with the C horizon extending beyond the control section, and moderately well drained formed on nearly level to moderately steep (0–3 % slopes) positions of fans composed of alluvial and colluvial deposits from old volcanic and sedimentary origins. The volcanic source materials are mainly andesitic in composition and the sedimentary source rocks include shale, siltstone, sandstone, and limestone. The soils have very dark grayish brown and dark brown friable to firm loamy and clayey A horizons no more than 40 cm thick that may have brownish and reddish mottles. The B horizon is composed of brown friable to firm silty clay loam, clay loam, clay and silty clay with distinct high and low chroma mottles (yellowish brown, strong brown, grayish brown, brown). The B horizon includes a weakly developed (incipient) argillic horizon. The C horizon is predominantly brown with distinct high and low chroma mottles (yellowish brown, strong brown, grayish brown, gray) and consists of gravelly clay loam and clay. This soil was first described in barangay Managok, Malaybalay City, in Bukidnon province and was proposed to be established in 1976 during the detailed survey of the Pulangui 3 Project Area in Valencia, Bukidnon.

3.1.2.6 Soils Underlain by Coarse Sandy Loam

Sinolon series was first delineated on the southern end of the Allah Valley, classified as *Typic Hapludands*, and occupying a level to undulating relief. This soil series is actually named after barangay Sinolon, municipality of T'boli, province of South Cotabato. Allah Valley refers to about 261,000 ha of watershed crossed by Allah River and several other rivers and creeks. Allah River is a tributary to Mindanao River, also known as the Rio Grande de Mindanao, traversing at least nine municipalities and one city within South Cotabato. About 102,000 ha are agricultural areas, of which some 30,000 are irrigated. Allah Valley is also the first of the three major areas of the province, the two others are the Koronadal Valley and the Coastal Plain. Only one soil type, Sinolon sandy loam, was delineated, and covers some 21,250 ha. The surface soil, with depth reaching to 15 cm from the surface, is dark gray to nearly black sandy loam; friable and granular; mellow when moist. The subsoil which reaches down to 90 cm in depth is brown to grayish brown, friable, loam to sandy loam with few gravels in some places. The substratum starting at 90 cm and below is light brown to light grayish brown coarse sandy loam; gravels and pumice-like materials are present occasionally; loose and structureless (Mojica et al. 1963). Sinolon sandy loam is situated in the sparsely settled portion of the Allah Valley the land and widely cultivated.

3.1.2.7 Soils Underlain by Sand

Lawigan soil series was first delineated in barangay Lawigan, municipality of Labason, Zamboanga del Norte. It occurs in the undulating to slightly rolling areas of the south western portion of Zamboanga del Norte, covering 2,688 ha. It is formed from older alluvial deposits. The surface soil is dark brown loam sands which is the granular in structures; friable and loose. The subsoil is yellowish brown, almost firm and weakly counted sand. The external drainage is good. Permeability is moderately slow. The principal crops grown are coconut, and fruit trees. There is only one soil type mapped in the province under this series is Lawigan loamy sand; and the typical profile is as follows. The surface soil of this soil type is dark brown (10YR 3/2) when moist and grayish brown (10YR 3/2) when dry, loamy sand; fine granular structure; nonsticky and nonplastic and loose; few fine roots are present; the depth is about 15 cm; the boundary to lower layer is clear and smooth. The subsoil is strong brown (10YR 3/6) when moist and very pale brown (10YR 7/4) when dry, loamy sand; slightly sticky and nonplastic; very few roots are present; the boundary to the lower layer is smooth and clear. The lower limit of this layer is 60 cm from the surface. The substratum is

Fig. 3.5 Soil profile of Lawigan series taken in Zamboanga del Norte

yellowish brown (10YR 5/6) when moist and brownish yellow (10YR 6/4) when dry; firm, weakly cemented sand. This soil type is partly planted to coconut, some fruit trees, and vegetables. The rest of the area is covered by shrubs and grasses. It was noted during the field survey that vegetables do not thrive well on this soil (Fig. 3.5).

3.1.2.8 Soils Underlain by Very Loose Sand and Gravels

Makar series is classified as *Typic Hapludands*, developed from recent alluvial deposits and is usually found on upper footslopes of level to undulating relief. The surface soil is dark brown to almost black friable loam, extending down from 5 to 10 cm. The subsoil is grayish brown, very loose and structureless silt loam, reaching as far down as 60–70 cm. The substratum is grayish brown, very loose sand with gravels (Mojica et al. 1963). The drainage is good. It covers about 10,000 ha of Makar loam in what was then Cotabato province. Makar, where this soil series was first described, is located in General Santos City, a component city of South Cotabato. Makar is known for the Makar Wharf which is an international port of call and considered the best in the country. This series occupies the upper and middle portion of the Makar plain and associated with Dadiangas sandy loam. The native vegetation is "giron," a type of pasture grass, cogon (*Imperata cylindrical,* L.), and talahib (*Saccharum spontaneum,* L.). Lanete trees (*Wrightia pubescens*) are also scattered.

3.1.2.9 Soils Underlain by Volcanic Rocks, Cinders, and Tuff

Pasil series is classified as *Typic Hapludults.* Pasil, where this soil was first described, is a barangay of the municipality of Indanan, province of Sulu. This is a residual soil from volcanic rocks, cinders, and tuff. The relief is undulating to rolling, the drainage condition is good. The surface soil is light brown, medium granular clay, friable when dry and slightly plastic when wet, with depth reaching down from 25 to 40 cm. The subsoil is reddish brown to light brown, medium granular clay loam, embedded with volcanic cinders, and depth ranging from 40 to 70 cm. The substratum is composed of highly weathered volcanic cinders, rocks, and tuffs which easily crumble into cubes and pulverize into fine particles when pressed between the fingers, depth varying from 70 to the control section at 150 cm (Sindayen et al. 1965a). These soils are planted to cassava, corn, sugarcane, fruit trees, coconuts, and abaca. A total of 21,657 ha of Pasil clay and clay-steep phase were mapped in Sulu province. Additional 450 ha of Pasil-Adtuyon Complex were delineated in Sulu.

3.2 Soils that Developed from Volcanic Tuff

There are certain soils in the country that developed on basic volcanic deposits including volcanic ash. Basic lavas are characteristically very fluid and spread easily as compared against acid igneous rocks which are generally very viscous and lack flow. Tuff is a type of rock consisting of consolidated or compacted volcanic ash ejected during volcanic eruption. Soft and porous, tuff is a general term as geologists would be more concerned with differentiating tuff into volcanic ash, breccias, igneous rock, welded tuff, rhyolite tuffs, trachyte tuffs, andesitic tuffs, basaltic tuffs, ultramafic tuffs. These are not our interest because we are more after the weathering of these materials into soil as an important national resource especially for agriculture. There are soils of tuffaceous origin, developed in place, resulting from the weathering of the underlying parent materials. These soils occupy plains, residual terraces, and hills.

3.2.1 Soils Underlain by Diliman Tuff, Poorly Drained Soils, Characterized by Presence of Redoximorphic Features

3.2.1.1 Soils Underlain by Tuffaceous Materials of Varying Degrees of Weathering

The substratum of *Guadalupe* series is Diliman Tuff, a massive suite of soft tuffaceous Quaternary volcanic rocks formed from water laid volcanic sediments, part of the

Guadalupe Formation which is also referred to as the Guadalupe Tuff.

Guadalupe series (Plate 2C) is residual soil of water laid volcanic tuff. These soils are generally found on rolling to gently rolling areas of volcanic footslopes but they are also found on some flat areas of slightly degraded tuffaceous plains of the residual volcanic footslopes. Often times, these Guadalupe soil series on volcanic plains are extinct, buried by urban development and industrialization. The soil was first described in barangay Guadalupe, what is now Makati City, when it was but still a municipality of the province of Rizal. Makati is the financial center of the Philippines and was founded in 1578 by Miguel Lopez de Legazpi, the first Spanish Governor General of the Philippines. Guadalupe is named after Guadalupe town in Spain. What were rice fields and sugar cane fields then are now dotted by skyscrapers. The Guadalupe series in lowland rice areas is normally classified as fine, montmorillonitic, isohyperthermic *Leptic Udic Haplustert.* However, when found in rolling to undulating areas, it is classified as *Lithic Troporthents*. These are shallow to moderately deep poorly drained clayey soils. The surface soil is dark brown to nearly black clay, with depth reaching down from 2 to 3 cm. The subsoil is light brownish black clay, and spherical tuffaceous concretions are present. Depth is from 50 to 80 cm from the surface. The substratum is light grayish brown tuffaceous materials of varying degrees of weathering. Tuffaceous concretions are present. Below this layer is hard and massive tuff (Alicante et al. 1938). A total of 118,925 ha of various textural types of Guadalupe series—sand, silt loam, loam, clay loam, silty clay, and clay adobe phase were mapped in the provinces of Rizal, Cavite, Quezon, Batangas, Surigao, and Laguna (Fernandez et al. 1980). The extent of Guadalupe series has significantly changed in the semi-detailed soil survey of Rizal to 12,780 ha including 4,418 ha of Guadalupe-Urban Land Complex and the remainder are Guadalupe clay; from the original reconnaissance soil survey of Rizal province of 20,660 ha of Guadalupe adobe and eroded phases. In addition, the 4,768 ha of Guadalupe clay adobe phase in the reconnaissance survey of the province of Laguna were reclassified during the semi-detailed soil survey in 1987 (Soil Survey Division 1989). The adjusted extent of Guadalupe soil series in the country is 106,277 ha.

Arpa (2005) mentioned that volcanism in Luzon is produced largely by subduction and in the southwestern portion, extension. During subduction, the overriding crust is modified by emplacement of subduction-related magmas and partially melted by hot basaltic intrusions generated in the mantle wedge beneath southwest Luzon. Based on the Guadalupe Formation (Smith 1913), the Guadalupe geomorphic surface is a tuff sequence along the Pasig River, in Guadalupe, Makati City and hence called as *Guadalupe Tuff* by (Corby et al. 1951). This geological formation consisted of Alat Conglomerate (conglomerates, silty mudstone, tuffaceous sandstone) and Diliman Tuff (vitric tuff, ignimbrite, volcanic breccia). Arpa further stated that the location of the actual vent or volcano source of the upper Diliman Tuff deposit is uncertain; her studies showed that it is chemically distinct with respect to deposits from the adjacent Taal and Laguna calderas. The upper Diliman Tuff is a basaltic to dacitic pyroclastic flows; the pumice fragments are glassy and mainly plagioclase and pyroxene (Arpa 2005). *Guadalupe* soil series developed from this Diliman Tuff which formed part of the Guadalupe Formation; the formation is also referred to as Guadalupe Tuff in other geological literatures.

3.2.2 Soils Underlain by Macolod Corridor Tuff, Poorly Drained Characterized by Presence of Redoximorphic Features

Maahas, *Lipa*, *Carmona*, and *Ibaan*, series are underlain by tuff of the Makiling-Malepunyo Complex (referring to numerous Pliocene-Pleistocene volcanic centers in southwest Luzon), one of the three sub-formations that constitute the Macolod Volcanic Complex also known as the Macolod Corridor by Forsters et al. 1990. The two others are Taal Volcano which for our purpose of discussing soil genesis shall be referred to as the Taal geomorphic surface and the Laguna de Bay, also referred to in other geological literatures as the Laguna Caldera and which for our purpose of studying soil genesis, will be referred to as the Laguna de Bay Caldera geomorphic surface to include the neighboring Taal-Banahaw volcanic and pyroclastic deposits on the western and southern side, and the Caliraya Plateau on the eastern side of the lake. Maahas tuff materials would have originated from Mount Makiling while those of Lipa, Carmona, and Ibaan would have originated from Mount Taal. Despite the same tuff parent materials, Lipa soils could be distinguished from Ibaan. The substratum of Lipa is tuffaceous rock, that of Ibaan is fine-grained tuffaceous materials also but with sand. Both Carmona and Ibaan soils are underlain by yellowish brown tuff, both have the same drainage characteristics but Ibaan's underlying tuff material is mixed with sand while that of Carmona is mixed with clay.

3.2.2.1 Soils Underlain by Clay Grading to Highly Tuffaceous Tuff

Maahas series is fine, clayey, montmorillonitic, moderately deep, isohyperthermic *Andaqueptic Haplaquolls*. These are poorly drained soils primarily derived from volcanic tuff. The surface soil is grayish brown, very dark brown to black clay, 25–40 cm in depth. The subsoil is grayish brown, very dark grayish brown, or very dark brown clay loam to clay, waxy and stiff with tuffaceous and manganese concretions.

There are light brown to light gray mottling. Depth is 30–60 cm from the surface. The substratum is grayish brown, brown to dark brown clay grading to highly tuffaceous tuff with numerous manganese and tuffaceous concretions. Depth is 60–140 cm. Below is tuffaceous rock (Soil Survey Division 1987a). Maahas series is associated with Carmona and Lipa series. Maahas and Carmona are moderately deep, poorly drained soils with grasses or paddy rice vegetation. Lipa series is moderately deep to deep well-drained soils with tree crops, grasses, and sugarcane as vegetation. Maahas is classified as *Andaqueptic Haplaquolls* while Carmona and Lipa series are classified as *Vertic Eutraquepts* and *Typic Eutrudepts*, respectively. About 500 ha of Maahas series were mapped in the province of Laguna. This soil series was named after barangay Maahas, municipality of Los Banos, Laguna. Maahas soil series was first described at the plains on the foot of Mount Makiling, a mountain on the southwest rim of Laguna de Bay. This is a dormant stratovolcano with 16 km diameter that reaches up to 1,115 m, above sea level (Dovetail Ventures Asia Incorporated 2011). Pyroclastic flow, lahar, airfall, and lava deposits comprise the cone. The lava consists of tachyandesites, tachydacites, and rhyolites. Plinian-type eruption is evidenced by welded ash-flow tuffs. Smaller satellitic edifices include La Mesa tuff ring, Bijiang, Mapinggon, and Masaia. Immediately south of Mount Makiling is a deeply eroded north–south trending volcano range that includes Mapinggon, Bulalo, and Malepunyo. This composite volcano consists predominantly of lava flows and breccias at the upper portions and pyroclastic flows and lahars on its eastern flanks. This Makiling-Malepunyo, plus the Taal Volcano, and the Laguna de Bay constitute the Macolod Volcanic Complex referred to as the Macolod Corridor by Forsters et al. (1990). Other smaller monogenetic cones in the Macolod Corridor erupted basaltic lava. Scoria cones and tuff cones are common, formed from strombolian-type eruptions, such as those in neighboring Batangas province like Anilao Hill, Tombol Hill, and Soroso Hill. Maars and tuff rings in the San Pablo area show typical features of base surge and airfall deposits resulting from phreatic or phreatomagmatic eruptions. Mount Atimbia, one of the cones in San Pablo is andesitic (Dovetail Ventures Asia Incorporated 2011).

3.2.2.2 Soils Underlain by Tuffaceous Rock

Lipa series (Plate 2D) is classified as fine clayey, mixed, shallow, isohyperthermic *Typic Eutrudepts* and are residual soils of volcanic tuff. The soil is moderately well drained found on undulating to rolling moderately dissected tuffaceous piedmont plain, and evolved mainly from materials produced by the weathering of hard tuffaceous rocks. The surface soil, 25–30 cm in depth, is dark brown, brown to light brown loose fine loam. In more advanced state of soil development, the color could be very dark yellowish brown, very dark brown, and strong brown and have soil texture that is either clay, clay loam, silty clay, or silty clay loam. The upper subsoil, 60–65 cm, is dark brown fine loam to clay loam with tuffaceous materials and concretions. In older landscapes undisturbed by fresh depositions, the subsurface horizon is mainly clayey and characterized by moderate fine and medium angular blocky structure and sticky and plastic consistency. The lower subsoil, extending down from 115 to 120 cm, is highly weathered tuff with tuffaceous gravels and concretions. The substratum is light brown tuffaceous rock (Alicante et al. 1938). In older landscapes (undistrubted by fresh volcanic deposits), the tuffaceous rock has weathered to brown to dark brown or dark yellowish brown clay that contains common to many and highly weathered light yellowish brown, mainly volcanic tuff fragments. Sometimes, this is pure volcanic tuff saprolite. This soil series was first mapped in Lipa City in the province of Batangas. Lipa as a settlement traces its origin from two of the ten datus of Borneo lead by Datu Puti that purchased the island of Panay from Aetan king Marikudo sometime in the thirteenth century—these were the clans of Datu Dumangsil and Datu Balkasusa (Wikipedia 2012b). Lipa series covers a total of 91,127 ha of Lipa loam, loam-deep phase, and loam steep phase but only 83,362 ha of Lipa soils originated from tuff materials. These are found in the provinces of Batangas, Laguna, and Quezon. Of the total hectarage, Lipa clay loam encompassed some 46,180 ha in Laguna plus 56 ha of Lipa loam steep phase during the 1948 reconnaissance soil survey of the province. The 1987 semi-detailed soil survey of Laguna in 1987 showed that only 14,030 ha of Lipa clay were mapped. Due to the more detailed nature of soil survey, the remaining areas were delineated as other soil series. Lipa series developed from Taal Tuff which is intercalated and composed of lapilli beds, ash-rich beds, isolated laharic deposits, scoria beds rich in pumice and ash, and ignimbritic beds (welded tuff), and volcanic breccia.

3.2.2.3 Soils Underlain by Soft Highly Weathered Tuff with Clay

Carmona series (Plate 2B) was first described in the municipality of Carmona, now highly urbanizing, province of Cavite. This soil series is classified as fine, clayey, mixed, isohyperthermic *Vertic Eutraquepts*. These soils are shallow to moderately deep and poorly drained soils on rolling to strongly rolling relief with slopes ranging from 8 to 15 %. The surface soil ranges from 15 to 25 cm, and are very dark gray, gray, to dark grayish brown clay. The subsoil ranges from 40 to 80 cm thick, and are predominantly of very dark gray, olive gray, and dark gray, greenish gray with light olive brown and yellowish brown mottles. Few to common partially and highly weathered yellowish red. Yellowish brown and strong brown volcanic tuffaceous materials are observed. The substratum is highly weathered volcanic tuff materials in dark greenish gray, dark gray to dark grayish brown, yellowish brown and brownish yellow in color. It is composed of highly weathered tuff of yellowish brown, light olive brown, with dark gray illuviated clays in between the crevices (Soil Survey Division 1987a). This soil series is associated with Maahas soils which are both shallow to moderately deep and derived from volcanic tuff. Carmona series is found on rolling to strongly rolling slightly degraded tuffaceous footslope while Maahas series is located in gently sloping lower volcanic footslopes. The subhorizon of Carmona series is finer in texture than that of Maahas series. About 13,945 ha of Carmona sandy clay loam, clay loam, and clay loam steep phase were mapped in the provinces of Cavite and Laguna. Additional 696 ha of Carmonay clay were mapped in Rizal.

3.2.2.4 Soils Underlain by Soft Highly Weathered Tuff with Sand

Ibaan series is classified as *Typic Eutrudepts* are residual soils that developed from volcanic tuff found from level to mountainous relief. These are poorly drained soils. The surface soil is light reddish brown, brown to dark brown clay loam to loam, reaching down to a depth of 20–25 cm. The upper subsoil is reddish brown, brown to dark brown, blocky to columnar clay loam to clay, depth ranges from 45 to 60 cm from the surface. The lower subsoil is highly weathered tuffaceous materials with numerous concretions, depth is about 80–90 cm from the surface. The substratum is yellowish brown, soft highly weathered tuff, 110–120 cm. Below to a depth of 125–130 cm is fine-grained tuffaceous materials with some amount of sand. Below is highly weathered and unweathered tuff (Alicante et al. 1938). About 107,878 ha of various textural types of Ibaan series—loam, loam gravelly phase, clay loam, silty clay loam including undifferentiated were mapped in the provinces of Batangas and Quezon. This soil series was first described in the municipality of Ibaan, province of Batangas. Ibaan series was established, classified, and mapped by Clarence Dorsey in 1903 during the soil survey and classification of Batangas and certainly one of the oldest soil series in the Philippines (Fig. 3.6).

3.2.2.5 Soils Underlain by Silty Clay with Many Partially and Highly Weathered Rock Fragments

Cabanbanan series was named after barangay Cabanbanan, municipality of Pagsanjan, Laguna. But the typical pedon of this soil series was taken from barangay Santisimo Rosario,

Fig. 3.6 Soil profile of Ibaan series

San Pablo City, Laguna. This soil series is classified as fine, clayey, mixed, isohyperthermic *Typic Tropaquepts.* Cabanbanan series is deep to moderately deep, poorly to somewhat poorly drained soils found on gently sloping to undulating slightly dissected tuffaceous piedmont plain landscape. These soils are derived from the weathering of tuffaceous materials and mainly cultivated for paddy rice. The Ap horizon has matrix color of dark gray, very dark gray, grayish brown and dark olive gray and soil texture of silty clay loam, clay loam, and clay. The surface soil has yellowish red strong brown, dark yellowish brown and brown to dark brown mottles. The subsurface soil is about 110 cm thick, with matrix color of brown, dark brown, yellowish brown and texture of clay loam, with few to common dark gray mottles. Some few to common soft tuffaceous fragments and soft iron–manganese concretions were observed. The substratum is dark grayish brown silty clay with many partially and highly weathered rock fragments. About 673 ha of Cabanbanan silty clay loam were mapped in Laguna province. Cabanbanan is associated with Alipit series. Both occur on gently sloping to undulating slightly dissected tuffaceous piedmont plain landscape. They differ in drainage conditions. Alipit is well drained while Cabanbanan soils are poorly drained. Alipit is generally cultivated to upland crops. Alipit is also classified as an Alfisol and would be geologically older and the subsurface soil would have an argillic horizon.

3.2.3 Soils Underlain by Western Cordillera Tuff, Poorly Drained Soils and Characterized by Presence of Redoximorphic Features

Bani soil series is mapped in geologically part of Western Cordillera, also known as the Zambales Range and also as the Cabusilan Mountain. The range is an area of orogenic uplift (mountain formation) extending from the western coastline to the central lowlands and eastward in which Mount Pinatubo is the highest. It consists of volcanic extrusives, andesites, with marls and shales on the flanks (Smith 1913). Wernstedt and Spencer (1978) reported that the basement-complex materials consisted of basic, coarse-grained rocks and volcanics, including andesites, diorites, and gabbros (Wernstedt and Spencer 1978). The DOT study team preparing the Pinatubo Development Plan 2002–2006 reported that the underlying older volcanic rocks consists mostly of andesitic agglomerates, tuff breccias, and tuffaceous sandstones interspersed with andesitic or basaltic flow rocks (Department of Tourism 2002). This mountain range extends from north to south, from the mountains of western Pangasinan, the whole length of Zambales Province, to the tip of Bataan Peninsula. Included also are mountains and some hills in the provinces of Tarlac and Pampanga. We can thus, refer to the Bani tuffaceous parent material as the Western Cordillera Tuff. We have also the *Tarlac* soil series developing from this Western Cordillera Tuff. Both Bani and Tarlac soil series have poor drainage and characterized by presence of redoximorphic features but they differ in the nature of the tuff parent material—tuffaceous rock and lime concretions for Bani soils and tuffaceous sandstone for Tarlac soils.

3.2.3.1 Soils Underlain by Highly Weathered Tuffaceous Rock and Lime Concretions

Bani series (Plate 2A) is developed from residual soils of tuff and limestone. It was first described in the municipality of Bani, province of Pangasinan. This municipality was named after the bani tree, also known as the pongam oil tree. This soil series is classified as *Aquic Eutrustepts*. This soil occurs in rolling to hilly with level areas. The surface soil is very dark brown to nearly black, coarse granular and nutty clay. Its depth ranges 30–40 cm. The subsoil is light brownish gray, waxy and sticky clay. Lime precipitates are present in the lower subsoil, 35–65 cm depth from the surface. The substratum is highly weathered tuffaceous rock and stratified and the lime concretions are present (Alicante et al. 1940a). These soils are used for pasture while the cultivated areas are planted to maguey, rice, corn, coconut, vegetables, and some fruit trees. The surface drainage is good to excessive in rolling and hilly areas, poor in level areas. The subsoil drainage is poor. A total of 69,515 ha of Bani clay were mapped in the provinces of Pangasinan and Zambales.

3.2.3.2 Soils Underlain by Tuffaceous Sandstone

Tarlac series is classified as *Aquic Eutrustepts* and was first delineated in Tarlac City, Tarlac province. It consists of light gray, gray, dark gray, to nearly black fine granular to cloddy surface soils, clay loam, 30–60 cm in depth. The subsoil is grayish brown, dark gray to nearly black columnar to coarse granular clay loam. Limestone precipitates and reddish brown concretions are present. The depth ranges from 55 to 110 cm from the surface. The substratum is brownish gray to grayish brown chalky tuff or tuffaceous sandstone. It occurs in roughly rolling to hilly with small intervening flat. The parent material is whitish gray fine-grained water laid tuffaceous rock (Alicante et al. 1940b). The surface drainage is generally good to excessive, but the internal drainage is poor. These soils are generally grasslands and the cultivated areas are grown to upland rice, corn, sugarcane, fruit trees, and vegetables. A total of 197,880 ha of Tarlac sandy clay loam and clay loam, including clay loam-lowland and gravelly phases, as well as undifferentiated Tarlac series were mapped in the provinces of Tarlac and Pangasinan.

3.2.4 Soils Underlain by Diliman Tuff, Well-Drained Soils and Do Not Exhibit Redoximorphic Features

3.2.4.1 Soils Underlain by Clay, with Weathered Rock Fragments, Below is Hard Tuff

Camarin series is classified as fine, mixed, isohyperthermic *Typic Eutropepts*, first described in the undulating to rolling conglomeratic footslopes over tuff with localized valleys in barangay Camarin, in Northern Caloocan City. This soil series is deep, moderately well-drained. The A horizon 10–15 cm thick is dark brown or dark reddish brown clay, firm when moist, sticky and plastic when wet, with angular to subangular blocky structure. The B horizon is 60–110 m thick, dark reddish brown, reddish brown, or yellowish red clay with yellowish brown or dark reddish brown mottles, firm when moist, sticky and plastic when wet, few to many gravel-size angular and subangular rock fragments occur at 35–70 cm. The C horizon is reddish brown or dark reddish brown clay with embedded weathered rock fragments, firm when moist, very sticky, very plastic when wet, iron–manganese concretions occur within this layer. Below is hard volcanic tuff. A total of 1,312 ha of Camarin clay were mapped in Rizal province. This soil series is somewhat similar to Novaliches series. Their main difference is the presence of conglomeratic materials in Camarin soils. Camarin has also redder matrix color.

3.2.5 Soils Underlain by Various Macolod Corridor Tuff, Well Drained and Do Not Exhibit Redoximorphic Features

3.2.5.1 Soils Underlain by Soft Dark Yellowish Brown and Dark Brown Tuffaceous Rocks Below is Consolidated Tuffaceous Bedrock

Alipit series was named after barangay Alipit in the municipality of Santa Cruz, Laguna but the typical pedon selected for the soil survey report wa taken in the municipality of Pila, Laguna. This soil series is classified as very fine clayey, mixed, isohyperthermic *Typic Tropudalfs.* The soils are moderately deep to deep well drained, developed from volcanic tuff. The solum thickness ranges from 80 to 150 cm from the surface. The A horizon ranges from 20 to 35 cm thick, dark brown, very dark brown, and yellowish brown clay with few dark brown, strong brown, and yellowish brown mottles. The argillic B horizon is dark brown, very dark brown, dark grayish brown and dark yellowish brown clay with brown to dark brown to yellowish brown mottles. Few patchy clay film or clay cutans were observed. Common small highly weathered yellowish brown or dark brown subangular volcanic tuff fragments or tuffaceous gravels at the lower B horizon were noted. The C horizon is dark yellowish brown and dark brown tuffaceous rock that can be pulverized into yellowish brown, brown to dark brown or grayish brown clay which is similar to the underlying consolidated tuffaceous bed rocks. A total of 26,132 ha of Alipit clay were mapped in Laguna province. The Alipit series is associated with Cabanbanan, Abo, and Lipa series which occur on tuffaceous piedmont plain landscape and formed from volcanic tuff. The Alipit, Abo, and Lipa series are well-drained soils while Cabanbanan is poorly drained. The solum thickness of Alipit, Cabanbanan, and Abo is moderately deep to deep. Abo series is classified as a Mollisol.

3.2.5.2 Soils Underlain by Clay Loam to Clay with Platy Hard Volcanic Tuff

Abo series is underlain by tuff of the Makiling-Malepunyo Complex and developed from tuff originating from the Taal-Banahaw volcanic and pyroclastic deposits. This soil series was first described in Barangay Abo, municipality of Nagcarlan, province of Laguna. Abo series is classified as fine clayey, mixed, isohyperthermic *Oxic Argiduolls*. These soils are shallow to moderately deep, well-drained and formed from volcanic tuff. This soil series occurs in three different landscapes: gently sloping to undulating slightly dissected tuffaceous piedmont plain, strongly rolling moderately dissected upper volcanic footslope, and low volcanic hills and ridges. These soils are generally fine clayey soils with brownish in color. The argillic B horizon ranges from

Fig. 3.7 Soil profile of Abo series

30 to 60 cm deep, composed of dark brown, very dark brown, brown, and dark yellowish brown clay. The C horizon is dark yellowish brown, dark grayish brown and dark brown clay loam to clay, with platy hard volcanic tuff. Buried soils occur at 100 cm depth and has dark brown as matrix color and heavier in texture. A total of 12,047 ha of Abo series were mapped in the province of Laguna (Soil Survey Division 1987a) (Fig. 3.7).

3.2.6 Soils Developed from Other Tuffaceous Materials

3.2.6.1 Soils Underlain by Highly Weathered Tuffaceous Rocks

The soils of *Dahinob* series have been derived from the residuum of highly weathered tuffaceous rocks occurring on dissected slopes and hills. The soils have dark brown to very dark brown A horizon; 15–25 cm deep; the B horizons are light yellowish brown 70–90 cm deep; and the C horizon are composed weathering saprolite rocks with original structure visible. Only one soil type, Dahinob clay, was mapped under this series. The typical soil profile of this series is as follows: The soil surface soil is dark brown (7.5YR 4/2) when dry and very dark grayish brown (10YR 3/2) when moist, clay; fine to coarse granular in structure; slightly sticky, and slightly plastic when wet; firm when moist, hard when dry; the few fine discontinuous inped tubular simple open pores; many fine roots present; boundary to next horizon is clear and smooth; depth is about 15 cm. The subsoil is light yellowish brown (10YR 4/4) when dry and yellowish brown (10YR 4/3) when moist, clay; weal sub angular blocky structure; sticky and plastic when wet; very few gravels present; has few fine pores; coarse roots are abundant; boundary to next horizon is clear and smooth; depth is about 55 cm. The substratum is brownish yellow (10YR 6/4) when dry, clay; slightly sticky and plastic when wet, firm when moist and hard when dry; black concretions are common. Weathered saprolite with original structure visible which could be broken between fingers is found in this layer. This soil series was named after Barangay Dahinob in the municipality of President Manuel A. Roxas, Zamboanga del Sur. The soil type extends to the municipality of Katipunan covering about 26,250 ha in the province of Zamboanga del Norte. Coconut, bananas and other fruit trees in small patches are found in this soil. Upland rice and corn are also grown. The higher portion of this soil type is under grass.

3.2.6.2 Soils Underlain by Highly Weathered Tuffaceous Rocks and Basalts

Panabutan soil series was firs mapped in barangay Panabutan, municipality of Sirawai, Zamboanga del Norte. These soils developed from the residuum of weathered tuffaceous rocks and basalts. They occur on hilly and rolling areas, extending along the coast from the municipality of Sirawai to the municipality of Sibuco. This soil is well drained but moderately slow in permeability. The soil color ranges from pale brown to reddish yellow. The cultivated areas are planted to coconuts and fruits. Only one soil type, Panabutan sandy loam was mapped in this series in the provinces of Zamboanga del Norte and Zamboanga del Sur which today includes the province of Zamboanga Sibugay, carved from Zamboanga del Sur in 2001, covering some 102,813 ha. The surface soil is very pale brown (10YR 7/3) when dry and dark grayish brown (10YR 4/2) when moist, sandy loam; fine granular in structure; nonsticky and nonplastic when wet, friable; fine roots are abundant; boundary to the next layer is abrupt and smooth; depth is about 25 cm. The subsoil is pale brown (10YR 6/3) when dry and dark brown (7.5YR 3/2) when moist, sandy clay loam; subangular blocky in structure; slightly sticky and plastic when wet, slightly firm when moist, and slightly hard when dry; boundary to the next horizon is gradual and wavy, the thickness is about 25 cm. The substratum is reddish yellow (7.5YR 8/6) when dry and yellowish red (5YR 5/6) when moist, clay loam; coarse subangular blocky in structure; sticky and slightly plastic when wet, slightly firm when moist, and hard when dry; thin brown cutans are present; has few fine discontinuous oblique inped tubular simple open pores; few fine roots present. Below this layer is weathered tuff. In some places, few gravels are present in the B horizon.

3.3 Soils that Developed from Igneous Rocks

Both basalts and andesites are igneous rocks produced in a volcanic eruption but they differ in chemical composition depending on where in the earth's crust the magma came from. Basalts usually come from deep in the mantle of the earth, from around 50–200 km in depth. Andesites come from shallower sources, near the continental plate margins.

Because of the differences between basalts and andesites, when these weather, the resulting soils will also differ. Basalts contain plagioclase and pyroxene with iron minerals such as olivine. Soils will usually have dark gray to almost black color. And because of the iron minerals, the old soils can also be bright red. Andesites are usually made up of plagioclase, pyroxene, feldspar and/or hornblende and the soils are lighter in color than those soils that originated from basalt.

Igneous rocks can also be intrusive or extrusive. Intrusive igneous rocks cool and solidify within the crust and are formed from magma that cools slowly and thus, the rocks are coarse grained. Extrusive igneous rocks result from partial melting of rocks within the mantle and crust, solidify quicker than intrusive igneous rocks; the rocks cool very quickly and are fine grained. Basalt is a common extrusive volcanic rock. Andesite is also an extrusive igneous rock.

Igneous rocks can also be classified based on the amount of silica that they contain. A rock that contains more than 66 % silica is *acidic*, between 66 and 52 % silica is *intermediate*, between 52 and 45 % silica is *basic*, and less than 45 % silica and consists almost entirely of ferromagnesian minerals is *ultrabasic* (also called ultramafic). Soils developed from acidic igneous rocks such as rhyolite and granite have the lowest capability to retain needed crop nutrients. Soils that were formed from basic igneous rocks like basalt and gabbro have the higher crop nutrient retention capability.

The common igneous rocks and their chemical composition are as follows:

	Extrusive	Intrusive
Acidic	Ryolite	Granite
Intermediate	Andesite	Diorite
Basic	Basalt	Gabbro
Ultrabasic		Peridotite

3.3.1 Soils Developed from Predominantly Andesite Parent Materials

Most of these soils are on the footslopes of a major mountain.

Kidapawan and *Tugbok* soil series were originally delineated on the footslopes of Mount Apo but on almost opposite sides, Kidapawan series on the western side while Tugbok is on the eastern side with the Central Mindanao Highlands dividing the two, the highest peak of which is Mount Apo. The Kidapawan soil series would form part of the watershed that constitutes the Carmen Basin, a broad synclinal basin that gently plunges toward the south. Tugbok soil series as originally mapped would be part of the Davao piedmont. The geomorphic surface where the two soil series are should be able to make the distinction where it becomes difficult for soil surveyors to differentiate the two. Kidapawan is reddish brown to brick red, matching the color of Antipolo soils of Rizal Province and Luisiana soils of Laguna province; the subsoil and substratum are yellowish brown. In fact, it is almost identical with Luisiana even in soil depth except that Luisiana has white splotches while Kidapawan has none. Kidapawan is also similar to Parang series as they appear in almost the same geographic position but Parang series has concretions while Kidapawan has none. As for Tugbok series, it also belongs to the group of soils with reddish brown to red soils such as those of Antipolo, Alaminos, and Luisiana soils. Tugbok differs from Antipolo in that there are no concretions in the surface nor in the subsoil. The Luisiana soils are generally deeper and more pronounced in red color. We have placed Kidapawan soil series under hilly and mountain soils and discussed in the next chapter but Tugbok is considered an upland soil and placed here. *Miral* series is also on the footslopes of Mt. Apo, originally mapped in what is now Bansalan, Davao del Sur. This soil series is underlain by andesites and consolidated gravelly sand and would be easier to differentiate between Kidapawan and Tugbok series.

Parang series as originally mapped, would have been highly dominated by soil parent materials coming from the Ragang Volcanic Complex, a geological formation characterized by Pliocene to recent andesite to pyroclastic rock lithology distributed in the North Cotabato and Lanao del Sur provinces. In this geological formation, Ragang Volcano is on the northeast end of series of relatively young volcanic cones which include Kitabud Mountain, Makaturing, Maranat, Mariyug, Salagabanog, and Magampo. The color of Parang soil series resembles Antipolo and Luisiana but it lacks the brick red color of Antipolo and the even coloring of Luisiana. Parang series is also characterized by presence of iron concretions in the substratum which is absent in Luisiana while Antipolo series is characterized by presence of tuffaceous concretions.

3.3.1.1 Soils Underlain by Weathered Andesites

Soils with Poor Drainage and Presence of Redoximorphic Features

Tagum series, classified as *Aquic Hapludalfs* was first mapped in the municipality of Sta. Cruz principally in the barrios of Alabo, Morales, down to Angas, and from Malibunan to Buyabod down to Pantain in the island province of Marinduque. Tagum is one of the barangays of the municipality of Sta. Cruz. It is a primary soil derived from andesites and other volcanic rocks and occurs on undulating to slightly rolling relief. The surface drainage is excessive but the internal drainage is poor. The surface soil is grayish brown to very dark gray clay loam, with numerous rust-colored concretions of different shapes and sizes, with depth extending down from 20 to 30 cm. The subsoil is black, fine granular and compact clay with concretions similar to the upper horizon and black at the core, with depth varying from 70 to 150 cm from the surface. The substratum is highly weathered andesites that turn grayish when crushed (Salazar et al. 1962). The uncultivated areas are usually under cogon, shrubs, and second growth forest. In the cultivated areas, the crops grown are upland rice, corn, cassava, and coconuts. About 2,939 ha of Tagum clay loam was mapped in the province of Marinduque.

Pantao series was first described in barangay Pantao, municipality of Talipao, in the province of Sulu. The soil series is classified as *Typic Hapludult*. This series is of residual formation, derived from igneous rocks. The relief is rolling to hilly. Its elevation is about 69 m above sea level. External drainage is good to excessive, internal drainage is poor to fair. The soils of this series are deep and are easily penetrated b y roots. The surface soil is dark brown or black silty clay to clay. It has a fine granular structure. This layer contains a fair amount of organic matter. Rock outcrops are present. The depth ranges from 40 to 50 cm from the surface. The upper subsoil is light orange brown to grayish brown clay loam with fine to medium granular structure. It is sticky and plastic when wet, slightly friable when dry. A few andesitic rocks are embedded in this layer. Its depth is about 50–70 cm from the surface. The lower subsoil is light orange brown to grayish brown loam to silt loam with gray and brown splotches. It has fine granular to columnar structure and is mellow when moist but slightly brittle when dry. This layer is free from any coarse skeleton. Its depth is about 70–115 cm from the surface. The substratum consists of yellowish brown highly weathered agglomerates, mainly andesites. This layer has light orange mottling (Sindayen et al. 1965b). A total of 5,311 ha of Pantao silty clay were mapped in Sulu, in the sitios of Langtad and Pantao, Jolo Island, in the northern, eastern and southern sides of Tapul Island, in the central part of Lugus Island, and in the eastern half of Tara Island. This soil series is planted to citrus, coconut, abaca, banana, and other fruit trees.

Soils with Good Drainage and Characterized by Absence of Redoximorphic Features

Tugbok soil series is developed from igneous rocks, predominantly andesites. This is classified as *Typic Hapludults*. Tugbok, where this soil series was named after, is a district of Davao City and noted for the location of the southern Mindanao campus of the Philippine Science High School. This soil series occurs on undulating to gently rolling relief on the upper portions of the gently rising Daliao-Talomo valley and on the lower slopes of the eastern side of Mount Apo. The surface soil is brown to weak reddish brown, prismatic, and slightly compact clay, hard and brittle when dry, plastic when moist, with depth is from 30 to 35 cm. The subsoil is reddish brown to yellowish red, slightly compact clay loam, with depth from 95 to 100 cm. The substratum is light brown clay with weathering rocks and boulders (Mariano et al. 1953). The drainage is good externally and fair to good internally. The vegetation is mostly second growth forest with few patches of cogonals. The cultivated areas are planted to abaca, coconut, corn, bananas. A total of 87,970 ha of Tugbok clay were mapped in Davao provinces.

3.3.1.2 Soils Underlain by Andesites and Consolidated Gravelly Sand

Soils with Good Drainage and Absence of Redoximorphic Features

Miral series are moderately deep to deep primary soils developed from parent materials originating from the weathering of consolidated gravels and boulders of igneous rocks and sedimentary origin, with andesitic materials dominating. This soil series is classified as *Typic Hapludalfs.* The dominant relief is rolling to hilly. On narrow alluvial plains, these soils are found on landforms from apical to distal terraces varying in soil thickness and occurrences of coarse fragments in the profile. Because of its aquic moisture regime in these landforms, these soils are used for paddy rice. The surface soil ranges from 25 to 30 cm and consists of dark brown or light reddish brown, slightly compact clay loam. This horizon merges gradually and irregularly into the subsoil which is brown to reddish-brown columnar clay, slightly more compact than the surface soil, and reaches a depth of 50 cm from the surface. The lower subsoil consists of partially weathered rocks from 80 down to a depth of 100 cm from the surface. The substratum is consolidated gravelly sand with some imbedded boulders. Below the substratum is massive bedrock (Mariano et al. 1953). The surface drainage is free to excessive, but the internal drainage is fair. Miral where this soil was first described is the former name of Bansalan, Davao del Sur. The cultivated areas are mostly planted to corn, abaca, and fruit trees. About 34,418 ha of Miral clay loam were mapped in Davao and another 1,688 ha in Zamboanga del Norte or a total of 36,106 ha. The term Davao province nowadays actually refers to Davao del Norte; but before 1967, Davao originally encompassed also the three other provinces of Davao del Sur, Oriental, and Compostela Valley.

3.3.1.3 Soils Underlain by Gravelly Clay Further Underlain by Highly Weathered Rock, with Good Drainage

Parang series (Plate 2E) was first mapped in Parang, what was then Cotabato province, but has been carved out and is now a municipality of the province of Maguindanao. Parang series is classified as *Typic Hapludults.* This soil series occupies undulating to rolling and steep relief north and south of Parang and in the vicinity of Nuro. The topsoil is light reddish brown to brown, blocky clay loam, extending down to 20 cm. The upper subsoil reaches down to 70 cm, brown to reddish brown blocky clay, slightly compact; coarse skeleton is absent. The lower subsoil reaches down to 100 cm, brown to reddish brown granular clay, also coarse skeleton is absent. The substratum that extends down to the control section is structureless gravelly clay, and a great deal of iron concretions are present. Below this horizon is highly weathered rock (Mojica et al. 1963). This soil series belongs to well-drained upland soils, the red color is due in part to the oxidized condition of the soil and resembles Antipolo and Luisiana soil series. It lacks, however, the even brick red color of Antipolo and the even coloring of Luisiana although they have similarity in topographic occurrence, drainage characteristics, and even in vegetation. Parang series can also be distinguished from the two by the presence of iron concretions in the substratum which is absent in Luisiana series and we find instead tuffaceous concretions in Antipolo series. This soil series is mostly covered by second growth forest and primary forest and most of the cultivation is done in Parang and Bugasan with coconut as the main crop. Fruits and vegetables are also grown. A total of 90,000 ha of Parang clay loam were mapped in Cotabato provinces.

3.3.2 Soils Developed from Predominantly Basalt Parent Materials

3.3.2.1 Soils Underlain by Clay, with Gravels and Stones, with Good Drainage

Sampaloc series (Plate 2E) comes from a word that literally means the tamarind fruit and was first described in barangay Sampaloc, municipality of Tanay, province of Rizal. This area rose to national prominence when then Gloria Macapagal Arroyo took over the presidency of Joseph Estrada in what was dubbed as the "EDSA Revolution of 2001" and placed him under house arrest, confined to his rest home in Sampaloc, Tanay, Rizal. Sampaloc series is classified as very fine, mixed isohyperthermic *Typic Kandiudults*. These are moderately well-drained soils on undulating to rolling moderately dissected upper basaltic plateau. They have brown to dark brown, dark reddish brown, dark yellowish brown clay A horizon not more than 25 cm thick. The argillic Bt horizon is 85–150 cm deep, brown, strong brown, dark yellowish brown, reddish brown, dark reddish brown, or yellowish red clay with dark brown mottles. Few weathered rock fragments occur. The C horizon or the substratum is yellowish red or yellowish brown clay with common to many angular and subangular basaltic rock fragments (Soil Survey Division 1989). The Sampaloc series is somewhat similar to Inarawan series as both have the same parent materials and both are classified as Orthoxic Eutrudults. However, Sampaloc series occurs on undulating to rolling moderately dissected upper basaltic plateau of volcanic footslopes while Inarawan series is found on slightly to moderately dissected upper plateau with hillocks of the volcanic hills landscape. Sampaloc series is also somewhat similar to Lumbangan, San Luis, and Bugarin series. Both Lumbangan (found on very steep highly dissected hills with angular crests on volcanic hills landscape) and Bugarin soils (found on slightly to moderately dissected upper plateau with hillocks) have no argillic horizon and are classified as Typic Eutrudepts and Typic Dystrudepts, respectively while the San Luis series is classified as Ultic Tropodalfs and occurs on undulating basaltic plateau of the volcanic footslopes. Sampaloc series is generally vegetated with cogon, shrubs, grasses, and patches of fruit trees. A total of 2,194 ha of Sampaloc clay in various slopes and erosion status were mapped in Rizal province (Fig. 3.8).

Fig. 3.8 Landscape view of Sampaloc series taken in Tanay, Rizal

Zamboanguita soil series was first described in the municipality of Zamboanguita, province of Negros Oriental covering most of the elevated areas between the municipalities of Zamboanguita and Siaton. This soil series is classified as *Typic Kandiudults*. This soil series is residual soils developed from basalt. The relief occurs on slightly rolling to strongly rolling areas, some portions are broken and steep to warrant cultivation. The external drainage is good to excessive while internal drainage is good. A major characteristic of this soil series is the presence of many rock outcrops, making this soil series not suitable for cultivation. The rocks are from 30 cm to a meter in diameter, either outcrops or lie buried several centimeters below the surface. The surface soil is dark gray, grayish black to almost black, mellow, fine granular clay loam; moderately friable but slightly hard when dry. Boulders are present as outcrops. Depth reaches down from 20 to 30 cm. The upper subsoil is dark reddish brown to reddish brown, good medium granular clay loam; moderately friable slightly hard and compact when dry. Gravels and concretions are present, depth reaching down from 45 to 50 cm. The lower subsoil is reddish brown, slightly compact, massive clay. Weathered basalts are present. The depth is from 95 to 100 cm. The substratum is yellowish red, compact, massive clay and boulders are present (Barrera and Jaug 1960). This soil series resembles Guimbaon clay loam—stony phase described in Negros Occidental but delineated as a separate series in view of the more boulders imbedded in Zamboanguita and that this soil series could not be cultivated throughout the year because the soil easily dries up during summer as compared to less frequent boulders and that farming operations could be conducted throughout the year in Guimbalaon soils. Rocks present in Zamboanguita and La Castellana series are identical but they differ in substratum color with La Castellana having dull brown to gray substratum while Zamboanguita has reddish brown subsoil and substratum. This soil series is not much planted except during the rainy season. Little patches of farm are planted to corn, upland rice, and kadios or pigeon pea (*Cajanus cajan*). A total of 23,433 ha of Zamboanguita sandy loam and clay loam were mapped in the provinces of Negros Oriental and Romblon.

Tulay series is classified as fine, illitic, isohyperthermic *Oxic Dystropepts* first described in nearly level to slightly sloping localized valleys of the undulating to rolling hills and ridges of the volcanic footslopes. "Tulay", the soil series name, literally means "bridge" and with hundreds of bridges in the province of Rizal where this could have been first described, it would seem difficult to trace. But the soil series was actually first described in sitio Tulay, barangay Tandang Kutyo, municipality of Tanay, Rizal province. Tulay soils are deep, well-drained. The A horizon is 10–30 cm thick, brown to dark brown, dark reddish brown, dark yellowish brown clay loam or clay with distinct brown to dark brown, reddish brown or dark yellowish brown mottles, blocky to granular in structure, friable, slightly firm when moist, sticky and plastic when wet. The cambic B horizon 100–150 cm deep is dark reddish brown, brown to dark brown, or yellowish red clay loam or clay with dark reddish brown, yellowish red, brown to dark brown, or red mottles, firm when moist, sticky and plastic when wet, few to many small medium and coarse weathered volcanic fragments commonly present at 30–90 cm depth, with few small soft iron–manganese concretions. The C horizon is brown to dark brown, yellowish brown or yellowish red clay with common to many partly or highly weathered rock fragments. Few boulders mainy basalt are sometimes embedded in this layer. A total of 7,453 ha of Tulay clay in various slopes and erosion condition were mapped in Rizal province. Tulay series is associated with San Luis, Sampaloc, and Inarawan series. All these soils are acidic and developed from basaltic rocks. Except for Inarawan soils which occur on volcanic hills, the other soils are found on volcanic footslopes of the hilly landscape. Both Tulay and San Luis soils have few to many weathered volcanic rock fragments within 30–90 cm depth but Tulay series has no argillic horizon while San Luis has. Sampaloc and Inarawan soils have also argillic horizons. Tulay is Oxic Dystropepts, San Luis is Ultic Tropudalfs, while both Sampaloc and Inarawan are Orthoxic Tropudults.

3.3.3 Soils Developed from Predominantly Andesite-Basalt Parent Materials

3.3.3.1 Soils Underlain by Clay, with Good Drainage

España series is classified as *Typic Hapludults*. These are residual soils developed from the weathering of basalts and andesites. A total of 7,421 ha of España loam-stony phase and sandy clay loam were mapped in the province of Romblon. España where this soil series was first described and mapped is a barangay of the municipality of San Fernando in the island province of Romblon. This soil series has some similarities with the Luisiana series, differing from the latter only in the presence of metamorphic pebbles in the surface and subsoils. The external drainage is good to excessive while the internal drainage is fair to good. The surface soil extending down to 25 cm is sandy clay loam; reddish brown (10YR 6/6) when moist and pale brown (10YR 7/4) when dry; with numerous red (2.5YR 5/8) streaks; coarse granular structure; slightly friable when moist, slightly sticky and moderately plastic when wet, and slightly hard when dry; few metamorphic sand and pebbles are present. The upper subsoil reaches down to 70 cm, reddish yellow (7.5YR 6/8) when moist, and yellow red (5YR 5/8) when dry; fine granular structure; sticky and plastic when wet and hard when dry; few metamorphic sand are present in this layer. The lower subsoil is clay, yellowish red (5YR 5/6) when moist and reddish yellow (5YR 6/6) when dry; with numerous yellowish red (5YR 5/8) streaks; fine granular structure; sticky and plastic when wet and hard when dry (Castillo et al. 1973). Coconut is the principal crop grown. On nearly level areas, rice and corn are grown in patches. The steeply rolling to hilly and mountainous areas are under secondary and primary forests. The stony phase of course makes cultivation impractical and mostly under shrubs and grasses while those adjacent to settlements are planted to rice, corn, and vegetables despite the limitation.

3.3.3.2 Soils Underlain by Clay with Highly Weathered Volcanic Tuff, with Good Drainage

Jasaan where this soil series was first described is a coastal municipality of the province of Misamis Oriental. This soil series is classified as *Typic Hapludults*. Jasaan series is developed from basalts and andesites. The relief occurs from flat to mountainous areas, and thus, would be expected to be found also in lowlands, hillylands, and mountains. The external drainage is good to excessive while the internal drainage is fair. The surface soil is brown to light brown, moderately compact and columnar clay loam to clay; slightly friable and soft when moist, sticky and plastic when wet, hard when dry. Boulders are embedded. Depth is from 30 to 35 cm. The upper subsoil is light brown to reddish brown, moderately compact and columnar clay, with depth ranging from 45 to 50 cm. The lower subsoil is similar to upper layer, gravels are present, and depth ranges from 95 to 100 cm. The substratum is light brown to reddish brown, loose and very friable, massive clay loam (Lopez et al. 1954). The vegetation is basically primary and secondary forest and cogon. The cultivated areas are devoted to coconuts, abaca, bananas, root crops, sugarcane, upland rice, and corn. A total of 105,307 ha of Jasaan clay loam, clay, and clay-stony phase were mapped besides the province of Misamis Oriental, also in Misamis Occidental, Lanao provinces, Sulu, Surigao, and Bukidnon.

San Luis series is classified as very fine, mixed, isohyperthermic *Typic Hapludults*, well drained both internally and externally. Originally described in barangay San Luis, Antipolo City, province of Rizal, the soils are deep, well drained occurring on undulating plateau; and derived mainly from the weathered product of basaltsv and andesites. The surface soil is not more than 20 cm thick, reddish brown to very dark grayish brown clay with dark brown to dark reddish mottles. The argillic Bt horizon reaches down from 130 to 150 cm from the surface, and are red, yellowish red to dark reddish brown clay. Weathered tuffaceous fragments commonly occur and increase with depth. Iron-coated manganese concretions are usually present. The substratum is red to dark reddish brown clay. Coatings of yellowish brown and black, probably iron and manganese, occur between crevices (Soil Survey Division 1989). San Luis is somewhat similar to Pinugay and Antipolo soils but the three differ in the subgroup level of classification. San Luis is *Ultic Eutrudalfs*, Pinugay is *Oxic Eutrudalfs*, and Antipolo is *Typic Eutrudalfs*. San Luis soils have thicker solum than Antipolo and Pinugay series and occur on undulating basaltic plateau of the volcanic footslopes. Antipolo series are derived from basalt but occurs on undulating to rolling volcanic hills and ridges with localized valleys. Pinugay soils are mainly derived from shale and found on upper rounded hills and ridges of the volcanic landscape. San Luis soils also exhibit somewhat similar morphological characteristics with those of Inarawan, Sampaloc, and Tulay series. San Luis soils have higher base saturation >35 %) compared to Sampaloc and Inarawan. Sampaloc soils occur on undulating to rolling moderately dissected upper basaltic plateau of the volcanic footslopes. Inarawan soils are found on slightly to moderately dissected upper plateau with hillocks of the volcanic hills. The Tulay soils are moderately deep to deep well-drained *Oxic Dystrudepts*. A total of 3,422 ha of San Luis clay were mapped in Rizal province.

3.3.3.3 Soils Underlain by Clay with Concretions, with Good Drainage

Banto soil series was first described in barangay Banto, municipality of Mogpog, province of Marinduque. Banto series belongs to fine, isohyperthermic *Typic Eutrudepts* and is derived from igneous rocks, primarily andesite and basalt. The relief is rolling to hilly. The external drainage is excessive while the internal drainage is good. The surface soil is reddish brown to almost red, friable, slightly compact, fine granular clay loam; sticky and plastic when wet. Black concretions are present. The horizon depth is about 25–30 cm. The subsoil is pale to dark red, granular clay; sticky and plastic when wet, slightly friable when dry. Soft concretions that produce a black powdery mass are present. Depth ranges from 100 to 105 cm. The substratum is reddish brown to almost red, clay with black specks band contains highly weathered concretions; sticky and plastic when wet, hard and compact when dry. Lower portion has yellowish brown mottlings (Salazar et al. 1962). This soil series is covered by cogon, talahib, aguingay (*Rottboellia cochinchinensis*) and other trees. The cultivated areas are grown to coconuts, upland rice, bananas, corn, root crops, and fruit trees. About 41,887 ha of Banto clay loam were mapped in the island provinces of Marinduque and Mindoro.

3.3.3.4 Soils Underlain by Clay to Silty Clay Loam with Rock Fragments

Soils with Poor Drainage and Characterized by Presence of Redoximorphic Features

Bolaoen series was first mapped in the province of Zambales and the revisit to the soil series classified this as fine kaolinitic isohperthermic *Typic Hapludults*. The origin of this soil series name is quite interesting because Bolaoen is the name of four barangays in four municipalities of the province of Pangasinan—a barangay of Urdaneta City, a barangay of San Fabian, a barangay of Bugallon, and a barangay of Sual. These barangays are unlikely to have soils with characteristics of Bolaoen series. There is no barangay named Bolaoen in Zambales. This soil series must have been named after barangay Bulawen in the municipality of Palauig, Zambales. This is residual soil developed from igneous rocks occurring on flat uplands to undulating and rolling. The internal drainage is poor. The original soil series concept has surface soil extending down from 20 to 30 cm, brown to dark grayish brown, loose, friable, and fine granular sandy loam. Andesite and basalt boulders are present. The subsoil reaches down from 30 to 60 cm, brown to reddish brown clay loam with plenty of gravels and iron concretions. In some places, boulders are embedded in this horizon. The substratum that reaches down to the control section is brown to strong brown, massive and friable clay loam. Boulders are also embedded in this layer (Alicante et al. 1951b). The revisited soil series, done after the 1991 Mount Pinatubo eruption and conducted in the Aeta Resettlement Area, Loob-bunga, Botolan, Zambales were mostly clays, except for the BC horizon which is clay loam; and hence the observed argillic horizon formation. This soil series is generally covered by second growth forest, cogon, and shrubs. The cultivated areas are grown to upland rice, corn, and diversified upland crops. A total of 146,461 ha of Bolaoen sandy clay loam and clay loam were mapped in the provinces of Zambales, Mindoro, and Zamboanga del Sur.

Tagburos series is classified as *Typic Hapludults* and was first described in Tagburos, a barangay of Puerto Princesa

Fig. 3.9 Soil profile of Tagburos series taken in Narra, Palawan

Fig. 3.10 Landscape view where Tagburos series occurred in complex with Luisiana series in Narra, Palawan

City, province of Palawan. This soil series occurs on rolling to hilly relief. The drainage is poor, the soils are rather sticky and difficult to cultivate. These soils developed from igneous rocks mostly basalts and andesites. The surface soil is dark brown clay to clay loam, extending down to 25 cm, the subsurface soil is drak brown to brown clay reaching to a depth of 80 cm from the surface. Within this is a 30 cm layer composed of fragments of stones and gravels. The substratum down to the control section is dark brown clay, compact, with some weathered rocks (Barrera et al. 1960). The cultivated areas are planted to corn, upland rice, and root crops. The uncultivated areas are forested. A total of 72,780 ha of Tagburos clay and clay loam were mapped in the provinces of Palawan and Sulu (Figs. 3.9, 3.10).

Soils with Good Drainage and Characterized by Absence of Redoximorphic Features

La Castellana soil series (Plate 2C) was first described in the municipality of La Castellana, province of Negros Occidental, located at the foot of Kanlaon Volcano. It is named after the famous "Paseo de la Castellana" in Madrid, Spain and famous for its natural springs and waterfalls. This soil series is classified as *Typic Humitrudepts*. This series is a residual soils developed from basalt, andesites and other igneous rocks. In other areas, the soil parent material included partly volcanic tuff and breccia. A distinct characteristic of this soil is the abundance of basaltic and andesitic boulders. The relief occupies the rolling to hilly with some level areas. The external drainage is good to excessive while the internal drainage is fair. The surface soil is brown to almost black when wet, gray to light brown when dry, good fine granular clay loam, friable when moist. Depth is 15–30 cm. The subsoil is brown, mottled with reddish brown to gray, good fine granular clay, slightly compact; plenty of pebbles and some boulders. Depth is 50–50 cm. The substratum is gray to reddish brown, compact and hard clay with pebbles and boulders (Alicante 1951a). The uncultivated areas are covered with cogon, binayoyo (*Antidesma ghaesembilla*), bamboo, and talahib. The cultivated areas are grown to sugarcane, upland rice, and diversified upland crops. A total of 138,127 ha of La Castellana clay loam, including the steep phase, and clay were mapped in the provinces of Negros Occidental, Negros Oriental, Marinduque, Bukidnon, Cotabato, and Samar. Additional 91,001 ha of La Castellana-Jasaan-Luisiana complex were mapped in the provinces of Zamboanga del Norte and Zamboanga del Sur (Alicante 1951a).

Adtuyon series (Plate 2A and Fig. B.1) was first described in barangay Adtuyon in the municipality of Pangantucan, province of Bukidnon, and the most extensive soils in the province covering almost the entire Bukidnon plateau. This soil series is classified as *Typic Paleudults*. This soil series is a residual soils developed from parent material that originated from volcanic lava or mud-flows (lahar) composed of mixed boulders but chiefly basalts and andesites. These rocks are deeply weathered, sometimes reaching to four and a half meters. The relief is nearly level to strongly sloping with the slope ranging from 2 to about 20 %, external drainage is good to excessive while internal drainage is good. The surface soil is light brown, brown to dark brown, friable and granular, clay. Good root penetration. Boundary to subsoil is gradual. Depth is 10–25 cm. The subsoil is dark reddish brown to brown, prismatic to granular clay; sticky and plastic when wet, brittle and hard when dry. Depth is 70–80 cm. The substratum is dark yellowish brown to light reddish brown, slightly compact clay; hard and cloddy when dry. Partially weathered igneous rocks are occasionally present (Mariano et al. 1955). A few areas are forested and some areas are used as pasture. In the cultivated areas, corn, upland rice, abaca, fruit trees, coffee and cacao, peanuts, rootcrops, and diversified upland crops are grown. Adtuyon series is extensive—a total of

552,369 ha of Adtuyon loam, loam-stony phase, clay loam, clay, and clay-stony phase were mapped not only in the province of Bukidnon but also in the provinces of Lanao, Misamis Occidental, Zamboanga del Norte, Zamboanga del Sur, and Sulu. Additional 13,368 ha of Adtuyon-La Castellana Complex were mapped in the provinces of Lanao.

3.3.3.5 Soils Underlain by Clay to Clay Loam with Weathered Volcanic Rocks Below, with Good Drainage

Tiptipon series was first described in Tiptipon, is one of the barangays of the municipality of Panglima Estino, province of Sulu. This soil series is classified as *Typic Dystrudepts.* This soil series is developed from basalt and andesite. Its relief is nearly level to moderately undulating to rolling. Has a good external and internal drainage. The surface soil is brown to dark brown clay loam to clay fine granular and friable, moderately sticky and plastic when wet, moderately hard when dry. Depth is from 20 to 30 cm. The subsoil is brown to light brown fine granular, porous and friable clay loam to clay, moderately plastic when wet, but easily crumbles at optimum moisture content. Moderately hard when dry. Depth is 65–90 cm. The substratum is light brown to yellowish brown clay loam, friable and angular. Porous and underlain by highly weathered volcanic rocks (Sindayen et al. 1965b). The uncultivated areas are covered by teak binayoyo trees and cogon. About 10,520 ha of Tiptipon series were mapped in Sulu.

Timbo series was first described in barangay Timbo, also known as Sanggulong, municipality of Buenavista, island province of Marinduque. The soil series is classified as *Typic Hapludults*. Timbo is a typical red soil derived from the decomposition and disintegration of igneous rocks like basalts and andesites in place. It differs from Luisiana soils because the andesite and basalt boulders are found in the lower subsoil. It differs from Antipolo soil series because Timbo has brown to reddish brown color surface soil while Antipolo has dark red. The soils are found in undulating to slightly rolling relief with good drainage conditions. The surface soil is brown to pale reddish brown, fine granular clay loam, extending to a depth from 25 to 45 cm. The subsoil is pale to dark reddish brown, friable clay. The lower portion is dark reddish brown clay loam mixed with highly weathered basalts and andesites, with depth varying from 65 to 100 cm from the surface. The substratum reaches down to the control section and is reddish brown to almost red clay mixed with stones and boulders (Salazar et al. 1962). The uncultivated areas are mostly grasslands while the cultivated areas are planted to upland rice, coconut, root crops, and banana. This soil series covers 3,856 ha.

3.3.3.6 Soils Underlain by Clay Loam, with Gravels, with Good Drainage

Annam soil series (Plate 2A) was first described in barangay Annam, municipality of Umingan, province of Pangasinan and classified as *Typic Hapludults*. It is developed from andesite, basalt and tuffaceous rocks. The relief of this series is rolling to roughly rolling to hilly. The drainage is good to excessive. The surface soil, 25–35 cm in depth, is brown to grayish brown to light reddish brown, friable and granular clay loam. The subsoil, 55–70 cm in depth, is chocolate brown red to almost brown, loose and friable clay loam to clay. Concretions and gravels are present. The substratum is brown to chocolate brown gravelly clay loam. Stones, boulders and tuffaceous rock are embedded in this horizon (Alicante et al. 1940a). Annam series can be differentiated from Alaminos series in terms of texture. Alaminos soil is loose and sandy while Annam series is slightly compact and heavier both in the surface soil and in the subsoil. There are plenty of concretions in the Alaminos series while the Annam series has only occasional amount of gravel and concretions scattered in the subsoil. The Annam series is also developed from a variety of highly weathered rock materials, occurring extensively throughout the area while the Alaminos series has developed purely from basaltic rocks. This soil is covered by commercial and noncommercial forest. The open area is grassland. The cultivated areas are planted to upland rice, corn, diversified upland crops including root crops. There are also some fruit trees. A total of 666,655 ha of Annam silt loam, including gravelly phase, sandy clay loam, clay loam, and clay were mapped in the provinces of Quezon, Nueva Ecija, Kalinga-Apayao, Albay, Benguet, Bontoc, Camarines Sur, Ifugao, Ilocos Norte, La Union, Nueva Vizcaya, Pangasinan, Sorsogon, and Bohol (Fernandez et al. 1980).

3.3.3.7 Soils Underlain by Coarse Sand, with Gravels and Boulders, with Good Drainage

Tupi (Plate 2F), where this soil series was named after, is a municipality in the province of South Cotabato, nestled at the foot of dormant volcano, Mount Matutum, a volcanic cone formed by uplift during previous activities, dominated by pyroxene andesites. The municipality is considered the fruit, vegetable, and flower basket of the province. The name "tupi" is derived from a vine chewed by B'laan tribes who first inhabited the land. The soil is classified as *Typic Hapludands*. Tupi series is underlain by coarse sand, with gravels and boulders. Rather than Mount Apo, Tupi series is highly influenced by deposits from Mount Matutum and hence would be more similar in morphology to those soils influenced by Mount Pinatubo in Luzon island. This series is formed from basalts and andesites and influenced by volcanic ejecta. The relief is nearly flat to rolling. So this soil series also occurs in the lowlands. The external drainage is good to excessive while the internal drainage is good. The surface soil is light gray, fine sandy loam to sandy loam and silt loam, boulders are present as outcrops. Boundary to subsoil is smooth and clear. Depth is 15–30 cm. The subsoil is light yellowish brown to yellowish brown, structureless, friable but slightly compact fine sand. Depth is 55–70 cm. The substratum is light gray, slightly compact and friable coarse sand. Gravels and boulders are present which are light, soft, and porous (Mojica et al. 1963). A great portion of the Koronadal Valley is occupied by Tupi series, extends from Polomolok on the south to Marbel on the north; and from Matutum range on the east to the range of hills on the west, all in varying topographic conditions. The land cover is primary and secondary forest, cogon and other grasses and the cultivated areas are grown to sugarcane, fruit trees, and diversified upland crops. A total of 144,402 ha of Tupi sandy loam, silt loam, and loam were mapped in the provinces of Cotabato, Negros Occidental, Negros Oriental, and Romblon.

Basco soil series was first described in the municipality of Basco, province of Batanes. This town is named after Capitán General José Basco y Vargas, the 44th Governor General of the Philippines under the Spanish colonial rule who lead the Philippines to freedom from the control of the Viceroyalty of New Spain, which is Mexico today. Spain used to govern the Philippines from Mexico as part of the Spanish East Indies comprising of the Philippine Islands, Mariana Islands, the Caroline Islands, Taiwan, and parts of Moluccas. A *viceroy* in Mexico City governed the Philippines on behalf of the King of Spain. The Basco soil series is classified as *Typic Eutrudepts*. This soil series is derived mostly from basalts and andesites. The relief occurs on gently rolling to roughly rolling to hilly areas. The surface drainage is good while the subsoil is fair. The surface soil is very dark gray to almost black when moist; grayish brown to very dark gray when dry; loose, friable and granular sandy loam to loam with occasional coarse skeletons diffused wavy boundary to subsoil and depth ranges from 20 to 45 cm. The subsoil is gray to light grayish brown, loose, friable and granular loam with gravels. Some gravels are volcanic cinders. Boundary to next layer is clear and wavy. Permeability is moderate and the depth is from 60 to 80 cm from the surface. The substratum has alternating layers of slightly compact gravelly sandy loam and compact sand which are yellowish brown. The uppermost layer is slightly compact gravelly sandy loam 15–20 cm thick. The succeeding layers below are thicker than 20 cm. The sand layers are thicker than gravelly sandy loam (Simon et al. 1974). This soil series is principally grown to sugarcane, rootcrops, corn, upland rice, and fruit trees. The open areas are covered with cogon, Palo-maria trees (*Calophyllum inophylluym*), and shrubs. A total of 3,562 ha of Basco loam and loam-deep phase where mapped in the province of Batanes.

3.3.3.8 Soils Underlain by Weathering Rock Materials, with Good Drainage

Guimbalaon series (Plate 2C and Fig. B.8) was first described in barangay Guimbalaon, Silay City, province of Negros Occidental. This soil series was first described by Pendleton (1927, 1931) in his soil survey of Silay-Saravia area and La Carlota District. This soil series is classified as *Typic Hapludands*. The soils formed around the slopes of Mounts Mandalagan and Silay, including Kanlaon Volcano are generally of older alluviums of country rocks and washed-out materials from the upper slopes which developed into brown soils. These soils occur on varied topography from roughly rolling with steep slopes and deep gullies and ravines to gently rolling with those close to mountains more broken by gullies compared to those near the coastal alluvial soils. Both external and internal drainage are fair. On the other hand, the Guimbalaon soils east of Silay that have elevation of 150 m reaching to 305 m in the Araal on the western slope of the Kanlaon Volcano are made up of fairly matured soils developed from basalts and andesites. In some areas, the solum has a depth of more than 2 m while in other areas, the true soils are only about half a meter in depth. The parent materials exist as partially weathered rock fragments, brittle, coarse granular with concentric circles showing the degree and manner of weathering takes place in a rock. The surface soil is good, fine granular clay, loam to fine sandy loam; reddish brown to dark reddish brown and slightly sticky when wet, brown to dark brown and friable when dry. Boulders are occasionally present. The depth reaches down from 25 to 30 cm. The subsoil is reddish brown to dark reddish brown, good medium granular clay; slightly sticky when wet, friable when dry, and extends down from 65 to 70 cm. The substratum is brownish red, weathered, fragmentary rocks; soft to brittle. Boulders are sometimes present (Alicante 1951a). Guimbalaon series closely resembles Luisiana soils except for the presence of rock outcrops in Guimbalaon and the deeper and darker red soils of Luisiana. Guimbalaon also resembles Antipolo series but Antipolo series has a layer of tuffaceous materials below the subsoil. Guimbalaon also resembles Alaminos series but the Alaminos soils have well-developed profile and is deep with dark red brick color throughout the whole depth. Guimbalaon series are dark brown to reddish brown and contains concretions. Guimbalaon is also similar to Kidapawan series but the latter has gray sand far below the substratum. These soils are widely cultivated to upland rice, corn, and sugarcane. Parts close to mountain are forested with cogon growing on the grassland borders. Bamboos are abundant along the banks of creeks and gullies. A total of 311,481 ha of Guimbalaon sandy loam, loam, loam gravelly phase, clay loam, clay-loam-gravelly phase, clay loam-stony phase, clay loam-eroded phase, and clay have been mapped in the provinces of Negros Occidental, Negros Oriental, Isabela, Misamis Occidental, Nueva Vizcaya, Quezon, Leyte, Palawan, and Sulu. Additional 22,553 ha of Guimbalaon-Annam Complex were mapped in the provinces of Benguet and Nueva Viscaya.

3.3.4 Soils Developed from Predominantly Dioritic and Basalt Parent Materials

3.3.4.1 Soils Underlain by Fine Sand, with Gravels, with Good Drainage

Guimaras soil series was named after an island province in Western Visayas, formerly a sub-province of Iloilo until 1992. It was the fourth Spanish governor and captain-general of the Philippines, Gozalo Ronquillo de Penaloza (1580–1583) who established a settlement in Guimaras to Christianize the natives of the island (Wikipedia 2012a). This soil series is classified as *Typic Eutrudepts.* This soil series is developed from diorite and basaltic rocks. The relief is strongly rolling to hilly. So this soil series also occurs in hilly areas. The external drainage is excessive while internal drainage is good. The surface soil is brown to grayish brown, dark brown to black, structureless, gravelly loam; very friable when wet. Concretions are present, and depth ranges from 20 to 25 cm. The subsoil is light brown, slightly compact, structureless, fine sand. Concretions and gravels are numerous, and depth is from 75 to 80 cm. The substratum is dark brown, structureless, slightly compact, fine sand, few gravels are present (Alicante et al. 1947). The vegetation is generally second growth forest. The cultivated sections are planted to coconut and fruit trees. A total of 38,029 ha of Guimaras clay loam—gravelly phase and sandy clay loam were mapped in the provinces of Iloilo and Leyte.

3.3.5 Soils Developed from Undifferentiated Igneous Rock Parent Material

These are soils of the upland developed from hard igneous rock which could be either andesites or basalts.

3.3.5.1 Soils Underlain by Highly Weathered Rocks, with Good Drainage

Tapul series was first described in what was then a barrio of Puerto Princesa City, in the province of Palawan. But Tapul was renamed as Salvacion in 1957 and basically remains a rural barangay to these days. This series is a residual soils developed from igneous rocks of Pliocene-Quaternary origin. The relief is gently undulating to hilly. The external drainage is good and the internal drainage is fair. This soil series is classified as *Typic Hapludults.* The surface soil is reddish brown or dark reddish brown, grayish brown, dark brown to deep brown, good coarse granular clay loam; slightly sticky when wet, slightly hard when dry. This soil layer is rich in organic matter content. Boundary to subsoil is irregular and gradual. Depth is 20–50 cm. The upper subsoil is reddish brown to brown, coarse granular to almost moderately columnar clay; sticky when wet, hard and compact when dry. This layer is fair in organic matter content. Boundary to lower layer is wavy and diffused. Depth is 55–70 cm. The lower subsoil is dark brown, columnar to massive clay; sticky when wet, hard and compact when dry, poor in organic matter content. Boundary to substratum is irregular and abrupt. Depth is 95–110 cm. The substratum is gray, light yellowish brown to light yellowish gray, massive, hard and compact, highly weathered igneous rocks most likely diorite (Barrera et al. 1960). The soil cover is generally thick growth of virgin forest and secondary forest. The cultivated areas are planted to upland rice, corn, and diversified upland crops. A total of 56,171 ha of Tapul clay loam and clay were mapped in Palawan and Sulu provinces (Fig. 3.11).

Fig. 3.11 Soil profile of Tapul series taken in Narra, Palawan

3.3.5.2 Soils Underlain by Clay, with Good Drainage

Baliangao series was first described in the municipality of Baliangao, on the northern part of Misamis Occidental. This soil series is classified as *Typic Hapludults*. This soil series is primary derived from igneous rocks. Its relief occupies the nearly level to slightly undulating areas. The surface soil is reddish brown to dark brown granular and friable clay loam with a depth of 20–30 cm from the surface. The subsoil is brown to reddish brown clay. It is prismatic, plastic when wet, brittle and hard when dry. Depth is 70–90 cm from the surface. The substratum is brown clay and massive. The depth is from 90 to over 150 cm (Sindayen et al. 1970). The surface drainage is poor while internal drainage is fair. This soil series is generally grown to coconut, upland rice, corn, vegetables, and fruit trees. A total of 903 ha of Baliangao clay loam were mapped in Misamis Occidental.

Buldun series was first described in the municipality of Buldon, what is now the province of Maguindanao, and classified as *Typic Hapludults*. This soil series is dark, very friable, and loose. This soil series is very similar to Langkong but Buldun has heavier texture of the substratum while that of Langkong is light to moderate. This is a residual soil from igneous rock and influenced by volcanic ejecta. The surface soil, with depth varying from 15 to 20 cm from the surface, is dark brown, very friable, loose, and granular sandy loam. The upper subsoil, with depth reaching down from 25 to 30 cm is reddish brown to brown, slightly compact friable clay. The lower subsoil reaches down from 75 to 80 cm is reddish brown, soft, sticky and plastic clay. The substratum that reaches down to the control section is reddish brown to yellowish brown friable clay (Mojica et al. 1963). The drainage is good. Almost the whole area is cultivated and upland rice is the principal crop. Corn and other diversified upland crops are also grown. The native vegetation is primary forest of mixed species. Durian grows luxuriantly in the area. Buldun sandy loam covers 5,625 ha in Maguindanao province.

3.3.5.3 Soils Underlain by Silty Clay Loam, with Good Drainage

Langkong series was first described in barangay Langkong, municipality of Matanog, what is now province of Maguindanao but used to be part of Cotabato province. It should not be mistaken from another barangay also named Langkong in the municipality of M'lang, province of what is now North Cotabato. Langkong soil series is mapped along what used to be the Cotabato-Lanao boundary on the northwest corner, from Lake Baranibud on the east, moving southwest to Mount Cabugao, and to Bugasan at Matimus Point in the west. This soil series is of volcanic origin, mainly volcanic sand. The soil series is classified as *Typic Hapludults*. The surface soil is 15–20 cm thick, dark grayish brown to very dark brown loose, mellow, and crumbly sandy loam. The subsoil, extending from 35 to 45 cm down, is almost the same as the surface soil but of denser materials. The substratum, reaching down to the control section at 150 cm is reddish brown to dark brown, prismatic and plastic silty clay loam to silt loam that breaks easily into granules. The drainage is good. The Langkong soil series is associated with Buldun soils and in fact, adjacent to each other. But Buldun has heavier substratum (Mojica et al. 1963). This soil series is usually covered by forest but *kaingin* (slash-burn agriculture) are found scattered. Where cultivation has marked the land, abaca, coffee, and banana grow well. We also find vegetables, upland rice, and corn. Among the fruits, durian is very common. Langkong sandy loam covers an area of 27,500 ha in Maguindanao.

3.3.6 Soils Developed from Conglomerates/ Agglomerates Parent Material

3.3.6.1 Soils Underlain by Loam to Clay Loam, with Rock Fragments, with Good Drainage

Alaminos soil series (Plate 2A) was first described in the city of Alaminos in the province of Pangasinan and in fact, the largest of the soil groups in the western part of the province. This soil series is classified as *Typical Hapludults.* This soil series is a residual soils derived from volcanic rocks. The relief occurs on rolling to hilly with level areas, and thus would be expected also to occur in lowlands and in hilly and mountain areas. The drainage is good to excessive and soil dries after heavy rains. The distinguishing characteristics of this soil is its color which ranges from pale reddish brown, reddish brown, to brick red; and its considerable depth with no defined horizon from the surface down to the substratum. The gravel and iron concretions vary with depth. The physical characteristics are almost uniform from the surface down to the underlying parent materials which consist of limestone, basalts, conglomerates, and other volcanic rocks. In many places, cobblestones of basalt rocks are abundant in the surface soil. The soil cracks easily on drying. When wet, it is sticky but dries so quickly that plowing is possible within a few hours after a heavy rain. The soil is very friable and water percolates easily. This is a typical red loam soil in the Philippines. The surface soil is pale reddish brown, reddish brown to brick red, friable and loose loam to clay loam. Iron concretions are present. Depth is 20–35 cm. Outcrops present. The subsoil is almost the same color as the surface soil. It is loose and friable clay loam. Depth is 40–100 cm from the surface. Concretions present. And the substratum is almost the same characteristics as the above horizons, but with the presence of highly weathered basalts and andesites. Iron concretions present (Alicante et al. 1940a). The cultivated areas are planted to upland rice, corn, maguey (*Agave cantala, Roxb*.), coconut, vegetables, root crops, and some fruit trees. The uncultivated rolling and level areas are grasslands. The hill and mountain areas are primary and secondary forest. A total of 428,090 ha of Alaminos undifferentiated, sandy loam, loam, loam-degraded phase, clay loam, silty clay loam, and clay were mapped in the provinces of Pangasinan, Zambales, Cagayan, Kalinga-Apayao, Isabela, Mindoro, Nueva Viscaya, Camarines Norte, and Quezon. Additional 159,000 ha of Alaminos-Antipolo Complex were mapped in Zamboanga del Sur (Fernandez et al. 1980).

Boac series was first delineated in the municipality of Boac, province of Marinduque. Boac was derived from the Tagalog word *biak* which means divided, referring to the river that divides the municipality running from the eastern hinterland and comes down to the western plains to drain into the sea. This soil series is classified as *Typic Eutrudepts.* The relief is undulating to slightly rolling with good drainage conditions. The surface soil is pale brown to dark brown, medium granular clay loam, with occasional presence of pebbles, depth ranging from 20 to 25 cm. The subsoil is brown to grayish brown, clay loam with partially weathered conglomerates and reaching down to a depth from 65 to 70 cm. The substratum is yellowish brown silty clay loam with numerous gravels, pebbles, and stones; boulders are present in some places (Salazar et al. 1962). This is considered an agriculturally important soil as the greater part is under cultivation, with coconut as the most important. The soil series is also planted to corn, and various fruit trees—mangoes, jackfruit, tamarind, chico, caimito, and santol. A total of 5,950 ha of Boac clay loam and clay were mapped in the provinces of Marinduque, Lanao, and Quezon.

3.3.6.2 Soils Underlain by Clay, and Rests on Highly Weathered Sandstone and Tuff, with Good Drainage

Casiguran series is classified as *Typic Hapludults*. It was first described in the municipality of Casiguran, province of Sorsogon, and in fact, one of the extensive soil series of the province. This is a primary soil developed in place from the weathered products of volcanic massive rocks, mainly agglomerate, tuff, andesite, and basalt. This soil occurs on rolling to hilly relief, with good to excessive surface drainage and fair internal drainage. The surface layer has a grayish black to reddish brown clay loam, with coarse skeleton in areas along rivers, and with depth ranging from 45 to 60 cm. The upper subsoil is dark brown, reddish brown, to strong brown coarse granular to columnar, moderately compact clay, with coarse skeletons occasionally present, and extending down from 65 to 80 cm. The lower subsoil is dark brown, reddish brown, to reddish yellow coarse columnar clay with dark olive mottlings, reaching down from 110 to 120 cm from the surface. The substratum is reddish yellow to reddish brown, coarse granular clay with yellow and black specks. This layer rests on highly weathered sandstone and tuff (Aristorenas et al. 1963). The vegetation is usually second growth forest and cogon. The cultivated areas are planted to coconut, abaca, upland rice, and other crops. About 38,120 ha of Casiguran clay loam were mapped in Sorsogon.

3.4 Soils that Developed from Sedimentary Rocks

Sedimentary rocks, as its name implies, are rocks formed from sediments deposited in layers over time usually at ocean and lake bottoms. Sediments can come in the form of tiny pieces of other rocks, from dead animals, plants, and microorganisms. Sediments precipitated inorganic chemicals. These are formed by weathering of other rocks, transported, and deposited. The cementation takes place when dissolved minerals deposit in the interstices of the sediments.

3.4.1 The Limestone Soils of the Philippines

Limestone is a chemical type of sedimentary rock composed mostly of the mineral calcite or calcium carbonate. Its metamorphic rock equivalent when subjected to very high temperature and pressure is marble. Limestone rocks are rather dense and easy to work with. An example is chalk teachers use to explain the day's lessons to their students. Limestone rock is also commonly used as a building decoration, especially in the façade of houses, churches, and banks.

As an archipelago, it is not unusual that there are many islands in the country or parts of the islands of coralline limestone origin. Limestone is a sedimentary rock composed primarily of calcium carbonate ($CaCO_3$) in the form of the mineral calcite. It is usually an organic sedimentary rock that forms from the accumulation of shells, corals, algal and fecal debris. It can also be a chemical sedimentary rock formed by the precipitation of calcium carbonate from the lake or ocean water. When the sea bottom rises, a coral reef or atoll may be lifted out of the water making a raised coral island with a platform or old reef and lagoon, several meters above sea level.

Karst topography is a geologic formation shaped by the dissolution of layers of carbonate rocks such as limestone or dolomite. Karst topography is characterized by subterranean limestone caverns, carved by groundwater. The word originated from Germanicised "kras" when geographer Jovan Cvijic (1865–1927) described the Dinaric Kras region in Slovenia which later on is applied to dissolutional landforms and aquifers (New World Encyclopedia 2011).

Fig. 3.12 A limestone mountain in Manukan, Zamboanga del Norte planted to coconut. The limestone soils that developed are classified according to *color*, not according to the usual nature of the underlying subsoil. Limestone formations are characterized by rounded peaks and foothills

Soils that developed from limestone are generally high in calcium, shallow, and have a rather limited type of plants that can be grown successfully. These soils are also called calcareous soils. Limestone and calcium-rich sedimentary rock soils generally have high pH because of the presence of free calcium and magnesium carbonates, especially as we go down the soil profile. High soil pH is associated with limiting availability of phosphorus, boron, manganese, and zinc which could result to nutrient imbalance for the crop we are growing. Soils tend to be finer in texture than the non-calcareous soils and hence tend to be more susceptible to compaction (for the clayey soils) and erosion (for the silty soils). Soil disturbances such as cultivation practices may intensify the adverse condition (Fig. 3.12).

Asio et al. (2006) studying the Quaternary limestone in Leyte province found the soils of the upper slopes (summit, shoulder, and upper backslope) to have thin solum, black surface horizon, clayey texture, granular structure, high organic matter, nitrogen, calcium, and calcium carbonate contents but low in phosphorus, potassium, iron, manganese, boron. The soils of the lower footslopes (footslope and middle and lower backslopes) have thicker solum, higher clay content, subangular blocky structures that turn hard when dry and become plastic and sticky when wet. They also have neutral to strongly alkaline pH values, high organic matter, nitrogen, calcium, calcium carbonate contents but are generally low in phosphorus, potassium, iron, manganese, and boron. It was stressed that soil management should be based on holistic approach rather than on being focused to physical and chemical constraints (Asio et al. 2006).

Soils that developed from the weathering of coralline limestones are classified based on soil color and the underlying limestone rock, irrespective of their landscape position and land management unit. These limestone soil concepts do not follow the usual substratum characterization.

3.4.1.1 Brown to Red Colored Soils, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Generally, we have the *Bolinao* and the *Sibul* series. The Bolinao soils have the characteristics of the dark or black-colored Faraon series except for the soil color and the consistency of the bedrock. The Bolinao soils are red or dark reddish brown or chocolate brown and the bedrocks are harder and whiter than those of the black-colored soils of the Faraon series. Sibul is more associated with deeper clayey soils of volcanic hilly landscapes and slightly clayey gravelly series of the conglomeratic and agglomeratic ridges and hills. Sibul series is characterized by the underlying massive lime rock. Limestone soils are expected to occur in lowland, upland, hillyland, and mountain landscapes.

Bolinao series (Plate 2B and Fig. B.4) is classified as *Typic Hapludalfs* and a primary soils developed in place from the weathered products of coralline limestone. These soils are grouped under the red soils of the Philippines. These soils are found on mildly rolling to rolling to hilly and mountainous areas, with some level areas. Thus, we could expect these soils to occur not only on the plains but on undulating, rolling, and hilly to mountainous areas. When found on lowlands, these soils usually occupy solutional depressions or sinkholes. The internal drainage is poor but the external drainage is from good to excessive. The surface soil is reddish brown to chocolate brown to almost red, fine granular and compact clay, limestones are present, and reach down to 20–35 cm. The subsoil is brownish gray to light reddish brown, fine granular and compact clay. Presence of limestone gravels and weathered limestone rocks can be observed. The depth is 40–80 cm from the surface. The upper substratum is reddish brown weathered limestone rock and the lower substratum is hard limestone rock (Alicante et al. 1940a). It was first identified in the municipality of Bolinao, province of Pangasinan. It is significant that on November 18, 2007, Bolinao challenged the historical claim that the first Catholic mass in the Philippines was held on March 31, 1521 at Limasawa in Southern Leyte by claiming that in 1324, Franciscan missionaries led by an Italian priest named Odorico celebrated a thanksgiving mass on Santiago Island off the coast of Bolinao and baptized the natives (Wikipedia 2012d). The uncultivated areas are generally covered by cogon, primary and secondary forest while the cultivate areas are planted to rice, corn, coconut, fruit trees, vegetables, bananas, and root crops. A total of 843,352 ha of various Bolinao soil types—silt loam, loam, clay loam with deep phase, silty clay loam, clay, and clay with steep phase were mapped not only in the province of Pangasinan but also in Agusan, Ilocos Norte,

Fig. 3.13 Landscape view where Bolinao series occurs in Calayan, Cagayan

Sulu, Batanes, Cagayan, Kalinga-Apayo, Lanao, Mindoro, Nueva Vizcaya, Quezon, Surigao, Zamboanga del Sur, Zamboanga del Norte, Mindoro, Abra, Bohol, Bukidnon, Cebu, Davao, La Union, Leyte, Marinduque, Masbate, Misamis Oriental, Negros Occidental, Negros Oriental, Palawan, Samar, and Sorsogon (Fernandez et al. 1980) (Fig. 3.13).

Sibul series (Plate 2F) is classified as fine mixed, *Typic Eutrudepts* and are considered residual soils of limestone origin. Sibul, where this soil series was named after, is a barangay of the municipality of San Miguel, Bulacan. This San Miguel municipality has the historic solutional cave known as Biak-na-bato (meaning Split Rock) that came to prominence during the revolution against Spain being the headquarter of the first Philippine Republic. Then Spanish Colonial Governor General in the Philippines, Fernando Primo de Rivera, signed a truce with the revolutionary government president Emilio Aguinaldo to end the Philippine Revolution. Aguinaldo and the revolutionary leadership went into a voluntary exile in Hongkong (Wikipedia 2012e). Sibul series occurs on level to hilly land and can be expected to be found also on lowland areas. The Sibul series consists of moderately deep well-drained fine clayey soils that occur on sloping to rolling moderately dissected rounded limestone foothills or on very steep limestone hills and ridges of the hilly landscape. When occurring on the lowland pedoecological zones, these are usually found on lower terraces of karst plains. The surface soil of Sibul series is brown to light grayish brown, dark brown to dark gray clay with whitish to dark brown concretions, reaching down from 20 to 30 cm from the surface. The upper argillic subsoil is dull brown to dull grayish brown, dark brown to dark gray, compact, coarse granular to blocky clay with calcareous materials. Depth is from 40 to 50 cm. The lower subsoil is light gray, friable, coarse granular, columnar to blocky gray with calcareous materials, and with depth reaching down from 60 to 70 m. The substratum is whitish gray or light brown, light gray to gray, clay with whitish to white specks of limestone concretions and highly weathered calcareous and tuffaceous materials (Soil Survey Division 1987b). Various species of shrubs, grasses, and trees grow on uncultivated areas while the cultivated soils are planted top rice and corn. Various textural types of Sibul series—loam, clay loam, and clay were mapped in the provinces of Bulacan, Batangas, Sulu, Nueva Ecija, Nueva Vizcaya, and Palawan totaling 195,260 ha. It should be noted that in the semi-detailed resurvey of the Sibul series in Bulacan, the original 40,680 ha of Sibul undifferentiated was down to 29,544 ha of Sibul clay and hence, the revised estimate for the extent of Sibul series in the country stands at 184,124 ha. The difference were either mapped as new soil series or converted to urban areas.

3.4.1.2 Black or Dark Colored Soils, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Binangonan and *Faraon* are underlain by a bed of soft and calcareous rock; white for Binangonan and colored for Faraon. Faraon is also characterized by good drainage and absence of redoximorphic features. *Batuan* series is underlain by hard nearly white calcareous rock. *Medellin* series is underlain by gravelly clay with gravels consisting of undecomposed limestone which resist weathering; further down the substratum is grayish partially weathered limestone bedrock, sometimes mixed with weathered shale.

Binangonan series is developed from alluvium of volcanic and limestone origin. It is a member of the very fine, montmorillonitic, isohyperthermic family of *Aeric Epiaquerts*. Binangonan, where this soil series was first described, is now an urbanizing municipality of the province of Rizal. The soil has good to excessive external drainage on rolling and mountainous areas and poor internal drainage. While on the valleys and level areas drainage conditions are poor. The surface soil is dark brown to nearly black clay, stiff and cloddy when dry but sticky when wet, with depth ranging from 40 to 50 cm from the surface. The upper subsoil is light brownish black clay which becomes lighter in the lower subsoil and containing whitish calcareous from the surface. Usually a bed of stratified soft calcareous rock of nearly white in color is found in the substratum. Its upper portion is highly weathered limestone rocks (Soil Survey Division 1989). Rice is the principal crop in cultivated valleys while in the rolling and mountainous areas is cogonal and forest. A total of 20,730 ha of Binangonan clay and Binangonan clay lowland phase were mapped in the provinces of Abra and Rizal. The 1989 semi-detailed soil survey of Rizal province had 1,340 ha of Binangonan clay, down from the reconnaissance survey of mapped 17,550 ha. Thus, the Binangonan series is estimated now at 4,520 ha for the whole country. The decrease in hectarage is attributed to urban expansion and also due to the reclassification to other soil series.

Batuan series (Plate 2B) is classified as *Aquic Argiudolls*. It is black and heavy clay soil developed from limestone. Batuan differs from Faraon series in topographic occurrence, in depth, and in the absence of outcrops or erosion pavements. Batuan has more level relief, deeper, and has no rock outcrops compared to Faraon series. Drainage is poor. The soil was first described in the central municipality of Batuan, the island province of Bohol, covering an extensive undulating to flat land in the middle portion of the province between the "haycock" hills. A great portion of the area is classed under the Batuan–Faraon Complex. The relief is nearly level to undulating plateau, and thus, this soil series would also be expected to occur on lowland areas. It covers an extensive undulating to flat land in the middle portion of the island province of Bohol. The soil is derived mainly from the underlying calcareous shales and sandstones, and from the hills found all over the area. The drainage is impeded due to the impervious rock beneath the soil which prevents water percolation. In undulating portion, the bedrock is exposed in places where water has eroded the shallow soil. The surface soil reaches down to 20 cm, dark brown to grayish brown when dry and black when wet, heavy clay. The subsurface extends down to 40 cm, brown to light brown, columnar, plastic and sticky clay. The substratum is hard white and compact coralline limestone rock (Bureau of Soil Conservation 1952). This soil series is mostly cultivated and grown to rice, corn, banana, sugarcane, coconut, fruit trees, and vegetables. A total of 24,782 ha of Batuan loam including the gravelly phase, clay loam, and clay were mapped in the provinces of Bohol, Lanao, Negros Occidental, and Negros Oriental. Additional 47,765 ha of Batuan-Faraon complex was delineated in the province of Bohol.

Medellin series (Plate 2D) was first mapped in the municipality of Medellin, on the northern part of the island province of Cebu; with small areas of this soil series distributed in Talisay, Oslob, and Pacijan Island on flat to gently undulating upland. The municipality name is traced to that of Medellin, the second largest city of Columbia founded in 1616; also to that of Medellin, a village in the province of Badajoz, Extremadura, Spain and named after Roman General Quintus Caecilius Metellus Pius who established it as Metellinum in 75 BC as a military base during the Sertorian War. Medellin, Cebu became a municipality by virtue of a royal decree promulgated by Queen Isabel of Spain in 1881 (Wikipedia 2012c). Medellin series is classified as *Typic Eutrudepts*. The soil is very poor in drainage condition. Medellin soils developed from parent materials derived from limestone with occasional shale rocks. The limestone appears as a mass of soft and crumbled material and the shale rocks are soft and easily pulverized. There are no outcrops on the surface. The surface soil is black to very dark brownish gray, fine clay, non-calcareous, ranging in depth from 25 to 30 cm, no rock nor stone outcrops. The subsoil is blackish-brown or very dark brown heavy clay, non-calcareous, no rock or any coarse skeleton in this layer, with depth ranging from 55 to 60 cm. The upper substratum is grayish brown, good medium blocky to columnar clay, non-calcareous, with depth reaching down from 135 to 140 cm. The lower substratum is gray, coarse gravelly clay with undecomposed limestone gravels that resist weathering, calcareous and slightly alkaline. Farther down the substratum is a grayish partially weathered bedrock consisting of highly disintegrated limestone. Weathered shales are sometimes mixed with the limestone rocks (Barrera et al. 1954). Cogon and shrubs are normally found in this soil series, and the cultivated areas are grown to corn and coconut. Medellin soil is found on the northern part of Cebu, from flat to gently undulating upland with an aggregate size of 7,710 ha.

3.4.1.3 Black or Dark Colored Soils, with Good Drainage

Faraon series is underlain by weathered limestone rocks. *Lugo* is underlain by silty clay resting on calcareous shale. *Inabanga* is underlain by highly weathered calcareous rock and almost similar to Lugo in soil color, texture, and relief except for the presence of concretions in the Inabanga soil series. *Sevilla* series is also much like Lugo in many ways except for the presence of limestone gravels in Sevilla.

Faraon series (Plate 2C and Fig. B.7) is classified as fine, isohyperthermic *Lithic Rendolls* and derived from the decomposition of soft coralline limestone. This soil series was first mapped in Faraon Hacienda, barangay Cabahug, Cadiz City, Negros Occidental. This soil series occurs on rolling to hilly relief; and thus, these soils are also found on the hilly and mountainous areas. The internal drainage is fair owing to varied pores which the limestone naturally contains. Soils of the Faraon series are black and usually clayey. When the land is highly eroded, the parent rocks become exposed giving the appearance of being rocky. In extreme cases of erosion, the land cannot be plowed because of the exposed rocks. But compared to those of other soil series of similar limestone parent materials, the limestone rocks in Faraon series are soft, roughly angular, and oftentimes colored. The surface soil is black, gray to dark gray clay to sandy loam. Limestone rocks are sometimes found on the surface. Depth is 15–30 cm from the surface. The subsoil is dark yellowish gray to light gray, grayish black to dark gray coarse to moderate fine clay. Partially weathered limestone rocks are present. Depth is from 35 to 45 cm. The substratum is yellowish gray, soft and weak coarse granular highly weathered limestone rocks, reaching down from 60 to 60 cm. The lower portion is grayish to white porous soft and friable limestone rocks (Alicante 1951a). This series differs from Binangonan or Sibul series in that the limestone rocks in these latter two are hard, massive, and white. These soils are generally covered by primary and secondary forest. Where cultivated, the principal crops are rice and corn. Faraon series is rather extensive in the country, a total of 1,012,836 ha of various types of Faraon series—sandy loam, clay loam, clay, and clay-steep phase were mapped besides Negros Occidental, in the provinces of Negros Oriental, Zamboanga del Norte, Zamboanga del Sur, Ilocos Norte, Palawan, Albay, Batanes, Bohol, Bukidnon, Cagayan, Camarines Sur, Capiz-Aklan, Cebu, Cotabato, Davao, Iloilo, Lanao, Marinduque, Masbate, Misamis Oriental, Nueva Vizcaya, Quezon, Samar, and Leyte (Fernandez et al. 1980).

Lugo series (Fig. B.10) was first described on the northern part of Cebu, originally a barrio bearing the name. Today, Lugo is a barangay of Borbon municipality, Cebu province. This soil series is classified as *Typic Eutrudepts.* Lugo series are upland soils with a characteristically rolling to roughly rolling hilly areas dissected by many gullies, creeks, and rivers. The area must have been once level plain referred as *mesetas,* meaning table land or highland plateau; however, accelerated erosion has greatly scoured the land into its present condition. These *mesetas* are not really flat table lands but rather roughly rolling to almost hilly in topography that range in elevation from 76 to 177 m above sea level for areas between Carcar and Barili and from 91 to 213 m for areas between Lugo and Bogo. In general, this soil series has a rough terrain owing to the numerous gullies, streams, and creeks which cut the surface. The drainage is good. Lugo series is residual soils developed from shale rocks, referred to by geologists as the Barili limy clay. The shale rocks are calcareous or highly impregnated with carbonates. Limestone rock is not found in this soil series. The shale rock is soft, white to grayish white, stratified materials laid in horizontal layers. There are no stones on the surface nor in the deeper layers of the profile. Outcrops of limestone rocks maybe observed near the boundaries with the Faraon soil series; and highly eroded areas may show gravels of limy shale rocks. The surface soil is black to dark gray; medium to fine granular clay; sticky and strongly plastic when wet, slightly friable when almost dry. Fairly rich in organic content. The boundary to subsoil is smooth and diffused. Depth is 15–20 cm. The subsoil is dark brown to yellowish brown, good coarse granular clay; slightly friable when dry, strongly plastic when wet. The boundary to substratum is abrupt and smooth. Depth is 30–35 cm. The substratum is grayish brown silty clay; strongly gritty and weak coarse platy. Limy consolidated shale rocks are present (Barrera et al. 1954). The vegetation is mainly secondary growth forest and cogon. The cultivated areas are planted to corn, coconut, tobacco, sugarcane, bananas, and fruit trees. A total of 171,649 ha of Lugo clay loam and clay were delineated in the provinces of Cebu, Samar, Bohol, Leyte, Mindoro, and Negros Oriental (Fernandez et al. 1980).

Inabanga series is developed from calcareous sandstone and shale and classified as *Typic Eutrudepts.* The soil series was first described in Inabanga municipality, province of Bohol. The drainage is good. The soils occupy rolling to hilly topography and would be expected to occur also on hills and mountains. The surface soil, reaching down to a depth of 15–25 cm, is brown to dark brown, fine granular, friable clay. Few gravels are present. The subsoil is 25–45 cm from the surface, reddish brown to brown, structureless, gravelly clay. Iron concretions are present. The substratum is pale yellow, highly weathered calcareous rocks mixed with small amount of clay (Bureau of Soil Conservation 1952). The uncultivated areas are covered by cogon and shrubs while the cultivated areas are grown to rice, corn, root crops, and banana. A total of 470 ha of Inabanga clay were mapped in the island province of Bohol occupying the rolling to hilly topography between the town of Inabanga and Clarin. The Lugo and Inabanga soils are similar in color, texture, and relief but Inabanga has concretions while Lugo has none.

Sevilla series (Plate 2F) is classified as *Typic Eutrudepts* and first described in the municipality of Sevilla, province of Bohol. In the island province, this series covers an extensive rolling to hilly area from Loay on the southern coast to Loboc, northward to Sevilla, to the middle part. This soil series is also found in other provinces, along the coast which are geologically of sedimentary rock formation. The relief ranges from flat upland to gently rolling and hilly to mountainous with characteristic narrow valleys dissected by intermittent streams and ravines. Surface drainage is good to excessive, internal drainage is good. Sevilla series is like Lugo soils, derived from the underlying calcareous sandstone and shale. Both are very much alike in external and internal characteristics except for the presence of limestone gravels in Sevilla. The surface soil is dark brown to almost black, slightly compact, waxy and granular clay, some calcareous gravels and cobblestones are present, depth extends down from 45 to 55 cm. The subsoil is yellowish brown to brown, granular and sticky clay, with limestone gravels, depth reaching down from 85 to 100 cm. The substratum is yellowish brown, sticky clay, mixed with considerable amount of limestone gravels and fragments of calcareous sandstone and shale, depth reaching down even beyond the control section at 150 cm (Bureau of Soil Conservation 1952). The uncultivated areas are covered by cogon and second growth forest while the cultivated areas are planted to rice, corn, coconut, root crops, vegetables, and bananas. A total of 193,842 ha of Sevilla sandy clay loam, clay loam, clay loam—stony phase, and clay were mapped in the provinces of Abra, Nueva Vizcaya, Quezon, Sulu, Albay, Bohol, Masbate, and Sorsogon (Fernandez et al. 1980).

3.4.2 Soils Developed from Shale Parent Material

Shale is a fine-grained clastic sedimentary rock composed of mud that is a mix of clay minerals and other minerals like quartz and calcite.

3.4.2.1 Soils Underlain by Shale, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Cabantian series soil is derived from soft shale. This soil series was first described in Cabantian, one of the barangays of the district of Buhangin, Davao City, on the north and northwest. This soil series is classified as *Typic Eutrudepts.* The relief occupies the undulating to hilly areas, with elevation ranging from 60 to 150 m above sea level. This soil series can also be found on hills and mountains. The surface drainage is free but the internal drainage is poor because of the heavy yellowish brown to red surface soil and subsoil, its most distinguishing characteristics. The soil series originated from soft shales with admixtures of water-worn gravels and pebbles. The surface soil is grayish brown, brown to reddish brown, medium blocky clay; sticky and plastic when moist, hard when dry, extending down 15–18 cm. The subsoil is yellowish brown to reddish brown, clay; plastic and sticky when wet, nutty or blocky and brittle when dry, with depth from 40 to 50 cm. The substratum is highly to partially weathered shale, about 75–85 cm in depth from the surface. Below is light gray yellowish brown to yellow, shale with occasional water-worn gravels (Mariano et al. 1953). The vegetation cover are grasses and second growth forest while the cultivated areas are planted to abaca, corn, coconut, banana, root crops, and fruit trees. About 30,303 ha of Cabantian clay were mapped in the provinces of Davao (Figs. 3.14, 3.15).

Fig. 3.14 Soil profile of Cabantian series

Fig. 3.15 Landscape view where Cabantian series developed in San Isidro, Davao Oriental

Bantay series (Plate 2A) is classified as *Typic Eutrustepts* and was first described in the vicinity of the municipality of Bantay, province of Ilocos Sur. It comprises the low hills scattered at random on the plain and foothills of the northeastern part of the province. The topography is undulating to rolling and the elevation ranges from 100 to 385 m above sea level. This soil series is expected to occur also on hills and mountains. The external drainage is free to excessive while the internal drainage is poor because of the massive shale substratum. Like Bauang series, Bantay series developed from parent materials that originated from Tertiary sediments of shale with some mixtures of coralline limestone s. The soils of this series consist of light brown to brown surface soil, friable fine granular loam to clay loam that grades into a light yellowish brown nutty and brittle clay loam. The lower subsoil is a zone of highly weathered shale which has a tendency to break into cubes, with some concretion-like pellets of grayish while lime precipitate. The substratum is a dense mass of yellowish very light brown shale of variable thickness (Mariano et al. 1954). A few gravels and pebbles are sometimes imbedded in this layer in some places. The vegetation is grasses and second growth forest, bamboo (*Bambusa* sp.), and boho (*Schizostachvum textorium, Blanco*) while the cultivated areas are planted to sugarcane, rice, corn, root crops, maguey, and vegetables. About 15,528 ha of Bantay loam were mapped in Ilocos Sur.

Maasin soil series is classified as *Typic Paleudults* and was first described in Maasin City, the provincial capital of Southern Leyte. It is residual soils developed from shale. It occurs on rolling to somewhat hilly relief and could also be expected to be found on hills and mountains. The drainage condition is excessive externally but poor internally. The surface soil is dark brown to reddish brown, good coarse granular clay to clay loam, sticky to moderately plastic when wet, slightly friable to compact when dry, with depth ranging from 10 to 25 cm from the surface. The upper subsoil is light brown, good coarse granular clay to clay loam, sticky to moderately plastic when wet, slightly friable to compact when dry, with depth ranging from 45 to 55 cm. The lower subsoil is light yellowish brown, massive clay with dark red streaks, moderately sticky when wet, hard to compact when dry. Limestone rocks are sometimes present, and depth is from 85 to 90 cm from the surface. The substratum is grayish brown, massive, very hard and compact, highly weathered shales with red streaks developing into clay loam or silty clay (Barrera et al. 1954). The uncultivated areas are generally cogonal while the cultivated areas are planted to upland rice, corn, banana, coconutV, fruit trees, and vegetables. About 58,783 ha of Maasin clay were mapped in Leyte provinces.

3.4.2.2 Soils Underlain by Shale, with Good Drainage

Kudarangan series (Plate 2C) is developed mainly from shale. It was first described in Kudarangan Hills between Midsayap and Dulawan in Cotabato province. This soil series is classified as *Typic Hapludults*. Its relief is rolling to steep. The drainage is excessive externally but fair internally. The surface soil is dark gray to almost black or dark reddish brown, friable and granular clay with a good root penetration; plastic and sticky when wet, hard when dry; the depth is from 10 to 15 cm. The upper subsoil is grayish to reddish brown, coarse granular clay; plastic and sticky when wet, hard when dry. Roots penetrate up to a depth of 35 cm. The boundary to lower layer is diffused and smooth, depth is from 75 to 80 cm. The lower subsoil is grayish brown or reddish brown, plastic, coarse granular clay with orange and rust-brown mottling. Depth is from 105 to 110 cm. The substratum is soft shale or sandstone either calcareous or non-calcareous (Mojica et al. 1963). These soil series is mostly grassland with secondary forst. The cultivated areas are grown to rice, abaca, corn, coconuts, vegetables, and fruit trees. A total of 61,171 ha of Kudarangan clay were mapped in Cotabato and Lanao provinces.

3.4.2.3 Soils Underlain by Clay to Clay Loam with Weathered Shale Fragments, with Poor Drainage and Presence of Redoximorphic Features

New Iloilo soil series (Plate 2E) was named after barangay New Iloilo, in the municipality of Tantangan in what is now South Cotabato where it was first described. This soil series is classified as *Typic Eutrudepts.* This soil series developed on consolidated sedimentary rock, shales and sandstones, but predominantly shale. The relief is rolling to hilly. The surface soil is brown to dark brown, structureless and friable, fine sandy loam. Roots penetrate easily. The boundary to subsoil is gradual and smooth, 10–15 cm in depth. The upper subsoil is brown to grayish brown, gritty, granular, plastic and sticky clay. The boundary to lower layer is diffused and wavy, 35–45 cm in depth. The lower subsoil is gray to brownish gray, granular, plastic and very sticky clay. The boundary to substratum is clear and wavy, 95–100 cm in depth. The substratum is brownish gray, plastic and sticky clay with limestone gravels which are brown when wet, but turns to white or gray upon drying (Mojica et al. 1963). The external drainage is good while the internal drainage is poor. The uncultivated areas are covered by grasses and second growth forest while the cultivated areas have rice as the principal crop. About 6,875 ha of New Iloilo sandy loam were mapped in Cotabato provinces.

Madunga series is classified as *Typic Hapludults*. This soil series was named after Madunga City in Davao del Sur. These are primary soils developed from parent materials originating from shale and thick deposits of sand, gravel, and pebbles. The soils are found on moderately rolling to hilly topography with elevation ranging from 150 to 300 m above mean sea level. These soils would also be expected to occur on hills and mountains. The internal drainage is fair to poor. The soils of these series consists of grayish brown to brown clay surface soils underlain by yellowish brown to light brown clay subsoils. The surface soil reaches down to a depth of 15 cm. The upper subsoil is yellowish brown to light brown clay of medium to hard consistence and fine to medium nutty structure and reaches to a depth of 45–50 cm. The lower subsoil is yellowish brown to gray loam with plenty of fine gravels. There is a little amount of partially weathered shale in this layer in some places. This layer reaches down to 100 cm from the surface. The substratum is light grayish brown gravelly clay which is compact and hard when dry (Mariano et al. 1953). The uncultivated areas are mostly second growth forest and grassland while the cultivated areas

Fig. 3.16 Profile of Madunga series

are grown to corn, root crops, upland rice, coconut, vegetables, and abaca. A total of 63,839 ha of Madunga clay loam were mapped in the provinces of Davao and Cotabato. These are along the eastern slopes of Mt. Magolo on the southwestern part of Davao provinces downward toward Malungon in the Cotabato provinces (Fig. 3.16).

3.4.2.4 Soils Underlain by Clay to Clay Loam with Weathered Shale Fragments, with Good Drainage and Absence of Redoximorphic Features

Ubay series is mainly developed from shales and classified as *Typic Eutrudepts*. It was first described in the municipality of Ubay, the island province of Bohol. It is the largest group of soils mapped in Bohol, occupying the northeastern part, almost a third of the island province, on a wide range of topographic features, with relief from undulating to rolling, to hilly. These soils are expected to be found also on hills and mountains. The soil series is characterized by a surface soil of grayish brown, light reddish brown, brown to dark brown sandy loam, clay loam to clay, with depth ranging from 20 to 25 cm. Gravels are occasionally present. The upper subsoil is reddish brown to dark brown, columnar sandy clay; slightly sticky when wet, hard when dry. Iron concretions which impart purplish black smudge when crushed, are present. The depth is from 50 to 55 cm. The lower subsoil is brown to dark grayish brown, structureless gravelly clay; slightly sticky when wet, hard when dry. Iron concretions and gravels are also present. The depth is from 60 to 65 cm. The substratum is yellowish brown, mottled black, brick-red gritty clay and the concretions are present. The large amount of concretions in the subsoil and substratum impart a distinct layering of the concretions, most especially in the lower subsoil (Bureau of Soil Conservation 1952). The brick-red color of the substratum oftentimes gives the badly eroded parts of the area the appearance of Luisiana soil series, Alimodian, or Antipolo. The concretions, however, belie the appearance. These concretions are strewn carpet-like in depressions and gentle slopes and are visible everywhere. Where we have only the surface soil eroded, the soils appear more like Buenavista and Prensa series. The external drainage is good to excessive while the internal drainage is good. The uncultivated areas are generally grasslands while the cultivated areas are devoted to rice, corn, root crops, banana, and coconut. A total of 338,441 ha of Ubay sandy loam, clay loam, clay, and clay-steep phase were mapped in the provinces of Bohol, Masbate, Samar, and Sorsogon.

3.4.3 Soils Underlain by Sandstone

Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains.

3.4.3.1 Soils Underlain by Sand, with Poor Drainage and Presence of Redoximorphic Features

Quilada soils (Plate 2E) are primary residual soils developed from sandstone. This was first described in Kilada, a barangay in the municipality of Matalam, in what is now the province of North Cotabato. This soil series is classified as *Typic Eutrudepts*. The relief is slightly rolling. The external drainage is good to excessive while the internal drainage is poor. The surface soil is brown to yellowish brown, gritty and structureless sandy clay loam with a considerable amount of concretions present in the lower portion of the horizon. Depth is from 20 to 30 cm. The subsoil is brownish gray to light brownish gray, compact, gritty and blocky clay with little or no concretions and a mottled orange color. White sand grains are present in the lower portion. Depth is 70–95 cm from the surface. And the substratum is brown to reddish brown, structureless sand which changes into gray, hard and very compact sand (Mojica et al. 1963). Below this layer is sandstone at about 2 m deep. A big portion of the area is commercial timber. The cultivated areas are grown to rice, corn, and diversified upland crops. About 51,875 ha of Quilada sandy clay loam were delineated in the provinces of Cotabato.

Fig. 3.17 Soil profile of Matulas series

3.4.3.2 Soils Underlain by Gravelly Sand, with Good Drainage

Matulas series is classified as *Typic Hapludands* and was originally mapped in a strip of undulating to rolling relief between Banga, a municipality of South Cotabato and Marbel which is now known as Koronadal City, also in South Cotabato, covering some 2,500 ha. This soil series is named after Matulas which is now a part of barangay Paraiso, Koronadal City. It is a primary soil derived from sandstone. The surface drainage is good to excessive while the internal drainage is good. The surface soil is dark brown to brown, structureless, slightly compact sandy loam, with depth ranging from 8 to 10 cm. The upper subsoil is brown to medium brown, structureless sand, coarse skeleton is absent, depth reaches down from 55 to 60 cm. The lower subsoil is brown, structureless, coarse sand, no coarse skeleton, and depth extending down from 110 to 120 cm. The substratum is grayish brown or gray, very coarse sand, with gravels (Mojica et al. 1963). The uncultivated areas are generally covered by second growth forest while the cultivated areas are devoted to rice, corn, and abaca (Fig. 3.17).

Magsaysay series was first described in the municipality of Magsaysay facing Mindoro Strait, Mindoro Occidental when it was still a barangay of San Jose municipality in 1961. It was separated and created as a new municipality and named after Philippine President Ramon Magsaysay in 1969 to honor his efforts to subdivide and distribute the vast agricultural land of Yu Kee Tay, called *Hacienda Caguray* abandoned by the Chinese businessman after the war. These soils occur on slightly sloping to rolling topography. It is a residual soil developed from the weathering of sandstone. Classified as *Typic Eutrudepts*. The surface soil is silty clay, light brown to reddish brown, fine granular structure and friable. In undisturbed condition, the soil is brown and almost compact; and in some places, fine to coarse whitish gravels are present. The depth is 15–20 cm. The subsoil is sandy clay loam, light grayish brown, friable when dry, slightly sticky when wet, with reddish brown splotches. Few gravels and concretions are present. The depth reaches from 75 to 80 cm from the surface. The substratum is sandy clay, light gray, slightly sticky and gritty. Highly weathered sandstone is present (Dagdag et al. 1961). These soils are grown to upland rice, fruit trees, and root crops. The uncultivated areas are covered by cogon, as well as primary and secondary forest. About 12,032 ha of Magsaysay series were mapped in Mindoro Occidental.

3.4.3.3 Soils Underlain by Clay to Sandy Clay and Weathered Sandstone, with Poor Drainage and Presence of Redoximorphic Features

Culis series soil is developed from sandstone and occurs in an undulating to gently rolling areas with slopes ranging from 3 to 8 %. Culis, where this soil series was named after, is a barangay of the municipality of Hermosa, on the northern part of the province of Bataan. This soil series is classified as *Typic Eutrustepts*. Its surface soil is brownish gray, gray to dark gray, fine to medium granular, slightly compact, loam, with depth ranging from 15 to 19 cm. The upper subsoil is dark gray, slightly compact, fine to medium blocky clay loam to clay with numerous buckshot-like iron concretions. Poor root penetration. Boundary to lower layer is gradual and wavy. Depth is 23–27 cm. The lower subsoil is gray to dark gray, hard, stiff, moderately compact, medium to coarse cloddy, clay with depth ranging from 80 to 85 cm. The substratum is whitish gray, compact mixture of sandy clay and weathered sandstone. Water-worn gravels and pebbles are occasionally present (Alicante et al. 1949). The drainage is good externally but poor internally. A total of 5,573 ha of Culis loam and sandy clay loam were mapped in the province of Bataan and Misamis Occidental. This soil series is not considered agriculturally important. The clayey subsoil is heavy and prevents normal penetration of water in the lower layers and also restricts root penetration. In places where the natural vegetation is disturbed, the soil is susceptible to intense erosion conspicuously exposing to the surface the buckshot-like concretions. The soil is poorly suited to most crops and where used for agriculture, we would find upland rice, corn, mangoes, and other fruit trees.

Cauayan series (Plate 2C) is classified as fine, kaolinitic, isohyperthermic *Plinthaquic Kanhaplustults* as a major upland soils developed from sandstones. It was first described in the city of Cauayan, province of Isabela. This is a well-drained soil, found on level to slightly undulating relief. Thus, we would expect this soil series to occur also on lowlands. The surface soil, 15–20 cm deep, is dark brown with reddish clay loam. The argillic subsurface soil, 50–150 cm deep, is red clay with presence of plinthites. The Cauayan series is considered major lowland soils of Isabela province. The surface soil is pale grayish brown with reddish streaks clay loam. The gleyed subsoil is gray and massive clay. The substratum, varying in depth from 60 to 150 cm, is pale grayish brown clay with few fine reddish concretions (Barrera et al. 1969). The extent is about 127,103 ha of varying textural types—sandy loam, loam, clay loam, and clay mapped in Isabela and Nueva Vizcaya provinces. This soil series is generally utilized for rice production. The sandstone-derived soils is 4,863 ha and found mostly in Nueva Vizcaya.

3.4.3.4 Soils Underlain by Weathered Sandstone, with Good Drainage

Villar series is classified as *Typic Hapludands* and are residual soils that developed from sandstone. The soils are well-drained, with level to rolling relief. This soil series is expected to be mapped also in lowland areas. The surface soil, 15–30 cm deep, is gray to dark gray to almost black loose sandy loam to silt loam. The upper subsoil, 35–45 cm is highly weathered chalk-like sandy material, almost white in color. The mid subsoil, 55–65 cm, is highly weathered sandstone, whitish gray in color with reddish streaks. The lower subsoil, 110–120 cm, is the same as the surface soil in color, texture, and structure. The substratum is indefinite depth of weathered sandstone, whitish gray and with sandstone boulders (Alicante et al. 1951b). The uncultivated areas are covered by cogon, second growth forest, and shrubs. The cultivated portions are devoted to rice, corn, root crops and fruit trees. About 4,662 ha of Villar sandy loam were mapped in the province of Zambales. Villar, where this soil was first described, is a barangay of the municipality of Botolan, Zambales. Botolan is the largest municipality in the province in terms of land area and known for its large Aeta population, gray sand beaches, and the location of Mt. Pinatubo. Aetas are the aborigines of the Philippines, believed to have arrived in the country from the Asian mainland through land bridges.

Aroman series (Plate 2A) is classified as *Typic Eutrudepts* and was named after barangay Aroman in the municipality of Carmen, province of Cotabato. It was originally mapped occupying a belt south of Mount Table between Maridago and Pulangui Rivers, from the foothills of Mount Table on the north southward embracing Carmen on the south where the land acquires its soft contours and merges with the level area of the Kabacan series. This is a residual soil, derived from sandstone, with undulating to rolling relief. The drainage is good to excessive externally, and fair internally. The surface soil ranges from 10 to 20 cm, brown or reddish brown to dark grayish brown, prismatic clay loam. The subsoil reaches down to a depth from 40 to 45 cm, and is reddish brown, plastic, clay loam, hard and brittle when dry. The substratum with depth ranging from 65 to 75 cm is highly weathered sandstone. Below the substratum is massive sandstone (Mojica et al. 1963). The uncultivated areas are generally covered by primary and secondary forest while the cultivated areas, mostly kaingin, are planted to rice and corn. The areal extent is about 37,500 ha.

3.4.3.5 Soils Underlain by Sandy Clay Mixed with River Washed Stones, Below is Weathered Sandstone, with Poor Drainage and Characterized by Presence of Redoximorphic Features

San Juan series (Plate 2E) is quite similar to Rugao series which developed from shale-sandstone. But San Juan series is very shallow and badly eroded, and its substratum is full of river washed stones. San Juan soils represent the upper terraces in the valley and found adjoining the mountain ranges in the western part of Isabela province bordering the Ifugao province where this was first described. San Juan is a barangay of Aurora municipality, Isabela. But like Rugao series, San Juan soils are found also from rolling to hilly. The external drainage is excessive while the internal drainage is poor. However, the soil survey report does not indicate presence of redoximorphic features. The parent material of this series is derived from old alluvium. The stones beneath the substratum, consisting mostly of sandstone and a variety of other kinds, contribute very little to the formation of the soil. The vegetation is mostly native grasses. The surface soil, reaching a depth of 15 cm from the surface, is light gray (5Y 7/1) to gray (5Y/1) sandy clay loam, loam, to clay; slightly friable and loose when moist; fine granular structure. The subsoil that extends down to 40 cm is brownish gray (5Y 5/2) to dark grayish brown (9.5Y 5/2) clay; slightly compact, plastic and sticky. The substratum reaches down to 150 cm from the surface, and is sandy clay mixed with plenty of river washed stones ranging in size from 2 to 10 cm in diameter. Weathered stones, consisting mostly of sandstone are found beneath this layer; very compact (Barrera et al. 1969). This soil series is classified as *Typic Eutrustepts* and covers. A total of 83,236 ha of San Juan loam, sandy clay loam, and clay were mapped in the provinces of Bontoc, Cagayan, Isabela, Ifugao, Kalinga-Apayao, and Nueva Vizcaya.

3.4.4 Soils Developed from Shale-Sandstone

3.4.4.1 Soils Underlain by Gravelly Clay to Clay Loam, Poor Drainage and Presence of Redoximorphic Features

Rugao series (Plate 2E) is classified as *Aquic Hapludalfs*. These soils developed from shale and sandstone and occur on level, undulating to hilly relief. The external drainage is excessive but the internal drainage is poor to fair. The color of the different layers is more or less alike and concretions exist from the surface to the substratum. The surface soil, 20–35 cm in depth, is brown to reddish brown (5YR 4/4) when wet, dark brown why dry; sandy clay loam, sandy loam, clay loam to clay; with few manganese concretions and fine gravels. The upper subsoil, 50–80 cm in depth, is pale gray, dark brown to light brown when wet, and yellow (10YR 7/6) when dry; clay loam to clay with concretions and gravels. The lower subsoil reaches down to 100 cm; yellowish brown (7.5YR 4/4) when wet, yellow (10YR 7/6) when dry; clay to sandy clay loam; coarse granular; some weathered rocks are mixed with gravels and cobbles. The substratum reaches down to the control section, and is very pale brown (10YR 7/4) when dry, yellowish brown (10YR 5/4) to light grayish brown when wet, mottled clay to sandy clay loam; several weathered rocks mixed with riverwash stones and concretions were observed. Some stones beneath this layer were water deposited (Barrera et al. 1969). These soils were first delineated in barangay Rugao, municipality of Ilagan, province of Isabela. This soil series is generally covered by grasses with patches of cultivated crops. A total of 99,008 ha of Rugao sandy loam, sandy clay loam, clay loam, and clay were mapped in the provinces of Isabela, Nueva Vizcaya, and Cagayan. Of these total, 48,051 ha developed from shale alone and found mostly in Nueva Vizcaya (Fig. 3.18).

Fig. 3.18 Landscape view where Rugao series occurs

3.4.4.2 Soils Underlain by Clay, with Good Drainage

Sinapangan series is classified as *Aquic Eutrustepts* and developed from recent alluvial deposits derived mainly from shales and sandstones. This soil series is named after barangays Sinapangan Norte and Sinapangan Sur in the municipality of Balaoan, province of La Union. The general topographic feature of the area is gently undulating to flat. Drainage, both internal and external, is fair to good. The vegetative covers consists of economic crops, such as rice, corn, sugarcane, coconuts, bananas, vegetables, and fruit trees. The soils of this series are characterized by light brown, brown to yellowish brown clay, loose, friable and granular surface soils, ranging in depth from 10 to 50 cm underlain by grayish brown to almost black compact clay subsoil that reaches down from 60 to 80 cm from the surface, sticky to plastic when wet and brittle and hard when dry. The substratum is yellowish brown to light brownish red, loose, friable, and granular clay (Alicante et al. 1950). Like the Bigaa series, clay predominates in the different horizons of the Sinapangan series. But Bigaa is characterized by the presence of concretions and Sinapangan contains a large amount of silt which accounts for its better physical condition. A total of 897 ha of Sinapangan clay were mapped in the province of La Union.

3.4.4.3 Soils Underlain by Sandy Loam to Sandy Clay Loam, with Good Drainage

Tadao series is classified as *Typic Haplustalfs* and was first delineated in barangay Tadao, municipality of Pasuquin, province of Ilocos Norte. This is a primary soil developed through the weathering of calcareous sandstone. The relief is undulating to roughly rolling. The external drainage is good to excessive while the internal drainage is good. The surface soil extends down to 20 cm, grayish brown to reddish brown sandy clay loam, no coarse skeleton. The subsoil reaches down to 70 cm, dark reddish brown to red sandy clay loam, columnar and gradually turns to yellowish red toward the lower part of the subsoil. The substratum that reaches down to the control section at 150 cm is pale brown to yellow sandy loam to sandy clay loam, columnar, with red mottlings and manganese concretions, no coarse skeleton (Manloñgat et al. 1968). This is mostly under grass and the cultivated areas are planted to rice, corn, banana, or sugarcane. About 4,729 ha of Tadao sandy clay loam was mapped in the province of Ilocos Norte.

3.4.5 Soils Originating from Mix of Calcareous Materials, Shale, and Sandstone

3.4.5.1 Soils Underlain by Clay and with Concretions and Gravels, with Good Drainage

Cataingan series is classified as Typic Eutrudepts and residual soils of the transverse valley, developed from sedimentary rocks like calcareous limestones and gravelly sandstones at various states of weathering. This soil series was first described in the municipality of Cataingan, province of Masbate. The soils are found on undulating to moderately rolling relief. The soils are black, dark gray, brownish gray to reddish brown silty clay to clay. The surface soil reaches down from 10 to 15 cm deep. The upper subsoil is brownish black, reddish brown to grayish brown; heavy, cheesy, columnar clay with a depth of 15–40 cm from the surface. The layer has plenty of reddish brown and dark brown iron buckshot-like concretions. The lower subsoil is lighter in color, coarse to medium columnar and gravelly clay. Limestones and quartz-like gravels are present. In other places, rounded and smooth-surfaced stones and boulders are also found. The depth ranges from 40 to 60 cm (Aristorenas et al. 1964). The solum rests on a brownish orange and grayish white gravelly clay admixed with 70 % highly weathered limestones and sandstones. The drainage is good. Cataingan series is very similar to Sevilla series except for the presence of buckshot-like iron concretions in the upper subsoil of Cataingan but not found in Sevilla. Despite its being shallow, Cataningan soils are considered best for rice and corn production. The other crops grown are tobacco, coconut, root crops, legumes, banana, and fruit trees. The uncultivated areas are grasslands. A total of 68,308 ha of Cataingan sandy loam and Cataingan clay were mapped in the province of Masbate covering almost the entire Ticao Island, the islets of Masbao, Magkaragit, and Deagan including the broad transverse valley from Barrio Sta. Cruz in Dimasilang to Cataingan proper in the northeast.

3.5 Soils that Developed from Metamorphic Rocks

Metamorphic rocks are recycled rocks previously subjected to varying degrees of pressure and temperature. The resulting rocks display a preferred orientation of minerals, perpendicular to the maximum pressure exerted on the rock. In the process of rock metamorphism, sandstone becomes quartzite, limestone becomes marble, shale becomes slate or schist or gneiss depending on the degree of heat and pressure.

Metamorphic rocks are rather uncommon at the earth's surface, so they do not contribute greatly to the formation of soils. Because also of their hardness these weather very slowly. Expectedly, here in the Philippines, we have very few soils that developed from metamorphic rocks.

The metamorphic rocks in the Philippines can be categorized into pre-Cretaceous of continental origin and into post-Jurassic of insular arc affinity (Aurelio and Peña 2004). The pre-Cretaceous metamorphic formations are in North Palawan, Mindoro, Panay, and the neighboring islands. The post-Jurassic metamorphic rocks are distributed sporadically within the whole archipelago.

3.5.1 Soils Developed from Underlying Quartzite, Schist, Slate, and Marble

3.5.1.1 Soils Underlain by Schist, with Good Drainage

Calauaig series was first mapped on the low grassy hills east of Malaybalay, Bukidnon covering 4,363 ha and classified as *Typic Eutrudepts.* The relief ranges from gently rolling to hilly with slopes ranging from 8 to 100 %. The 10–15 cm surface soil consists of brown to light brown clay that is friable and granular when dry but mellow when moist. It is underlain by a light brown to yellowish brown clay which is plastic and sticky when moist but blocky and hard when dry. The upper subsoil reaches to a depth of 30 cm from the surface. It merges gradually into the lower subsoil which has almost similar characteristics except for lighter color and less developed structure. The lower subsoil reaches to a depth of 55 cm from the surface. The substratum is a layer of weathering schist which looks like fragmental coal. In other places, the bedrock of schist which is usually in slab form is encountered in the lower part of the substratum. External drainage is free to excessive but internal drainage is slow. The native vegetation is grass.

3.5.1.2 Soils Underlain by Numerous Metamorphic Sand and Gravels, with Good Drainage

Lonos series was identified in Barangay Lonos, municipality of Romblon, in the island province of Romblon. It is a residual soil derived from the weathering of the underlying metamorphic rocks such as quartzite, schist, slate, and marble. Lonos sandy loam and Lonos loam occupy some 24,734 ha in the south western portion of Romblon Island and the north eastern section of Tablas Island. The relief ranges from strongly sloping to hilly and mountainous. Rock outrcrops are present in some portions. The external drainage is good to excessive and the internal drainage is also good. This soil is classified as *Typic Eutrudepts*. The surface soil, extending down to 20 cm is sandy loam, olive brown (5Y 4/4) when moist and pale yellow (5Y 7/4) when dry; very soft and friable when moist, nonsticky and non-plastic when wet, and soft when dry. The structure is coarse granular. Few metamorphic pebbles and stones are present. The subsoil, extending down to 60 cm is sandy clay loam, olive yellow (2.5Y 6/8) when moist and yellow (2.5Y 7/6) when dry; reddish yellow (7.5YR 7/6) streaks are present; coarse granular structure; soft and friable when moist, and slightly hard when dry; metamorphic rocks are present. The substratum reaches down to 150 cm, sandy clay loam; light yellowish brown (2.5Y 6/4) when moist and pale yellow (2.5Y 8/4) when dry; with numerous yellowish red (5Y 5/8) streaks; coarse granular structure; soft and friable when moist, slightly hard when dry. Numerous metamorphic sand and gravels are present in this layer (Castillo et al. 1973). The soils is principally grown to coconut. Upland rice, corn, root crops, fruit trees, and vegetables are cultivated in patches.

3.6 Soils that Developed from Mixed Parent Materials

These are soils of upland areas developed from a mixture of two or more kinds of rocks. Examples are igneous-sedimentary, igneous-metamorphic, and sedimentary-metamorphic.

3.6.1 Soils Developed from Mixed Sedimentary and Igneous Rocks

3.6.1.1 Soils Underlain by Clay, with Concretions, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Castilla series (Plate 2B) is classified as *Typic Paleudults* and occurs in gently undulating to hilly. This soil series was first described in the municipality of Castilla, province of Sorsogon. The town was founded by the Dominican friars in 1827 and was named after the Spanish town of Castilla, the birthplace of Queen Isabela upon the recommendation of Don Eugenio Santos. The soil is developed from weathered products of loosely consolidated calcareous tuff, clay, basalts and agglomerates. The top soil, 30–40 cm, is dark brown, brick reddish brown to reddish brown, coarse granular to blocky clay loam; highly plastic when wet, brittle when dry. The upper subsoil, 100–120 cm in depth, is reddish brown, dark brown to brown, moderately compact, coarse granular to columnar clay with black and gray mottling; highly plastic and sticky when wet, brittle and hard when dry. Boulders are present occasionally. The lower subsoil, 160–170 cm in depth, is dark brown to reddish brown, blocky to columnar clay with gray and bluish streaks and concretions. The substratum is dark brown to reddish brown, moderately compact, columnar clay with numerous concretions. Underneath are reddish and gray and highly weathered parent materials. The external drainage is good to excessive but poor internally (Aristorenas et al. 1963). The uncultivated areas are generally cogonal. The cultivated areas are grown to coconut, abaca, fruit trees, upland rice, corn, and other diversified upland crops. A total of 114,472 ha of Castilla clay loam and clay were mapped in the provinces of Misamis Occidental, Sorsogon, Zamboanga del Norte, Zamboanga del Sur, and Quezon. Additional 6,800 ha of Castilla-Bolinao complex were delineated in Sorsogon (Fig. 3.19).

Fig. 3.19 Landscape view where Castilla soil series developed in Mutya, Zamboanga del Norte

3.6.2 Soils from Undifferentiated Metamorphic/ Igneous-Metamorphic-Shale

3.6.2.1 Soils Underlain by Clay Loam to Clay with Concretions and Gravels, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Mauraro series (Plate 2D) was first described in Mauraro, Guinobatan, province of Albay and classified as *Typic Hapludolls*. It was developed from weathered products of basalt, tuff and gravelly conglomerates basically from sandstone, shales and limestone. It presents a profile composing of several distinct layers varying in the degree of development. The surface soil is reddish brown to dark grayish brown; the subsoil is brown to reddish brown moderately compact gravelly clay. It occupies a broad rectangular area southwest of Mayon Volcano, running in southwesterly and south easterly directions from barrios Pinaglaban and Malabog of Daraga up to sitios Cagonsagnan, Aliang of Ligao and Barrio San Juan of Oas. It has a flat upland to gently rolling and hilly topography with an elevation of from 67 to 168 m above mean sea level. The external drainage is good to excessive but the internal drainage is poor. The profile characteristics of this soil type are as follows: the surface soil with depth extending down to 40 cm from the surface is gravelly sandy loam; reddish brown to dark grayish brown; columnar to blocky; slightly compact; numerous dark brown rounded and angular concretions present. The upper subsoil reaches down to 70 cm; is gravelly clay; brown to reddish brown; coarse columnar. There are more gravel concretions in this layer than in the surface soil. The lower subsoil extends down to 85 cm; is gravelly loam; brown with grayish brown speckles, structureless to coarse columnar structure; compact. Gravels are abundant in this layer. The substratum with depth from 85 cm below is clay loam; brown to light brown; structureless to coarse columnar; concretions like those found in the surface layer are abundant (Aristorenas et al. 1965). Mauraro gravelly sandy loam has a total area of 19,150 ha mapped on flat uplands, and gently rolling to hilly relief. It has good to excessive external drainage and poor internal drainage. Coconut, upland rice, corn, fruit trees, banana, cassava, camote, vegetable and other fruit trees are also grown.

ADTUYON *(Typic Paleudults)* **ALAMINOS** *(Typic Hapludults)* **ANNAM** *(Typic Hapludults)* **AROMAN** *(Typic Eutrudepts)* **BANI** *(Aquic Eutrustepts)* **BANTAY** *(Typic Eutrudepts)*

Plate 2A Soil profiles of Adtuyon, Alaminos, Annam, Aroman, Bani, and Bantay series (*Photo credit* BSWM and UPLB)

BARCELONA *(Aeric Epiaquepts)* **BATUAN** *(Aquic Argiudolls)* **BOLINAO** *(Typic Hapludalfs)* **CADIZ** *(Typic Eutrudepts)* **CARMONA** *(Vertic Eutraquepts)* **CASTILLA** *(Typic Paleudults)*

Plate 2B Soil profiles of Barcelona, Batuan, Bolinao, Cadiz, Carmona, and Castilla series (*Photo credit* BSWM)

CAUAYAN *(Plinthaquic Kanhaplustults* | **FARAON** *(Lithic Rendolls)* | **GUADALUPE** *(Leptic Udic Haplusterts)* | **GUIMBALAON** *(Typic Hapludands)* | **KUDARANGAN** *(Typic Hapludults)* | **LA CASTELLANA** *(Typic Humitrudepts)*

Plate 2C Soil profiles of Cauayan, Faraon, Guadalupe, Guimbalaon, Kudarangan, and La Castellana series (*Photo credit* BSWM)

LIPA-1 *(Typic Eutrudepts)* | **LIPA-2** *(Typic Eutrudepts)* | **MALALAG** *(Typic Hapludults)* | **MANAPLA** *(Typic Hapludults)* | **MAURARO** *(Typic Hapludolls)* | **MEDELLIN** *(Typic Eutrudepts)*

Plate 2D Soil profiles of Lipa, Malalag, Manapla, Mauraro, and Medellin series (*Photo credit* BSWM)

Plate 2E Soil profiles of New Iloilo, Parang, Quilada, Rugao, Sampaloc, and San Juan series (*Photo credit* BSWM and UPLB)

Plate 2F Soil profiles of Sevilla, Sibul, Sta. Filomena, Tupi, and Victorias series (*Photo credit* BSWM and UPLB)

3.6.2.2 Soils Underlain by Massive Rock of Slates, Limestone, Schists, and Igneous Rocks, with Good Drainage

Malalag series (Plate 2D) is classified as *Typic Hapludults* and was first mapped in the hilly and mountainous region from Malalag southward to Caburan, Butulan, and Batulaki in Davao provinces and includes also the eastern side of Davao Gulf from Point San Agustin of the peninsula northward up to Mati. Malalag is now a municipality of Davao del Sur. Malalag series is a primary soil developed from mixture of metamorphic, igneous, and shale rocks. It is well-drained soils but because of the hilly and mountainous relief, it is best suited to forestry than to agriculture. The surface soil, about 10–12 cm deep, is brown to grayish brown friable and granular loam. It is underlain by a subsoil of light brown to brown slightly compact granular clay loam reaching a depth of 40 cm from the surface. The substratum is a massive rock consisting mostly of slates, calcareous limestones, schists, and igneous rocks. Some shale rocks also occur at times in some places (Mariano et al. 1953). In the uncultivated areas, the soils are generally covered by second growth forest and partly primary forest, with few cogonal areas. The cultivated areas are grown to rice, coconut, abaca, corn, and other diversified upland crops. A total of 414,720 ha of Malalag silt loam, loam, and clay were mapped in the provinces of Davao, Agusan, Surigao, Cotabato, and Palawan. Additional 8,844 ha of Malalag-Faraon Complex was mapped in Romblon. We also have Banto-Malalag Complex mapped in Mindoro covering 3,127 ha.

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Soils that Developed from Mixed Parent Materials

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4 The Soils of the Hills and Mountains

Abstract

Soils of the hills and mountains are defined to be those found in areas with altitude above 300 m above sea level and slope of 18 % and above. They were developed from various rocks mostly shale and sandstone, basalt and andesite, and limestone. Major land uses in these soils include forest, grasses, and shrubs. In areas where springs abound, soils are cultivated for upland crops such as rice, corn, sugarcane, fruit trees, and vegetables. The uncultivated areas are either covered with grasses or second growth forest with some primary forest. In general, soils in this group are acidic and are low in fertility, they have steep slope, and are prone to erosion. The soils of the hills and mountains are similarly grouped as in the upland soils. As these soils occur mostly in high elevation and slopes, these soils can also be found in the lower elevations and gentler slopes. But these are considered as hill and mountain soils on the basis of how they were first described and mapped. The soils are grouped according to their parent materials—igneous, sedimentary, or metamorphic. As in the upland soils, although tuff is considered igneous, we have separated the tuff-derived soils because of research interest on these soils. Owing to their high elevation and the natural downward movement of water, the soils are mostly well-drained. There are also fairly drained and poorly drained soils that exhibit redoximorphic features.

4.1 Alluvial Soils of the Plateaus

These soils would have been much like the lowland soils derived from alluvium but they would not qualify in the definition because of elevation, being higher than 300 m above sea level. La Trinidad soils are at 1,290 m elevation while Bukidnon where Maapag, Mailag, and Maramag soil series are found has an average of more than 1,000 m elevation. Bukidnon is a gently rolling plateau cut by deep and wide canyons of the Cagayan, Polangui, and Tagoloan Rivers. We have classified these alluvial soils of the plateaus as highland soils, or those of the hills and mountains.

4.1.1 Soils of the Plateaus with Poor Drainage or Presence of Redoximorphic Features

4.1.1.1 Soils Underlain by Sandy Loam with Gravels and Mottles

La Trinidad series (Plate 3E) classified as *Fluventic Hapludolls* is not just formed from alluvial deposits and occupies a relief that is flat or almost flat. Since it forms the valley of the municipality of La Trinidad, province of Benguet, this soil series is located some 1,290 m of elevation. This is an alluvial soil of a plateau. The surface soil, reaching down to a depth of 22 cm is brown (10YR 4/-) to dark brown (10YR 3/3) fine granular firm loam. The subsoil extends down to

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108 cm, and is dark brown (10YR 3/3) fine granular friable firm loam to sandy loam. The upper substratum that reaches down to 127 cm is reddish brown (5YR 4/4) fine granular friable sandy loam with 5 % gravels by volume. The substratum extends down to the control section at 150 cm is dark brown (10YR 3/3) friable loam with mottles. The drainage is good except on depressions where water may stagnate (Calaustro and Ganawan 1968). This soils are utilized for growing of vegetables, strawberries, and cut flowers. A total of 499 ha of La Trinidad loam was mapped in Benguet.

4.1.1.2 Soils Underlain by Massive Clay

Maapag series (Plate 1D) is classified as fine, mixed, nonacid, isohypethermic *Typic Endoaquepts*. These soils are deep and poorly drained. They are formed from nearly level low parts of alluvial terraces of mixed alluvium that originated from old volcanic and sedimentary rocks. The surface soil that extends down to 30 cm, is dark to very dark grayish brown when moist, and grayish brown when dry, coarse granular and prismatic to massive clay. The subsoil, extending down from 50 to 80 cm is yellowish brown to light brown, wax-like sticky to massive and plastic clay that becomes fine granular after a few days of exposure. The substratum is light gray to light brownish gray massive clay (Mariano et al. 1955). About 20,001 ha of Maapag clay were mapped in Bukidnon. This soil was first described in barangay Maapag, Valencia City, province of Bukidnon at the heart of the extensive Bukidnon–Lanao plateau built by successive basaltic flows. The alluvial materials of Maapag would be basaltic and expected to be rich in pyroxenes, olivines, and calcic plagioclase.

4.1.1.3 Soils Underlain by Clay with Concretions and Gravels

Mailag series is classified as fine, mixed, nonacid, isohyperthermic *Aeric Endoaquepts*, deep, and somewhat poorly drained soils. Maramag occurs in level areas with few depressions where water collects during the rainy season. Due to the level relief and presence of slight depressions, the surface drainage is poor and the internal drainage is likewise poor due to the clay subsoil. The 20–25 cm surface soil consists of dark grayish brown granular clay loam; some waterworn cobblestones present. The subsoil is gray to light gray plastic and sticky blocky clay with plenty of concretions of round and angular forms of 2–5 mm diameter mixed with gravels of different sizes. It reaches to a depth of 50–55 cm from the surface. The substratum is composed of light gray, somewhat loose clay containing concretions and gravels like the subsoil (Mariano et al. 1955). The native vegetation is grass consisting mostly of velvet grass, redtop, silibon, and others. The cultivated plants are corn, banana, cassava, and lowland rice. About 1,864 ha of Mailag clay loam were mapped in Bukidnon. It was first described in barangay Mailag, Valencia City, Bukidnon province.

4.1.2 Soils of the Plateaus with Good Drainage

4.1.2.1 Soils Underlain by Clay Loam, Silty Clay Loam, or Clay, with Gray Mottles

Maramag series is fine, mixed, acidic, isohyperthermic *Aeric Endoaquepts*. The soils are somewhat poorly drained, formed on nearly level to gently sloping alluvial terraces and fans of young volcanic origin occurring on young volcanic landscapes. The surface soil is very dark gray or dark grayish brown, friable to firm silty clay loam, or clay, not exceeding 40 cm thickness with yellowish brown and strong brown mottles. The underlying cambic B horizon is gray clay loam, silty clay loam, or clay with brown mottles. The substratum is usually below 100 cm, similarly textured as the subsoil, brown and gray mottled (Mariano et al. 1955). These soils were first described in Maramag municipality, province of Bukidnon. The name is a contracted form of Manobo term "Ag Ramag Ki Dini" which means "Let us eat our breakfast here", referring to Manobos stopping by the bank of Pulangi River to eat breakfast in flat stones every time they set out for battle against neighboring Maranaos, or just to take respite from travel, trekking, hunting, etc. (Wikipedia 2013).

4.2 Soils that Developed from Volcanic Tuff

Following the classification of upland soils of volcanic tuff origin, these soils developed in place, resulting from the weathering of the underlying parent materials. The soil series will be grouped based on the source of volcanic tuff. Tuff materials are also classified as igneous but we separated them from the rest of the soils that evolved from igneous parent materials because of the special research interest that they generated.

4.2.1 Soils Underlain by Diliman Tuff, Well-Drained

4.2.1.1 Soils Underlain by Clay, with Weathered Rock Fragments

Novaliches series are classified as fine, mixed, isohyperthermic *Typic Eutropepts*. These soils were originally described in Novaliches which used to be a municipality of the province of Rizal. But currently, Novaliches is a district of Quezon City and basically a residential area. The La Mesa Dam Watershed occupies the eastern portion. The Novaliches series consists of moderately deep well-drained clayey soils on undulating to rolling low tuffaceous plateau or rolling to steep moderately dissected volcanic foothills and ridges. The surface layer is about 10–20 cm thick, very dark brown, dark grayish brown, grayish brown clay or clay loam. The subsoil reaches down to a depth from 50 to 70 cm, dark brown or brown, sticky, plastic, firm clay or clay loam with few to common weathered tuffaceous rock fragments. The substratum below 50–100 cm, is dark grayish brown, pale gray, brownish yellow clay or clay loam, with yellowish brown mottles and partially weathered rock fragments that become strongly weathered as we go down the profile. Below the substratum is hard volcanic tuff (Soil Survey Division 1987). The Novaliches soils are closely associated with the higher lying and deeper Kay Bamban series and the lower lying gravelly Paradise series of the conglomeratic/agglomeratic hills and ridges. The Novaliches series are also somewhat similar to Lumbangan and Camarin soils. The Novaliches soils are shallow to moderately thick, the Camarin soils have moderate solum thickness, and the Lumbangan soils are generally of thicker solum and occur on very steep highly dissected volcanic hills with angular crests. Camarin soils are found on undulating to rolling conglomeratic footslopes over volcanic tuff as against Novaliches soils which occur on undulating to rolling tuffaceous plain plateau. About 3,331 ha of Novaliches clay were mapped in the semi-detailed soil survey of Bulacan province. There were additional 6,121 ha of Novaliches clay and 10,565 ha of Novaliches Urban Land Complex mapped in the semi-detailed soil survey of Rizal province.

4.2.1.2 Soils Underlain by Clay or Clay Loam, with Highly Weathered Volcanic Tuff, Below is Hard Tuff

Calantas series was actually named after Calantas in barangay Quisao in the municipality of Pililla, province of Rizal. But the typical pedon for this soil series was described in Bulawan, Pililla. This soil series is classified as fine, mixed, isohyperthermic *Lithic Troporthents.* These are well-drained shallow soils on low tuffaceous hills and ridges and rolling to steep convex agglomerate hills of the volcanic hills landscape. The A horizon, 5–20 cm thick, is brown to dark brown, dark yellowish brown or very dark grayish brown clay or silty clay. The consistence is sticky and plastic when wet, firm when moist. Few angular to sub angular partially weathered rock fragments occur. The substratum or the C horizon is brown to dark brown, yellowish brown or dark yellowish brown clay or clay loam with common to many partly or highly weathered tuff fragments. Underlying this horizon is hard tuff. About 4,389 ha of Calantas clay were mapped in Rizal. Calantas series is somewhat similar to Kay Barbon since both soils are shallow, have an AC horizon, and classified as Lithic Troporthents. But Calantas is underlain by lithic tuff while Kay Barbon is underlain by embedded stones, rocks fragments, and boulders (Soil Survey Division 1989).

Kay Barbon is classified as clayey, skeletal, mixed, isohyperthermic *Lithic Troporthents*. These soils were first described in sitio Kay Barbon, barangay Plaza Aldea, municipality of Tanay, Rizal province. Kay Barbon soils are well-drained and shallow. These soils are found on undulating to rolling hills and ridges with localized valleys of the volcanic footslopes. The A horizon 10–20 cm thick is brown, brown to dark brown, or yellowish brown clay, clay loam, or silty clay, slightly sticky and slightly plastic when wet, friable to firm when moist, weak subangular blocky in structure. Few common gravel-size rock fragments are usually present in this layer. The C horizon or the substratum 30–50 cm deep is brown to dark brown, yellowish brown, dark greenish brown or dark brown clay or clay loam with common to many gravel- and stone-sized rock fragments, moderately weak subangular blocky, stricky, and plastic when wet, firm when moist. Below this layer is hard volcanic tuff bedrock. A total of 2,755 ha of Kay Barbon clay at various slopes and erosion conditions were mapped in Rizal province. Kay Barbon series is very similar to Calantas series. Both are shallow, well-drained soils and are classified as Lithic Troporthents. Their main differentiating characterisistics are their physiographic position and the underlying horizon. The Kay Barbon is on undulating to rolling hills and ridges of the volcanic footslope while Calantas is on low tuffaceous hills and ridges of the volcanic hills landscape. Kay Barbon substratum contains embedded gravel-sized rock fragments while Calantas is underlain by highly weathered tuff (Soil Survey Division 1989).

4.2.2 Soils Underlain by Various Macolod Corridor Tuff

4.2.2.1 Soils Underlain by Soft Tuffaceous Rock, Well-Drained

Magallanes series (Plate 3E) is fine, isohyperthermic *Typic Hapludalfs*, first described in the municipality of Magallanes, Cavite. The municipality was named after Ferdinand Magellan whose expedition was the first to circumnavigate the world. The municipality is bounded on the north by Maragondon where we have the historic Mount Buntis and Mount Nagpatong, the municipality of General Emilio Aguinaldo on the northeast, Alfonso municipality on the southeast, and Nasugbu, Batangas on the southern end. Adjacent on the eastern side is Taal Volcano that highly influence soil formation and development. The soil drainage is good. Since this soil series is underlain by soft tuffaceous rock similar to Lipa series, Magallanes can be distinguished from Lipa by drainage properties. Lipa series has poor drainage and characterized by the presence of redoximorphic features which are absent in Magallanes series. The surface soil is brown, pale brown to light reddish brown or yellowish brown, friable and fine to coarse granular clay loam to loam, reaching down from 15 to 30 cm. The upper subsoil is pale brown to yellowish brown, slightly friable and granular clay loam, extending down from 40 to 50 cm from the surface. The lower subsoil is pale brown, cloddy clay loam with numerous brown, highly weathered tuffaceous materials and concretions, reaching down from 70 to 80 cm. The substratum is yellowish brown, soft tuffaceous rock (Alicante and Rosell 1938). Below this layer is a layer of soil similar to the one above it. A total of 67,726 ha of Magallanes sandy loam, sandy loam—gravelly phase, and loam were mapped in the provinces of Cavite and Batangas.

Tagaytay series (Plate 3G) was first described in Tagaytay City, the northern ridge overlooking Taal Volcano, in what is considered as remnant ancient Taal caldera which is believed to include Mount Batulao in the west, Mount Sungay in the east, and Mount Macolod on the opposite side in the south. Tagaytay ridge is actually the edge of the northern Taal caldera. The surface of Tagaytay series is brown, dark brown to nearly black in color. The virgin soils that have been recently under cultivation are dark brown to nearly black while that are already under cultivation for several years brown to dark brown. The thickness of the surface soil depends upon the elevation and topography of the land. The surface soils in the upper part of the rolling area are shallow, while those in the valley and sloping districts are deep. The surface soil from 12 to 50 cm is dark brown, nearly black granular sandy loam with considerable amount of volcanic sand. The subsoils are either brown or light yellowish brown depending on the extent of weathering of the tuffaceous parent material, varying in texture from clay loam to clay. Both the surface soils and the subsoils are friable and granular, containing some tuffaceous concretions. The substratum is tuffaceous material of volcanic origin extending to indefinite depth (Alicante and Rosell 1938). Tagaytay loam, Tagaytay sandy loam, Tagaytay loam—deep phase were mapped covering 57,900 ha were mapped in the provinces of Batangas, Cavite, Laguna, and Mindoro. These soils are classified as *Typic Hapludolls.* The soils of this series are devoted to diversified farming. Crop rotation is practiced throughout the area. Upland rice is planted during April and May with corn and mongo as rotation. Tomatoes, peanuts, and several seasonal crops are also used in rotation. In wooded and shaded areas are coffee, cacao, citrus, avocado, chico, jackfruit, cainito, mango, and cashew. There are also patches of coconut plantations.

4.2.3 Soils Underlain by Southern Sierra Madre Tuff

4.2.3.1 Soils is Underlain by Clay to Sandy Clay, Well-Drained

The *Buenavista* series (Plate 3B) is not found in the updated Bulacan Soil Survey Report. This soil series was first described in Buenavista, San Ildefonso, Bulacan. These soils are brown, light brown to light reddish brown. The surface soil is brown sandy clay with some concretions and gravels but the silt loam type has yellowish brown to light reddish brown, with few concretions; friable and loose; depth ranging from 20 to 40 cm. The clay loam type is medium brown and fine in texture. The peculiarity of this series is the presence in the subsoil of almost impervious light gray to light yellowish clay and concretions. The subsoil ranges in depth from 60 to 100 m in the sandy clay loam type could reach to indefinite depth light gray to whitish gray, stiff and sticky clay in the silt loam type. In the clay loam type, the subsoil is mottled black and brown, and concretions are also present. The substratum from 100 cm down is yellowish gray clay, sometimes mottled light gray and brown sandy clay. In some localities, it is slightly compact (Alicante et al. 1939). This series is found in the rolling and hilly regions of San Rafael, San Ildefonso, and San Miguel municipalities. These soils are principally used for rice. The hilly areas are used for grazing. Originally, a total of 30,184 ha of Buenavista silt loam, sandy clay loam, and clay loam were mapped in the provinces of Bulacan and Pampanga. These soil series have been reclassified during the more detailed soil mapping of Bulacan and Pampanga provinces. This soil series is classified as *Typic Eutrustepts*. The Buenavista soil series in the reconnaissance soil survey of Bulacan is already reclassified in the semi-detailed survey.

4.3 Soils that Developed from Igneous Rocks

4.3.1 Soils Developed from Predominantly Andesite Parent Materials

4.3.1.1 Soils Underlain by Sand, Well-Drained

San Rafael as a soil series name would be quite difficult to trace. There are two municipalities and one barangay in the Philippines named after San Rafael. There are several more towns in many other Spanish-influenced countries. This soil was first described by San Rafael municipality, province of Iloilo and classified as *Typic Hapludults*. This is residual soil derived from igneous rocks. The soil consists of dark gray to black shallow surface soil underlain by reddish brown gravelly sand. The substratum is gray to almost white porous and structureless coarse sand and quartz gravels. A typical soil profile has the following characteristics: The surface soil is dark brown to almost black loam, excellent medium granular; strongly crumbly when dry and soft when wet, depth ranges from 10 to 12 cm. The subsoil is brown loam, excellent medium granular, sort strongly friable and very strongly crumbly, depth ranges from 28 to 30 cm. The substratum is gray to reddish brown, gravelly sand, soft and structureless; weathered andesites may be found (Alicante et al. 1947). The relief occurs on hilly and mountainous areas and the drainage is good to excessive. A great part of this soil series is covered with secondary forest. About 64,797 ha of San Rafael loam were mapped in the Capiz–Aklan provinces.

4.3.1.2 Soils Underlain by Weathered Andesites, Well-Drained

Given the same andesitic parent material and the same soil development in place, the same physiographic position, almost the same soil color features, it would be difficult to differentiate one soil series from the other. The distinguishing features of *Macolod* series are the presence of boulders of a mixture of fine rounded and sharp angular weathered andesites on the surface and the dark brown color of the surface soil. Macolod series was originally mapped on the footslopes of Mount Macolod, believed to be geologically part of Taal Volcano, most probably the original summit. *Taal* series would come closest in terms of soil mineralogy but the two soil series are easier to distinguish. The substratum of Macolod is weathered andesite while that of Taal series is loose sandy loam, tuffaceous sand in some places, and gravel in other places. Such wide variation in substratum characteristics of Taal series could be explained by the various eruptions of Taal Volcano, one of the most active volcanoes in the Philippines. *Kidapawan* and *Rizal* series are also easier to distinguish despite similarity of parent material due to the differences in the color of the soil surface and in the nature of the substratum that underlain these soils.

Macolod soil series (Plate 3E) was named after Mount Macolod in Cuenca municipality, province of Batangas. This mountain is about 600 m (2,000 ft) high volcanic rock wall located next to Taal Lake and believed to be part of Taal Volcano's crater rim when it was still a massive volcano before the violent eruption that caused the slopes to cave in, forming a lake and leaving Mount Macolod as the tip of the previous peak, the highest volcanic cone on the south side. The soil series was first among the mapped by Dorsey in 1903 when he surveyed the soils of Batangas, Macolod soil series is almost similar to Ibaan. Macolod series is classified as *Typic Dystrudepts.* This is a primary soil, characterized by brown, tenacious clay loam surface soil with abundant coarse skeleton made up of a mixture of fine rounded and sharp angular, weathered andesite. The relief is rolling to hilly and mountainous. External drainage is excessive while internal drainage is good. The surface soil, 10–15 cm thick, is brown to grayish brown, plastic and sticky clay. Below is light reddish brown, slightly compact clay, reaching down to 65 cm. The substratum is weathered rocks, generally andesites (Alicante et al. 1938). In uncultivated areas, we can find cogon, talahib, shurbs, ipil–ipil, and second growth forest. The cultivated areas are planted to upland rice, corn, root crops, sugarcane, lanzones, and coconuts. A total of 129,151 ha of Macolod series was mapped in the provinces of Laguna, Camarines Sur, Bukidnon, Quezon, and Cotabato provinces consisting of sandy loam, loam, clay loam, clay loam steep phase, clay, and complex of Macolod-undifferentiated. Additional 19,637 ha of Macolod–Pili soil series complex was mapped in Albay and Camarines Sur provinces.

Kidapawan series (Plate 3E and Fig. B.9) was first described in Kidapawan City, the capital of what is now the province of North Cotabato. Its name originated from "tida" which means spring and "pawan" which means highland. Thus, Kidapawan literally means, "A spring in the highland". It is at the foot of Mount Apo, the highest mountain in the Philippines. Kidapawan series is classified as *Typic Paleudults.* It is a residual soil developed form igneous rocks mostly andesite. The relief is rolling to hilly and mountainous. The external drainage is good to excessive while the internal drainage is good. The surface soil is reddish brown to brown, very slightly compact, prismatic clay loam to sandy clay loam, with depth from 20 to 25 cm. The subsoil is reddish brown to yellowish brown, slightly compact, brittle, columnar clay; plastic and slightly sticky when moist, depth is from 100 to 120 cm. The substratum is yellowish brown, columnar clay; more compact than upper layers. Red mottlings are sometimes present. Below is compact sand with some andesite or other igneous rock boulders (Mojica et al. 1963). This soil series is generally covered by primary and secondary growth forest but the cultivated areas are grown to abaca, corn, sugarcane, coconut, upland rice, vegetables, banana, and fruit trees. A total of 260,581 ha of Kidapawan loam, sandy clay loam, and clay loam were mapped in the provinces of Bukdinon, Cotabato, Davao, and Lanao.

Rizal series was established in what was then Barrio Rizal, Jomalig, an island municipality of Quezon Province. Jomalig was itself a former barrio of Polilio Island and was derived from *humalik* meaning "to kiss". This soil series is derived from the weathered andesite rocks. The relief is undulating to gently rolling and hilly with slopes ranging from 3 to 60 %. The soil is deep and well-drained. Only one soil type, Rizal clay, is mapped under this series, covering some 4,300 ha and classified as *Typic Hapludalfs*. However, there is another soil type, Rizal clay loam, identified in small patches in Jomalig and Patnanongan Islands that are not mappable at the given map scale. The profile description of Rizal series as represented by Rizal clay are as follows: The upper plowed surface soil (Apl) from 0 to 2 cm from the surface are ashes from burned cogon mixed with partially decayed organic matter and clay. The lower plowed surface soil (Ap2) extending down to 22 cm, is reddish yellow (5YR 7/6) clay; friable when dry, sticky and plastic when wet, iron concretions, calcareous material, and partially decayed organic matter are present. The upper subsoil, extending down to 38 cm, is reddish yellow (5YR 6/8) clay; with many red and brown mottles; many iron concretions. The lower subsoil that reaches down to 95 cm is reddish yellow (5YR 6/8) light clay; slightly friable; highly weathered rocks are present. The subsoil that reaches down to the control section is strongly weathered red rocks; the decomposed rocks are easily crushed between fingers; plastic and sticky when wet (Renales et al. 1975). This soil type is under primary and secondary growth forests and cogon grass. The cleared areas are utilized for the growing of rice, corn, coconut, root crops, and banana.

4.3.1.3 Soils Underlain by Loose Sandy Loam, Well-Drained

Taal series (Plate 3G) were first mapped in the municipality of Taal, province of Batangas. Originally located within the famous Taal Lake and Volcano, and present-day San Nicolas municipality, the town has moved to its present location because of the 1754 Taal eruption. Taal is an old settlement that is traced from the Bornean settlers of Panay and founded by two of the ten datus, Datu Dumangsil and Datu Balensuela. Taal got its name from the presence of Taa-lantres in what used to be called Taa-lan River but now known as Pansipit River. Taal, in the Tagalog dialect, means “indigenous” and is considered the center or origin of the Tagalog dialect. Taal series is classified as *Typic Hapludands* and comprises several soil types influenced largely by the successive eruptions of Taal Volcano. This soil occurs from level to mountainous, and thus, would be expected to be found in lowland and upland areas, too. The surface soil is generally grayish brown to light gray when dry and dark brown to nearly black when wet. The substratum is composed of loose sand and gravel in some places and tuffaceous sand and gravel in other places. Near Calaca, the substratum consists of burnt volcanic tuff somewhat resistant to erosion. In lowland areas, the substratum consists of several thin layers of volcanic sand. These different strata of sand indicate different stages of volcanic deposition. A typical profile has a surface soil reaching down to 40 cm of light gray, loose, fine sandy loam of volcanic origin. The subsoil, 40–75 cm from the surface, is gray fine sand, loose and structureless. The substratum is from 75 to 120 cm, brown sandy loam, loose and structureless (Alicante et al. 1938). The drainage is good to excessive externally and good internally. In cultivated areas, the crops planted are generally root crops, sugarcane, upland rice, citrus, and vegetables. A total of 64,135 ha of Taal fine sand, sand, and sandy loam were mapped in Batangas province.

4.3.2 Soils Developed from Predominantly Basalt Parent Materials

4.3.2.1 Soils Underlain by Clay, Splotched with Light Gray to Yellowish Gray to Yellow Color, with Good Drainage

Luisiana soil series (Plate 3E) was first described in the municipality of Luisiana, province of Laguna. This munici pality is a plateau 1,400 ft atop the Sierra Madre mountain range. In 1678, what was then known as the Terreno de Nasunog was divided into three parts: Nasunog de Calamba, Nasunog de Cavinti, and Nasunog de Majayjay. The Nasunog de Majayjay was granted ecclesiastical independence in 1854 by the Governor General (the Marqués de Novaliches) through the efforts of Don Luis Bernárdo and his wife Doña Ana (Wikipedia 2012a). The town was renamed “Luis y Ana” and later shortened to Luisiana to honor them. The soils of this series are developed from igneous rocks, and found on rolling to mountainous relief. The external drainage is good to excessive and the internal drainage is good. Luisiana soil series is classified as fine, clayey, acidic, deep, illitic, isohyperthermic *Orthoxic Palehumults.* The surface soil of this series is brown to light reddish brown, clay loam to clay, prismatic to columnar and coarse granular; sticky when wet, loose and friable when dry. Boundary to subsoil is smooth and obscure. Depth is 25–30 cm. The subsoil is yellowish brown to light reddish brown clay with reddish purple streaks; friable, mellow, and columnar. It is also splotched with light gray, yellowish gray or yellow color. Boundary to substratum is smooth and obscure. Depth is 50–70 cm. The substratum is very friable clay, splotched with light gray to yellowish gray to yellow (Alicante et al. 1948). Some portions are primary and secondary forests and the open lands are cogonal with shrubs. A total of 514,737 ha of Luisiana loam, sandy clay loam, clay loam, and clay were mapped during the reconnaissance soil survey in the provinces of Laguna, Iloilo, Quezon, Camarines Sur, Capiz–Aklan, Catanduanes, Ilocos Norte, Mindoro, Nueva Vizcaya, Zamboanga del Sur, Albay, Batanes, Leyte, Camarines Norte, Negros Occidental, Samar, Sorsogon, Sulu, and Zamboanga del Norte. Another 1,127 ha of Luisiana–Annam Complex were mapped in Nueva Vizcaya, 63,588 ha of Luisiana–Jasaan Complex were mapped in Zamboanga del Norte and Zamboanga del Sur (Fernandez and Clar de Jesus 1980). In the updated semi-detailed soil survey of Laguna, 32,666 ha of Luisiana clay of 5–8, 8–15, and 15–25 % slopes were mapped. Because of the semi-detailed nature of the soil survey, this extent for Luisiana series in Laguna province was increased from 27,154 ha by 5,512 ha or a new total of 520,249 ha of Luisiana series for the whole country.

4.3.2.2 Soils Underlain by Clay, with Numerous Iron Concretions and/or Weathered Rock Fragments, with Good Drainage

Antipolo soil series was first described in Antipolo City, province of Rizal. This city is popular as the pilgrimage site of the Marian image, Our Lady of Peace and Good Voyage brought in from Mexico in 1626. The city was named after the breadfruit tree called Tipolo (*Artocarpusincisa*) which is abundant in the area. It was initially established as a settlement by Franciscan missionaries in 1578 and replaced in 1591 by the Jesuits. It became a town in 1650 as part of Tondo Province but later on separated to be part of the District of Morong (Wikipedia 2012b). Antipolo soils are classified as fine, mixed, isohyperthermic *Typic Tropudalfs*. Antipolo series is formed from basalt, igneous, and other volcanic rocks. The relief is rolling basaltic hills and ridges to mountainous and some portions are slightly rolling to almost flat, especially the localized valleys. Thus, this soil series is also expected to occur on upland areas. The Antipolo series are well-drained soils and permeability is moderate. The surface soil, 20–30 cm in depth, is light reddish brown to almost red, friable, and finely granulated clay. Spherical tuffaceous concretions are present. The subsoil, depth ranging from 50 to 90 cm, is reddish brown, granular, and friable clay with fine spherical concretions. Lower subsoil is weathered tuffaceous material with few concretions. The substratum is reddish brown to light reddish brown coarse granular clay with numerous iron concretions (Alicante et al. 1938b). Antipolo series is somewhat similar to Pinugay soil series. Although both soils are classified as Tropudalfs, Antipolo soils are generally shallower and derived from basalt while Pinugay soils are deeper and derived from shale. Antipolo soils are also somewhat similar to the well-drained shallow to moderately deep Novaliches and Bugarin series and the generally deeper Camarin soils. They differ in physiographic position and parent materials. Novaliches soils are derived from volcanic tuff, Camarin from conglomerates, while both Bugarin and Antipolo series developed from basaltic materials. Novaliches soils are found on undulating to rolling dissected tuffaceous plateau, Camarin on undulating to rolling conglomeratic footslopes, and Bugarin on dissected upper plateau of the volcanic hills landscape. Most of the Antipolo series are utilized for rainfed rice or just grassland on the lower slopes and cogon, grasses, shrubs, and patches of fruit trees on the higher slopes. A total of 525,951 ha of Antipolo clay loam, sandy clay, clay, and undifferentiated were mapped during the reconnaissance soil surveys in the provinces of Rizal, Bataan, Laguna, Zamboanga del Sur, Quezon, Bataan, Lanao, and Zambales. Additional 86,726 ha of Antipolo–Alimodian–Luisiana Complex were mapped in Camarines Sur, and 54,062 ha of Antipolo–Bolaoen Complex were mapped in Zamboanga del Sur. In the updated and semi-detailed soil survey of Rizal province, a total of 9,139 ha of Antipolo clay were mapped at 5–8, 8–15, and 25–45 % slopes. In the reconnaissance soil survey of Rizal, there were 8,680 ha of Antipolo clay loam, 51,540 ha of Antipolo clay or total of 60,220 ha. There was a reduction by 51,081 ha of Antipolo soil series as these were either reclassified as other soil series or converted to urban areas, bringing down the total of Antipolo soil series to 35,645 ha for the whole country.

Lumbangan series is quite interesting as to the origin of the name since there are several places in the Philippines named Lumbangan such as those in the provinces of Batangas in Luzon, Negros Oriental in the Visayas, and even Zamboanga City in Mindanao. But this soil series was named after a place in Rizal province. A large portion of this soil series is mapped in the northern part of the area covering Mount Baytangan, Mount Mataba, and Mount Binicayan as well as on the north and northeast of barangay San Isidro, municipality of Montalban (now known as the municipality of Rodriguez) on steep and highly dissected volcanic hills with angular crests of the volcanic hills landscape. Lumbangan series is classified as very fine, mixed, isohyperthermic *Typic Eutropepts.* These soils are moderately deep to deep and well-drained. The A horizon 10–20 cm thick is dark red, dark yellowish brown, or dark grayish brown clay, firm when moist, sticky and plastic when wet. The structure is subangular and angular blocky that sometimes break upon moderate pressure into granular structure. The cambic B horizon, 65–150 cm thick, is dark reddish brown, red, yellowish red, brown to dark brown clay with diffuse red, yellowish red or dark yellowish brown mottles. The consistence is firm when moist, sticky and plastic when wet; structure is angular and subangular blocky. Few weathered rock fragments occur at the lower B horizon. The C horizon or the substratum is dark red, yellowish red, or brown to dark brown clay or clay loam with common to many partly or highly weathered rock fragments. Structure is subangular and angular blocky, firm when moist, sticky and plastic when wet. A total of 9,433 ha of Lumbangan clay were mapped in Rizal province. Lumbangan series is quite similar to Inarawan series since both occur on hilly volcanic landscapes but these two soils are found on different physiography. Lumbangan is found on very steep highly dissected volcanic hills with angular crests. Inarawan is on moderately dissected upper plateau with hillocks. Inarawan is also an Ultisol, geologically older and has an argillic horizon (Soil Survey Division 1989).

Inarawan series is named after barangay Inarawan in the municipality of Antipolo, province of Rizal. This soil series is classified as *Orthoxic Tropudults.* The soils are deep, well-drained occurring on slightly to moderately dissected upper plateau with hillocks of volcanic hills landscape. The A horizon 10–17 cm thick is dark brown, strong brown, or dark reddish brown clay with brown to dark brown mottles; firm when moist, slightly sticky and plastic when wet. Structure is angular to subangular blocky breaking to granular structure. The argillic B horizon 110–150 cm deep is reddish brown, dark reddish brown, red, yellowish red or dark yellowish brown clay with diffused red, yellowish red, or dark reddish brown mottles. The consistence is firm when moist, sticky and plastic when wet; structure is angular to subangular blocky breaking upon moderate pressure to granular structure. Few weathered yellowish brown, black or yellowish red rock fragments commonly occur at the lower B horizon. The C horizon is red or dark reddish brown clay with red mottles. The consistency is firm when moist, sticky and plastic when wet; structure is angular to subangular blocky. Common to many partially or highly weathered rock fragments are found on this layer. About 2,449 ha of Inarawan clay was mapped in Rizal province covering part of Mount Mataba, Mount Baytangan, and Mount Kaymayuman. This soil series is somewhat similar to Lumbangan, San Luis, and Sampaloc series. Although they are all derived from basaltic rocks and are well-drained, these soils differ in their taxonomic classification and in physiographic position. Inarawan and Sampaloc are classified as Orthoxic Tropudults while San Luis is classified as Ultic Tropudalfs. Lumbangan is Typic Eutrupepts. Inarawan and Lumbangan occur in the volcanic hills landscape while San Luis and Sampaloc are found on volcanic footslopes (Soil Survey Division 1989).

4.3.2.3 Soils Underlain by Clay, Mottled by Red Splotches, Has Highly Weathered Stones and Cobblestones at Lower Substratum, with Fair Drainage

Dolores soil series were mapped in the hilly and mountainous areas of Barangay Dolores, municipality of Sta. Cruz, island province of Marinduque. Because of the relief, the external drainage is excessive while the internal drainage is fair. This soil series is classified as *Typic Eutrudepts* and only one soil type, Dolores clay loam, was mapped covering 1,057 ha in Marinduque. The surface soil, reaching down to 25 cm, is brown to grayish brown clay loam; friable when dry with medium granular structure. The subsoil, reaching down to 70 cm from the surface, is reddish brown, slightly compact clay, sticky and plastic when wet; highly weathered gravels and cobblestones are found. The substratum, extending down to the control section at 150 cm, is brown, sticky clay, mottled by red splotches; at lower substratum are highly weathered stones and cobblestones (Salazar et al. 1962).

4.3.2.4 Soils Underlain by Clay Loam with Gravels, with Good Drainage

Bayho series was first established in Bayho, Catarman, Samar and classified as *Typic Eutrudepts*. Presently, Bayho is a barangay of Lope de Vega municipality, province of Northern Samar. This soil series is deep and moderately permeable, developed from weathered igneous rocks. It occurs on rolling, hilly, to mountainous relief. Bayho is similar to Luisiana series in relief and in parent materials but differs in the soil color, depth, and profile development. Luisiana series is deep while Bayho series is shallower and lighter in color and the profile is less intensively developed than Luisiana. Bayho is also similar to Libertad series except for the absence of concretions which are present in the Libertad series. This soil series is characterized by brown to dark brown loam to clay loam granular structure surface soil underlain by a light brown to reddish brown granular clay loam layer containing some soft gravels over a layer of gravels. Some of the gravels can be broken easily between fingers. The surface soil extends down to 30 cm from the surface, brown to dark brown clay loam, granular structure. The subsoil reaches down to 70 cm, light brown or dark brown to reddish brown clay loam granular to block structure with few gravels sporadically embedded which can be broken easily between the fingers. The substratum is light brown to reddish brown clay loam granular to blocky structure with more gravels than the above layers. Coconut and sweet potato are the principal crops grown (Simon et al. 1975). Other crops are upland rice, corn, abaca, banana, and some fruit trees. A total of 60,563 ha of Bayho clay loam were mapped in the Samar provinces.

Barotac was first described in Iloilo province. There are two municipalities in the province bearing this name—Barotac Nuevo and Barotac Viejo. Classified as *Typic Eutrudepts*, this soil series occupy the hilly and mountainous areas north of Barotac Viejo to the south of Ajuy. This soil series is a residual soil, developed from basalts overlaid on shales. The relief is hilly to mountainous, the topography is irregular and the slopes are steep. The elevation reaches up to 76 m above mean sea level. The drainage characteristic is excessive externally and fair internally. The surface soil, reaching down from 20 to 30 cm, is brown to light reddish brown, moderate and medium granular, moderately friable loam to clay loam, gravels and other sizes of stones are present. The upper subsoil, extending down from 60 to 70 cm, is dark brown, slightly crumbly, slightly compact, coarse granular clay loam. Gravels and other sizes of stones are present. The lower subsoil, reaching down from 100 to

110 cm, is dark brown to light brown, moderately hard and brittle, compact, clay loam with gravels and other sizes of stones. The substratum, reaching down to the control section at 150 cm, is light gray to grayish brown, moderately hard, brittle, and slightly compact clay loam with stones and gravels (Alicante et al. 1947). The cultivated areas are planted to rice and corn while the uncultivated areas are cogonal and secondary growth forest. A total of 34,434 ha of Barotac loam (mountainous), loam—lowland phase, and clay loam (hilly) were mapped in the provinces of Iloilo and Sulu. This soil series differs from Annam and other reddish soils by the presence of stones and gravels in all horizons, and by the presence of boulder and cobblestone outcrops on the surface soil.

4.3.2.5 Soils Underlain by Weathered Basaltic Rocks, with Fair Drainage

Sigcay series was first described in barangay Sigcay, municipality of Banga, province of Aklan when Aklan was still considered part of Capiz province. Hence, references to the origin of the soil series would refer to a place in Capiz. This municipality has repeatedly won national competitions as the "Most Beautiful Town" contests in the country and the site of the Aklan State University. Its history dated back to fifteenth century with the arrival of the Ten Datus from Borneo and its ancient name of Bakan, ruled by Datu Dangandanan and succeeded later on by Datu Manduyog (Wikipedia 2012c). This soil series is classified as fine isohyperthermic *Typic Hapludults*. This series is a residual soil developed from igneous rocks, mostly basalts. It consists of red soils on rolling and hilly to mountainous places, quite deep similar to Luisiana series. Sigcay and Luisiana series have many similarities but they differ in one particular respect: In Sigcay series, there is a deep layer of massive white soil materials, known locally as *isu*, found below the subsoil which does not exist in Luisiana series. The external drainage is good to excessive while the internal drainage is fair. The surface soil of this series is brown, brownish red, yellowish brown to light brown, medium coarse granular clay; slightly sticky and plastic when wet, hard and compact when dry, with soil depth ranging from 20 to 25 cm. The upper subsoil is brown, yellowish brown, light brown to yellowish red with few orange splotches, slightly friable and slightly loose, coarse granular clay loam to sandy clay loam with depth reaching to about 45–50 cm. The lower subsoil is grayish brown to brick red, friable, and gritty sandy clay loam with some gravels, depth ranging from 60 to 65 cm. The substratum is gray to white, highly weathered basaltic rocks, loose, friable, and gritty. Dark grayish brown mottlings are present. Below this layer is a bed of consolidated rocks (Calimbas et al. 1962). Generally, this soil series is covered by secondary forest and grassland. The cultivated areas are grown to upland rice, corn, root crops, vegetables, coconuts, bananas, fruit trees, and bamboos. A total of 4,479 ha of Sigcay clay were mapped in Capiz–Aklan provinces.

4.3.2.6 Soils Underlain by Weathered Basaltic Rocks, with Good Drainage

Sapian series was first described in Sapian municipality, province of Capiz. Sapian was started as a settlement in the sixteenth century after the occupation of the country by Spain. The morphology maybe similar to Luisiana and Sigcay series but Sapian series is shallow and light brown to brown. This soil series is classified as fine, isohyperthermic *Typic Hapludults*. The soils of this series are developed from igneous rocks, mostly basalts. The relief is rolling and hilly to mountainous. The external drainage is good to excessive while the internal drainage is fair. The surface soil of this series, extending down to 25 cm from the surface, is brown to light brown clay, medium coarse granular; slightly sticky and plastic when wet, hard and compact when dry. The upper subsoil, reaching down to 50 cm, is brown to light brown clay loam to sandy loam, coarse granular structure; slightly friable, and loose. The lower subsoil, extends down to 65 cm, is grayish brown sandy clay loam, loose, friable, and gritty; some gravels present. The substratum, reaching down to the control section at 150 cm, is highly weathered basaltic rocks, gray, with dark grayish brown mottles. Below this layer is a bed of consolidated rocks (Calimbas et al. 1962). This soil series is generally covered by cogon and secondary forest. The cultivated areas are planted to upland rice, corn, rootcrops, coconuts, bananas, mango, beans, and fruit trees. A total of 31,571 ha of Sapian clay loam, silty clay loam, and clay were mapped in the provinces of Capiz–Aklan and Sulu.

4.3.3 Soils Developed from Andesite–Basalt Parent Materials

4.3.3.1 Soil is Underlain by Clay with Gravels and Pebbles, with Good Drainage

Balanacan series was first established in barangay Balanacan, municipality of Mogpog, the island province of Marinduque, on the northwestern shore of Port Buyabod on the northeastern coast of the province, covering the hilly and mountainous northern area facing the sea. External drainage is excessive, the internal drainage is fair and good. This soil series was formed from the weathering and decomposition of igneous rocks in place, such as basalts and andesites. It is fairly well-drained soil, even excessive externally due to relief. The surface soil is brown clay, friable when dry, sticky and plastic when wet, with gravels and pebbles and has a depth from 20 to 30 cm. The subsoil is dark brown clay loam mixed with concretions and gravels

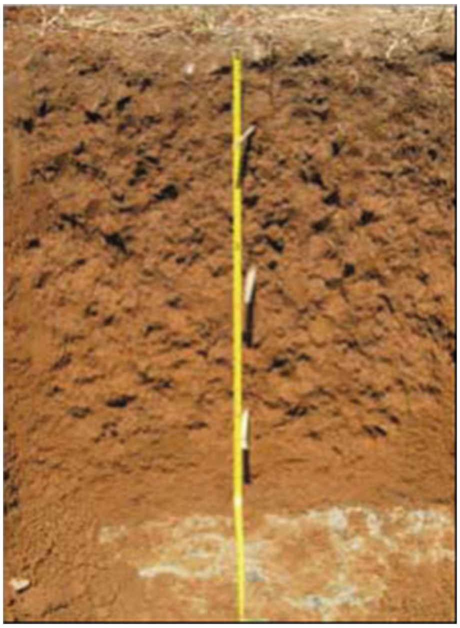


Fig. 4.1 Soil profile of Maranlig series

which become black powdery mass when crushed. The lower subsoil contains gravels and cobblestones instead of concretions, and reaches down from 70 to 110 cm from the surface. The substratum is dark yellowish brown clay mixed with highly weathered stones (Salazar et al. 1962). A total of 5,975 ha of Balanacan clay were mapped in the island province of Marinduque. This soil series is classified as fine, isohyperthermic *Typic Eutrudepts.*

Maranlig series is classified as fine, isohyperthermic *Typic Hapludults* and was first described in barangay Maranlig, municipality of Torrijos, island province of Marinduque. This is a primary soil derived from basalt and andesite. The relief is rolling to mountainous. The drainage is good to excessive externally and fair internally. The surface soil is brown, yellowish brown to dark reddish brown, fine granular clay, sticky and plastic when wet, friable to slightly compact when dry, depth is from 25 to 30 cm. The subsoil is dark brown to reddish brown, massive clay, very sticky and plastic when wet, hard and compact when dry, depth is from 95 to 110 cm. The substratum is reddish brown clay. Weathering iron-stained stones of varying sizes are found and impart pinkish red splotches (Salazar et al. 1962). This soil series covers extensive rolling to hilly areas under secondary forest and grasses. The cultivated areas are principally grown to coconut, upland rice, corn, bananas, and root crops. A total of 86,009 ha of Maranlig loam, sandy clay loam—gravelly phase, and clay were mapped in the two island provinces of Mindoro and Marinduque (Fig. 4.1).

4.3.3.2 Soils Underlain by Massive Clay Loam to Sandy Loam, Mottled, with Weathered Sandstone, with Fair Drainage

Camiguin series (Plate 3C and Fig. 1.82) was named after Camiguin, formerly part of Misamis Oriental but is now an island province located in the Bohol Sea in the northern coast of Mindanano. The name was derived from *kamagong*, a species of ebony tree that thrived in Surigao del Norte where the earlier inhabitants of the island came from, the Manobos. Kinamigin, the local dialect of this island, is closely related to the Manobo language. Old Spanish documents seem to indicate that Ferdinand Magellan and Miguel Lopez de Legazpi landed in Camiguin in 1521 and 1565, respectively (Wikipedia 2012d). The Camiguin soil series is closely associated with Mambajao and Jasaan soils. It differs from the last two soils in that the Camiguin soil has big boulders of basalt and andesite as well as rock outcrops scattered in abundance on the surface soil. These are also embedded in the profile. The relief is rolling, hilly, and mountainous. The elevation is from 91 to 914 m above mean sea level. Due to the relief, the surface run off is good to excessive. The internal drainage is fair. The soil is developed from the weathered products of volcanic sand, basalt, and andesite rocks. The surface soil reaches down to 25 cm, dark brown to light brown compact lay, hard when dry, sticky and moderately plastic when wet; medium granular structure. The upper subsoil extends down to 55 cm, brown to light brown clay, compact and hard; columnar structure. The lower subsoil extends down to 70 cm, light brown to reddish brown clay with few sandstone gravels; columnar in structure. The substratum reaches down to the control section at 150 cm, light brown, strong brown, to reddish brown clay loam to sandy loam spotted with mixture of brick red and dark brown weathered sandstone; massive structure (Lopez et al. 1954). The cultivated areas are devoted to rice, corn, fruit trees, banana, and root crops. Coconut grows well along the coast. A total of 80,488 ha of Camiguin clay loam and clay were mapped in the provinces of Misamis Oriental, Misamis Occidental, and Sulu. This soil series is classified as *Typic Hapludands.*

4.3.3.3 Soils Underlain by Clay Loam, with Highly Weathered Rock Fragments, with Good Drainage

Kay Bamban series is classified as very fine, mixed, isohyperthermic Typic Tropudalfs and was named after barangay Kaybanban, San Jose del Monte City in the province of Bulacan. This soil series consists of deep well-drained clayey soils that occur on rolling to steep moderately dissected volcanic foothills and ridges of the hilly landscape. The surface layer, 18 cm thick, is very dark brown clay with few reddish brown mottles. The subsoil (argillic horizon), reaching to a depth of 122 cm, is reddish brown or dark reddish brown clay. The substratum is dark reddish gray slightly sticky, slightly plastic, slightly firm clay loam, with many partially and highly weathered rock fragments (Soil Survey Division 1987). Kay Bamban series is associated with shallower lower lying Novaliches series and gravelly and moderately deep Paradise series of the hilly landscape. The main vegetative cover consists of orchard trees, diversified upland crops and native trees but the higher slopes (15–25 %) are mostly covered with grasses, brushes, and trees. About 5,490 ha of Kay Bamban clay were mapped in the province of Bulacan.

4.3.3.4 Soils Underlain by Clayey and Gravelly Materials and Weathered Rock, with Fair Drainage

San Fabian series (Plate 3G) was first described in the municipality of San Fabian, province of Pangasinan. The soils of this series consist of very dark brown to dark gray gritty surface soils and grayish brown to dark brown subsoils. The surface soil reaches down to 25 cm, dark brown to dark gray clay loam, nutty to cloddy in structure; gravelly and plastic when wet, hard and cloddy when dry. The subsoil reaching down to 45 cm is grayish brown clay loam; granular to nutty in structure; cloddy when dry, sticky and plastic when wet. The substratum, extending down to 120 cm, is pale gray to whitish gray, soft, cheesy, or powdery clay loam to clay; a mixture of gravelly materials and highly weathered parent material of chalk white soft rock (Alicante et al. 1940). The unplowed soil during the dry season is compact hard, and cracks into big clods to a depth of 30 or more centimeters. The surface soil is coarse and fragmental, attained during the first rain, making plowing possible without producing clods. Within the series are included areas that are reddish brown from the surface down to the parent material, occurring in small patches. The topographic feature is hilly to rolling and only small areas are slightly level. The buri palm is the characteristic vegetation growing in this soil. In hilly areas, cogon grows when trees are cut. A total of 31,012 ha of San Fabian clay loam were mapped in the provinces of La Union, Mindoro, Nueva Ecija, and Pangasinan. These soils are classified as fine, loamy, isohyperthermic *Typic Eutrustepts.*

4.3.3.5 Soils Underlain by Clay Loam to Clay, with Weathered Fragments, Consolidated Materials Below, with Good Drainage

Burgos series (Plate 3C) is classified as *Typic Hapludults* and was first described in the municipality of Burgos, province of La Union. This is a residual soil that developed from andesites, basalts, and diorites. It occurs on hilly to mountainous relief. The drainage is good to excessive externally and good internally. The surface soil is light brown, dark brown, reddish brown to brownish red, medium coarse granular, slightly compact clay, friable when dry, sticky when wet, and depth ranging from 20 to 30 cm. The subsoil is coarse granular, friable to sticky clay loam to clay, lighter in color than the upper layer, depth is from 40 to 60 cm. The substratum is similar to the above layer with some weathered fragments of basalts and andesites. Consolidated basalt and andesite is found below the substratum (Alicante et al. 1950). Burgos clay covers 14,015 ha in the provinces of Benguet and La Union.

4.3.3.6 Soils Underlain by Clay Loam to Clay, with Weathered Fragments, Consolidated Materials Below, with Fair Drainage

Bugarin series is classified as fine, mixed, isohyperthermic *Typic Dystropepts.* This soil series was first described in sitio Bugarin, barangay Halayhayin, municipality of Pililla, province of Rizal. Mount Sembrano lies between the boundaries of Pililla and Jalajala of Rizal Province and Pakil municipality of Laguna province. Mount Sembrano is part of the pre-caldera Pleistocene volcanism formed from basaltic to basaltic–andesitic volcanoes of what is known as the Laguna Caldera. This is the middle lake-filled basin of the three-pronged, dinosaur-footprint-shaped Laguna de Bay believed to have been formed at least during two major explosive eruptions about 1 million and 29,000 years ago. Jalajala is a solfataric field on the flank of Mount Sembrano on the Jalajala Peninsula which forms the eastern rim of the caldera (Smithsonian National Museum of natural History—Global Volcanism Program Undated). Pililla is between Mount Sembrano and Jalajala. These soils that eventually developed are shallow to moderately deep, well-drained occurring on slightly to moderately dissected upper plateau with hillocks of the volcanic hills landscape. The soils are brown to dark brown, very dark brown clay or clay loam in the A horizon, usually not more than 20 cm thick. The cambic B horizon, 40–100 cm deep, is brown to dark brown, dark yellowish brown clay or silty clay loam with diffuse brown to dark brown or strong brown mottles. The C horizon is dark yellowish brown, strong brown or brown to dark brown clay or silty clay loam with common to many weathered rock fragments. Underlying this horizon is hard bedrock (Soil Survey Division 1989). Bugarin series is somewhat similar to Lumbagan and Tulay series. Both Tulay and Bugarin belong to great group Dystropepts having less than 50 % base saturation by ammonium acetate. The Lumbagan soils belong to Eutropepts and have greater than 50 % base saturation. Tulay series has thicker solum than Bugarin and Lumbagan. Bugarin and Lumbagan occur on slightly to moderately dissected upper plateau with hillocks and very steep highly dissected hills with angular crests of the volcanic hills landsacape. Tulay soils are found on undulating to rolling hills and ridges with localized valleys of the volcanic footslopes. Except for some areas devoted to citrus, mango, and other patches of fruit trees, this soil series is generally uncultivated, the lower slopes utilized as pasture, and the higher slopes are covered by cogon, shrubs, and other grasses. A total of 1,413 ha of Bugarin clay was mapped in Rizal province.

4.3.3.7 Soils Underlain by Sandy Clay with Pebbles and Stones, Well-Drained

Nupol series got its name from Nupol Hill at the foot of Mount Matutum in Cotabato. Nowadays, Nupol refers to a sitio in Barangay Conel, General Santos City, a highly urbanized city of South Cotabato. Nupol Hill is also known as Conel Hills as it borders barangays Conel and Mabuhay. This soil series is associated with the Tupi series which developed at the footslopes of Mount Matutum. Only through the examination of the profile are the distinguishing characteristics differentiated. While the substratum of Tupi is gray coarse sand with gravels and boulders, Nupol is sandy clay also with boulders. Below this layer is sandy clay, reddish brown, or brown with no coarse skeleton. Cogon dominates the vegetation of the area. Secondary growth forest grows along the banks of gullies. Rice is the principal crop planted in the kaingin. Nupol sandy loam covers 5,625 ha and classified as *Typic Hapludands*. Nupol soil is very dark gray to almost black. On drying it becomes gray or nearly so. The surface soil of this series, reaching to a depth of 15 cm is dark brown to almost black sandy loam, friable and structureless; slightly compact; stones are absent. The subsoil extends down to 60 cm and is medium brown to brown sandy loam, slightly compact; structureless; gravel are sometimes present. The substratum, 60–170 cm in depth is a layer of pebbles and stones imbedded in sandy clay. Below this layer is sandy clay (Mojica et al. 1963).

4.3.3.8 Soils Underlain by Sand, with Rounded and Smooth-Edged Gravels, Cobblestones, and Boulders, Poorly Drained and Characterized by Presence of Redoximorphic Features

Mayon series was first mapped embracing the eastern half of Mayon Volcano in Albay province, with moderately to roughly sloping relief, generally cut by gullies and deep ravines radiating from the summit of Mayon Volcano. Mayon Volcano is an active strato volcano. The rock type is usually basalt to olivine-bearing pyroxene andesites, with historical eruptions ranging from Strombolian to basaltic Plinian type. The cyclical activity usually begins with a basaltic eruptions followed by longer term andesitic lava flows (Isaac Kerlow and Earth Observatory of Singapore 2010). This soil series was developed mostly from the

Fig. 4.2 The landscape feature where the Mayon series occurs

products of weathered massive lava rocks, volcanic ashes agglomerates, tuff and breccias. It is well to excessively drained externally but poorly drained internally. The elevation is from 91 to 823 m above mean sea level. The surface soil is grayish brown to brown. The subsoil is brown to yellowish brown with mottlings sandy loam. Boulders are found on the surface as well as imbedded in the profile. Under the substratum is a deposit of volcanic sand, gravels, cobblestones, and boulders. External drainage is good to excessive but the internal drainage is poor to fair. The surface soil, reaching down to 30 cm from the surface is gravelly sandy loam; grayish brown, brown to dark brown; structureless; loose, porous, soft and mellow when wet, friable when dry; boulders are present on the surface which sometimes hamper cultivation. The subsoil, extending down 75 cm in depth is sandy loam; brown to yellowish brown with black and mottlings; structureless to granular; soft when wet; porous and friable when dry; a few boulders are imbedded. The substratum, at 75 cm and below, is a deposit of sand, rounded and smooth-edged gravels, cobblestones and boulders, light to dark gray with black speckles (Aristorenas et al. 1965). The profile characteristics of these soils portray a recent deposition resulting from a series of volcanic eruptions. The unsustainability of the profile characteristics is due to the intermittent deposition of lave and ashes, together with volcanic rocks over the area. Thus the degree of development of the solum is less distinct except for the color changes. There is a clear transition line for zones of eluviation and illuviation. This soil series is classified as *Typic Hapludands* and occupies a total of 14,910 in the provinces of Albay (Mayon sandy loam gravelly phase) and Cagayan (Mayon loam). The rocky and roughly sloping areas are devoted to some fruits and coconut but mostly to abaca. The moderately to slightly sloping areas are devoted to gabi, upland rice, camote, cassava, peanut, beans and other seasonal crops (Figs. 4.2, 4.3).

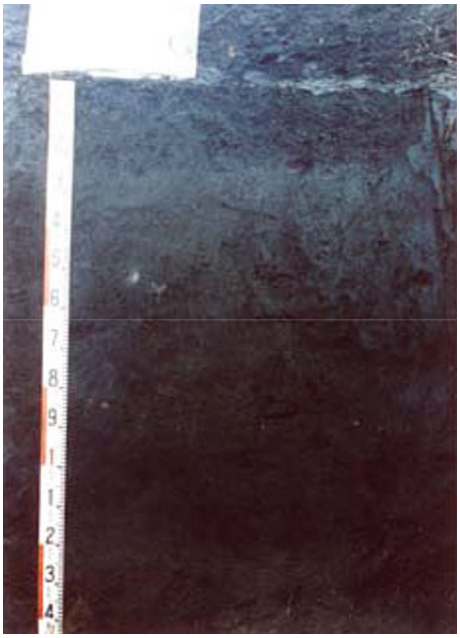


Fig. 4.3 Soil profile of tephra-derived Mayon series with the melanic epipedon and greasy feel characteristics of the more commonly known Andisols

4.3.3.9 Soils Underlain by Weathered Rocks, Poorly Drained, and Characterized by Presence of Redoximorphic Features

Bulusan series represent the soils of the south and southwest footslopes of Mount Bulusan. These are primary soils developed from the weathering of massive to fragmental volcanic rocks, mostly basalt and andesite. Delfin (1991), McDermott et al. (2005) discussed that the pre-caldera volcanics of Bulusan Volcanic Complex consist of older basalt and pyroxene andesites intercalated with tuffs and laharic breccia and younger pyroxene andesites, some of them hornblende bearing. The relief is generally undulating to rolling and mountainous. The elevation ranges from 27 to 1,433 m above mean sea level. Bulusan Volcano itself rises to 1,565 m above mean sea level. The natural surface drainage is good to excessive with slow internal drainage. The surface soil, extending down to 50 cm from the surface, is dark brown, brownish black to black loam; fine granular, loose and friable; boulders are found in the surface soil in some places. The upper subsoil reaches down to 95 cm, light brown, grayish brown to light yellowish brown clay loam; medium fine granular; free from stones. The lower subsoil, reaching down to 115 cm, is yellowish brown, grayish brown to light yellowish brown loam to silt loam; with splotches of gray; fine granular to coarse columnar; slightly compact and free from stones. The substratum starting from 115 cm to indefinite depth below is highly weathered rocks, light orange brown to light brown mottled with orange and gray; pebbles and conglomerates are present (Aristorenas et al. 1963). A large area is planted to abaca and coconut. The rest of the cultivated areas are devoted to upland rice, corn, root crops, some fruit trees, and vegetables. Bulusan series is classified as *Typic Hapludands,* and Bulusan sandy loam and loam covers 37,310 ha in the province of Sorsogon.

4.3.3.10 Soils Underlain by Weathered Rocks, Well-Drained

Paete series (Plate 3F) was first mapped in the lower slopes of the South Sierra Madre mountain ranges in the vicinity of Pagsanjan, San Juan, Longos, Paete, Pakil, and Pangil in the province of Laguna. This soil series was named after the municipality of Paete on the northeastern part of the province, along the shores of the Laguna de Bay (pronounced as Ba-i). This town has also a long history, with inhabitants of Malay lineage believed to have sailed in their sturdy boats called "balangay", all the way from Borneo. Paete is known for its highly skilled word carvers, carried to these days by present generation artists (Wikipedia 2012e). The soil series has a hilly and mountainous topography. Classified as *Typic Eutrudepts,* a typical profile is as follows: The surface soil, extending down to 15 cm from the surface, is brown to dark brown slightly granular clay loam with plenty of pebbles, stones, and boulders. The upper subsoil reaches down to 50 cm, reddish brown to brown granular clay loam to clay; pebbles and stones are present. The lower subsoil that reaches down to 90 cm, is brown to reddish brown clay with big basaltic boulders. The substratum that extends down to the control section at 153 cm is weathered andesitic and basaltic rocks (Alicante et al. 1948). These soils are generally planted to coconut. Other crops are banana and citrus. A total of 49,829 ha of Paete loam, clay loam, and clay were mapped in the provinces of Laguna, Sulu, and Zamboanga del Norte.

Lupa series was first mapped in barangay Puting Lupa, municipality (now component city) of Calamba, province of Laguna. Lupa series is classified as fine, clayey, mixed, isohyperthermic *Typic Eutropepts.* These soils are shallow to moderately deep, well-rained soils formed from volcanic cinder deposits appearing either as volcanic hills, cinder cones, and ridges with moderate relief. The A horizon is brown, dark brown, and dark grayish brown clay loam, with few and medium faint and diffuse brownish mottles. Soil structure is moderate fine granular and the consistency is slightly sticky and slightly plastic when wet. The cambic B horizon ranges from 15 to 40 cm in depth, mainly brownish in color and has generally clayey texture. The substratum is brownish in color, with common to many fine and medium rock fragments, with weathering as well as fresh gravelly materials. About 1,529 ha of Lupa series was mapped in Laguna province. Lupa series is associated with Lipa series. These are two well-drained soils and both are shallow to moderately deep. Lipa series, however, is classified mainly on undulating to rolling moderately dissected tuffaceous piedmont plain while Lupa series is found on higher slopes of low hills, cinder cones, and ridges. Lipa series is darker than the brownish Lupa series. Lipa series is extensively utilized to sugarcane while Lupa is marginal to this crop except in lower slopes. Coconut is the main landuse of Lupa soils.

4.3.3.11 Soils Underlain by Unweathered Rock (Hard Conglomerates), with Fair Drainage

Malitbog This soil series was first described in the municipality of Malitbog, now province of Southern Leyte. This municipality when reorganized in 1893 under the provisions of the Maura Law, covered the island of Limasawa, which is now a separate municipality, and claimed to be the place where the first Catholic mass was held in the Philippines, on March 31, 1521 based on the chronicles of Antonio Pigafetta, the diarist of Ferdinand Magellan (Wikipedia 2012f). Malitbog series is classified as *Typic Eutrudepts.* Malitbog series is developed from andesite and basaltic rocks. The relief is hilly and mountainous. The external drainage is good to excessive and the internal drainage is fair. The surface soil is dark grayish brown, good coarse granular clay to clay loam, slightly sticky when wet, slightly compact when dry. Boulders are present as outcrops, with depth ranging from 15 to 20 cm. The upper subsoil is reddish brown to light brown clay with structure and consistence similar to those of the surface soil. Some boulders are present and depth is from 35 to 40 cm. The lower subsoil is yellowish brown, massive clay; soft, and sticky when wet and slightly compact when dry, with depth ranging from 75 to 80 cm. The substratum is dark brown, structureless rock and very hard conglomerates (Barrera et al. 1954). The vegetative cover of this soil series is primary and secondary forests, and cogon in grassland areas. The cultivated areas are grown to upland rice, corn, and coconut. A total of 11,661 ha of Malitbog clay were mapped in the province of Leyte.

4.3.4 Soils Developed from Diorites

Ambassador series is brownish in color while *Atok* series is darker. *Bakakeng* is reddish and has no weathered parent materials in the substratum.

4.3.4.1 Soils Underlain by Silt Loam with Highly Weathered Parent Materials and with Good Drainage

Ambassador series (Plate 3A) is derived from highly weathered diorite and quartz diorite. This soil series was first described in Barangay Ambassador, municipality of Tublay, province of Benguet at kilometer post number 266.8 of the Benguet–Bontoc Road. Classified as *Typic Hapludults*, only one soil type, Ambassador silt loam was mapped in Benguet covering 10,489 ha. The relief is moderately steep to steep with slope crest of 5–8 %. The drainage is good. The elevation is 1,400 m from the mean sea level. This soil series is mostly covered by pine trees and some portions are planted to vegetables. The surface soil extends down to 15 cm is dark brown (7.5YR 3/2) fine granular friable silt loam. The upper subsoil reaches to a depth of 36 cm from the surface, and is yellowish red (10YR 7/6) fine granular friable silty clay loam. The lower subsoil reaches a depth of 90 cm, light red (2.5YR 6/8), red (2.5YR 5/8) fine granular friable silt loam with highly weathered parent materials. The upper substratum reaching a depth of 130 cm is yellowish red (5YR 5/6) and (5R 5/8), fine granular friable silt loam with highly weathered parent materials. The lower substratum that extends down to the control section at 150 cm is weak red (7.5YR 5/4) coarse angular blocky loam (Calaustro and Ganawan 1968).

4.3.4.2 Soils Underlain by Loam, with Poor Drainage and Characterized by Presence of Redoximorphic Feature

Bakakeng series (Plate 3A) is formed from the weathering of igneous rocks. It was first described at Bakakeng Road, kilometer post number 4 from Baguio City to Mount Sto. Tomas. This soil series developed from diorite and occupies 1,253 elevation. The relief is moderately steep to very steep. The external drainage is good to excessive while the internal drainage is moderately slow. Vegetables such as cabbage, Baguio beans, tomatoes, and potatoes, as well as sweet potato, coffee, and cutflowers are grown. The topsoil reaches down to 23 cm from the surface, dark reddish brown (2.5YR 3/4) to dark red (2.5YR 3/2) fine granular sandy clay loam. The upper subsoil extends down to 65 cm is dark reddish brown (2.5YR 4/6) medium granular very firm clay loam. The lower subsoil reaches down to 122 cm, and is red (2.5R 5/6) medium granular very friable loam. The upper subsoil reaches down to 140 cm, red (2.5R 4/6) medium granular loam with black concretions. The lower subsoil extends to the control section at 150 cm, and is dark red (2.5YR 3/6) medium granular loam (Calaustro and Ganawan 1968). This soil series is classified as *Typic Dystrudeps* and only one soil type, Bakakeng sandy loam was mapped in Benguet covering 13,557 ha, occupying the eastern half of Baguio City including Loakan air strip, Antamok and Balatoc mines up to the ridge west of Biaga Dam.

4.3.4.3 Soils Underlain by Loam, with Good Drainage

Atok series (Plate 3A) developed from highly weathered diorite materials. This soil occurs at elevation of 1,253 m.

The relief is steep to very steep. External drainage is good to excessive while internal drainage is good. This soil series, classified as *Typic Hapludolls,* was first described in the municipality of Atok, province of Benguet, along the road to Atok starting from the junction of the Benguet–Bontoc Road, and Atok Road up to Atok poblacion and along the Amburayan River. The name is the short term for a dialect word that means "mountain top". The soil is mostly barren with patches of pine trees. There are rice terraces along the Amburayan River. The steep slopes are also planted to coffee and vegetables. The surface soil, with depth of 15 cm, is dark reddish brown (5YR 3/4) medium granular friable sandy loam. The upper subsoil, reaching down to 38 cm, is reddish brown (5YR 3/4) friable coarse subangular blocky clay loam. The lower sub soil, extending down to 65 cm from the surface is red (2.5YR 4/8) coarse subangular friable clay loam. The substratum that reaches down to the control section at 150 cm is red (2.5YR 4/8) coarse subangular blocky friable loam (Calaustro and Ganawan 1968). Only one soil type, Atok sandy loam was mapped in Benguet province covering 1,356 ha.

4.3.4.4 Soil is Underlain by Clay with Concretions, with Good Drainage

Guinaoang series (Plate 3D) is derived from igneous rocks, mostly diorite. This was first described in Barangay Guinaoang, municipality of Mankayan, province of Benguet extending from the vicinity of barangays Baculongan in the municipality of Buguias to Barangay Colalo in the municipality of Mankayan, province of Benguet near the boundary of Benguet and Ilocos Sur. This soil series occurs at elevation of 1,200 m above mean sea level. The external drainage is good to excessive while the internal drainage is good. The vegetation is generally primary and secondary forests. The relief is mountainous. The areas which are not very steep are cleared and planted to cabbage, sweet potatoes, Baguio beans, and sweet peas. The surface soil, extending down to 17 cm from the surface is very dark brown (10YR 2/2) fine granular friable sandy loam; slightly sticky and plastic when wet, soft when dry. The upper subsoil reaches down to 74 cm from the surface, and is yellowish red (5YR 4/6) (5YR 4/8) coarse subangular blocky friable clay, sticky and plastic when wet and hard when dry. The lower substratum that extends down to 105 cm from the surface is light red (2.5YR 6/6) (2.5YR 5/6) coarse subangular blocky friable clay with concretions; sticky and plastic when wet, hard when dry. The substratum that reaches down to the control section is light red (2.5YR 6/6) and red (2.5YR 5/6) coarse subangular blocky friable clay with concretions; sticky and plastic when wet, hard when dry (Calaustro and Ganawan 1968). This soil series is classified as *Typic Hapludults* and a total of 17,006 ha of

Fig. 4.4 Soil profile of Tarug series

Guinaoang sandy loam and loam were mapped in the provinces of Benguet, Ifugao, and Bontoc.

4.3.4.5 Soils Underlain by Highly Weathered Diorites with Some Clay Between Weathered Rocks, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Tarug series is primary soil derived from diorites. It was initially mapped in barangay Tarug, municipality of Mogpog, island province of Marinduque and classified as *Typic Eutrudepts*. The external drainage is good but the internal drainage is poor. The surface soil is grayish brown to pale brown clay loam, slightly friable when dry, slightly sticky and plastic when wet, depth ranges from 10 to 20 cm. The subsoil is brown to yellowish brown, fine granular clay loam to clay, with depth varying from 60 to 90 cm from the surface. The subsoil is highly weathered diorite, and in between the weathered rocks is some clay (Salazar et al. 1962). Tarug clay loam covers 1,414 ha in the island province of Marinduque. Another 1,954 ha of Tarug-Faraon series are also mapped in this island province (Fig. 4.4).

4.3.5 Soils Developed from Diorites and Quartz

4.3.5.1 Soils Underlain by Clay Loam with Weathered Parent Material, with Good Drainage

Daclan series (also referred to as Daklan series in other literature citations) developed from weathered quartz and diorite (Plate 3D). This soil series was first described in

Barangay Daclan, municipality of Bokod, Benguet province, covering south of Ambuklao Reservoir extending northwards to Bokod and Kabayan municipalities up to Barangay Gusaran in Kabayan. The elevation is about 1,200 m above mean sea level. The relief is sloping to very steep with undulating areas which are terraced and planted to rice. The drainage is good to excessive. The native vegetation is pine trees and grasses but the cultivated sloping areas are grown to coffee, corn, and bananas. This soil series is classified as fine isohyperthermic *Typic Hapludults*. The surface soil extends down to a depth of 38 cm from the surface, dark reddish brown (5YR 3/4) coarse granular firm clay. The upper subsoil reaches down to yellowish red (5YR 6/6) (5YR 4/8) subangular blocky friable clay with few highly weathered parent materials. The lower subsoil reaches down to 120 cm, yellowish red (5YR 5/6) (5YR 5/8) friable subangular blocky silty clay; with big red spots (2.5YR 4/6) (2.5YR 4/8); slightly compact with few gravels of highly weathered parent materials. The substratum reaches down to the control section at 150 cm, reddish brown (5YR 4/4) very friable coarse granular loam with pinkish gray (5YR 6/2) parent materials (Calaustro and Ganawan 1968). Only Daclan clay was mapped in Benguet province covering 7,397 ha.

4.3.6 Soils Developed from Quartz and Siliceous Rocks

4.3.6.1 Soils Underlain by Weathered Quartz and Siliceous Rocks, with Good Drainage

Tagkawayan series was first identified and mapped in what was then Barrio San Jose, municipality of Tagkawayan, the last municipality of Quezon province going to Bicol Region. *Kawayan* is the Tagalog word for "bamboo" where this used to grow in abundance here; and hence, people living in this locality were referred to as coming from bamboo forest. This is a residual soil developed from weathered quartz and siliceous rocks. This soil series has rock outcrops in some places. The relief is hilly and mountainous. External drainage is rapid to excessive while internal drainage is good. The vegetation consists of primary and secondary forests, and some patches are devoted to the growing of crops like corn, coconut, banana, upland rice, and sweet potato. So far, only Tagkawayan sandy loam has been mapped, covering 6,212 ha in the municipality of Tagkawayan between the Alimodian and Faraon soils. This soil series is classified as *Typic Dystrudepts.* The plowed surface soil (Ap) reaches down to 30 cm, and is very pale brown (10YR 7/4) when dry and brown (10YR 6/3) when moist, sandy loam; slightly compact and friable; with fine angular fragments of quartz and siliceous rocks; rock outcrops found in some places. The upper subsoil extends down to 50 cm from the surface, brown (10YR 5/3) fine sand mixed with coarse angular fragments of quartz and siliceous rocks; few reddish brown streaks. The lower subsoil extending down to 70 cm from the surface is brownish yellow (10YR 6/10) sand mixed with vey coarse quartz fragments and siliceous rocks; with reddish brown streaks. The substratum that reaches down to the control section at 150 cm, is strongly weathered angular (3–6 mm diameter) quartz and siliceous rocks; many reddish brown streaks (Renales et al. 1975).

4.3.7 Soils Developed from Conglomerate and Agglomerate Rocks (Mixed Igneous)

4.3.7.1 Soils Underlain by Clay

Paradise series was first described in Barangay Tukod, San Rafael, Bulacan, and classified as *Typic Eutropepts.* This soil series consists of well-drained moderately deep clayey soils occurring on low gently sloping to rolling, with none to moderately eroded conglomeratic and agglomeratic ridges and low hills. In a representative profile of this series, the surface soil is 7 cm thick, dark brown clay with few dark yellowish brown mottles and medium subangular gravels. The subsoil to a depth of 64 cm is brown to dark brown clay with few to common embedded subangular gravels. Consistency when moist is slightly sticky, slightly plastic, and slightly firm. Few medium krotovinas are present. The substratum from below 64 to 130 cm is pale brown clay with common light yellowish brown mottles and few medium subangular gravels. This soil series covers 7,465 ha in Bulacan. This soil series is associated with higher lying moderately steep Novaliches series and the deep Kay Bamban series of the rolling to steep volcanic foothills and ridges (Fig. 4.5).

4.3.7.2 Soils Underlain by Sandy Loam, Below Which is a Layer of Highly Weathered Agglomerates, with Good Drainage

Sabtang series was first classified in Sabtang Island, Batanes province. It is a residual soil derived from agglomerates—rocks made of up angular gravels, cobbles, and stones cemented together by a binding material. This is found on a plateau southwest of San Vicente proper. The relief is gently rolling. This soil series is classified as *Typic Eutrudepts* and covers some 444 ha in the province of Batanes. The surface soil reaches down to 40 cm, very dark gray to almost black when moist and dark gray to very dark gray when dry; loam, no coarse skeletons. The subsoil reaches down to 90 cm and is reddish brown; brown to dark brown when moist and light brown to brown when dry, sandy clay loam; coarse granular to block structure. The substratum, extending down to 200 m is light brown sandy

Fig. 4.5 Soil profile of Paradise series taken in Bulusukan, San Ildefonso Bulacan

loam, underlain by highly weathered agglomerates (Simon and de Jesus 1974). The crops grown are mostly root crops.

4.3.7.3 Soils Underlain by Highly Weathered Agglomerates, with Good Drainage

Uyugan series was first described in Uyugan, Batan Island. It is a residual soil developed from weathered agglomerates. This soil occurs on upland, hilly, and mountainous relief, with slopes from 15 to 100 %. It is excessively drained. Erosion is seriously observed in the cultivated and overgrazed areas. This is a moderately deep soil. Uyugan series has similar parent material, relief, and vegetation as those of Sabtang series. Their differences are in the color of the surface soil, depth, and presence of coarse skeleton in the solum. Uyugan series has reddish brown to brown surface soil, slightly shallower solum, an contains weathered fragments in the lower layers. While Sabtang series had dark gray to almost black surface soil, deeper solum and has no coarse skeleton. This soil series is classified as *Typic Eutrudepts* and covers 3,363 ha in Batanes province. The surface soil reaches down to 30 cm, reddish brown to brown clay loam, coarse granular to blocky structure, no coarse skeleton. The upper subsoil reaches down to 60 cm, reddish brown to dark reddish brown clay, columnar to blocky structure, no coarse skeleton. The lower subsoil extends down to 80 cm, light yellowish brown to brown heavy clay, blocky structure; some fragments of very highly weathered agglomerates are sporadically embedded, easily cut and crushed with a spade. The substratum, down to 150 cm, is variegated reddish gray, highly weathered agglomerates. Highly weathered materials can be readily cut and crushed with a spade (Simon and de Jesus 1974). Gullies are common. A fourth of the area is under cultivation with root crops, corn, rice, and vegetables.

4.3.7.4 Soils is Underlain by Coarse Sand, with Good Drainage

Guinobatan series is intimately associated with Mauraro. This soil series was first described in Guinobatan, Albay and covers the western rough slope of Mount Mayon at elevation from 107 to 786 m above sea level. This soil series is developed in place from the weathered products of volcanic ejecta such as massive lava rocks, agglomerates, tuff, breccias, gravelly conglomerates, sandstones, and volcanic ash. The subsoil is grayish brown to grayish black, speckled orange and reddish yellow, medium to coarse sand. The presence of alternate layers of volcanic ash deposits in its profile is a distinguishing feature. Boulders and outcrops are found on the surface and sometimes imbedded in the profile. The surface soil extends down to 45 cm, sandy loam; brownish gray, brown to grayish brown; structureless to very fine granular structure; gravels are present in the layer. The upper subsoil reaches down to 60 cm, medium to coarse sand; grayish brown to dark gray with yellowish to reddish speckles; single grain; gravels are present. The mid subsoil reaches down to 105 cm, sand; loam to silt loam; brownish yellow to grayish brown; structureless; silt, mellow, friable, and slightly compact. The lower subsoil reaches down to 135 cm, fine gray sand, loose, porous with a mixture of gravels and stones; at some places, partially weathered pebbles are found. The substratum extends down to 150 cm, coarse sand; gray to black; slightly compact and structureless. Below this layer is a horizon of orange speckled brown to grayish brown, sandy loam to silt loam (Aristorenas et al. 1965). Coconut and abaca are the principal crops grown. Upland rice, corn, banana, fruit trees, root crops, and vegetables are also grown. Guinobatan series covers some 9,270 ha and is classified as *Typic Hapludands.*

4.3.7.5 Soils Underlain by Silt Loam, with Gravels and Weathered Parent Material Below, with Fair Drainage Characteristics

Halsema series (Plate 3D) was formed from the weathering of conglomerates and igneous rocks. It was mapped in Acop, Tublay along Halsema Road. This Halsema highway is also known as the Baguio–Bontoc Road and the highest highway in the country, with waterfalls by the side every now and then, and rice terraces on opposite side. Halsema refers to Mayor Eusebius Julius Halsema, the last American mayor of Baguio City, 1920–1937. A renowned engineer, besides this road and many other roads in Baguio City, Halsema was also known for building Cebu's Osmeña Waterworks (the second to the built in the Philippines), the railroad to the Malangas Coal Mines in Zamboanga, and Baguio City's electric power plant, high school, auditorium, market, and numerous elementary schools. He remained in Baguio after retirement but died during the American liberation of Baguio City from the Japanese forces in the aftermath of World War II (Halsema 2004). The relief of this soil series is moderately steep to very steep. External drainage is good to excessive while internal drainage is moderately slow. Elevation is 1,290 m above mean sea level. The natural vegetation is pine trees and grasses. The crops grown are cabbage, potatoes, chayote, and pechay. The surface soil, reaching down to 21 cm in depth is dark brown (7.5YR 3/2) granular friable firm fine loam; few gravels of about 5 % by volume are present. The subsoil extends down to 54 cm from the surface, and is dark reddish brown (5YR 3/4) coarse granular friable firm clay loam; gravels of about 5 % by volume are present. The substratum, extending to 84 cm are red (2.5YR 5/3) fine granular friable silt loam; gravels of about 5 % by volume are present. The lower substratum that reaches down to the control section at 150 cm is reddish brown (5YR 4/4) fine granular friable loam; with weak red (7.5YR 5/4) and pale brown (10YR 8/4) highly weathered parent materials, and black (10YR 2/1) mixture 1–2 mm diameter (Calaustro and Ganawan 1968). This soil series is classified as *Typic Eutrudepts* and only one type, Halsema loam, was mapped in Benguet province covering 452 ha.

4.3.8 Soils Developed from Andesitic, Basaltic, Dacitic, or Ultrabasic Rocks

4.3.8.1 Soils Underlain by Sandy Loam or Fine Sandy Loam, with Gravels, and Stones, and Highly Weathered Rock Fragments

Malimono series (Plate 3F) occurs on gently sloping or undulating to very steep moderately dissected hills and ridges on andesitic, basaltic, or dacitic rocks. They are shallow to moderately deep and classified as coarse loamy mixed, *Typic Kanhapludults* in the USDA Soil Taxonomy. These soils have strongly to medium acid soil reaction and inherent fertility is low to moderate. The main land use and vegetative cover are coconut and banana, grasses and shrubs and patches of fruit trees and root crops. The A horizon, 10–15 cm thick, are brown, brown to dark brown, dark reddish brown, yellowish brown and dark yellowish brown clay loam to loam. Consistency is slightly sticky to sticky and slightly plastic to plastic when wet and friable when moist. Structure is weak to moderate fine and medium angular to subangular blocky breaking to granular structure upon pressure. Soil reaction varies from strongly to medium acid. Argillic B (subsoil), 30–80 cm thick, are strong brown, very pale brown, brown to dark brown, reddish brown, dark yellowish brown, yellowish brown, reddish brown or red clay loam, loam or silty clay loam with mottles of brownish yellow, reddish yellow, light yellowish brown or yellowish brown. Few soft and hard manganese nodules and few partially and highly weathered rock fragments commonly occur in this layer and increases with depth. Soil reaction is strongly to medium acid. C horizon (substratum), 80–150 cm thick, are strong brown, pale brown, brown, dark yellowish brown, yellowish brown and brown to dark brown, sandy loam, or fine sandy loam. Krotovinas sometimes occur at the substratum. Few to many partially and highly weathered rock fragments and many angular to subangular gravels and stones are also present. Soil reaction is also strongly to medium acid. Malimono series covered 27,688 ha in Surigao provinces. This soil series was named after Malimono, a municipality in the province of Surigao del Norte.

4.3.8.2 Soils Underlain by Clay, Sandy Clay Loam, or Loam, with Gravels and Stones and Highly Weathered Rock Fragments

Kabatohan series (Plate 3E) occurs on gently sloping or undulating to very steep moderately dissected hills and ridges on andesitic, basaltic or dacitic rocks. They are shallow to moderately deep and classified as coarse loamy mixed, *Typic Kanhapludults* in the USDA Soil Taxonomy. These soils have strong to medium acid soil reaction and inherent fertility is low to moderate. The main land use and vegetative cover are coconut and banana, grasses, and shrubs and patches of fruit trees and root crops. The A horizon, 10–15 cm thick, are brown, brown to dark brown, dark reddish brown, yellowish brown and dark yellowish brown clay loam to loam. Consistency is slightly sticky to sticky and slightly plastic to plastic when wet and friable when moist. Structure is weak to moderate fine and medium angular to subangular blocky breaking to granular structure upon pressure. Soil reaction varies from strongly to medium acid. Argillic B (subsoil), 30–80 cm thick, are strong brown, very pale brown, brown to dark brown, reddish brown, dark yellowish brown, yellowish brown, reddish brown or red clay loam, loam or silty clay loam with mottles of brownish yellow, reddish yellow, light yellowish brown or yellowish brown. Few soft and hard manganese nodules and few partially and highly weathered rock fragments commonly occur in this layer and increases with depth. Soil reaction is strongly to medium acid. C horizon (substratum), 80–150 cm thick, are strong brown, pale brown, brown, dark yellowish brown, yellowish brown and brown to dark brown, sandy loam, or fine sandy loam. Krotovinas sometimes occur at the substratum. Few to many partially and highly weathered rock fragments and many angular to subangular gravels and stones are also present. Soil reaction is also strongly to medium acid. The argillic Bt horizon (subsoil) are dark brown, strong brown, dark reddish brown, reddish brown, reddish yellow, yellowish brown clay, clay loam or silty clay loam with few to common distinct yellowish brown, reddish brown, dark reddish brown or strong brown mottles. Structure is weak to strong angular to subangular blocky. Highly weathered fragments occasionally occur in the lower subsoil. Soil reaction is medium acid to neutral. The C horizon (substratum), 90–150 cm from the surface, are dark reddish brown, dark red, dark yellowish brown, reddish yellow clay, sandy clay loam or loam with many coarse and medium angular to subangular gravels and stones and many partially and highly weathered rock fragments. Soil reaction is from slightly acid to neutral. A total of 95,087 ha of Kabatohan loam was mapped in Surigao provinces. Kabatohan, where this soil is named after, is a barangay of the municipality of San Isidro, Surigao del Norte.

4.3.9 Soils Developed from Undifferentiated Igneous Bedrock, with Good Drainage

4.3.9.1 Soils Underlain by Sand

Cervantes series (Plate 3D) was first described in the municipality of Cervantes, province of Ilocos Sur. This is a primary soil developed from a wide variety of igneous rocks. The parent material is of sandy nature, whitish gray to brownish gray in color. This soil series is classified as *Typic Hapludults* and belongs to the group of tropical red loam soils. The distinguishing characteristics of this soil series are the very friable nature of the whole soil mass and the lack of well-defined horizons until the substratum. It is similar to the Alaminos soil series in color but differs in the nature of the substratum. Alaminos has a clay loam substratum with highly weathered basalts and andesites. Cervantes has sandy substratum which becomes powdery when dry. Cervantes differs from Antipolo in terms of concretions—Antipolo has while Cervantas has none. This soil series occurs on gently rolling to hilly and mountainous. The external drainage is free to excessive while the internal drainage is good. The 7–10 cm surface soil consists of reddish brown to red loam or sandy loam which is very friable, with coarse fragmental structure. The subsoil is bright reddish to red clay loam to clay, with columnar structure, depth reaching down from 115 to 120 cm from the surface. It is friable and with few gravels. The lower subsoil is slightly similar to the upper layers but lighter in color and has coarser texture. The substratum is whitish gray, loose, sandy material that becomes powdery when dry (Mariano et al. 1954). The native vegetation consists of scraggly second growth forest and grassland. The cleared hilly areas have moderately dense growth of trees along the streams. Bamboo, binayuyo (*Antidesma ghaesembilla* Gaertn.), duhat (*Eugenia cumini* Linn.) and other softwood trees grow in patches. Near the town of Cervantes are a few pine trees. This soil is not used for crop production because of unfavorable topography. Permanent crops like fruit trees, however, are grown on gentler slopes. This soil series is appropriate for pasture under proper range management. A total of 131,431 ha of Cervantes sandy loam, loam, and clay loam were mapped in the provinces of Quezon, Benguet, Bontoc, Ilocos Norte, Ilocos Sur, and Abra.

4.3.9.2 Soil is Underlain by Silty Clay Loam, with Many Iron Concretions

Libertad soil series was first described in Libertad, Lavezares in what is now Northern Samar. This is a primary soil developed from weathered igneous rock. This soil series is similar to Bayho and Luisiana series in color and occurs on similar relief. All of them are red soils. However, the color of Libertad soils is slightly lighter than that of Luisiana soils. Libertad soils are deeper than Bayho soils but shallower than Luisiana soils. The main difference of Libertad series from either Luisiana or Bayho series is the presence of concretions in Libertad which are absent in neither of Bayho and Luisiana. Likewise, Libertad series has more dense subsoil and more pronounced horizon differentiation than the two other soil series. The surface soil reaches down to 15 cm from the surface, brown to dark brown when moist, light brown to reddish brown when dry, clay; coarse granular to blocky structure. The upper subsoil reaches down to 35 cm, yellowish brown when moist, brownish yellow when dry, clay loam; coarse granular to blocky structure with iron concretions which produce light yellow streaks. The lower subsoil reaches down to 85 cm, yellowish brown when dry, reddish yellow when moist, silty clay loam; columnar and blocky structure; many iron concretions are present which produce brownish yellow to yellow color when crushed; layer appears as an interwoven orange, red, and yellow mass. The substratum is from 85 cm and below, yellow silty clay loam; columnar and blocky structure; has many prominent yellow and light yellow mass. At 130 cm deep and downward, the iron concretions are usually absent (Simon et al. 1975). Libertad clay, classified as *Typic Hapludalfs*, covers 18,397 ha in Samar and grown to rice, coconut, sweet potato, corn, bananas, cassava, and sugarcane.

4.4 Soils that Developed from Sedimentary Rocks

4.4.1 Soils Developed from Limestone

4.4.1.1 Soils Underlain by Weathered Limestone, with Good Drainage

Binangonan series was first described in Binangonan, Rizal. It is a residual soils derived from limestone, with rolling to mountainous reliefs. This soil series belongs to black colored limestone or calcareous soils. The surface soil, ranging in depth from 20 to 25 cm is very dark brown, brownish gray to nearly black; coarse granular to cloddy when dry and sticky when wet. The upper subsoil is clay, lighter in color than the surface soil. The lower subsoil ranges in depth from 40 to 55 cm, is a calcareous horizon, light brown to nearly white, constituting highly weathered and disintegrated limestone. The substratum is a bed of stratified soft calcareous rock (Alicante et al. 1938). Binangonan series is much like Sibul in that both soils are of limestone origin. The difference is that the Sibul series is lighter in color, brown to medium brown while the Binangoan series is very dark to nearly black. The subsoil of Sibul has less calcareous materials than the Binangonan soils. Binangonan series is usually planted to rice and corn. The soils are classified as *Lithic Rendolls*. Binangonan clay, and clay lowland phase total to 20,730 ha in the provinces of Abra and Rizal.

4.4.1.2 Soils Underlain by Loam with Highly Weathered Parent Materials, with Good Drainage

Buyagan series (Plate 3C) was formed from the weathering of limestone rocks on older terrace. This soil series, classified as *Eutropeptic Rendolls* was first described in the municipality of La Trinidad, province of Benguet and includes the site of the Capitol Building north of Pico Road, extending westward up to Sitio Buyagan in Barangay Poblacion. It is moderately steep to very steep. Drainage is good to excessive. The elevation is at 1,238 m above mean sea level. The native vegetation is pine trees and grasses; cabbage, pechay, coffee, and chayote are grown. Few limestone outcrops characterize the series. The surface soil extends down to a depth of 30 cm from the surface, reddish brown (5YR 4/4) to yellowish red (5YR 5/6) coarse to fine granular friable clay. The subsoil reaches down to 60 cm, yellowish red (5YR 5/6) to red (2.5YR 5/8) fine granular friable clay loam. The substratum reaches down to the control section at 150 cm, red (2.5YR 5/8) (2.5YR 4/6) fine granular, very friable loam; pinkish white (7.5YR 4/2) concretions with pale brown (10YR 7/4) and light yellowish brown (10YR 6/4) highly weathered parent materials are observed (Calaustro and Ganawan 1968). Only Buyagan clay loam was mapped in Benguet Province covering 523 ha.

4.4.1.3 Soils Underlain by Loam with Limestone Gravels, with Moderate Drainage Properties

Balakbak series (Plate 3A), classified as *Eutrupeptic Rendolls*, is formed from the weathering of limestone. This was first described and delineated along Kapangan–Kibuagan Road starting from Barangay Balakbak in the municipality of Kapangan up to Barangay Sagpat in the municipality of Kibungan, province of Benguet. This soil series occupies an elevation of 1,530 m above mean sea level. The relief is moderately steep to very steep. The external drainage is good to excessive while the internal drainage is moderately slow due to high water table. Boulders of limestone characterize the soil series. Lowland rice is the principal crop; the other crops are Baguio beans and sweet potatoes. The surface soil reaches down to 25 cm from the surface, dark brown (7.5YR 4/2) medium granular friable firm gravelly loam; the gravels occupy 30 % by volume. The subsoil reaches down to the control section at 150 cm and is yellowish brown (10YR 5/8) medium granular friable loam; embedded with limestone gravels 30 % by volume (Calaustro and Ganawan 1968). Only one soil type, Balakbak loam, was mapped covering an aggregate area of 761 ha in the province of Benguet.

4.4.1.4 Soils Underlain by Clay Loam with Limestone Gravels, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Tacdian series (Plate 3G) developed from the weathering of limestone and was first mapped in Tacdian, La Trinidad municipality, Benguet province. Tacdian was the first name given to certain areas consisting of Bahong, Tomay, Shilan, and Kilometer 12. It was in 1945, after the liberation of the Philippines by General Mc Arthur that Tacdian was divided into what is now known as Barangay Shilan and Barangay Bahong (Municipality of La Trinidad 2011). Besides the soil series name, only the private Catholic school called Tacdian Elementary School in Tomay, La Trinidad carries the name Tacdian. The elevation is about 1,215 m above mean sea level. The relief is loping to very steep. The external drainage is good to excessive, the internal drainage is moderately slow. This soil series is characterized by presence of rough boulder outcrops. The crops grown are pechay, onion, Baguio beans, tubers, and chayote. The surface soil reaches down to 10 cm, and is dark reddish brown (5YR 3/3) fine granular friable loam with few pebbles, around 5 % by volume. The upper subsoil, reaches down to 50 cm, and is dark reddish brown (5YR 3/4) dark brown (7.5YR 3/2) fine granular clay loam with few pebbles, about 5 % by volume. The lower subsoil reaches down to 120 cm, and is yellowish red (5YR 4/3) to red (2.5YR 4/6) firm silty clay loam with black (2.5YR N2) concretions, with white limestone gravels, 5 % by volume, and with fragments of highly weathered parent materials. The substratum reaches down to the control section at 150 cm, dark reddish brown (5YR 3/4) firm clay loam with gravels of limestone, 80 % by volume (Calaustro and Ganawan 1968). Only Tacdian loam was mapped in the province of Benguet covering 1,831 ha. This soil series is classified as *Typic Eutrudepts.*

4.4.1.5 Soils Underlain by Sandy Loam, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Mirador series (Plate 3F) developed from the weathering of limestone. This soil series was first described in the vicinity of Mirador Hill in Baguio City, including the site of Tuba Poblacion and extends southward to the western side of Kennon Road down to Twin Peaks. This hill is famous for the Lourdes Grotto, constructed at the initiative of Fr. Jose Algue, S. J., then Director of the Manila Observatory where they have here a branch for meteorological and seismic observations that later on became a summer retreat house. This soil series occurs at elevation of 1,350 m above mean sea level. The relief is moderately steep to very steep. The external drainage is good to excessive while the internal drainage is slow. The native vegetation is pine trees and grasses. In the cultivated areas, the crops grown are Baguio beans, cabbage, chayote, and sweet potatoes. The surface soil, reaching down to 24 cm from the surface, is reddish brown (5YR 4/4) yellowish red (5YR 5/6) medium granular friable firm clay loam with distinct mottlings. The upper subsoil extends down to 48 cm, yellowish red (5YR 5/6), yellowish red (5YR 5/8) medium subangular blocky firm clay with many fine distinct reddish mottlings. The lower subsoil reaches down to 81 cm, reddish yellow (5YR 6/6) reddish yellow (5YR 6/8) coarse subangular blocky very firm clay loam with few faint fine reddish mottlings. The subsoil reaches down to the control section at 150 cm, mixture of reddish yellow (5YR 6/6) to reddish yellow (5YR 6/8) and red (10YR 4/6) red (1010 4/8) fine subangular blocky very friable sandy loam with fine common distinct red mottlings (Calaustro and Ganawan 1968). This soil series is classified as *Typic Hapludalfs,* and only one soil type, Mirador clay was mapped in the province of Benguet, covering 6,836 ha.

4.4.2 Soils that Developed from Shale Parent Material

4.4.2.1 Soils Underlain by Unweathered Shale, with Good Drainage

Himayangan soil series is classified as *Typic Eutrudepts* and was first described in barangay Himayangan, municipality of Liloan, province of Southern Leyte. This is a residual soil developed from shale. The relief is rolling to mountainous. The drainage is good to excessive externally and fair internally. The surface soil is light brown, yellowish gray to gray, poor coarse granular. Clay loam to sandy loam with depth ranging from 15 to 20 cm from the surface. The upper subsoil is brown to grayish brown, slightly compact, poor coarse granular, clay loam to sandy clay loam, with depth reaching down from 45 to 50 cm. The lower subsoil is gray to yellowish red, poor coarse granular clay loam, with depth varying from 95 to 100 cm from the surface (Barrera et al. 1954). The substratum is yellowish gray to light gray, compact, massive sandy shale. A total of 37,476 ha of Himayangan soil series were mapped in the provinces of Masbate and Leyte.

Palompon soil series is classified as *Typic Hapludults* and was first described in the municipality of Palompon, province of Leyte. This is a residual soil from shale rocks. It occurs on hilly to mountainous relief. The drainage condition is excessive externally, fair internally. The surface soil is light brown to brown, good coarse granular clay, slightly sticky when wet, friable when dry, with depth ranging from 15 to 25 cm. The upper subsoil is yellowish brown, good coarse granular clay with few gravels, very sticky when wet, slightly compact and friable when dry, depth is from 35 to 45 cm. The lower subsoil is yellowish gray to light brown, coarse play clay to sandy clay, slightly friable when wet, hard when dry, depth is from 75 to 80 cm. The substratum is reddish brown to dark brown, coarse play and partially weathered to fairly hard shale rocks, very brittle. Some veins of coal and andesite rocks are sometimes present (Barrera et al. 1954).

4.4.2.2 Soils Underlain by Weathered Shale, with Fair to Poor Drainage and Characterized by Presence of Redoximorphic Features

Bantay series (Plate 3B) was first described in the municipality of Bantay, province of Ilocos Sur, located northeast of Vigan, the provincial capital. The word *bantay* in the Ilocano dialect means mountain and could refer to the hilly and mountainous nature of the natural and physical features of the place. This is less extensive than Bauang series. Classified as *Typic Eutrustepts*, Bantay soils comprise the low hills scattered at random on the plain and foothills of the northeastern part of the province which adjoins Ilocos Norte. The soils of this series consist of light brown to brown, friable, fine granular loam to clay loam that grades into light yellowish brown nutty and brittle clay loam. The surface soil could reach down to 20 cm from the surface; the upper subsoil extends down to 35 cm. The lower subsoil, reaching down to 60 cm, is a zone of highly weathered shale which has a tendency to break into cubes about a centimeter in diameter, with some concretion-like pellets of grayish white lime precipitate. The substratum that reaches down to the control section or 150 cm, is a dense mass of yellowish very light brown shale of variable thickness. A few gravels and pebbles are sometimes imbedded in this layer in some places (Mariano et al. 1954). The topography is undulating to rolling and the elevation ranges from 30 to 117 m above mean sea level. External drainage is free and excessive but internal drainage is poor because of the massive shale substratum. Like the Bauang series, the soils were developed from parent material that originated from Tertiary sediments of shale with some mixture of coralline limestone. The most common native vegetation is grasses and only a small portion is cultivated to sugarcane, upland rice, corn, cassava, and vegetables. This soil series covers a total of 198,780 ha in the whole country further differentiated as sandy loam in Abra, loam in Ilocos Norte and Ilocos Sur, clay loam in the provinces of Cagayan, Ilocos Norte, Kalinga–Apayao, Negros Occidental, and Quezon, silty clay loam in Bontoc, and clay in Sulu. The total also includes Bantay–Bauang complex mapped in Nueva Viscaya. (This Bantay series is the same soil as Sect. 3.4.2.1 and Plate 2A. It occurs not only in uplands but in highlands as well.)

Alimodian soil series (Plate 3A and Fig. B.2) is classified as *Typic Hapludalfs*. This soil series was first described in the municipality of Alimodian, province of Iloilo. The soil of this series is derived from the weathered products of shale and sandstone, with shale dominating. The relief is rolling to hilly and mountainous. The external drainage is good to excessive while internal drainage is fair. The surface soil is brown to reddish brown clay loam, good medium granular structure, slightly friable when moist and brittle when dry. Rounded gravels and stones are present on the surface. Depth is from 20 to 30 cm. The subsoil is light brown clay loam, weak medium columnar structure, slightly brittle and slightly compact. Depth is from 55 to 60 cm from the surface. The substratum is gray to grayish brown, highly weathered shale and sometimes weathered shale and sometimes weathered sandstone, weak coarse platy and slightly compact (Alicante et al. 1947). The vegetation consists of primary and secondary growth forest, cogonal and mango groves occupy hilly and mountain areas. A total of 786,629 ha of Alimodian—sandy loam, silt loam, loam, sandy clay loam, clay loam, sandy clay, clay, and undifferentiated were maped in the provinces of Iloilo, Bontoc, Kalinga–Apayao, Quezon, Mindoro, Agusan, Abra, Catanduanes, Camarines Norte, Camarines Sur, Capiz–Aklan, Misamis Oriental, Zamboanga del Sur, Antique, and Bukidnon. Additionally 21,984 ha of Alimodian–Barotac Complex were mapped in Iloilo and Capiz–Aklan provinces, 3,379 ha of Alimodian–Bolinao Complex were delineated in Antique province, and 7,812 ha of Alimodian–Castilla Complex were mapped in Zamboanga del Sur (Fernandez and Clar de Jesus 1980).

Mantalongon series was first mapped in barangay Mantalongon, municipality of Dalaguete, province of Cebu, classified as *Typic Hapludalfs* and covering 20,225 ha of clay loam type. This series is similar to Baguio series and characterized by high, rough mountains with steep slopes. Its altitude reaches up to 305 m or even more above mean sea level. Unlike Baguio series, Mantalongon has bedrock of sandstones and shales. The shale rocks, however, are not limy in contrast to those of Lugo. Deep in the substratum are veins of coal which are mined. There are also outcrops of limestone in distributed areas, but not as common as those of the Faraon series. The soils are residual materials developed from the underlying rocks which are mostly shale, sandstone, and conglomerates. The surface soil reaches down to 15 cm from the surface, light brown clay loam; with medium coarse granular structure. The subsoil extends down to 45 cm; yellowish brown to light brown silt loam; with medium to very coarse granular structure. The substratum is reddish brown to grayish brown weathered silty shale. It has a good to very coarse platy structure. Veins of coal maybe found in some cuts along the road (Barrera and Aristorenas 1954). It is dominantly covered by cogon and the remaining areas are planted to coconut, corn, bananas, abaca, sweet potatoes, and some lowland rice.

4.4.2.3 Soils Underlain by Clay or Clay Loam with Many Weathered Shale Fragments, with Good Drainage

Pinugay series is fine, mixed, isohyperthermic *Oxic Tropudalfs*; first described in barangay Pinugay, municipality of Baras and province of Rizal. This is a moderately deep to deep well-drained soils occurring on upper rounded volcanic hills and ridges with slopes ranging from 15 to 65 %. The top soil is from 10 to 25 cm thick, brown to dark brown, dark reddish brown, or reddish brown clay loam or silty clay loam. The argillic B horizon is strong brown, yellowish brown, yellowish red, reddish brown, or red with very few to small weathered rock fragments and iron–manganese concretions on the lower B horizon. The substratum is red or yellowish red clay or clay loam with few reddish yellow, yellowish red or red mottles. Common to many weathered shale fragments are commonly present. Few soft manganese concretions occur (Soil Survey Division 1989). These soils are somewhat similar to San Luis and Antipolo series which are all classified as Tropudalfs. They differ in parent material and physiographic position. The San Luis and Antipolo series are of basaltic origin while Pinugay series is derived from shale. San Luis occurs on undulating basaltic plateau of the volcanic footslopes, the Antipolo series on undulating to rolling hills and ridges with localized valley while Pinugay series is on the upper rounded hills and ridges of the volcanic hills landscape. This soil series is mostly covered with cogon, grasses, and shrubs in areas of 15–25 % slopes while the higher slopes are generally covered by secondary forest, also cogon and brushes. A total of 5,054 ha of Pinugay clay of varying slopes and erosion status were mapped in Rizal province.

4.4.2.4 Soils Underlain by Weathered Shale Over Igneous Rock, with Good Drainage

Tacloban series was first described in the northeastern part of the island of Leyte and consists of the low range of hills and mountains between Palo on the south and Babatngon on the north. This soil series was named after the component city of Leyte province. The topography is hilly to mountainous with steep slopes. The drainage condition is good. There are no stones and boulders of any kind on the surface or in any layer of the profile. The reddish brown to dark brown clay loam had formed from the weathering of a thin layer of dark brown shale rock. This shale rock in turn lies over a thick layer of hard serpentine rock often quarried for road ballast. The shale rock in the Tacloban series is highly weathered and seldom shows layering common to shale. The surface soil reaches down to a depth of 20 cm, clay, dark brown to brown with good coarse granular structure. The subsoil reaches down to 45 cm, yellowish brown clay loam with good coarse granular structure. The substratum that extends down to the control section of 150 cm is yellowish brown, poor coarse platy weathered residual material derived from shale. It is noncalcareous and free from any coarse skeleton. Below the substratum is a layer of indefinite depth of hard gray serpentine rock. In other areas, beneath the weathered shale layer are unweathered consolidated igneous rocks extending to an indefinite depth (Barrera et al. 1954). A total of 72,200 ha of Tacloban clay loam and clay were mapped in Bukidnon, Cotabato, and Leyte provinces. This soil series is classified as *Typic Eutrudepts.*

4.4.2.5 Soils Underlain by Clay Mixed with Weathered Shale and Limestone Underlain by Stratified Shale and Limestone, with Good Drainage

Siain series was first identified and established in Siain, north of the town proper of Plaridel, province of Quezon. Siain used to be part of Atimonan municipality. But today, Siain refers to the municipality of Plaridel. This series is developed in place from weathered stratified shales and limestone. This soil series differs from the Bauang soils in the parent material. Siain soils developed mostly from shale and limestone while Bauang soils are mostly from shale. The solum of Siain series is underlain by stratified shale and limestone. The relief is hilly and mountainous. External drainage is good to excessive while internal drainage is good. The native vegetation consists of primary and secondary forests. The cultivated areas are planted to coconut, fruit trees and banana. Under this soil series, only one type, Siain silt loam, is mapped covering 9,320 ha. The profile description of Siain silt loam representing the series are as follows: The cultivated surface soil from 0 to 30 cm from the surface is grayish brown (10YR 5/2) when dry and dark grayish brown when moist; silt loam; friable and slightly sticky; angular fragments of shale and limestone are present. The subsoil extending from 30 to 70 cm from the surface is yellowish brown (10YR 5/6) clay loam to clay; fine granular structure; slightly sticky and plastic when wet and hard when dry; fragments of shale and limestone are present. The substratum from 70 to 150 cm from the surface is light brown clay mixed with weathered shale and limestone, underlain by stratified shale and limestone (Renales et al. 1975). The main crop is coconut. This soil series is classified as *Typic Eutrudepts.*

4.4.2.6 Soils Underlain by Clay, Below is Highly Weathered Shale, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Carig series (Plate 3C) is a residual soil from shale and sandstones initially identified and mapped in Carig and Cagayan and classified as *Typic Eutrustepts.* This place is now known as Santiago City, Isabela province, which became an independent component city in 1994. The depth of the surface soil is from 15 to 25 cm, light brown (7.5YR 6/4) to grayish brown (10YR 5/2) clay loam; fine granular, slightly sticky when wet and hard when dry. The subsoil ranges in depth from 50 to 75 cm, gray (10YR) to dark grayish brown ((10YR 4/3) clay to heavy clay; columnar; and compact; brown concretions are present. The substratum that reaches down to the control section at 150 cm, is light yellowish brown (10YR 6/4) heavy clay; fine granular; sticky and plastic when wet; hard and compact when dry; iron concretions are present; below is highly weathered shale (Dagdag et al. 1967). The external drainage is good in the rolling areas but fair in the nearly level portions. Internal drainage is poor. The relief ranges from slightly undulating to rolling and hilly with some level portions. It is grown principally to rice. The areal extent of Carig loam and clay loam, both mapped in Cagayan province is 51,934 ha.

4.4.2.7 Soils Underlain by Clay Loam, with Weathered Shale and Sandstone, with Poor Drainage and Characterized by Presence of Redoximorphic Features

Catbalogan series (Plate 3C and Fig. B.6, shallow phase to show the underlying shale material), is classified as fine, *Aquic Hapludalfs*. The soil is developed from stratified shales and sandstone, shale dominating. It was originally described in Samar, the road to Wright, about a kilometers from the poblacion of Catbalogan. This soil has an excellent to excessive surface drainage and fair to poor internal drainage. The surface soil is grayish brown to dark gray when moist, light grayish brown to gray when dry; coarse granular to blocky clay loam to silty clay loam with an easy root penetration, depth ranges from 10 to 30 cm from the surface. The upper subsoil is light yellowish brown, coarse granular to blocky clay loam with an easy root penetration. Grayish brown spots with some crumbs and fragments of highly weathered shale are observed. The depth is from 25 to 50 cm from the surface. The lower subsoil is yellowish gray to light gray, blocky clay loam with crumbs and blocks of highly weathered shale. The crumbs and blocks give either reddish brown colorations or reddish black tints when cut. The depth ranges from 45 to 90 cm from the surface. The substratum is yellowish gray to pinkish brown clay loam with reddish brown freckles of highly weathered and partly massive, stratified shale and sandstone (Simon et al. 1975). This soil is similar to Bauang soils. Both are derived from stratified shale and sandstone. They are both found on rolling, hilly, and steep to very steep relief. They differ slightly in color. Bauang series has brighter red color. But the main difference lies in the characteristics of the subsoil. The subsoil of Catbalogan series consists of coarse granular to blocky clay loam upper layer and blocky clay loam lower layer that contains crumbs and fragments of highly weathered shale. Bauang series is only a layer of highly weathered stratified shale and sandstone; the shales are cubical to hexagonal in shape. Catbalogan also differs in Alimodian series. Although both are derived from shale and sandstone but Alimodian soils are much deeper and darker in color. About 434,013 ha of Catbalogan clay loam were mapped in Samar province. The soils are generally covered by talahib, cogon, aguingay, secondary, and primary forest. The cultivated areas are grown to diversified upland crops. Additional 4,834 ha of Catbalongan-Tingib Complex were also mapped in Samar.

4.4.2.8 Soil is Underlain by Folded Stratified Shale, Sandstone, or Conglomerate, with Good Drainage

Bauang series (Plate 3B and Fig. B.3) is classified as *Typic Eutrustepts.* It was first delineated in the municipality of Bauang, province of La Union on rolling to hilly to mountainous landscape. This is a residual soil originating from highly weathered shale and sandstone, with shale as the dominating soil parent material. The surface drainage is good to excessive, and the internal drainage is good to fair, with water percolation regulated by the several layers of shale or sandstone. The surface soil ranges from 10 to 35 cm, and is brown to light brown, loose and friable clay loam. The subsoil is highly weathered stratified shales and sandstones, cubical to hexagonal in shape that becomes powdery when pulverized, depth is from 90 to 100 cm from the surface. The substratum consists of folded stratified shale, sandstone, or conglomerate with varying degrees of inclination of the strata (Alicante et al. 1950). A greater portion is cogonal while some portions are dipterocarp forest. The cultivated areas are planted to rice, corn, root crops, banana, vegetables, and fruit trees. A total of 224,016 ha of Bauang clay loam, silty clay loam, and clay were mapped in the provinces of La Union, Abra, Ilocos Sur, Kalinga–Apayao, Quezon, and Zamboangadel Sur (Fernandez and Clar de Jesus 1980).

4.4.3 Soils that Developed from Shale and Other Sedimentary Materials

4.4.3.1 Soils Underlain by Clay Loam or Sandy Loam Materials and Highly Weathered Rock Fragments, Well-Drained Soils

Surigao series consists of well-drained moderately deep fine loamy soils developed from colluvium and residuum from weathered sedimentary rocks (terrace gravel, conglomerate and shale). These soils are classified as fine loamy montmorillonitic *Typic Hapludalfs* in the USDA Soil Taxonomy. Their natural fertility is low to moderate. Soil reaction ranges from very strong acid to neutral. The surface layer (A horizon), 10–20 cm thick, are dark brown, brown to dark brown, very dark grayish brown, dark yellowish brown or yellowish brown clay, clay loam or silty clay loam with few to common distinct strong brown, light yellowish brown,

Fig. 4.6 Soil profile of Surigao series

pale brown or yellowish brown mottles. Consistency is slightly sticky to sticky, plastic to slightly plastic, wet; friable to slightly friable moist. Soil reaction is very strongly to slightly acid in this layer. The subsoil are brown, strong brown, dark brown, reddish yellow and brownish yellow, clay loam, sandy clay loam, sandy loam, or silty clay loam with few to common distinct or prominent sharp strong brown, reddish yellow brown mottles. Structure is weak to moderate angular to subangular blocky breaking to granular structure. In this layer, few to common small and medium subrounded to subangular gravels occur. Common highly weathered manganese is sometimes present in the subsoil. Soil reaction varies from very strongly to slightly acid with pH range of 5.0–6.5. The C horizon or substratum, 90–150 cm thick are dark yellowish brown, pale brown, reddish yellow, brownish yellow and grayish brown sandy clay loam, clay loam or sandy loam with many partially and highly weathered rock fragments and few to many coarse and medium angular to subangular gravels and stones. Soil reaction in this layer varies from strongly acid to neutral. Surigao clay loam covered about 1,875 ha in Surigao provinces. This soil series was named after the City of Surigao in Surigao del Norte (Fig. 4.6).

4.4.3.2 Soils Underlain by Clay, with Coarse Plinthites and Highly Weathered Fragments

The *Sison* series (Plate 3G) consists of moderately deep to deep well-drained fine clayey soils occurring on gently sloping to steep or hilly residual landscape underlain by shale and sandstone. These soils are affected by severe erosion and the soil cover consists of mostly of coconut and banana and small patches of fruit trees, root crops, and pineapple. Open areas are vegetated with shrubs and grasses. These soils have low to moderately low inherent fertility and are strongly to medium acid in soil reaction. They are classified as fine, mixed, *Typic Hapludults* in the family level of the USDA Soil Taxonomy System. The surface layer, A horizon, 10–20 cm, thick, are brown, dark brown, brown to dark brown, dark yellowish brown or yellowish brown clay or clay loam with few to common strong brown, yellowish brown, dark reddish brown and dark yellowish brown mottles. Consistency is sticky to slightly sticky, plastic to slightly plastic, wet; friable to firm, moist. Soil reaction is strongly to medium acid. The argillic Bt horizon (subsoil) are yellowish red, strong brown, reddish yellow, reddish brown or weak red clay, silty clay loam, or clay loam with few to common distinct or prominent sharp brownish yellow, yellowish brown, reddish brown and light yellowish brown mottles. Structure is moderate to strong angular to subangular blocky. In this layer, few to many partially and highly weathered rock fragments are present. Soil reaction varies from strongly to medium acid. C horizon or substratum, 100–150 cm, thick are dark yellowish brown, yellowish brown, brownish yellow, strong brown, reddish yellow, light reddish yellow, brown to dark brown, or reddish brown clay with few to common medium and coarse pale brown, reddish brown, reddish yellow, brownish yellow and yellowish red mottles. Few to many partially and highly weathered rock fragments occur. Presence of many medium and coarse plinthites is found on the lower subsoil. Soil reaction is strongly to medium acid. Sison clay loam covered 25,500 ha in Surigao provinces. The soil series was named after the inland municipality of Sison, Surigao del Norte.

4.4.4 Soils that Developed from Sandstone Parent Material

4.4.4.1 Soils Underlain by Weathered Sandstone, Characterized by Poor Drainage and Presence of Redoximorphic Features

Balut series (Plate 3B) is a member of *Typic Eutropepts* family. It is a residual soil derived mainly from sandstones. This soil series was originally mapped in the vicinity of

Lake Balut, occupying the rolling and hilly areas along the road across the Simuay River from Cotabato to Parang. Lake Balut is now part of Maguindanao province and Balut is a barangay of the municipality of Sultan Mastura. The internal drainage is poor but because of its rolling relief, the external drainage is quite excessive. The surface soil is dark gray to light gray, grayish black to gray, slightly compact, coarse and granular loam to clay loam. Its depth is from 5 to 15 cm. The upper subsoil, extending down to 50 cm, is medium brown to grayish brown clay loam to clay; columnar and compact which consequently slows down the permeability of water in this layer. The lower subsoil, with depth extending down to 100 cm from the surface is medium brown gravelly clay; columnar. Pebbles are present and mixed with highly weathered gravels. Internal drainage is poor but mottlings are not observed. The substratum reaches down to the control section at 150 cm, and is highly weathered sandstones with gravels, stones and boulders. Rounded edges indicate transportation or abrasion (Mojica et al. 1963). The vegetation is cogon with scattered brushes and some unidentified trees. A total of 25,166 ha of Balut loam in Marinduque province and Balut clay loam in Cotabato were mapped in the country.

Ilagan series (Plate 3D) was first described in the rolling to hilly areas around Ilagan City, a component city and capital of Isabela province and classified as *Typic Hapludults*. Ilagan City is the third largest city in the Philippines, behind Davao City and Puerto Princesa, respectively. The city was known as Bolo prior to the Spanish colonial era and was enshrined in Philippine history for the Gaddang Revolt of 1621 and lead by Felipe Cutabay and Gabriel Dayag when the natives on the western side of Cagayan River abandoned their settlement after burning their church and houses because of cultural shock brought by dominating social and cultural regulations introduced by the Spanish authorities. It was not until 1678 that the natives resettled to the eastern side of the river, giving the legendary name for Ilagan, actually the reverse of the word *nagali* meaning "transfer" (Wikipedia 2012g). The external drainage of this soil series is excessive but the compact nature of the substratum prevents the rapid infiltration of water so that during heavy rains, only an insignificant volume is absorbed. The parent rock of the Ilagan series is soft sandstone which is poorly stratified. The surface soil extends down to 20 cm from the surface, dark brown (7.5YR 5/6) when dry, yellowish brown (10YR 3/3) when wet; sandy clay loam, sandy loam to loam; hard to slightly compact when dry but becomes soft when wet; coarse granular structure. The upper subsoil extends down to 45 cm, yellowish red (5YR 5/6) when dry, yellowish brown (10YR 5/4) when wet; clay to sandy clay; compact; massive to coarse granular in structure; some red mottlings are present. The lower subsoil reaches down to 70 cm, very pale brown (10YR 7.4) when dry, yellowish brown (10YR 5/4) when wet, some cloudy specks of gray (2.5YR 5/0) are evenly distributed in this layer; clay loam to loam; compact and very hard when dry, soft when wet. The substratum that reaches down to the control section at 150 cm is yellowish brown (10YR 6/4) when dry, yellowish red (5YR 5/8) when wet; soft sandstone (sandy loam) intermixed with some thin layers of shale; very compact and massive (Santos 1969). The crops grown are tobacco, corn, and some vegetables. A total of 160,284 ha of Ilagan sandy loam, and sandy loam-eroded phase were delineated in the provinces of Cagayan and Isabela.

4.4.4.2 Soils Underlain by Gravelly Sands Below Which is Either Shale or Sandstone or Both, with Good Drainage and Characterized by Absence of Redoximorphic Features

Camansa series (Plate 3C and Fig. B.5) is classified as *Typic Eutropepts*. This was originally described and mapped in Camansa, currently a barangay of the municipality of Asuncion (formerly known as Saug), Davao del Norte province. This soil series is one of the most extensive in the Davao provinces occupying the hilly and mountainous regions on the north, northeastern, and eastern parts. The distinguishing characteristic of this series is its substratum of consolidated water-worm gravels, pebbles, and cobblestones mixed with gray sand at varying stages of decomposition. Below this layer is either shale or sandstone or mixtures of both. There are very few, if any, boulders on the surface due to the sedimentary origin of the parent material. The 15–18 cm surface soil is yellowish brown, light brown to brown friable, gritty clay loam. The subsoil is light brown to reddish brown, slightly compact, prismatic and gritty sandy clay loam which grads into clay loam in some places. This layer reaches to a depth of 45–50 cm from the surface. The substratum consists of a layer of weathering gravels and stones, shale or sandstone mixed with clayey materials (Mariano et al. 1953). The relief is hilly and mountainous. The external drainage is free to excessive while the internal drainage is good. The vegetation is thick dipterocarp and secondary growth forest. The cultivated areas are planted to corn, sweet potatoes, upland rice, and abaca. Camansa sandy loam, loam, sandy clay loam, and clay loam were mapped in the provinces of Agusan, Lanao, Davao, Surigao, and Zamboanga del Sur covering a total of 806,192 ha.

4.4.4.3 Soils Underlain by Clay Loam with Highly Weathered Sandstones

Banhigan series was first described in what was then barrio Banhigan, municipality of Buenavista, province of Marinduque. But currently, sitio Banhigan is considered a part of Barangay Duyay, municipality of Boac, the provincial capital. Banhigan is noted for its 100 m-Ginaras Falls with six adjacent waterfalls in the mountainous areas. This series has generally a rolling to hilly relief, with excessive external drainage. It is formed from the weathering and decomposition of sandstone in place. The surface soil has a depth of about 25 cm from the surface, pale to dark yellowish brown clay loam; slightly sticky and plastic when wet, slight compact when dry; medium to coarse granular structure. The upper subsoil extends down to a depth of 60 cm, yellowish brown medium granular clay; hard and compact when dry, sticky and plastic when wet. The lower subsoil reaches to a depth of 100 cm, reddish brown to yellowish brown clay; very sticky and plastic when wet, hard and compact when dry; rust-like mottlings are present and more pronounced at lower depths; occasional highly weathered play gray sandstones are present. The substratum extends down to the control section at 150 cm, pale gray clay loam; sticky and plastic when wet, hard and compact when dry; highly weathered sandstones are found in this layer (Salazar et al. 1962). This soil series is classified as *Typic Eutrudepts* and Banhigan clay loam covers 15,539 ha in Marinduque province mostly in Buenavista, Gasan, and Boac. Coconut, corn, and rice are the major crops grown in this soil.

4.4.4.4 Soils Underlain by Sandy Loam

Balili series (Plate 3B) was formed from the weathering of transported sandstone. It was first described northeast of the municipality of Mankayan, in Barangay Balili along the Benguet–Bontoc boundary. It occupies an elevation of 1,455 m above mean sea level. The relief is sloping to moderately deep. The drainage is good. Sweet potatoes are the most important crop grown in this soil. The other crops are leafy vegetables. Some portions are irrigated. The surface soil reaches down to 24 cm from the surface, and is very dark brown (10YR 2/2) fine granular friable firm gravelly loam; with gravels about 30 % by volume. The subsoil extends down to 84 cm from the surface, dark reddish brown (5YR 3/4), medium granular sandy loam. The substratum extends down to the control section at 150 cm, and is reddish brown (5YR 4/4) medium granular friable sandy loam (Calaustro and Ganawan 1968). Balili loam—gravelly phase was mapped in the provinces of Benguet and Bontoc covering 478 ha. This soil series is classified as *Typic Dystrudepts.*

4.4.4.5 Soils Underlain by Massive Clay to Sandy Clay with Weathered Sandstones

Nambaran series was first described in Barangay Nambaran in what is now Tabuk City, in the province of Kalinga–Apayao. It is located along the road from Tabuk to Cagayan Province through the town of Liwan. Nambaran soil was mapped mainly on the area commonly referred to as the "Tabuk Plateaus". It is nearly level to undulating with poor drainage conditions. It is traversed by numerous creeks and deep V and U-shaped gullies. Cultivated areas are being planted to lowland rice. A greater area is under grass with scattered patches of brushes and second growth forest mostly along creeks. The surface soil reaches down to 20 cm from the surface, dark yellowish brown (10YR 3/4) to very dark brown (10YR 2/2) sandy loam is to silty clay loam; loose and friable; medium fine to fine granular; reddish streaks along root channels; few reddish brown to black concretion. The subsoil extends down to 30 cm, dark brown (7.5YR 3/2) clay; loose and friable; coarse blocky and columnar; heavy plastic and sticky when wet, hard when dry; contain reddish concretions of 5 mm. The substratum reaches down to 70 cm, dark gray (10YR 4/1) clay; massive and compost to columnar; hard when dry, plastic and very sticky when wet; weathered reddish to black concretions present; whitish mottlings of weathered sandstone abundant. The lower substratum below 70 cm is dry (10YR 3/1) sandy clay; massive and compact; very plastic and very sticky when wet; contains numerous reddish to black, highly weathered concretions (Soil Survey Division Undated). This soil series is classified as *Typic Eutrustepts* and only one soil type, Nambaran sandy loam, was mapped in Kalinga–Apayao province covering 13.452 ha.

4.4.5 Soils Developed from Cherts and Jaspers

4.4.5.1 Soil is Underlain by Laminated Chert Rocks in Various Degrees of Faulting or Strikes

Coron series (Plate 3D) is classified as *Typic Eutrudepts.* Coron is a municipality in the province of Palawan and coves part of Busuanga Island and Coron Island which are part of the Calamian Group of Islands in Northern Palawan. This soil series was first identified and delineated in the hilly and mountainous areas common in Culion and Busuanga Islands, the northern part of Bacuit in the mainland of Palawan. Coron series developed from cherts and jaspers. Cherts are sedimentary rocks that contain small fossils, common as layers or nodules in limestone, including chalk and dolostone formations. Jasper is a variety of chert formed as primary deposits, found in connection with magmatic formations with red color due to iron inclusions. Coron soils are gray to brown, shallow, and in highly eroded areas, bedrock is exposed or fragments of rock litter the ground surface. The surface soil, about 10 cm thick, is gray to light brown clay loam; coarse granular; slightly friable when wet, slightly compact when dry; at times pebbles and gravels are present. The subsoil reaching down to 40 cm is dark brown to light reddish brown clay to clay loam; compact to slightly hard when dry, moderately plastic when wet; with coarse granular structure. The upper substratum extending down to 60 cm has presence of chert and jasper, dark brown clay mixed with fragments of rocks; hard when dry but plastic when wet. The lower subsoil reaches down to the control section at 150 cm, partly weathered to unweathered rocks of chert and jasper. Rocks are dark brown to reddish brown, laminated and usually faulting upward following slopes of the hills. In other places, this layer is found much deeper and the profile is similar to that of Tapul or Tagburos series (Barrera et al. 1960). Most of the Coron soils are eroded and unfit for cultivation. However, in upland areas, rice is the principal crop. A total of 194,811 ha of Coron silt loam and clay loam were mapped in the provinces of Palawan and Sulu.

4.4.6 Soils Developed from Mixed Metamorphic: Shale and Sandstone

4.4.6.1 Soils Underlain by Loam Mixed with Metamorphic Sand and Gravels, Limestone Pebbles and Below is Highly Weathered Shale, Limestone, and Sandstone

Odiongan series was first described and delineated in Odiongan, the most populated and most progressive municipality in the island province of Romblon. This is a primary soil derived from the weathering of the underlying limy shale and sandstone. It differs from the adjoining Tuguis series in the presence of numerous rounded metamorphic pebbles and stones on the surface and throughout the whole profile. Limestone pebbles which produced a white powdery mass when crushed are present in the subsoil and substratum. Marine shells are also embedded in the lower horizons. The relief is undulating to strongly sloping. The external drainage is excessive while the internal drainage is good. This soil series is classified as *Typic Eutrudepts* and only one soil type, the Odiongan clay loam was mapped in Romblon covering 3,953 ha. The surface soil reaching down to 15 cm from the surface is yellowish brown (10YR 5/8) when moist and light yellowish brown (10YR 6/4) when dry, clay loam; with few yellowish red (5YR 5/8) mottlings; medium granular structure; slightly friable when moist and slightly hard when dry; rounded metamorphic pebbles and stones are numerous. The upper subsoil that extends down to 30 cm is dark yellowish brown (10YR 4/4) when moist and yellowish brown (10YR 5/8) when dry, clay loam; with reddish yellow (7.5YR 7/6) streaks; coarse granular structure; slightly friable when moist, slightly sticky and moderately plastic when wet, and slightly hard when dry; metamorphic pebbles and stones are present but lesser than that of the surface layer. The lower subsoil that reaches down to 70 cm is yellowish brown (10YR 5/8) when moist and brownish yellow (10YR 6/6) when dry, clay loam; coarse granular structure; slightly sticky and moderately plastic when wet and slightly hard when dry; metamorphic pebbles and sand are present; limestone pebbles are also numerous. The substratum that extends down to the control section at 150 cm is brownish yellow (10YR 6/8) when moist and yellow (10YR 7/6) when dry, loam; coarse granular structure; slightly friable when moist; nonsticky and moderately plastic when wet; and slightly hard when dry; metamorphic sand and gravels are lesser compared to the upper horizon but limestone pebbles are numerous; the lower portion is mostly highly weathered shale, limestone, and sandstone (Castillo et al. 1973).

Tuguis series was identified in what was then Barrio Tuguis, municipality of Looc, island province of Romblon. Looc itself has a long history when it was still under the administrative jurisdiction of Capiz province until Romblon was created as a province; then Looc was abolished, then restored to municipal status, and then halved to its present size. Tuguis remains a barangay under Looc. Tuguis series is a residual soil derived from the weathering of the underlying limy shale and sandstone. The relief is undulating to rolling and hilly. Limestone pebbles which produced a white powdery mass when crushed are found in the lower horizons. This soil series has some similarities to Bauang series differing from the latter only by the presence of pale brown (10YR 8/3) stones of different sizes and shapes in the surface soil. The presence of these stones, however, does not interfere with the tillage operations. The surface soil, reaching down to 20 cm from the surface is very dark brown (10YR 2/2) when moist and dark grayish brown (10YR 4/2) when dry, clay; fine granular structure; sticky and plastic when wet and very hard when dry. The subsoil extends down to 70 cm from the surface, light yellowish brown (10YR 6/4) when moist and yellow (10YR 7/6) when dry, clay; soft brownish yellow (10YR 7/8) concretions are present; fine granular structure; sticky and plastic when wet and very hard when dry. The substratum is olive yellow (5Y 6/6) when moist, clay loam; coarse granular structure; slightly sticky and moderately plastic when wet, hard when dry; lower portion is mostly highly weathered shale and sandstone; few limestone pebbles are present which produce a white powdery mass when crushed (Castillo et al. 1973). Only Taguis clay covering 10,485 ha were mapped along the road from Rizal in Odiongan to Lemon Sur in Looc, extending to Manlilico. The principal crops grown are coconut, upland rice, and corn. The secondary crops are banana, fruit trees, root crops, and vegetables. This soil series is classified as *Typic Eutrudepts.*

4.5 Soils that Developed from Metamorphic Rocks

4.5.1 Soils Developed from Weathering of Marble

4.5.1.1 Soils Underlain by Clay, Mixed with Metamorphic Sand and Marble Boulders, Poorly Drained and Characterized by Presence of Redoximorphic Features

Romblon series was first described and delineated in the municipality of Romblon, the capital of the island province of Romblon. Aetas, the aborigines of the Philippines, and according to tradition, came in through the land bridges that once connected the archipelago to the Asian mainland, were the first settlers and still inhabit to these days the interior of the island. The next wave of migrants were the Malays during the golden period of the Hindu Kingdoms of Madjapahit Empire based in Surabaya; then later on, by people coming from the Sri Vishayan Empire based in Palembang, Sumatra, and Indonesia. The Romblon locals descended from this basic Malay stock with an admixture of other racial strains of later colonizers. This island of Romblon is an anthropologist's paradise with many unexplored ancient burial caves littered with countless broken potteries, gold tooth fillings, cosmetic refinements, and Visayan-Alibata Script in stone murals that reflect the ancient glory of pre-Islam Philippines. But many of these priceless wall writings, evidence of pre-Spanish era literacy of the Filipinos, were destroyed by careless treasure hunters such that only heaps of stones remained. During the Spanish conquest, Martin de Goiti came here in 1569 and conquered every native village to establish Spanish settlements (Wikipedia 2012h). The colorful history of Romblon is equally matched by the soil series that bears this name. Romblon series is a residual soil developed through the weathering of the underlying marble rocks for which the island of Romblon is known for. The relief of this soil series is rolling to hilly. Numerous marble rocks are exposed as outcrops. The external drainage is excessive while the internal drainage is poor. Coconut is the principal crop. Rice, corn, fruit trees, root crops, and vegetables are the secondary crops grown. Second growth forest is found in the interior. The profile description is as follows: The surface soil reaches down to 20 cm, olive brown (2.5Y 4/4) when moist and olive yellow (2.5Y 6/6) when dry, clay; with yellowish brown (10YR 5/8) streaks; angular block structure; slightly friable when moist, sticky and plastic when wet, very hard when dry; marble rock outcrops are numerous. The subsoil, reaching down to 70 cm from the surface, is yellowish brown (10YR 5/8) when moist and yellow (10YR 7/8) when dry, clay; angular blocky structure; sticky and plastic when wet and very hard when dry; marble stones and pebbles are present; marble blocks are embedded in this layer. The substratum reaches down to the control section at 150 cm, pale yellow (2.5Y 8/4) when moist and yellow (10YR 7/8) when dry, clay; blocky structure; sticky and plastic when wet and very hard when dry; metamorphic sand is found in this layer; marble boulders are embedded (Castillo et al. 1973). Only Romblon clay has been mapped, classified as *Typic Eutrudepts* and covers 13,928 ha in the northeastern part of Romblon Island, northern tip of Tablas Island, Alad, Cobrador, and Logbung.

4.5.2 Soils Developed from Metamorphic Rocks Underlain by Weathered Shale Rock

4.5.2.1 Soil is Underlain by Weathered Metamorphic Rocks, with Good Drainage

Tilik series (Fig. 1.40) was first described in barangay Tilik, island municipality of Lubang, island province of Mindoro Occidental; occupying almost half of Lubang Island, cutting the island in the center from the north of the Port of Tilik where the soil series got its name to the south and extending to Golo Island. This soil series is classified as *Lithic Eutrudepts.* It is a primary soil developed from the weathering of metamorphic rocks underlain below by shale rock. The relief is from rolling to hilly to mountainous, and thus could also be found on upland areas. The external drainage is excessive while the internal drainage is fair to good. The surface soil is silt loam, light brown to reddish brown, granular in structure, slightly friable when dry and slightly plastic and sticky when wet. Gravels are present. The depth is from 20 to 25 cm. The subsoil is clay loam, reddish brown to brown, sticky, slightly compact with highly weathered metamorphic and shale rocks. The depth is from 75 to 80 cm. The substratum that reaches down to the control section at 150 cm is light yellowish brown to light reddish brown, highly weathered metamorphic and shale rocks (Dagdag et al. 1961). The vegetation cover consists of primary and secondary forests, grass, and cultivated crops like upland rice, coconut, citrus, banana, coffee, and fruit trees planted mostly in *kaingin* clearings. A total of 10,252 ha of Tilik silt loam and silt loam-gravelly phase were mapped in Mindoro provinces.

4.5.3 Soils Developed from Predominantly Metamorphic Rocks

4.5.3.1 Soils Underlain by Weathering Schist

Calauaig series was first delineated on grassy hills, east of Malaybalay City, Bukidnon. This soil series is named after

Fig. 4.7 Landscape view of Calauig series in Bukidnon planted to corn

Kalawaig River, a tributary of Cagayan River, but certainly this is not a river terrace soil but a hilly land soil developed from schist. The soils are classified as *Lithic Eutrudepts.* The relief ranges from gently rolling to hilly with slopes ranging from 8 to 100 %. The 10–15 cm surface soil consists of brown to light brown clay that is friable and granular when dry but mellow when moist. It is underlain by a light brown to yellowish brown clay which is plastic and sticky when moist but blocky and hard when dry. This upper subsoil reaches to a depth of 30 cm from the surface. It merges very gradually into the lower subsoil which has almost similar characteristics except for its slightly lighter color and less developed structure. The lower subsoil reaches to a depth of 55 cm from the surface. The substratum is a layer of weathering schist which looks like fragmental coal. In other places, the bedrock of schist which is usually in a slab form is encountered in the lower part of the substratum (Mariano et al. 1955). External drainage is free to excessive but internal drainage is slow. A total of 4,363 ha of Calauaig clay was mapped in Bukidnon (Fig. 4.7).

4.6 Soils that Developed from Mixed Parent Materials

These are soils of upland areas developed from a mixture of two or more kinds of rocks. Examples are igneous–sedimentary, igneous–metamorphic, and sedimentary–metamorphic.

4.6.1 Soils Developed from Mixed Igneous and Metamorphic Parent Materials

4.6.1.1 Soils Underlain by Weathered Igneous Rocks, with Good Drainage

Baguio series was first described in north central Cebu. It represents the highest, bold, and rugged mountains, characterized by narrow, sharp-topped edges with steep, almost precipitous slopes, and separated from each other by deep V-shaped gorges. Elevation ranges from 60 to 305 m above mean sea level. Hence, this soil is named after the summer capital of the Philippines in Luzon, although this was first described in Cebu in the Visayas. The bedrocks of this mountain which were classed as basement complex and emerged during the Pre-Miocene time consist of igneous and metamorphic rocks of unknown ages. The igneous rocks like diorite, quartz diorite, and andesite flows make most of the big boulders along the Talisay–Toledo road. Farther north are the metamorphic rocks like greenstone and slate, and conglomerate and hard limestone. There are no rock outcrops in the Baguio series. The external drainage is good and the topography favors the rain water to flow easily as run off, with little chance for water to percolate into the ground. The soils are fairly deep. The surface soil reaches down to 25 cm from the surface, is brown to dark brown clay loam; medium, coarse granular structure, no stones or rock outcrops. The subsoil goes down to 30 cm, light brown to grayish brown clay loam; medium coarse granular to almost columnar structure; no stones or any rock. The substratum reaches down to the control section and consist of light brown to brown bedrocks of igneous formation. Some are partly weathered and soft and some are massively hard. This layer is separated from the above horizon by smooth gradual boundary. Farther down the profile are big boulders of rocks like andesite, diorite, quartz diorite, and greenstone (Barrera and Aristorenas 1954). This soil series is classified as *Typic Eutrudepts* and the clay loam type covers 97,240 ha in the provinces of Cebu and Sulu. In Sulu, the substratum consists of two layers—the upper layer is partly to highly weathered igneous rocks while the lower layer is hard and massive.

4.6.2 Soils Developed from Mixed Metamorphic and Sedimentary Parent Materials

4.6.2.1 Soils Underlain by Massive Clay Loam to Loam, with Good Drainage

Lourdes soil series was first described in barangay Lourdes, municipality of Alubijid, province of Misamis Oriental, lying in the environs of Lourdes, the western part of Lumbia, and in the southwestern part of Cagayan de Oro City. This soil series is classified as *Typic Hapludults.* This soil series is a primary soil developed from the weathering of undifferentiated metamorphic rocks and sedimentary rocks such as sandstone and shales. It has brown to dark brown moderately compact clay loam surface soil and a brown to light brown slightly compact sandy clay loam subsoil speckled with black and reddish color in the lower layer. The relief ranges from rolling to hilly to mountainous. Except the small valleys between the hills where the drainage is not adequate, the external drainage is good to excessive while the internal drainage is fair. The surface soil, with depth ranging from 20 to 25 cm from the surface is brown to dark brown clay loam; granular structure; moderately compact, sticky when sufficiently wet and slightly friable when most, hard when dry. In some places, gravels and stones are present. The upper subsoil, ranging from 40 to 45 cm in depth, is brown to light brown sandy clay loam; granular in structure; slightly compact, brittle and crumbly when dry, moderately friable when moist; iron concretions are found in some places. The lower subsoil, extending down to 100 cm from the surface, is ash brown to light brown clay speckled with black and reddish color, friable when moist and brittle with dry. It has massive structure. The substratum that reaches down to the control section at 150 cm, is brown to ash gray brown clay loam to loam, speckled with reddish yellow color and presence of dark brown mottlings; massive in structure (Lopez et al. 1954). The vegetation cover is primary and secondary forests as well as cogon. The cultivated areas are planted to coconut, root crops, corn, upland rice, and some fruit trees. A total of 35,227 ha of Lourdes clay loam were mapped in Misamis Oriental.

4.6.3 Soils Developed from Igneous and Sedimentary Parent Materials

4.6.3.1 Soils Underlain by Clay

Natubleng series (also referred to as Natubling series in some literature citations) developed from diorite, andesite, and sandstone (Plate 3F). This soil series was first mapped along the Mountain Trail starting in the vicinity of Patapat, Atok and extends northward beyond Sinipsip and Buguias. Natubleng is a barangay of the municipality of Buguias, province of Benguet. This soil series is classified as *Typic Dystrudepts*. The relief is moderately steep to very steep. The drainage is good to excessive. The elevation is 2,118 ha above mean sea level. The crops grown are cabbage, sweet potatoes, sweet peas, and calla lily (*Zantedeschia sp.*). Only one soil type, Natubleng sandy loam was mapped in Benguet and covers 12,868 ha. The surface soil extends to 34 cm from the surface, brown (10YR 4/3) very friable single-grained sandy loam. The upper subsoil, extending down to 56 cm, is dark reddish brown (5YR 2/2) fine granular friable silt loam. The mid subsoil reaches down to 75 cm, and is brownish yellow (10YR 6/6), fine granular friable sandy loam with fine pebbles. The lower subsoil, reaching down to 110 cm, is dark brown (7.5YR 3/2) medium granular loamy sand. The substratum that reaches down to the control section at 150 cm is yellowish red (5YR 4/8), fine granular clay (Calaustro and Ganawan 1968).

4.6.3.2 Soils Underlain by Loam to Sandy Loam/Loamy Sand

Paoay series (Plate 3F) is often mistaken to refer to the sand dunes of Paoay, Ilocos and Norte. But Paoay series is not a coastal lowland soil but a mountain soil. This soil series was formed from weathered quartz, diorite, and sandstone. It occurs at elevation even higher than Natubleng series, at around 2,262 m above mean sea level. The relief is moderately steep to very steep. The external drainage is good to excessive while the internal drainage is poor. This soil series is intensively cultivated to cabbage sweet potatoes, and sweet peas. It is classified as *Typic Hapludolls*. This soil series was first described in Barangay Paoay, municipality of Atok, province of Benguet, about 2 km west of Sayangan, Atok, a popular bus stop along the Mountain Trail. The surface soil, reaching down to 15 cm, is black (2.5YR N2) coarse angular blocky friable firm loam. The upper subsoil extends down to 36 cm from the surface, very dark grayish loam (2.5Y 3/2) to dark grayish brown (2.5Y 3/2) to dark grayish brown (2.5Y 4/2) fine subangular blocky friable sandy loam. The middle subsoil reaches down to 60 cm, yellowish brown (10YR 5/2) fine subangular blocky friable coarse sand with highly weathered parent materials. The lower subsoil reaches down to 86 cm, black (5YR 2/1) fine subangular blocky friable sandy loam. The upper substratum reaches down to 100 cm from the surface, very dark brown (10YR 2/2) coarse subangular blocky friable loam. The mid substratum extends down to 116 cm, and is dark grayish brown (2.5YR 4/2) fine subangular blocky friable sandy loam. The lower substratum extends down to the control section at 150 cm and is black (10YR 2/1) to very dark brown (10YR 2/2) compact medium subangular blocky loamy sand. Only Paoay sandy loam was mapped in Benguet covering 119 ha (Calaustro and Ganawan 1968).

Puguis series (Plate 3G) developed from transported conglomerates, diorites, and sandstones. It was first described in Barangay Puguis, municipality of La Trinidad, province of Benguet, about half a kilometer from the Capitol Building. Classified as *Typic Dystrudepts*, this soil series has moderately steep to very steep relief with undulating areas. The drainage is good to excessive. The elevation is around 1,350 m above mean sea level. The surface soil, reaching a depth of 20 cm, is strong brown (7.5YR 4/4) fine friable gravelly loam; with gravels about 20 % by volume. The subsoil extends down to 80 cm, and is reddish brown (5YR 4/4) to yellowish red (5YR 4/6) fine granular and friable loam; with gravels about 7–10 % by volume. The substratum extends down to the control section at 150 cm, and is yellowish red (5YR 4/6) yellowish red (5YR 4/8) sandy loam; with 15 % gravels by volume. This soil series is grown to pineapple, cabbage, pechay, and rice (Calaustro and Ganawan 1968). Only one soil type, Puguis loam—gravelly phase, was mapped in Benguet.

4.6.3.3 Soil is Underlain by Clay to Clay Loam, Poorly Drained and Characterized by Presence of Redoximorphic Features

Arayat soil series is (Plate 3A) classified as *Typic Eutrudepts* and confined to Mount Arayat and its vicinities. This extinct stratovolcano rises abruptly to a height of 1,026 m in the Central Plain of Luzon, north of San Fernando, province of Pampanga. It belongs to the Eastern Volcanic Chain which includes Mounts Balungao, Cuyapo, and Amorong. There is no recorded volcanic activity and its last eruption is placed probably during the Holocene era resulting in the formation of a lava dome on the western slopes. It is believed that Mount Arayat's cone is probably built upon an older crater of 900 m diameter, the remnants of which form the northern and the southern peaks. The rock types are basalts and andesites (Wikipedia 2012i). Lapuz (2012) reported that the rocks that comprise Mount Arayat are porphyritic dark colored basaltic lavas having crystalline groundmass. Olivine occurs as the primary mineral constituent, together with pyroxene. The groundmass mineralogy also includes plagioclase, magnetite and hornblende (Lapuz 2012). The Arayat soils developed from the weathered basalts, sandstones, tuff, and limestones. The soil parent material differs in many places according to the kinds of rocks. The surface soil consists of reddish brown friable and loose clay loam, 25–35 cm deep. The subsoil has a depth of from 60 to 70 cm from the surface, dark reddish brown, friable, and granular clay loam. Below is the substratum which differs from place to place, according to parent materials. In some places, it is a mixture of different rocks, and in other places, it is clay to clay loam (Yñiguez et al. 1956). In the reported Typical Pedon, the reddish brown to brown clay loam to clay substratum is further underlain by light gray tuffaceous rock. A total of 8,332 ha of Arayat sandy clay loam and Arayat clay loam were mapped in the province of Pampanga.

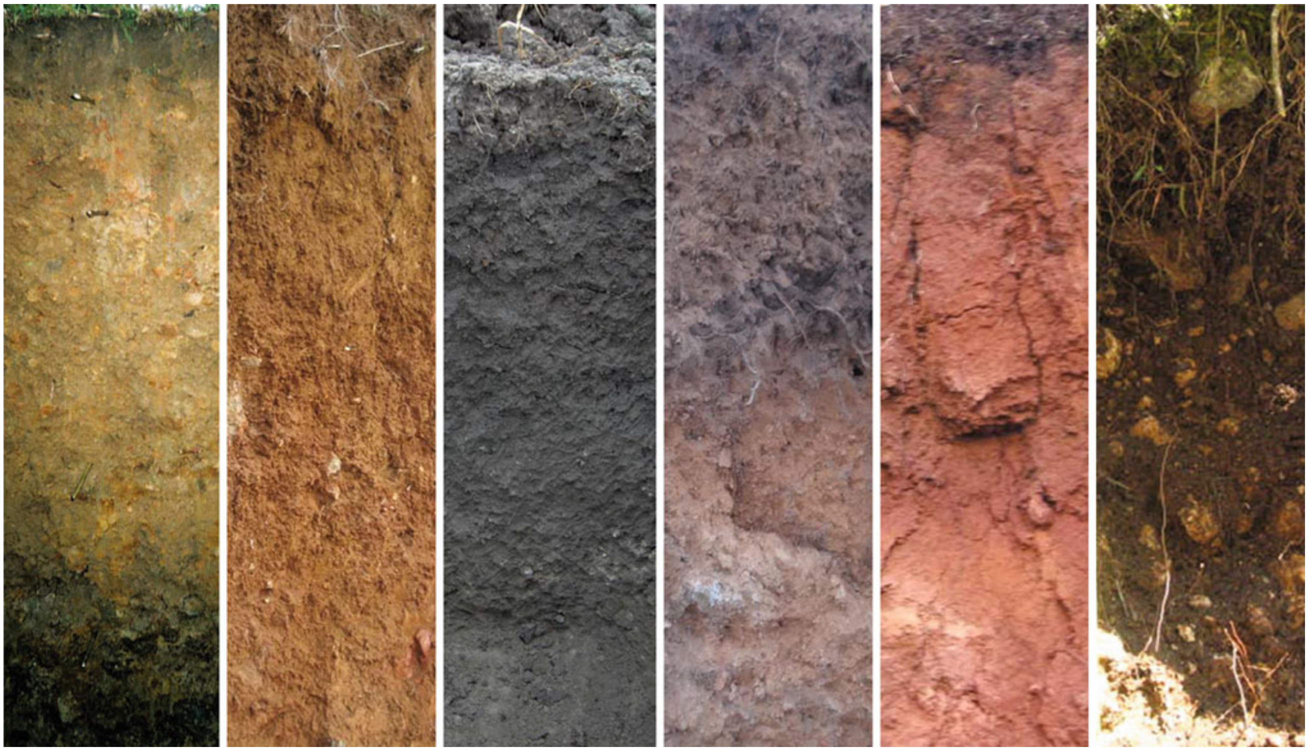
4.6.3.4 Soil is Underlain by Clay with Highly Weathered Gravels and Volcanic Materials

Tigaon series was first mapped between Mount Isaraog and Lake Baao in Camarines Sur. Tigaon is a municipality of this province. The relief is undulating to rolling east of Mount Iriga and, hilly to mountainous east of Lake Buhi. This soil series is of considerable depth with hardly definable horizons. These soils are derived from sandstone, basalt, and andesite. Tigaon series has good moisture retentivity; water easily percolates through the soil layers. The surface soil reaches down to 25 cm from the surface, reddish brown to brown clay; granular; boulders of basalt, gabbro, and andesite are found on the surface; boundary with the subsoil is smooth and diffused. The subsoil reaches down to 80 cm, reddish brown to brown clay loam to clay; slightly compact; boundary is diffused. The substratum extends down to the control section at 150 cm, light brown to brown clay; highly weathered gravels and sandstone are found. Below this horizon are sandstone, basalt, and andesite (Lucas et al. 1965). The natural vegetation consists of forests; the deforested areas are covered by cogon, talahib, and patches of secondary forest; while the cultivated areas are planted to upland rice and corn. Tigaon is classified as *Typic Hapludults* and covers a total of 59,007 ha of clay loam and clay soil types in the provinces of Camarines Sur and Albay (Fig. 4.8).

Fig. 4.8 Soil profile of Tigaon series

4.6.3.5 Soils Underlain by Highly Weathered Shale, Sandstone, and Igneous Rocks

Bituin series was first described in Bituin, municipality of Lagangilang, Abra province as per Soil Survey Report. Actually the word "Bituin" refers to a big white shapeless solid rock along the Kalinga–Apayao Road in Licuan Baay municipality and considered a local attraction. But Bituin series refers to primary soils developed from a variety of rocks—igneous, shale, and sandstone occurring on gently rolling to strongly rolling relief. It is well-drained soil and the external drainage is rapid to excessive. The distinguishing characteristics of this soil series is the presence of basalts and andesite rocks from the lower portion of the surface layer down to the substratum. Another distinguishing characteristic is the presence of basalts and andesite rock outcrops in some areas. The degree of the exposure of the outrcrops depends upon the slope and nature of vegetation. In gently sloping areas with thick growth of vegetation, the exposure is from 1/5 to 2/5 while areas with



ALIMODIAN *(Typic Hapludalfs)* **AMBASSADOR** *(Typic Hapludults)* **ARAYAT** *(Typic Eutrudepts)* **ATOK** *(Typic Hapludolls)* **BAKAKENG** *(Typic Dystrudepts)* **BALAKBAK** *(Eutrupeptic Rendolls)*

Plate 3A Soil profiles of Alimodian, Ambassador, Arayat, Atok, Bakakeng, and Balakbak series. Highland and mountain soils of the Philippines (*Photo credit* UPLB)

BALILI *(Typic Dystrudepts)* **BALUT** *(Typic Eutrupepts)* **BANTAY** *(Typic Eustrustepts)* **BAUANG** *(Typic Eustrustepts)* **BINENG** *(Typic Dystrudepts)* **BUENAVISTA** *(Typic Eutrustepts)*

Plate 3B Soil profiles of Balili, Balut, Bantay, Bauang, Bineng, and Buenavista series. Highland and mountain soils of the Philippines (*Photo credit* UPLB)

BURGOS	BUYAGAN	CAMANSA	CAMIGUIN	CARIG	CATBALOGAN
(Typic Hapludults)	*(Eutropeptic Rendolls)*	*(Typic Eutropepts)*	*(Typic Hapludands)*	*(Typic Eutrustepts)*	*(Aquic Hapludalfs)*

Plate 3C Soil profiles of Burgos, Buyagan, Camansa, Camiguin, Carig, and Catbalogan series. Highland and mountain soils of the Philippines (*Photo credit* BSWM and UPLB)

CERVANTES	CORON	DACLAN	GUINAOANG	HALSEMA	ILAGAN
(Typic Hapludults)	*(Typic Eutrudepts)*	*(Typic Hapludults)*	*(Typic Hapludults)*	*(Typic Eutrudepts)*	*(Typic Hapludults)*

Plate 3D Soil profiles of Cervantes, Coron, Daclan, Guinaoang, Halsema, and Ilagan series. Highland and mountain soils of the Philippines (*Photo credit* BSWM and UPLB)

KABATOHAN	KIDAPAWAN	LA TRINIDAD	LUISIANA	MACOLOD	MAGALLANES
(Typic Kanhapludults)	*(Typic Paleudults)*	*(Fluventic Hapludolls)*	*(Orthoxic Palehumults)*	*(Typic Dystrudepts)*	*(Typic Hapludalfs)*

Plate 3E Soil profiles of Kabatohan, Kidapawan, La Trinidad, Luisiana, Macolod, and Magallanes series. Highland and mountain soils of the Philippines (*Photo credit* UPLB)

MALIMONO	MIRADOR	NANGALISAN	NATUBLENG	PAETE	PAOAY
(Typic Kanhapludults)	*(Typic Hapludalfs)*	*(Typic Eutrudepts)*	*(Typic Dystrudepts)*	*(Typic Eutrudepts)*	*(Typic Hapludolls)*

Plate 3F Soil profiles of Malimono, Mirador, Nangalisan, Natubleng, Paete, and Paoay series. Highland and mountain soils of the Philippines (*Photo credit* BSWM and UPLB)

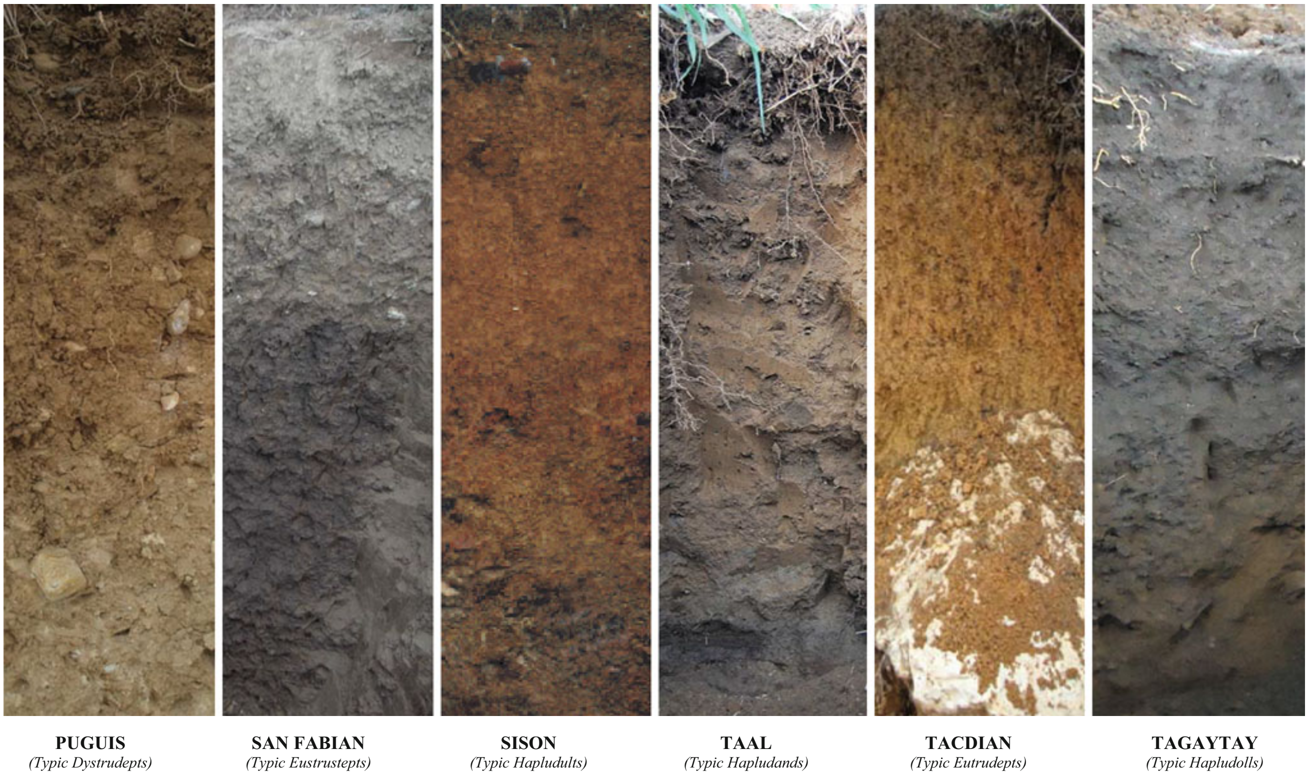


Plate 3G Soil profiles of Puguis, San Fabian, Sison, Taal, Tacdian, and Tagaytay series. Highland and mountain soils of the Philippines (*Photo credit* BSWM and UPLB)

steeper slopes and scanty vegetation, the exposure are almost 3/5. The soil cracks easily on drying. When wet, it is slightly sticky and plastic but friable when moist. The surface soil extending down to 20 cm from the surface is brown to dark brown clay; moderate, fine granular structure; some gravels are present in eroded areas. The upper subsoil reaches down to 45 cm, is reddish yellow to yellowish red, gravelly clay. The lower subsoil extends down to 130 cm, and is reddish yellow to dark red when dry, yellowish red to brownish red when wet, clay loam; strong medium columnar structure; few types of gravels than the above layer. The substratum reaches down to the control section at 150 cm, and is reddish yellow to yellowish red, mixture of highly weathered shale, sandstone, and igneous rocks; medium coarse granular in structure (Natividad et al. 1974). This soil series is classified as *Typic Dystrudepts* and covers 40,590 ha in Abra province.

4.6.3.6 Soils Underlain by Sandy Loam

Bineng series (sometimes referred to as Beneng or Bening series) developed from weathered sandstone and diorite (Plate 3B). This was first mapped in Barangay–Bineng in the municipality of La Trinidad, province of Benguet. Its elevation is about 1,050 m above mean sea level. Rice and Baguio beans are the principal crops. Coffee is also grown. The surface soil, reaching to a depth of 20 cm from the surface is reddish brown (5YR 3/4) (4\5YR 4/4) fine granular friable loam; iron pebbles present. The upper subsoil extends down to 60 cm, and is yellowish red (5YR 4/3) (5YR 4/1) fine granular friable sandy loam; pebbles are present, about 10 % by volume. The lower subsoil extends down to 90 cm, yellowish red (5YR 5/6) dark yellowish brown medium subangular blocky friable sandy loam; with pebbles, 10 % by volume. The upper substratum reaches down to 120 cm, dark brown (10YR 4/3) to dark yellowish brown (10YR 4/4) medium subangular blocky friable sandy loam with pebbles, 10 % by volume. The lower substratum that reaches down to the control section at 150 cm is dark yellowish brown (10YR 4/4) to strong brown (7.5YR 5/6) medium subangular blocky very fine friable clay loam (Calaustro and Ganawan 1968). This soil series is classified as *Typic Dystrudepts*, and Bineng loam was mapped in Benguet province covering 452 ha.

4.6.3.7 Soils Underlain by Loam with Highly Weathered Parent Materials

Nangalisan series (Plate 3F) developed from weathered sandstone and diorite. It was first mapped in Barangay Nangalisan, municipality of Tuba, province of Benguet, starting from the famous hot spring of Asin and extends westward along a road to the boundary of Benguet and La Union provinces. The relief is steep to very steep with patches of undulating areas. The elevation is about 570 m from the mean sea level. The external drainage is good to excessive while the internal drainage is poor. The crops grown in this soil series are rice, coffee Baguio beans, and cabbage. The surface soil is about 40 cm thick, dark brown (10YR 4/3) medium granular firm gravelly clay; there are angular gravels about 30 % by volume. The subsoil reaches down to 90 cm, and is brown (10YR 5/3) medium, subangular blocky firm gravelly clay loam; there are angular gravels of highly weathered parent materials, about 30 % by volume. The substratum that extends to the control section at 150 cm, is light yellowish brown (10YR 6/4) loam with highly weathered friable parent materials (Calaustro and Ganawan 1968). This soil series is classified as *Typic Eutrudepts*, and only one soil type, Nangalisan clay—gravelly phase, was mapped in Benguet province covering 547 ha.

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Soils and the Philippine Economy

5

Abstract

The soil is the foundation of the human civilization. As can be seen from the ruins of ancient civilizations, areas whose people are not conscious of erosion and land degradation eventually could not support a community. The ruins that are now tourist attractions only reflect the glorious and illustrious past of what were once flourishing and economically vibrant societies. Without soils, we cannot have a thriving and a bubbling economy. The chapter begins with an introduction to the three major ecosystem functions of the soil—as a biomass producer, as a platform for human activities, and as environmental regulator for atmospheric, hydrologic, and nutrient cycles. The next two sections focus on the role of the soil as biomass producer by discussing the major rice soils of the Philippines and the soils grown to other economically important crops. This is followed by discussions on the problem soils of the Philippines, problem soils from the point of view of agricultural production or the soil as biomass producer. The figures are updated to reflect currently available data. The next section is a treatise on land evaluation based on the FAO—developed methodology of matching soil qualities and characteristics with crop requirements. The basic concept and principles are applicable for other types of human endeavors that relate to the ecological function of soil as platform for human activities. Instead of crop requirements, we match soil qualities and characteristics with the specific land use requirements (LUR) which we would like to evaluate. The last soil function as regulator of atmospheric, hydrologic, and nutrient cycles is intangible, but there are current efforts being conducted by the National Statistics Coordination Board (NSCB) to address soil valuation and accounting. The soil is now recognized as part of the nation's economic and environmental assets, and there are national as well as international collaborative efforts to put monetary value on our soil resources corresponding to their ecosystem values and services. The next section is an update on emerging land degradation assessment. The current international trend is more holistic in approach rather than focusing on soil parameters like soil erosion. To cap the chapter, we have a policy advocacy to conserve and properly manage our soil resources considering their contributions to the economy. A sample political platform based on sound management of soil resources by an incumbent mayor in Dumingag, Zamboanga del Sur is presented to show that this is a realistic and attainable policy as the mayor received the 2012 One World Award Laureate given by the International Federation of Organic Agriculture Movement (IFOAM) and the Rapunzel Naturkost in recognition of his political agenda that is centered on the proper management of our soil resources.

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5.1 The Soil as the Patrimony of Our Nation and Vital Economic Resource

The soil is the foundation of human civilization. As could be seen from the ruins of ancient civilizations, by allowing erosion and land degradation to proceed unabated, the area cannot support a community. These tourist attractions—ruins that stand on bare rocks today only reflect their glorious and illustrious past, of what once were flourishing and economically vibrant human habitats. People could not repopulate a ruined city bereft of soils. Without soils, or with degraded soils, we cannot have a thriving and a bubbling economy (Lowdermilk 1939).

So in this chapter, we will discuss the economic role of soils as they relate to its three major functions—biomass production, platform for human activities, and environmental regulation. As biomass producer, we will look into the best of the Philippine soils for growing of rice, corn, and other economically important crops and where are they found. As a platform of human activities, we attempt to maximize the economic benefits derived from soils by discussing the principles of soil evaluation. Since the third soil function is rather intangible and the benefits derived therein are taken for granted by our citizenry, we look at the framework on soil resources valuation and accounting. We have another section on land degradation assessment. The last section concludes the three major functions of soils with an advocacy on soil conservation and management.

5.1.1 The Soil as Biomass Producer

The most commonly understood function of soil is related to its contribution to the Philippine economy, biomass production. We refer of course to agriculture, forestry, livestock, aquaculture, and freshwater fisheries. But slowly, the agricultural or primary industry-based Philippine economy is being transformed into secondary and tertiary industry-based. The 2009 statistics showed that agriculture contributed 18 % to the Philippine Gross Domestic Product (GDP) (Department of Agriculture 2010), quite low if we check the figures several decades ago. Agriculture appears to be declining in importance to Philippine economy. But in a country where rice importation is a very volatile issue, the declining trend is actually an erratic trend as agricultural production is greatly affected by many other factors other than soil factor such as climatic risks, and the law of supply, and demand. Where the population is high and the prices of agricultural commodities are consequently high owing to high demand, agriculture and fisheries remains a major contributor to Philippine economy (Fig. 5.1).

Our three sections on the soil as biomass producer begins with an exposition on the major rice soils of the country.

Fig. 5.1 The soil is the most important agricultural and forestry resource. Despite advances in hydrophonics, the soil is still the medium for growing our requirements for food, clothing, and shelter

While this is by no means exhaustive listing, this should present an idea as to how much of the food security and self-sufficiency goals we have set is attainable. Rice and corn importations are very controversial issues, which we are not in a position to propose policy directions because there are other factors besides the soil factor in crop production. Nevertheless, by knowing the extent and area of our rice and corn soils, we also know the maximum limits of our production given-projected crop yield. Given further the population figures and the per capita consumption, knowing the maximum extent of our rice soils can help our policy planners face more realistic scenarios and prepare more pragmatic plans to meet food security and self-sufficiency targets and estimate shortfalls. Soils have their carrying capacity; and the fact that only ten soil series were identified in the first section as major rice soils clearly implies that other soils used for rice production would have limitations in one way or another. In the parlance of soil evaluation, these ten soil series are the highly suitable soils; and in fact, a number of these soil series are characterized by dominance of smectite clays, poorly drained, and frequently flooded; and consequently, they would have the growing of rice as best land use option. The other soil series not mentioned in the article but part of our national soil heritage can be evaluated for suitability to rice, corn, and other crops. There is a separate section on the principles of soil suitability evaluations to derive maximum economic benefits from our soil resources.

5.1.2 The Soil as Platform for Human Activities

The soil is also the platform for human activities and for a host of infrastructures relating to housing, transport facilities, recreation, and industry. We cannot put up our homes, our commercial establishments, and our industries on bare

Fig. 5.2 As platform for human activities, our community life, especially our infrastructures relating to housing, transport, commerce, industry, and recreation stand on soils. With limited land resources, a major issue now is the competition for space between these different land uses

Fig. 5.3 The soil regulates atmospheric, hydrologic, and nutrient cycles, functions relating to ecological stability. Because these are rather intangible, we tend to take these for granted hoping that the resiliency of the soil system will restore equilibrium. There are now efforts to put monetary value on our soil resources and assess land degradation from holistic point of view

rocks. A major issue now is that many of our prime agricultural areas are giving way to urban development. In fact, despite land limitations for human habitation such as flooding occurrences or presence of expanding–shrinking clays in the soil, urban encroachment and population increase is accelerating the pace of real estate market and development, especially the conversion of prime agricultural areas to residential, commercial, and industrial uses. Soil resources assessment remains an important planning input in any economic development planning exercise. So in this chapter, we look into the principles of soil resources assessment and how it can improve further economic performance when the land is fit for the economic or land use activity we undertake therein (Fig. 5.2).

Core to maximize economic benefits derived therein is soil evaluation—or the matching of the requirements for the specific land use with the properties of the soil. The fourth article provides core principles of land use planning and soil evaluation. While the principles expounded here are basically developed by land evaluation experts for agricultural purpose, these are universal principles that can also be applied for other major land uses. For purpose of matching soil qualities of various soil series with the soil requirements of most common land uses, we have included rather common nonagricultural land uses.

5.1.3 The Soil as an Environmental Regulator for Atmospheric, Hydrological, and Nutrient Cycles

5.1.3.1 Soil Resources Valuation and Accounting

Often overlooked because for now we could not put a monetary value is the soil function relating to environmental regulations. This refers to the storing, filtering, and transforming capacity of the soil as it regulates atmospheric, hydrological, and nutrient cycles. For the fifth article, we look at the soils as significant component of our environment, of our national heritage, and of our economy. But we derive intangible benefits in terms of the soil's important role in environmental regulation, specifically those relating to atmospheric, hydrological, and nutrient cycles (Fig. 5.3).

In this section, we try to translate these environmental regulatory functions into tangible national assets as we discuss the framework for soil resources accounting. It is about time that we look at the soil as an important national heritage. Although these benefits are intangible, soil valuation is an emerging idea that is worth looking into. Soil resources accounting is a pioneering concept that attempts to inventory our soil resources and put monetary value therein. The National Statistics Coordination Board (NSCB) attempts to develop a framework to account for our soil resources as part of our National Environmental Assets, together with our other national heritage like forests, rivers and lakes, and biodiversity (NSCB 1998). The valuation and accounting of soils as an environmental heritage is considered a significant development in the assessment of the overall Philippine economic performance.

5.1.3.2 Land Degradation Assessment

The soil valuation concept in the previous section is premised on traditional land degradation assessment. This means that for the closing stock inventory, resource valuators will have to look into active land degradation processes to assess changes in the opening stock inventory and compute for soil losses or gains. The traditional method is to estimate the extent and magnitude of soil erosion, or how much additional areas we gained because of sediment deposition. The other losses or gains could also come in terms of how much were the problem soils expanded or decreased, especially those relating to nutrient mining and consequent soil fertility decline, soil acidity, soil sodicity and alkalinity, soil pollution (mostly coming from mining industry), etc.

However, in the international scene, specifically at the arena of United Nations Convention to Combat Desertification and Land Degradation (UNCCD) where the Philippines is a committed party, land degradation assessment is no longer just a soil issue. If we take the example of soil erosion, the parameter used by NSCB in soil valuation, the solution is not as simple as planting trees in the erosion site. This is because as long as we fail to address the economic roots of illegal logging, erosion will persist and the rate of deforestation or forest denudation will overtake the rate of reforestation or forest regeneration to the point we actually find ourselves today—landslides that buried communities whenever typhoons came; to think that the Philippines is visited by an average of about 19 typhoons a year. Emerging methodology in land degradation assessment involves the use of DPSIR framework in the analysis: Driving Forces, Pressures, State, Impacts, and Responses. The inclusion of other biophysical and socioeconomic factors in land degradation assessment is more holistic in approach. This was initially developed in arid countries by FAO under the Land Degradation Assessment in Drylands (LADA) Project, and hence referred to as the LADA tools and methods. The major assessment instrument is the Land Use System Map (LUS) (United Nations Environment Programme 2011).

Actually, a number of soil resource agencies, in other monsoon Asian countries, normally lodged in the agricultural ministry, are hesitant to officially adopt LADA for the obvious reason that we are not only concerned with agricultural ecosystems but with other ecosystems as well—forests, mangroves, grasslands, etc. This will unnecessarily increase existing hectarage of degraded lands compared with previously published official figures that political leaders could find alarming and could possibly put the blame as failure on the part of the soil resource agency which has no mandate to address and mitigate degraded nonagricultural lands. Why report on degradation of ecosystems that the soil resource agency has no mandate to report in the first place? This explains the quite passive responses by neighboring Asian countries toward LADA despite its holistic and more realistic approach to land degradation assessment. Generally, soil resource agencies would not want to revise officially released degraded lands to a significant figure because of political implications. Second, where there is no mandate, there is no authority to release politically volatile figures like extent of land degradation for nonagricultural areas.

Fig. 5.4 As a vital key to national economic development, the sustainable use of our soil resources through implementation of soil conservation and management technologies has to be inculcated among our farmers and natural resource managers

5.1.4 Sustainable Economic Use of Soil Resources

The last section is more of a policy advocacy to conserve and properly manage our soil resources given its important role in the Philippine economy, a fitting close that looks at the soil for its contributions to the Philippine economy (Fig. 5.4).

5.2 Major Rice Soils of the Philippines

5.2.1 Introduction

The Philippines consists of 7,107 islands with a total area of approximately 30 million ha. This is about 2 % of the total land area of the world and ranks 57th among 146 countries in terms of physical size. The country is divided into three major island groups—Luzon, Visayas, and Mindanao.

Of the 30 million ha that constitutes the country, about 14.2 million ha are considered as alienable and disposable. Of this figure, about 93 % or 13 million ha are classified as agricultural lands. This is distributed as follows (Food and Agriculture Organization 2010):

Food grains	4.01 million ha; the average for rice is about 3.31 million ha while for corn is about 3.34 million ha
Food crops	8.33 million ha; the average for coconut is about 4.25 million ha, sugarcane is about 673,000 ha, industrial crops is about 591,000 ha, fruits occupy about 148,000 ha, vegetables and rootcrops about 270,000 ha, pasture areas cover about 404,000 ha, and cutflowers occupy about 133,000 ha
Non-food crops	2.20 million ha

Actually, every year the statistical reports on the crop production area vary—the areas either contract or expand. But since we have already opened up the best of our agricultural lands by the 1980s, the annual variation in area can be explained by the dynamics of market forces and other relevant factors that make farmers decide which of the annual crops to plant.

Agriculture contributes an important share in the Philippine economy. Despite being one of the newly industrialized emerging market economies of the world, it is still an economy with a large agricultural sector. The country is predominantly rural, and about two-thirds of the population depend on farming for livelihood. Primarily, Philippine agriculture is basically rice, corn, coconut, sugar, banana, livestock, poultry, other crops, and the fishery sector. But as an archipelago, the agricultural economy is far more fragmented and vulnerable to various production risks and inefficiencies of support services, compared to its neighbors in the Asian continental mainland.

Rice is a staple food and has always been in the centerpiece of the national government's food production program. With an increasing population and slowly diminishing rice areas encroached by urbanization, coupled by drought and typhoon risks, the rice production statistics is closely monitored to compute for shortfall and reasonable buffer stocks to be sourced from importations and tide the population until the next harvest season. Rice importation is itself lamented by majority because it is a drain on scarce foreign exchange savings, and a very volatile national topic of discussion.

So much debates on the country's rice production statistics have been made, so much research and subsidies have been devoted to improve crop yield resulting to incremental increases, from an average of about 16 cavans per hectare for rice in 1909, to as much as an average of 70 cavans per hectare in 2002. With diminishing rice production areas, high production costs that eat up profit margins, a high average annual population growth rate of 2.04 % for the period 2000–2007, is the rice self-sufficiency target of the national government after so many years attainable? The rice program magnitude is considerable taking into account farmer support given in terms of inputs like seeds and fertilizers, irrigation and postharvest facilities, credit, and training.

Still, the key that holds rice sufficiency is the total area of rice soils available for their production. About 2.37 million ha of lowland rice and corn lands, representing 45 major soil series are located in Luzon. Around 470,000 ha in 15 major soil series are found in Visayas, and about 870,000 ha under 25 major soil series are located in Mindanao. But aside from the threat of land conversions, these prime rice and corn soils are also facing fertility decline resulting from intensive cropping and other natural causes

Fig. 5.5 As a rice-eating population, rice soils is a national patrimony threatened not only by the vagaries of production risks like typhoons and occurrences of pests and diseases, but also by intrusion of other land uses because of encroachment by urbanization

arising from improper soil management and overexploitation. Rice farmers also face the usual crop production risks—typhoons, pests, and disease incidence (Fig. 5.5).

5.2.2 The Ideal Soil for Growing Rice

Rice can grow practically on all types of soil but paddy rice is best cultivated on clay soils where percolation losses are low. These soils are usually found in river valleys, basins, deltas, estuaries, lake fringes, and coastal plains, and where water source is most easily accessible. An ideal rice soil contains about 60 % silt and sand fraction (Fig. 5.6).

Many paddy rice farmers practice puddling during land preparation to level rice fields and conserve water. Puddling refers to harrowing the top 10–15 cm at moisture contents above field capacity until most aggregates are destroyed and the soil is transformed into a slurry that flows (Sanchez 1973). In puddling, the soil structure is deliberately destroyed and the soil is dispersed by plowing and harrowing in flooded state. Ghildyal (1978) itemized the effects of puddling on soil properties: coarse aggregates are broken down; noncapillary pore space is destroyed; apparent specific volume decreases; water holding capacity increases; hydraulic conductivity and permeability decreases; evaporation decreases; and soil reduction is favored. Ghildyal further defines a puddled soil as "one whose structure has been destroyed, whose aggregates have lost their identity, and which has been converted into a structurally homogenous mass of fine aggregates and textural separates" (Ghildyal 1978).

Ponnamperuma (1981) summarized the changes brought about by puddling from the studies of Moorman and van Breemen (1978) and Sanchez (1976): the soil particles settle

Fig. 5.6 Pili clay, classified as a Vertisol, or soils with expanding-shrinking clays, here taken from an alluvial plain in the municipality of Polangui, Albay, is an example of soils best suited for rice production

and undergo stratification into clayey, silty, and sandy layers; the bulk density increases; the moisture content decreases in spite of the soil being flooded; and gases are trapped in the puddled layer. The thickness of the oxidized surface layer increases during the season and reddish brown streaks and mottles are visible in the reduced puddled soil. When the soil is drained and dried, it cracks. Alternate drying and wetting and tillage regenerate the soil aggregates. Soils high in organic matter or iron and aluminum oxides are easier to regenerate than other soils.

Ponnamperuma also quoted De Datta (1981) as to the benefits of puddling rice: reduced draft requirements for tillage, weed control, easy transplanting, conservation of rain and irrigation water, and increase in nutrient availability. Ponnamperuma further pointed out that of these, weed control and water conservation are the most important. De Datta also mentioned that soils with clay content exceeding 20 % favors puddling.

Ponnamperuma (1977) also studied the chemistry of water-submerged paddy soils. Of course, different soils such as acid soils, calcareous soils, and sodic soils would react differently to water logging or the reduced soil condition. The pH change resulting from water logging impacts the concentration of nutrients in the paddy soil. The increase in pH of acid soils and the decrease of pH of alkaline soils brought about by flooding favor nutrient uptake by rice. The decomposition of organic matter is done chiefly by anerobic bacteria and they function best at a pH near 7, at which the release of both nitrogen and phosphorus from soil organic matter should be maximum. Thus, the pH of the solution of a reduced soil is an important factor to determine the fertility of rice soils. Ponnamperuma determined that the optimum pH for rice, measured in the solution of the submerged soil, is 6.6. At this level, the microbial release of nitrogen and phosphorus from soil organic matter and the availability of phosphorus are high; the supplies of copper, zinc, and molybdenum are adequate; and the concentration of substances that interfere with nutrient uptake such as aluminum, manganese, iron, carbon dioxide, and organic acids are below the toxic level. However, he noted that the rates of denitrification and sulfate reduction are higher at pH 6.6 than at lower pH values. Maintaining the pH level 6.6 should be the aim of soil and water management from planting until panicle initiation. He also recommended that soils should be kept submerged for at least 2 weeks immediately before planting in tropical lowlands, and longer in cooler areas. Aside from pH, Ponnamperuma further studied the effects of electrical conductivity (EC), ionic strength, mineral equilibria, and the presence of toxic substances like organic acids, carbon dioxide, and hydrogen sulfide concentrations on the fertility of flooded rice soils.

Appendix 1 shows the major rice soils of the Philippines, a summary of their general characteristics based on typical pedon, and the extent of coverage based on reconnaissance soil maps (Bacatio et al. 2007). While much of the figures would require updating under a semi-detailed level of mapping as some of these areas could have been under urban development already, the figures nevertheless give a general picture as to area coverage for national rice production planning purposes. Note also that, not all of these soils are devoted to rice as can be seen from the major land uses for the particular soil series. Rice does compete with other economically important crops, and the dynamics of the annual total area devoted to rice are generally dictated by market forces and many other factors. Practically, all rice production areas in the country are located in basins, flood plains, and narrow alluvial valleys. Despite being visited frequently by floods, these are also considered prime residential and commercial areas, and urban development is strong. The transformation of these soils from rice land use to other land uses reflects not only on the changing economic times but also on the value system we have for our soil resources.

5.2.3 The National Rice Production Program

Starting with *Masagana99*, *Masaganang Maisan*, and *Masaganang Gulayan* for rice, corn, and vegetables, respectively, during the term of President Ferdinand E. Marcos (1965–1986) for which the Philippines exported rice from 1977 to 1978, every president hence has prepared a national rice, corn, and high value crop production program as the banner agricultural program from which all the other agricultural productivity enhancement programs take off as part of the holistic and integrated approach to rural development—irrigation, agricultural credit, extension, fertilizers, seed production, etc.

When Corazon Cojuangco Aquino (1986–1992) was swept into power by the tumult of the Peoples' Revolution, the *Grain Sector Development Program* was launched as an integrated package of five components of policy and institutional reforms for the grain sector to be globally competitive. The other major banner programs were Medium-Term Livestock Development Program, the Key Commercial Crops Development Program, and the Medium-Term Fisheries Management and Development Program.

The succeeding administrations launched their respective similar integrated agricultural programs—*Gintong Ani* Programs which literally means Golden Harvest during the term of President Fidel V. Ramos (1992–1998), *Agrikulturang Makamasa* during the short and interrupted term of President Joseph E. Estrada (1998–2001), *Ginintuang Masagang Ani* during the term of President Gloria Macapagal Arroyo (2001–2010), and *Agri-Pinoy* during the term of President Benigno Simeon Aquino (2010–2016). Note that *Makamasa* means pro-mass or pro-poor in reference to the political slogan of President Estrada, *Ginintuang Masaganang Ani* has GMA for acronym which is also the acronym of President Arroyo, and Pinoy is the colloquial word for Filipino but also the colloquial reference to President Aquino (the short term for "President Noynoy", which is his nickname; hence P-Noy). The Philippine National Food Production Program for rice, corn, high value crops, livestock, and fisheries have evolved into political platform of the incumbent administration but basically remains focused on productivity enhancement strategies specifically development of high-yielding varieties, rehabilitation and expansion of irrigation services, technology dissemination through extension services, and provisions for other support services like agricultural credit, fertilizers, and postharvest facilities. These national food production programs are accompanied by huge financial outlays in the General Appropriations Act (GAA) commonly referred to as the national budget.

Every president seeks food security for his people and all agricultural productivity enhancement programs of all presidents have food security and sustainable development for a goal. Generally, there is continuity in the national food production programs but to keep up with the change in administration, the targets are updated to conform with the incumbent's priority, and project nomenclatures are changed to avoid association with the previous administration. By the end of the administration's term, a new set of officials and their accompanying technocrats come in the government bureaucracy, goals are reset to reflect the political vision for the country and agenda of the incumbent, and the national food production programs are renamed to reflect their political slogan or highlight their program focus. But if one would care to read the major substance and framework of the national food production programs, nothing much has really changed since the time of President Marcos. After all, politicians come and go but the truly working bureaucrats remain.

At the national level, there is now a realization that the total area devoted to the growing of rice certainly defines the maximum production volume we expect to harvest per cropping season, assuming all other risk factors are within normal levels. Thus, a look at the current national food production program is no longer aiming for rice self-sufficiency but rather, for food staples sufficiency, with rice as one of the component subprograms.

The specific national government interventions in the rice program are centered on six pillars—production support, irrigation development services, other infrastructure and postharvest development services, market development services, extension support/education/and training services, and research and development services. Still with population increase, consumption outstripped production and rice importation has been steadily growing.

Every old timers' recall that we exported rice during President Marcos' time; how come the rest of the time we imported? Where have all the money gone that every president and the legislative body appropriated for agricultural development? In the first place, how much rice can we really produce given our soil resources?

Given our finite agricultural land resources and the national yield average per hectare, we can compute our yield projection given a normal rice production season. Hence, all these government appropriated funds for rice program are government crop production subsidies that keep production volume at the monitored levels. Without these subsidies, we would not attain the production volume we had, and definitely we will not know how much we are producing. And considering the law of supply and demand, without knowing how much is the supply, it will be even more difficult for the government to keep the price of the crop commodity such as rice stable and affordable to every Filipino and in continuous supply.

Most countries provide some form of agricultural subsidies to its people and in some advance countries, this is even so specific such as government price support program to compensate for price volatility of agricultural product by providing direct payments to farmers. In the Philippines, we do not have such agricultural subsidies paid directly to farmers. Our agricultural programs are primarily to set national food production targets, provide the mechanisms to attain the targets, and determine how much of these targets

Fig. 5.7 *Left* Set of tea brewer and shredder distributed to farmer groups and organizations for community-based production of organic fertilizers as part of the national government food production program to enhance productivity. The package comes with a kilogram of worms for vermiculture. *Right* A local farmer group shows visitors the shredding of farm biomass as preliminary step to vermicomposting

Fig. 5.8 *Left* Vermicompost beds for organic fertilizer production is the community's counterpart. *Right* Excess organic fertilizers unused in the rice fields are either sold or used by the farmer's group for other crops

were achieved and thereby have a clear picture of the demand-supply situation. As a matter of government policy, food imports are made to meet the supply gap and at the same time, stabilize the price. Rice, corn, and meat production are closely monitored. For rice, even as early as the planting season, the area expected to be harvested is already computed; and typhoon havocs and replantings are likewise estimated. Theoretically, food imports would tide us over in between the harvests. Or in the case of meat, to steady the price during the holiday season where the demand is unusually high. The government food production programs aim to stabilize supply and bring about peace, stability, contribute to poverty reduction, and support national economic growth.

The soil as a component of the national rice production program is under production support. Basically, the current soil-related projects are on organic fertilizer production, promotion of nutrient management tools for site-specific fertilization, and maintenance of soil laboratories for soil analytical services. The promotion of soil conservation-guided farms, soil survey and mapping, and agricultural land evaluation are production support to other food production programs such as those for corn and for high-value crops (Figs. 5.7 and 5.8).

5.2.4 Summary on Rice Areas and the Rice Program

Every president dreams of food self-sufficiency for his people. The various food production programs were launched to provide stimulus and assured continuity of supply and stable prices of commodities. Agriculture, fishery, and forestry, being soil-resource–based, and considered as primary industries, contribute significantly to the GDP and remain important sources of livelihood for majority of those living in the rural communities.

Based on reconnaissance soil maps, San Manuel series is the most extensive rice soils in the country and covers some 1,080,726 ha. Quingua series is another extensive rice soils, and covers 373,693 ha throughout the country. Bantog series covers 142,812 ha. The total for this top three soil series is about 1,597,231 ha. Of course, we know that some of these have been converted irrevocably to urban development and not all of these soils are planted to rice.

The Central Plain of Luzon is the top rice producing region in the country, followed by the Western Visayas, Cagayan Valley, and Ilocos Region. Practically, all rice production areas in the country are located in basins, flood plains, and narrow alluvial valleys.

As per FAO report, close to 3.31 million ha of lands are devoted to rice. Of this figure, we have about 1.4 million ha of irrigated lands, the rest of the rice areas are rainfed, with more than half devoted to rainfed lowland (wetland) rice, and the remaining are rainfed upland rice. Of the irrigated areas, only about a third constitutes large reservoir-backed national irrigation systems constructed in the 1960s and 1970s. By 1980s up to date, the nature of capital investments in irrigation is for small communal irrigation systems; and about two-thirds of the irrigated lands are too small to be reflected on national maps, farmer-operated, and managed.

Of the FAO report 4.01 million ha for cereals, we have about 3.31 million ha devoted to rice, and about 3.34 million ha for corn. The lowest rice production area recorded was in 1993 at 2.64 million while the highest so far was in 2005 at 4.20 million ha (Necesito 2009, Slide 24). The double cropping (wet and dry season harvests) as well as the dynamics of the market forces as a farmer would plant either rice or corn depending on the supply and demand scenario explains why the total for the average rice and corn area is only 4.01 million ha as per FAO report, and not around 6 million ha if we were to add the rice and corn areas. What the FAO report saying is that we have around 1.5 million ha for rice (mostly irrigated) and another 1.5 million ha for corn plus about a million hectares planted to either rice (rainfed lowland or bunded rice/rainfed upland rice) or corn. The 1 million ha-interphase areas are irrigable areas but not yet irrigated or uplands; and thus could be planted to either of the crops depending on the market forces. A decrease in rice area for a particular year could mean an increase in area for corn or for other crops. We should not also be confused that in many other official reports, studies, and publications, when it is stated that we have around 4.0–6.0 million ha cultivated to rice, of which close to 2.5 million ha are irrigated. Most of the figures from these various publications and sources are for two cropping seasons; but when analyzed, they still fall within the range of the FAO report. What would be confusing are the statistical reports from earlier decades, which could be the actual area planted as double cropping was not yet extensively practiced then or the increase in area refers to opening up of new rice or corn area rather than due to crop conversion between rice and corn or vice versa. In effect, despite earlier rice production area estimate between 2.8–3.5 million ha in the decades of the 1950s and 1960s (Necesito 2009) which is still within the 2010 FAO report, we have actually decreased our rice areas by about a third, because we have irrevocably converted them to nonagricultural uses and our current statistical reports are actually based on double cropping.

The soil component of the national rice program is basically concentrated on soil testing and fertility management to assure productivity. The focus on community-based production of organic fertilizers is an intervention intended to cushion the increase in price of inorganic fertilizers.

5.3 Soils Grown to Other Economically Important Crops

5.3.1 Introduction

The contribution of agriculture, forestry, and fisheries to the Philippine economy is substantial, despite increasing share of the secondary (manufacturing) and tertiary industries (service sector) in recent decades. The country is still predominantly rural and a significant percentage of the labor force is in the agricultural sector. The agriculture and fishery sector contributed 17 % to the GDP in 2010 but contracted by 0.34 % compared to previous years (Bureau of Agricultural Statistics or BAS 2010). The country's earnings from agricultural exports reached US$4,097.59 million in 2010 with coconut oil and tuna contributing about 40 % to the agricultural export earnings. Increasing agricultural imports, however, surpassed export revenues, with rice from Vietnam and Thailand, milk and cream products from New Zealand and the United States contributing significantly to the trade deficits in 2010.

Dolan (1991) in discussing agricultural geography mentioned that in late 1980, nearly 8 million ha or over 25 % of the total land area, were under cultivation, 4.5 million ha in field crops (slightly higher than the 4.01 million ha FAO estimates in the previous section, but certainly not statistically significant if we consider the dynamics of market forces that influence farmers on what crop to plant), and 3.2 million ha in tree crops. Growth in agricultural sector came mainly from multicropping and yield increases. For 1988, with double cropping and intercropping, we had about 13.4 million ha of harvested area, with about half coming from rice and corn. The remaining production areas were devoted to coconuts (about a half of the remaining area), sugarcane, pineapples, Cavendish banana.

The 2002 Census on Agriculture and Fisheries (CAF) placed agricultural land area as 9.7 million ha, about 32 % of the total area of the country (Bureau of Agricultural Statistics 2012). The top four crops are coconut—3.33 million ha, rice—2.47 million ha, corn—1.35 million ha, and sugarcane at 0.36 million ha. Except for paddy rice and the permanent crops like coconut and fruit trees, the annual increase and decrease in production area devoted to a particular crop would mean change of crop planted as

Fig. 5.9 Landscape view of Manapla series in Negros Occidental. This soil is traditionally grown to sugarcane

result of market forces rather than a reflection of opening of new areas for agriculture (for increase in area planted) or abandonment (for decrease in area planted). This means that a decrease in areas devoted to sugarcane in a particular year could be translated to increase in corn production area and upland rice for the same year, and vice versa (Fig. 5.9).

By the 1980s, we have already cultivated the best of our agricultural lands, and in fact started converting them to nonagricultural uses. Agricultural expansion since then and until now is toward what can be considered as marginal lands for agriculture.

5.3.2 Economically Important Crops and the Philippine Agricultural Geography

In the midst 1960s, Wernstedt and Spencer (1967) reported that five crop plants form the bases for all regional patterns of agriculture in the Philippines—rice, corn, yams, and sweet potatoes, bananas as food staples, and coconut as all-purpose plant. Regional specialization adds one crop or group of crops to the rice–banana base either as locally dominant item or as shared complements that bulk significantly in acreage patterns in the regional economy. In the Visayas, southeast Mindanao, and northeast Luzon, corn replaced rice as the primary food item. Sweet potatoes joined yams both in use and regional concentration. Papaya and avocado spread widely to join the jackfruit and pomelo, but none of the fruits rivals the bananas to the status of primary crop in any regional context. Sugarcane declined notably, and also abaca in relative frequency. Tobacco has lifted its importance as primary crop in northwest Luzon.

With this information, Wernstedt and Spencer described the agricultural patterns in regional landscapes: Northern and western Negros Island has sugarcane assuming dominant status, with rice, coconut, bananas, papayas, and mangoes as complements. Southeast of Manila, coconuts dominate the landscape and complementary crops show up in patches, gardens, and homestead plantings. Corn and coconut appear to dominate the landscape in much of Cebu whereas the rootcrops present an open landscape in the typhoon-swept Batan Island. For all the regional specializations, rice, bananas, corn, yams, sweet potatoes, and coconut dominate the cropping systems and the agricultural landscapes (Wernstedt and Spencer 1967).

Table 5.1 Comparative 1948 and 1963 agricultural areas (Wernstedt and Spencer 1967)

CROP	1948	1963
Rice	1,821,490	3,240,722
Corn	1,008,881	1,948,966
Root crops	272,758	264,259
Vegetables	116,549	123,833
Fruits	204,366	394,568
Tobacco	32,374	97,124
Coconut	1,050,563	1,391,713
Abaca	229,861	181,703
Sugarcane	82,746	258,594

With Philippine Census for 1948 data and Agricultural Economics Division of the Department of Agriculture and Natural Resources for 1963 data as their sources, the comparative areas (original figures in acres, converted to hectares) for the major crops are in Table 5.1.

The fruits in 1963 figure do not include some fruits surveyed in 1948 and the two areas would not be comparable. Also, the sugarcane industry had not yet risen from the war in 1948 and the damaged sugar centrals were not yet rehabilitated, which explained the abnormally low production area.

Wernstedt and Spencer detailed also in the Statistical Appendix the 1960 irrigated lands by province based on the 1960 Census of the Philippines, Agriculture. The total area irrigated was 1,533,490 acres which would be 620,581 ha. Certainly, a lot of agricultural expansion in terms of area had taken place right after the war and by the time of the nearest agricultural census when Wernstedt and Spencer wrote their book. The decades of 1960s and 1970s also marked the expansion of irrigated areas as the country embarked on huge irrigation projects to complement the infrastructural requirements of the Green Revolution, which was just commencing when they wrote their book (Wernstedt and Spencer 1967).

To assess changes in the agricultural landscape since 1967 when Wernstedt and Spencer wrote their book, a check on the website of the BAS, under the CountrySTAT Philippines shows the production areas (in hectares) in 1997 are as follows (Bureau of Agricultural Statistics

2012)—palay (3,842,270), corn (2,725,875), coconut (3,134,417), sugarcane (375,181), banana (348,648), cassava (230,522), sweet potato (141,701), coffee (136,533), mango (124,947), abaca (112,456), rubber (92,929), pineapple (42,924), tobacco (51,105), mongo (36,267), peanut (26,454), and calamansi (17,789). The total irrigated area is 1,335,517 ha.

For 2010, area (in hectares) harvested for palay is 4,354,161, for corn is 2,499,040, coconut is 3,575,944, sugarcane is 354,878, banana is 449,443, cassava is 217,662, sweet potato is 109,438, coffee is 121,399, mango is 189,437, abaca is 135,090, rubber is 138,710, pineapple is 58,547, tobacco is 29,707, mongo is 40,080, peanut is 27,123, and calamansi is 20,987. The total irrigated area is 1,542,668 ha (Bureau of Agricultural Statistics 2012).

From the statistics of the production areas between 1997 and 2010, it could be seen that the dynamics of the market forces or the law of supply and demand generally dictates what crops to grow which would explain the area expansion or contraction but the general agricultural landscape has not changed significantly compared to the 1963 agricultural census scene. Of course, the agricultural infrastructure, specifically irrigation greatly expanded in the 1960s to the 1970s. And by the mid-1990s, there is little room for agricultural expansion.

We have mentioned earlier that the reporting for rice and corn area is generally based on double cropping because if we check closely the BAS figure, it refers to area actually harvested. It is possible that the 1963 rice and corn production areas were based on actual rice areas cultivated since irrigation was not yet extensive then; and the double cropping not yet extensively practiced will be reflected in the production volume.

This means that we have reduced to about a third our rice and corn production areas despite comparative production area between 1963 (3,240,722 ha for rice) and 2010 (4,354,161 ha but refers to area harvested, and at double cropping means actual area devoted to rice is somewhat near 2,177,080 ha). In a great sense, while the agricultural landscape in terms of cropping pattern and dominant land use has not changed relatively through the decades, the rural physical landscape has significantly changed as many of what used to be rice and corn areas are now highly urbanized. We compensate urbanization of our best agricultural lands by opening up marginal areas for agriculture and improving crop yield through productivity enhancement program and strategies. We also reported area harvested rather than area devoted to rice and corn and these current statistical figures are not comparable to the early pre-war and post-war agricultural statistical reports.

So our major crops outside rice are corn, coconut, sugarcane, banana, rootcrops (cassava, sweet potato, yam), abaca, coffee, mango, pineapple, and a host of other fruits and vegetables. *Appendix* 2 lists the extensive upland and hillyland soils of the country considered suitable for their growing, their morphological characteristics, their distribution, and extent.

Fig. 5.10 A typical Paete soil series grown to corn is found on rolling to moderately steep hilly landscape. The photo above is taken in Manukan, Zamboanga del Norte

5.3.3 The Ideal Corn Soils

Corns are adaptable to a wide range of soil types and soil conditions. But the best corn soils are deep, fertile, well-drained clay loam to silty loams, with good water holding capacity. Generally, only very heavy clay soils with poor drainage properties are not best conditions for growing corn. Soggy soils deprive corn roots of oxygen. Waterlogged conditions also contribute to nitrogen losses. As roots die, whatever crops that survive prolonged flooding are stunted and pollinate late. Like other vegetables, the optimal pH for the growing of corn is between 5.8 and 6.8. When soils are not ideal for the growing of corn, the best that could be done is to improve the soil organic matter. Too sandy soils will be able to improve its nutrient holding capacity while heavy clay soils will improve its structure and improve drainage.

There are some sloping areas in the Philippines where corn is grown. Without soil conservation measures, erosion reduce the organic matter-rich topsoil resulting in reduced nutrient exchange capacity and water holding capacity of the soil. A good soil management program for corn addresses the issue of soil erosion and soil fertility build up (Fig. 5.10).

5.3.4 The Ideal Coconut Soils

Coconuts require good soil drainage and can adapt to a wide range of soil types. Loamy and coarse sandy soils are good. Coconut is known to thrive best in sandy loams, sandy

Fig. 5.11 Every administration has a rice program as the centerpiece of its agricultural agenda focused on various productivity enhancement strategies. Still, population growth is outstripping production gains; and with limited areas for growing rice, the importation of rice from neighboring countries is steadily increasing and a politically sensitive national issue

Fig. 5.12 The gently sloping to undulating areas of Alimodian series in Alicia, Zamboanga Sibugay are dominantly vegetated with coconut associated with fruit trees, bananas, shrubs, and grasses. Corn is also observed but in a small extent

coastal alluviums, and sandy river valleys. But clayey soils can also be a good medium provided the drainage is good. This crop can tolerate soil pH to as high as 8 such as those found on coralline atolls to as low as 4.5. Coconut also tolerates saline and infertile soils. But since it is deep-rooted which explains why it can survive in infertile soils, coconut requires relatively deep soils (Chan and Elevitch 2006).

Since coconuts require good drainage, it cannot tolerate flooding or waterlogged condition. Likewise, the coconut tree is quite sensitive to drought condition.

Low coconut productivity is generally associated with farmers' dependence on inherent soil productivity. With the rising cost of inorganic fertilizers, organic fertilization provides not only a cheap source of nutrients but also a versatile component of a coconut-based farming system (Fig. 5.11). In the Philippines, a number of studies were conducted for organic material sources: seaweed (Cadigal and Prudente 1983), ipil–ipil (Cadigal et al. 1983), goat manure (Cadigal et al. 1987), *Trichoderma*-activated compost in city garbage plus swine manure (Ebuña and Cagmat 1992), animal manures (Maravilla 1989), and chicken dung (Margate et al. 1993). In other coconut-growing countries like Sri Lanka, the use of glyricidia or *madre de cacao* as a green manure is reported to provide as much as 90 % of the nitrogen requirements (Prabu 2005).

Coconut-based cropping system is now being promoted to increase land productivity and farmer income. Coconut trees are planted as the base crop and other crops are intercropped using the vertical and horizontal spaces between coconut trees. There are several types of coconut-based cropping system. As a saying goes, there is nothing that a man cannot do under a coconut tree. We can use the land as if there are no coconut trees at all. In the Philippines, the most common intercrops are banana, pineapple, papaya, cacao, coffee as a multistoried cropping system. Intercropping with perennial plants as well as short-term crops does not affect the coconut yield negatively. Intercropping, however, demands a higher level of skill from the farmer to be able address some of the issues like competition for water and plant nutrients (Fig. 5.12).

5.3.5 The Ideal Sugarcane Soils

A well-drained, deep, and loamy soil is considered ideal for sugarcane. Good soil structure is considered important to promote good aeration. The soil needs to be loose and friable, with a minimum depth around 45 cm. The optimum soil pH is about 5.5–6.5 but sugarcane can tolerate considerable degree of acidity and alkalinity, between 4.3 and 8.4 based on studies conducted at Purdue University (Lerche 2012). Different varieties differ in their responses to soil acidity and alkalinity, and the germination and early stages are more sensitive than the later crop stages (Fig. 5.13).

A common problem where mechanization is intensive is soil compaction as indicated by increased in soil bulk density and soil penetration resistance. Where we have subsurface formation of hard pans, the recommended ameliorative practice is deep plowing and subsoiling. More number of ratoons and also sugarcane-rice rotation systems are suggested. To improve soil structure, the application of organic manures or green manure crops are further urged.

Fig. 5.13 Ramos series in Hacienda Luisita, here shown renewed by fresh ejecta from Mount Pinatubo, is traditionally grown to sugarcane

5.3.6 Best Soil and Water Management Practices for the Growing of Upland Crops

5.3.6.1 Cover Crops

Planting covers will primarily protect the soil from erosive forces of rainfall, suppress weeds, conserve nutrients from leaching out of the soil system, minimize water loss, improve soil fertility, help control pests and diseases, add organic matter to the soil, improve soil aeration, promote high water infiltration, and provide diversity in agroecosystems. These are generally planted in-between plots (in which case we can use perennials or grasses) or at the field plots after harvest as we rest the land for the next cropping season (we can use either annual or biennial crops). Legumes such as cowpeas and mungbeans are generally used after rice. When used as *green manures*, the practice is to incorporate the biomass into the soil by plowing while still in the vegetative stage. Melons, garlic, tomatoes, and other short maturing vegetables are planted also after rice as *catch crops* to utilize residual fertilizers and moisture and keep them from leaching out of the system. Where we have fruit orchards (mangoes, citrus, etc.), plantation crops (coconut, oil palms, coffee, etc.) or vineyards, *living mulches* such as carabao grass or pasture and forage crops are planted in between the trees (Fig. 5.14).

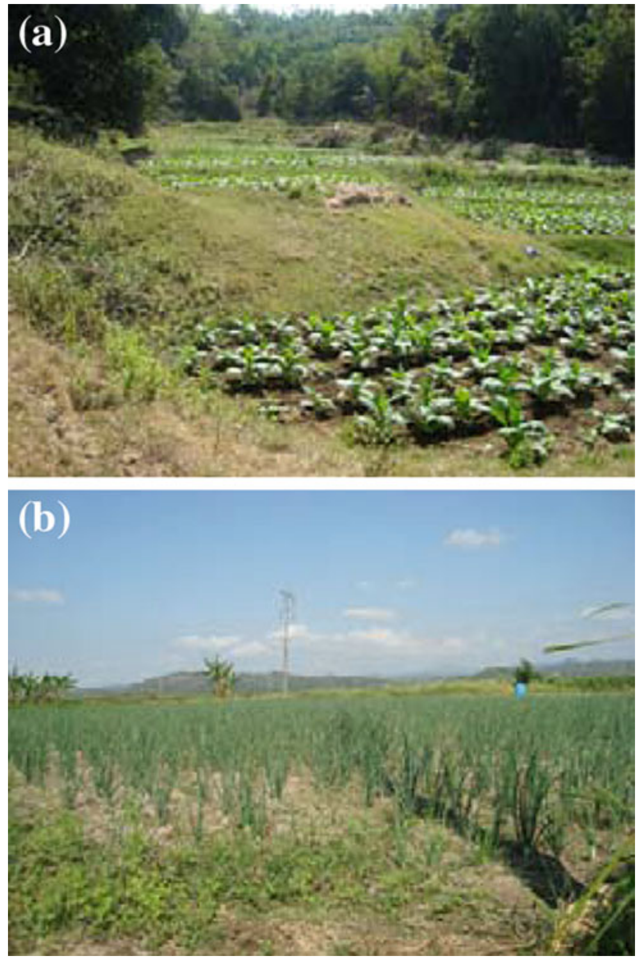


Fig. 5.14 **a** It is a good soil management practice not to leave the soil bare, especially between plots. Let natural grass cover unutilized agricultural production areas. **b** As cover crop, onion is planted after rice as *catch crop* to utilize residual fertilizers and moisture and keep them from leaching out of the system

5.3.6.2 Crop Rotation

Crop rotation is orderly planting of crops in the same field in a period of four to six cropping seasons. The succeeding crops are of different genus, species, and variety than the previous crop. Crops are generally grouped into four—(1) crops grown for their leaves or flowers (such as lettuce, pechay, cabbage), (2) crops grown for their fruits (such as tomatoes, eggplant, corn, squash), (3) crops grown for their roots (such as carrots, sweet potatoes, radish, turnips), and (4) leguminous crops (such as beans, peas, and peanuts). The vegetable farm is usually divided into four sections and the planting in each section is rotated among the four crop groups. Crop rotation is important from the point of view of weed and pest control, soil fertility and nutrient balance maintenance, and erosion management (Fig. 5.15).

5.3.6.3 Intercropping and Multiple Cropping

This refers to growing on the same land of two or more crops adjacent to each other. There are several types—row intercropping, strip intercropping, mixed intercropping, and relay intercropping. Crops recognized to perform better when grown together are referred to as companion planting. Intercropping contributes to agrobiodiversity and ecosystem stability thereby improving crop resilience to host-specific pests and diseases. There is also a complementary and efficient use of fertilizer and water inputs. The positive interactive effects are explained by differences in competitive ability for growth factors between intercropped components. Intercropping implies that there is overlap in the

Fig. 5.15 It is good agricultural practice never to plant the same crop in the same plot every cropping season. Here, tobacco is grown for their leaves and the next plot is planted to corn. In the next cropping season, the recommendation is grow leguminous and root crops in the same plots

Fig. 5.16 Row intercropping for highland crops involving cauliflower, spring onion, lettuce, cabbage, carrots, strawberries, and peanuts are demonstrated at the BSWM Highland Agricultural Research Center in Bukidnon

Fig. 5.17 Mulching is done by covering plots preferably with decomposable materials to reduce soil moisture and soil losses and at the same time improve soil fertility

Fig. 5.18 Eggplants are beginning to emerge in this minimum tillage sloping agricultural area. Conservation tillage practices include leaving biomass such as cut grasses in the area to contribute to organic matter enrichment

growth cycles. In multiple cropping such as double cropping and triple cropping, we have two or three crops planted sequentially without overlap in the growth cycle (Fig. 5.16).

5.3.6.4 Mulching

Although it is now a common practice to use plastic sheets to cover plots with openings limited to the germinating crop, the use of crop residue as soil cover is still the least expensive and has beneficial benefit of contributing to the increase in soil organic matter. Organic mulches eventually decompose with time and improve soil fertility. Crop residues can be either field residues left after the harvest (stubbles, straws, stalks, etc.) or process residues (bagasse, husks, pulps, peelings, brans, cakes, etc.) (Fig. 5.17).

5.3.6.5 Conservation Tillage Practices

Conservation tillage refers to practices that leave the harvest residues on the field to recycle back to the soil the nutrients taken up by the crops and to reduce soil erosion. There are also other side benefits like decreased weeds, and decreased evaporation of soil water. Among the conservation tillage methods are no-till, strip-till, ridge-till, and mulch-till. There are also variations within a method like minimum or reduced till rather than no till at all (Fig. 5.18).

5.3.6.6 Vegetative Buffer Strips

These are rows of highly dense plants intended to slow down the velocity of runoff during a rain event, trap soil sediments and pollutants carried by the runoff, and promote

Fig. 5.19 **a** The area is prepared for buffer strip by contouring. Book co-author Romeo Galanta (*left*) assists Soil Conservation staff lay out contour lines in a Soil Conservation Guided Farm using A-frame and bamboo posts. **b** Locally available grasses are the most commonly used material as vegetative buffer strips. In-between the strips, farmers can plant cash crops. Contour planting is the most effective way to control sheet and rill erosion as well as reduce the velocity of runoff water in sloping agriculture

water infiltration. The vegetative buffer necessarily has to be built along the contour, in the entire length of the downslope edge of the farm to control sheet and rill erosion. This soil conservation method is also excellent to control stream bank erosion and reduce river sedimentation. Grasses are generally used for regular maintenance purposes but the more imaginative ones also plant shrubs, and understory and overstory trees in an intermix zone of vegetation or greenbelts (Fig. 5.19).

5.3.6.7 Collection and Reuse of Surface Runoff

This refers to construction of small farm reservoir by digging storage pools to intercept water runoff for later use. The national government in cooperation with the local government units generally undertake a community-operated small water impounding earth dams. But this can also be undertaken at farm level, from as simple as use of

Fig. 5.20 A small farm reservoir in one of the BSWM Soil Conservation Guided Farms in Tanay, Rizal

storage drums to hold water to a more complicated construction of a farm pond, provided the farm site has an impermeable layer to reduce infiltration losses. The Bureau of Soils and Water Management (BSWM) provides technical assistance and feasibility studies in the construction of these farm ponds and community-level water reservoir. Important element in the design is some type of spillway where excess water can exit. The maintenance of a good watershed is vital and critical. Maintenance includes checking for pond bank erosion, striving for water quality, keeping out aquatic weeds while keeping in biodiversity. It is also important to keep farm animal wastes from going directly into the pond without some form of pretreatments (Fig. 5.20).

5.3.6.8 Fallow

Agriculture is nutrient mining and the soil can be overexploited and depleted. Fallow refers to resting the land for a period of time, usually two cropping seasons, from cultivation. The land is not tilled for economic gain and only natural vegetation is allowed to grow. Some farmers plant "green manure crops" such as leguminous crops or forage crops but the biomass is just plowed over. Others introduce stubble mulch to cover the bare soil. Since we take the land out from cash production, the usual practice is to fallow a fraction of the land so that the whole farm is fallowed given a fallow cycle, without necessarily disturbing the farm operation and the flow of farmer income. Fallow is considered the best practice to rehabilitate and rejuvenate naturally degraded crop lands (Fig. 5.21).

5.3.6.9 Farm Waste Management and Nutrient Cycling

Biomass wastes such as straws and stubbles are recycled back to the soil as compost or used as mulches. The use of compost fungus enhancers and vermiculture are promoted to speed up the decomposition process. Farm animal

Fig. 5.21 A fallowed land is rested and taken out from economic production for two cropping seasons. In a fallow cycle, a fraction of the land is fallowed until the whole farm is fallowed by the end of the fallow cycle. Given a good soil ecology, one would notice a variety of vegetation growing. Dominance of a single plant species in an ecosystem shows the land is healing itself often from human-induced stresses

manures are managed through rotational grazing for open-grazed livestock and free-range poultry; or when under feedlot or pens, the manures are either collected as input to compost, or collected in holding ponds or anaerobic lagoons for biogas production. The sludge from biogas digester is used as soil amendment (Fig. 5.22).

5.4 Problem Soils of the Philippines

5.4.1 Introduction

The Philippine medium-term development plan through the several administrations focuses on poverty alleviation in general and having a competitive and sustainable agriculture and fisheries sector in particular. Efforts address challenges relating to high cost of production inputs, inefficient supply chain and logistical systems, inadequate provisions for infrastructures like irrigation and farm-to-market roads, low rate of adoption of modern agricultural technologies, and limited access to agricultural credit and financing. Surprisingly, the challenge of sustainable use of agricultural land resources is under the environmental rather than under the agriculture and fisheries sector of the medium-term development plan for 2011–2016. Nevertheless, the agriculture and fisheries sector recognizes the competing uses of agricultural lands and its implication on food security. It also recognizes the intrusion of agriculture into ecologically fragile lands; and thus, the need for a rational land use policy that will rationalize the optimal allocation of land resources among the competing uses.

Fig. 5.22 **a** The traditional method of composing is enhanced by the use of compost fungus activator, *Trichoderma harzianum* to shorten decomposition period. For the National Rice Program, BSWM currently promotes in situ composting by mixing rice straw with the soil right in the field after harvest and applying compost fungus activators. **b** A small community vermicomposting facility in Dansuli, Isulan, Sultan Kudarat province using earthworms to recycle biomass and produce organic fertilizers. The materials are shredded and a shredding machine and training on composting comes with the BSWM-initiated organic fertilizer production project. **c** Biogas collection is also promoted as value added approach to composting. The sludge from biogas digester is used as soil amendment

As the national government thrust is to improve the productivity of agricultural lands, and as there are no more agricultural expansion areas except for the marginal areas, we need to take a look at these marginal areas to understand the limited options for agricultural production in areas beyond the 2002 Census of Agriculture and Fisheries statistics. Improving productivity in these marginal areas through provisions for irrigation, farm-to-market roads, fertility amendments, and credit facilitation are more of short-sighted vote-getting political steps. The more important issue we need to address is the encroachment of agriculture into these fragile ecosystems and to understand that as we increase their role in biomass production, we are also decreasing their function in environmental regulations such as those pertaining to hydrologic and nutrient cycling and those relating to ecosystem buffer functions.

5.4.2 Definition and Extent of Problem Soils in the Philippines

The discussion on problem soils emphasizes more on the agricultural applications, although we recognize the fact that the intrusions of economic activities in ecologically fragile areas are not restricted to agricultural production alone. Many of these soils can also be problematic for civil engineering applications because they expand and shrink, or they lack strength, or they are corrosive and can bring about damages on structures. Increase in human-induced problem soils in prime agricultural areas is also possible because of intensive agricultural practices, industrial contamination, irreversible urban encroachment, and land use conversion, or economic activities upstream such as mining and illegal logging that could impact soil productivity downstream and destroy coastal ecosystems and reefs. The works of Recel (1989) on the Problem Soils of the Philippines is not only classic but remains un-updated to these days and the basis of the discussions. It should be emphasized that while these are problem soils from the agricultural point of view and of low-economic value, they are important and valuable from the ecological point of view and they have roles to play for a balanced ecosystem.

5.4.3 Soils with Steep Slopes

The lowlands of the major islands contrast distinctly with the adjacent high mountain ranges such as those of the Central and East Cordilleras and the Zambales Mountains in Luzon. The Visayas islands are likewise traversed by mountain ranges except Samar and Bohol. Mindanao has also many mountains and volcanoes; and in fact, Mount Apo, the highest mountain in the Philippines at 2,954 m above sea level, is found in Mindanao. The distribution of soils with steep slopes is as in Table 5.2 (Recel 1989) (Fig. 5.23).

Table 5.2 Distribution of steep slopes in the Philippines (Recel 1989)

Slope	Area (ha)
30–50 % slope	6,293,362
>50 % slope	2,609,900
Total	8,903,262

Fig. 5.23 A view of upper footslopes of Pugaan Mountain Range in Iligan City with steep slopes

Table 5.3 Recalculated steep slopes in the Philippines based on BSWM digital spatial data holdings

Slope	Area (ha)
30–50 % slope	4,665,095
>50 % slope	5,773,911
Total	10,439,006

Based on BSWM digital spatial data holdings on slope map and using ArcGIS 10, the recalculated area is as in Table 5.3.

Traditionally, encroachment by upland farmers is the major cause of land use change. These areas are not suitable for agriculture but poverty-driven upland dwellers engage in illegal logging and slash-and-burn agriculture. Most recently, despite their best use for forestry and wildlife, these areas have not escaped residential development owing to the good views of the valleys and hills they offer, the proximity to nature, and the seclusion and privacy they afford. Where urban development has encroached significantly, the scenic beauty is destroyed and we have the loss of aesthetics appeal; water quantity and quality are diminished; we have landslides and erosion in these areas and consequent severe flooding in the lower areas; loss of wildlife habitat; and microclimate change. The high utility costs and high establishment and maintenance costs of civil works are also evident.

Slopes are inherently unstable and vulnerable to damages arising from site disruption. Rain is the most common contributor to instability; and the higher the slope, the greater is its erosive power. Trees keep soil in place and removal of vegetation increase the amount of sediment that goes with the runoff. Civil works can remove support and bring about excess weight thereby compromising the load-bearing capacity of the slope and change the drainage pattern of the area.

Steep slope development and utilization not only destroys the regulatory function of these ecosystems in terms of water and nutrient cycles, but the greater dilemma is the potential to start a cycle of erosion and flooding. On a high rainfall event, we have landslides in these areas and flooding on the lower areas. Roofs and concrete pavements do not compare with forests and grasslands in terms of infiltration rate and capacity to absorb rainwater. The excess runoff can accumulate below the structure weakening the fill created to level an edifice pad carved out of the landscape, contributing to instability and collapse over a period of time.

More than 8,000 people died and reportedly missing in the 1991 Ormoc Flash Flood brought about by continuous rains of Typhoon Uring (Wikipedia 2012a). The heavy rainfall dammed the upstream of the Anilao and Malbasag rivers, which were constricted by garbage and houses of illegal settlers. Interior areas of whole villages were reportedly buried as water and mud streams cascaded downwards from the hills and mountains toward the coastal city which stood on the mouth of two river systems. Isla Verde was also engulfed by rampaging flood waters. Illegal logging and slash-and-burn agriculture are blamed for the Ormoc tragedy. Only 10 % of Ormoc is forested and the watershed that constitutes the city is mostly agricultural, planted to sugarcane and coconut. Commercial logging started in the 1930s and was only briefly interrupted by World War II. By 1990, about 90 % of the Ormoc watershed had been converted to sugarcane and coconut plantation as forest lands were cleared to give way to settlers. Such government policy started as early as 1903 with the homestead system when the Public Land Act was enacted that allowed the government to distribute 16 ha of uncultivated public lands to individuals who could prove capable of taking care of it. Then we had the Land Settlement and Development Corporation under then President Manuel L. Quezon (1935–1941) that purchased landed estates for distribution to tenants. The Land for the Landless program of President Ramon Magsaysay (1953–1957) encouraged returning rebels to migrate to parts of Mindanao, Palawan, and Mindoro, clearing forests for settlers (Danguilan-Vitug 1993). The Ormoc tragedy was repeated several more times in different places in the country in the succeeding years. The most notable were the Marikina Flood by Typhoon Ondoy in 2009 recording 747 fatalities and some US$1.09 billion in damages to property (Wikipedia 2012b); the Cagayan de Oro Flood in 2011 by Typhoon Sendong with 1,257 deaths, 6,071 injured, 182 missing and infrastructure and agricultural damages placed at PhP1,633,310,487 (around US$ 38,888,345) (GMA News 2013); and the recurring Cotabato Floods that continue to devastate whenever we have series of rains to these days.

For urban development, we can cite the massive landslide that occurred in Cherry Hills Subdivision in Antipolo City on the night of August 2, 1999 that caused widespread damage and loss of life as Typhoon Olga brought about heavy rains. The foundations of the houses were filled with water and the whole complex slid down the hill on which it was built. More than 300 homes and 59 people were killed (Morales et al. 2001).

The municipality of Saint Bernard, in the province of Southern Leyte came to national prominence when a massive landslide, classified as rock slide-debris avalanche, followed a ten-day period of heavy rains and a 2.6 magnitude earthquake on the Richter scale in February 2006. The official death toll reached 1,125 and the worst of the tragedies was the burial of a local elementary school nearest the mountain ridge where a school full of children and school teachers were holding sessions. Scientific investigations concluded that this landslide was geological in nature, triggered by heavy rainfall, and not due to illegal logging as many believed (Felizardo et al. 2006). The prolonged and heavy rainfall penetrated through many cracks. The underground water weakened the strength of the fractured rock and of the colluvial soil on the impermeable layer due to water pressure until the mass collapsed. Eventually, geological and topographic features inherent with landslide hazards had been surveyed and mapped by the Mines and Geosciences Bureau (MGB).

But despite landslide hazard mapping by MGB, mining has contributed to landslide occurrences in the Philippines. The unregulated tunneling made the mountainside unstable as small-scale miners tunnel into the mountains in search of gold while the regulated mining by big firms were on search of other equally important copper and nickel deposits besides gold. Pantukan and nearby Monkayo in the province of Compostela Valley in Mindanao were the scenes of series of landslides in 2009, 2011, and 2012. The 2012 landslide were attributed to rains and a 2.8 magnitude earthquake on the Richter scale; 25 people died and 150 more were reported missing.

It is indeed important that these landslide-prone areas are kept from human economic activities. It is further recommended that no agriculture or structural development be conducted on areas with slopes higher than 25 %. It is best to leave these areas for wildlife, forests, and natural parks.

5.4.4 The Poorly Drained Soils

Soils are grouped into drainage classes based on the frequency and length of time the soils are saturated or partly saturated by water. Soils classified as poorly drained are characterized in scientific parlance by redoximorphic properties and routinely estimated based on soil color. These poorly drained soils have blackish surface layer underlain by a gray and mottled layer. Gray colors are associated with saturated conditions or chemically reduced (absence of oxygen) soil environment.

Well-aerated soils are usually yellowish brown due to the presence of iron oxide coatings in the soil particles. When the soil is flooded, oxygen is depleted, and anerobic conditions prevail. Certain anerobic soil microorganisms derive their energy from the reduction of compounds like oxidized iron (Fe^{3+} or ferric iron) to reduced iron (Fe^{2+} or ferrous iron). Over time, water saturation leads to formation of mobile ferrous iron which is redistributed throughout the soil profile. When drained, certain areas like those around pore spaces, cracks, and root channels dry more quickly than the rest of the soil. Ferric iron precipitates forming reddish brown spots. Ferrous iron does not move out of the soil profile completely and precipitates during the drying phase. We have therefore a soil layer that can be described by blotches of gray and reddish brown colors. As the water saturation period becomes longer and we have a more pronounced reduction process, the soil becomes more gray. This pattern where we have a gray matrix with blotches of varying shades of orange-reddish color is called soil mottling. Soil colors—the matrix and the mottles—are described in terms of hue, value, and chroma using the Munsell color system. Low chroma is the result from reduction/oxidation cycles over several years. Where we have short anerobic conditions and the aerobic soil condition is more dominant, low chroma is not formed (Fig. 5.24).

Very poorly drained soils have ponded water on the surface for most of the year. The soils developed either from mineral deposits or from organic materials. The very poorly drained mineral soils have black surface underlain by gray (gleyed) subsoil and substratum. The very poorly drained organic soils developed topsoil, subsoil, and substratum of well-decomposed organic matter.

The extent of poorly drained soils are as in Table 5.4 (Recel 1989).

Based on BSWM digital soil map and using ArcGIS 10, the recalculated area for Fluvaquents which includes Hydraquents from old soil maps is 511,456 ha. This figure represents the best estimates on the extent of wetlands in the Philippines based on soil survey and classification. Certainly this is underestimated even if we further update this figure using satellite images because of agricultural conversion of many wetlands.

Fig. 5.24 Soil profile of Coralan series taken in Coralan, Sta. Maria, Laguna. Such waterlogged soil is best for growing of rice

Table 5.4 Poorly drained soils in the Philippines (Recel 1989)

Poorly drained soils	Area (ha)
Lands associated with Fluvaquents	12,800
Hydraquents	78,080
Total	90,080

Wetlands are considered problem soils because these are traditionally valued from the point of view of agricultural use. Either development of a drainage system or the planting of water-loving crops are considered options to improve productivity. But in the same way from the ecological point of view that there is no such thing as weeds (defined in agriculture as unwanted plants), lately there has been a change in attitude toward wetlands and there is a greater appreciation of their ecological values. Not only is drainage a costly option, experiences in such countries as the United States also proved that these drained wetlands turned out to be not suitable for agriculture despite the investments.

Olathe (2012) mentioned the essential ecological features of wetlands: they are primary habitats for hundreds of species of waterfowl as well as many other birds, fish, mammals, and insects; they filter and recharge the water that comes downstream; they slow the flow of surface water and reduce the impact of flooding; they prevent soil erosion and buffer water bodies from potentially damaging land use activities; and they remove and store greenhouse gases from the earth's atmosphere. Wetlands also provide esthetic and recreation (Olathe 2012).

5.4.5 The Coarse-Textured Soils

These are coarse-textured land areas with less than 18 % clay and more than 65 % sand, or have gravels, stones, boulders, or rock outcrops on the surface layer. The soils belong to Tropopsamments along with other skeletal phases of other great groups. These soils look like beach sands or sand dunes in appearance. With the eruptions of Mount Pinatubo in 1991 changing a wide landscape of the Central Plains of Luzon, we may have to update our estimated figures of the extent of coarse-textured soils (Fig. 5.25).

Sand is the dominant component of these soils, deposited from surrounding highlands. The soils are weakly developed and excessively drained with deep to very deep water table. The major constraint to crop production is dryness or very low available water holding capacity and low fertility. Efforts to improve the agricultural productivity of these soils are more on organic amendments to increase the organic matter content and humus of the soil. With improved organic matter content, we can improve fertility and the water holding capacity.

Extent of soils with coarse textures and presence of rock outcrops at the surface which are Tropopsamments along with other skeletal phases of other great soil groups is 482,849 ha (Recel 1989). In the 2012 digital Soil Taxonomy Map of the Philippines, Typic Ustipsamments total 149,113.50 ha. The Mollic Ustifluvents are 25,539.37 ha. The total for the coarse textured soils based on digital soil map holding is 174,652.87 ha.

Although these soils are considered problem soils from the agricultural stand point and of low economic value, their ecological importance as a natural resource need to be highlighted and valued. These lands provide a habitat for a wide range of flora and fauna which contribute to sand stabilization, serving as traps for wind-blown sands. Unlike other countries, we do not have wind storms and significant wind erosion in the Philippines despite presence of these coarse-textured soils. As nature reserves, these areas serve as buffer between our good agricultural lands and the other conservation habitats like salt marshes and tidal flats. They also protect our more important land resources from the threats of erosion and impacts of adverse climatic events like flooding and other coastal hazards like sea water rise.

These coarse-textured soils are also fragile ecosystems and sensitive to impacts of human activities. Among the degradation threats are sand mining for the construction industry; different forms of trampling such as by tourists in beaches, construction of footpaths, roads, car parks, and houses; water extraction, and conversion to other uses. Management of these coarse-textured soils should recognize the natural sediment deposition processes as part of the natural environment, and that management will have to enhance rather than disrupt these sediment supply changes.

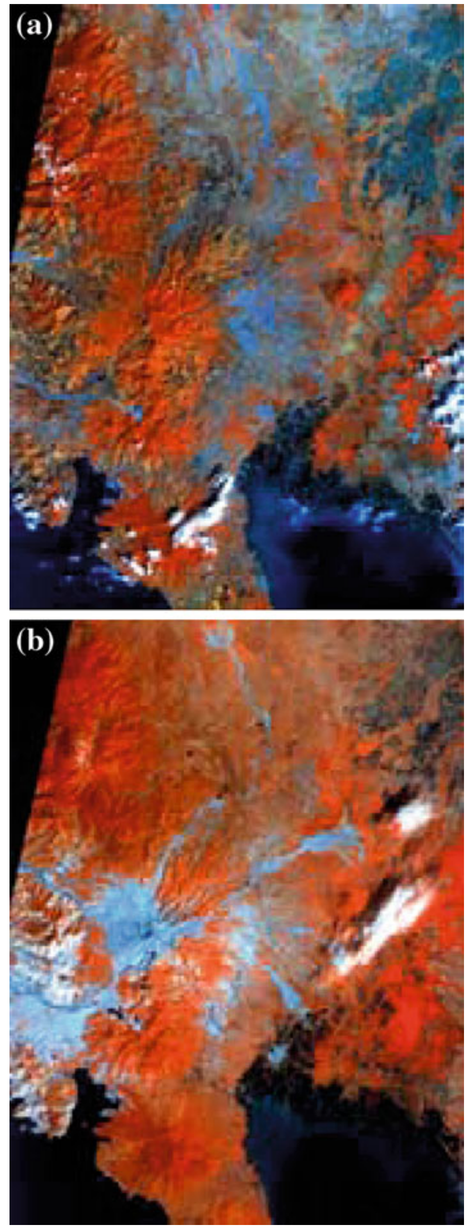


Fig. 5.25 **a** Satellite image taken by Japan Marine Observation Satellite (MOS) of Mount Pinatubo vicinities in 1990 and before the 1991 eruption showing the extent of lahar-influenced coarse textured soils in Central Luzon representing Mount Pinatubo ejecta four centuries earlier. **b** The Mount Pinatubo vicinities taken by MOS in 1992 showing how the new volcanic ejecta overlaid the old deposits and the extent of coarse textured soils in Central Luzon after the 1991 eruptions

5.4.6 The Heavy Cracking Clay Soils

Heavy cracking soils are classified as Vertisols. *Soil Taxonomy* defines a Vertisol in terms of four properties: (1) does not have a lithic or a paralithic contact, petrocalcic horizon, or duripan within 50 cm of the surface; (2) has 30 % or more clay in all subhorizons to a depth of 50 cm or more after the soil has been mixed to a depth of 18 cm; (3) has at some time in most years unless irrigated or cultivated, open cracks at a depth of 50 cm that are at least 1 cm wide and extend upward to the surface or the base of a plow layer or surface crust; and (4) has one or more of the following: gilgai, slickensides, wedge-shaped natural structural aggregates (Soil Survey Staff 2010).

Recel (1989) estimates the extent of Vertisols in the Philippines at 765,388 ha, some 2.55 % of the country's total area (Soil Survey Staff 2010). The 1994 Soil Taxonomy Map of the Philippines approximates Vertisols at 733,117 ha and represents about 2.40 % of the country's total area. Considering map scale for national-level maps at 1:1,000,000, these two figures may not be statistically different.

Vertisols are recognizable in the field as clayey, dark-colored, and has swelling-shrinking characteristics. The dominating montmorillonite clay in Vertisols is responsible for the swelling-shrinking property. Vertisols are usually found in basins and lower landscape positions or depressed topography. These soils are extremely hard when dry but become plastic when wet. The soil structure and consistency is a direct function of the ratio of clay to sand and the mineral composition of the clay (Fig. 5.26).

Fig. 5.26 A heavy cracking soil is difficult to work with. It is hard when dry and sticky when wet

Despite its high inherent fertility, the major limitation of these heavy cracking soils is the narrow range of soil moisture within which tillage operations can be conducted. Tillage is very difficult at dry stage and at moist state, the low bearing capacity and the plastic nature of the materials are deterrents. Tillage can only be conducted at close to, but not at field capacity soil moisture retention.

Management of Vertisols depends on moisture conservation during the dry season and removal of excess water during the wet season. Although Vertisols are clayey and have high water holding capacity resulting in a very low hydraulic conductivity and low infiltration rates, not all of this water is available for crop uptake. An important aspect of soil management for crops grown in Vertisol is maintaining soil moisture to prevent excessive drying of the soil. Cracks that develop can cause shearing of roots which can eventually lead to water stress.

In Philippines, Vertisols are generally utilized for rice production; and in fact, its best land use. Expectedly, workability of these soils during the dry season, especially for rainfed areas, is quite difficult. These soils with anthraquic soil moisture regime have unfavorable topsoil structure when the soils dry after harvest. Kanwar (1989) reported that the growing of other crops in Vertisols (such as mungbean, sunflower, maize, sorghum, and pigeon pea) should be able to alleviate waterlogging associated with this soil due to poor internal drainage; dry season tillage is best carried out soon after harvest of the post-rainy season or rainy season crops. Kanwar also recommended that the planting of crops in dry soil just ahead of the rain ensures early establishment and eliminates in a wet, sticky soil. The recommended cropping systems include intercropping of long duration crops with short duration ones, and sequential cropping. The Vertisol cropping technology espoused by Kanwar is actually a synergy of various components that includes fertility management, efficient farm machinery, and crop management which when applied together far exceeds the effects of individual components (Kanwar 1989).

Since most of the rice soils adjacent to the metropolis and urban centers have been converted to housing subdivisions, a major issue that has been ignored prior to enactment of laws that ban conversion of irrigated and irrigable rice area, and even now is the suitability of these areas for urban development.

5.4.7 Low Fertility Acid Soils

Recel (1989) described these soils of severe fertility limitations as land areas which to a greater or lesser degree, exhibit deficiencies in major secondary and minor plant nutrients when cultivated. He further described these marginal lands as belonging to Ultisols, formed on undulating to rolling plateau, hills and mountain areas, and to Oxisols which are also classified as lateritic soils or kaolinitic

Table 5.5 Extent of low fertility acid soils in the Philippines

Low fertility acid soils	Based on Recel (1989) (ha)	Based on soil taxonomy map (1994) (ha)
Ultisols	12,067,994	8,113,453
Oxisols	175,320	39,922
TOTAL	12,243,314	8,153,375

Fig. 5.27 Low fertility acid soils can be recognized by its red color due to leaching of crop nutrients leaving behind resistant soil minerals like iron oxides

latosols in some soil science literatures (Kanwar 1989). Ultisols and Oxisols are red soils due to the presence of iron oxides, the most resistant minerals to weathering. Ultisol is derived from "ultimate" as these are perceived to be the ultimate weathering products of minerals in humid tropics. Oxisols, on the other hand are derived from "oxides" in reference to its being rich is sesquioxides of iron and aluminum. In FAO soil classification, Oxisols are called ferralsols. These Ultisols and Oxisols, together with Alfisols are also called low activity clay (LAC) soils because of their characteristic low cation exchange capacity of ≤16 meq/100 g clay in the subsoil (Juo and Adams 1986). Alfisols, however, have higher base saturation compared to Ultisols, >35 % (Table 5.5).

As geologically old soils, Ultisols occur on old, stable, and highly weathered landscape positions such as those in sloping uplands, hills, and mountains where soils undergo fast weathering hastened by high temperature and high rainfall (Fig. 5.27). Since the theoretical soil development order is Alfisol → Ultisols → Oxisols, in pedogenic succession, Ultisols occupy younger and less stable landscape positions compared to those where Oxisols are found (Wilding et al. 1983). Further field determinations and mapping of Ultisols require a zone of secondary accumulation of clays developed from eluviation and illuviation. These soils are low in nutrient availability, a consequence of having low pH, high concentration of exchangeable aluminum and manganese, low base saturation and cation exchange capacity, low organic matter content, and low available phosphorus and high fixation capacity. The low inherent fertility and erosion susceptibility are major constraints to agricultural production.

Palawan and Mindanao islands have extensive Oxisol areas. It is not only in the Philippines but in other parts of the world such as Africa and Brazil where Oxisols is much less in extent than originally thought. Oxisols are limited to few old terrace formations and few volcanic areas of great age (Moorman and van Breemen 1978). These are strongly weathered red soils of the tropics characterized by low nutrient exchange capacity of the clay, lack of weatherable minerals, and absence of clay illuviation. The soil structure is weakly developed.

Aluminum toxicity is one of the agricultural production constraints with Ultisols and Oxisols, generally reflected through inhibited root growth, stunted appearance, and lack of plant vigor. Other nutritional problems associated with acid soils are manganese and copper toxicity as well as phosphorus, potassium, sulfur, zinc, boron, calcium, and magnesium deficiency. Plants also suffer from low nitrogen levels because the nitrogen-fixing bacteria are quite sensitive to low pH. There are, however, some crops that can tolerate high soil acidity like cashew, sugarcane, and pineapple.

The susceptibility to erosion is also an important consideration since Ultisols and Oxisols occur on sloping areas and dominate highland and mountain soils that were ultimately converted from forests to agriculture. The erosion rate used by the National Statistical Coordination Board (NSCB) for regional environmental accounting purposes for areas suffering from severe erosion ranges from 26.21 metric tons per hectare for Central Visayas to as high as 69.64 metric tons per hectare for Western Visayas based on 1991 data of the BSWM (National Statistical Coordination Board 2000). The regional mean is 56.20 metric tons per hectare and the regional median is 56.73 metric tons per hectare, showing a more or less symmetrical erosion rate estimation if we look at the state of soil erosion in the country as a whole.

As for other land uses, Ultisols and Oxisols, being acidic soils corrode metal pipes and dissolve concrete. The nature of the soil should be considered when undertaking civil works.

Liming and appropriate fertilization could improve productivity of LAC soils. The integrated soil fertility management can be achieved through the promotion of maximum recycling of plant residues such as in situ mulches from cover crops and hedgerow prunings, increased contribution of biological nitrogen fixers, improved nitrogen and phosphorus fertilization efficiency, organic amelioration, and use of acid tolerant cultivars. The use of low levels of chemical inputs in combination with fallowing and agroforestry systems showed also some success. (Khang and Tripathi Undated).

The Oxisols and the oxidic families of Ultisols are easily tilled because of their goodness to excellent physical properties such as predominance of kaolinitic clays and high sesquioxide content that forms a stable microstructure (Benites and Valverde 1981). Tillage practices certainly enhance the erosion hazards and crust formation. Soil conservation and management are recommended to address this issue. Benites and Valverde also discussed the myth of laterite (hard plinthite) hazard where soils go through irreversible hardening into brick-like materials upon drying. Plinthite occurs only in soils subjected to fluctuating water table in the upper part of the profile, in the upper 1.25 m. And unless the erosion is so severe so as to expose the plinthite layer, it is unlikely that a cleared forest of Oxisols will dry up and change into laterite (Benites and Valverde 1981).

5.4.8 The Saline-Sodic Soils

Salt-affected soils refer to dominance of high amount of salt in the soil, and the dominant salt in most salt-affected soils is the common salt or sodium chloride. However, there could be other chlorides present such as calcium, magnesium, and potassium chlorides. It is also possible that the source of salinity is sulfate salt such as sodium sulfate or carbonate salt or nitrate salt rather than a chloride salt.

The saline soils are generally classified as saline, sodic, and saline-sodic based on their total soluble salts, soil pH, and exchangeable sodium percentage (ESP). The total soluble salts are measured by EC and 4 dS/m is the threshold value. A pH meter measures soil pH and the threshold value is 8.5. The ESP refers to the concentration of sodium at the cation exchange site and the threshold value is 15 %. We can also measure the sodium adsorption ratio (SAR), the proportion of the concentration of sodium in the solution with that of calcium and magnesium and the threshold value is 13 %. The salt-affected soils can be classified as follows, based on Lamond and Whitney (1992) (Table 5.6).

Table 5.6 Classification of salt-affected soils (Lamond and Whitney 1992)

Classification	Electrical conductivity (dS/m)	Soil pH	Exchangeable sodium percentage	Soil physical condition
Saline	>4.0	<8.5	<15	Normal
Sodic (alkali)	<4.0	>8.5	>15	Poor
Saline-sodic	>4.0	<8.5	>15	Normal

Saline soils contain water-soluble salts at levels harmful to crops and have the characteristic of white crusts on the soil surface. The salts are usually sulfates and chlorides of calcium and magnesium. The saline soils with good drainage system can be reclaimed for agricultural use by irrigating with good quality water to wash and then flush out the salts.

Sodic-soils are low in total salts but in the process of leaching out the chlorides and the sulfates, it left behind high exchangeable sodium levels in the soil. As a result, the clay particles disperse and lose their property to bind together when wet, hard, and cloddy when dry, making the soil impermeable to both water and roots and easy to erode. Improving productivity will be slow and expensive and generally focused on replacing the sodium with calcium (such as by use of gypsum) and the excess sodium is leached out of the system. This is slow and requires repeated applications, allowing gypsum to first interact chemically with the sodium before saturating with water and flushing out. Destroyed soil structure will take time to form again and can be hastened by increasing soil organic matter.

The *saline-sodic* soils contain large amount of soluble salts of the sodium chloride type. Strangely, despite the presence of sodic property, saline-sodic soils do not exhibit symptoms of sodicity. The sodium and chloride ions dissolved in the soil solution prevent the clay particles from dispersing. Rehabilitation of saline-sodic soils recommends the application of gypsum ($CaSO_4$) to reduce the level of exchangeable sodium and removal of excess salts by flushing out with good quality water. Some literatures also recommend the application of sulfur, aluminum, and iron sulfates all of which form gypsum in soils containing calcium carbonate. In the Philippines, most of the salt-affected soils are of the saline-sodic type.

Unlike other countries, almost all the saline-sodic soils in the Philippines are coastal and highly influenced by sea water. Recel (1989) quoted Gonzales (1977) for the assessment of saline-sodic soils in the country at 400,000 ha or about 1.33 % of the total land area. This is disaggregated further as follows—100,000 ha mangrove areas, 175,000 ha fishponds, and 125,000 ha as idle lands (Guerrero 1977). Philippine Rice Research Institute (2001) estimates that about 70,000 ha of rice production area in Bicol and Cagayan Valley are potentially affected by saline water intrusion.

In the summary of the Philippine LUS under the FAO-BSWM Technical Cooperation for Land Degradation Assessment 2011–2013, the forest mangrove is 282,068 ha, based on the 2003 NAMRIA land cover map. The webpage of the Bureau of Fisheries and Aquatic Resources (BFAR), under Statistics, stated that as of 2009, the existing brackish water fishpond stands at 239,323 ha (Bureau of Fisheries and Aquatic Resources 2012). This brings the updated estimate of saline-sodic soils in the Philippines to

521,391 ha, excluding the PHILRICE estimate which needs to be validated in the field. It should be understood that the extent of saline-sodic soils is not limited to saltwater wetlands along the coasts such as the estuaries, salt marshes, mangrove forests, the active, and former tidal flats but could extend from 1 to 4 km inland in decreasing EC value, depending on the extent and magnitude of salt-water intrusion. This is the basis of the PHILRICE assessment on saline-sodic soils grown to rice, which is not yet included in the updated estimates. In addition to Cagayan Valley and Bicol Region, there are also several other coastal areas within the Philippine archipelago that extend inland to have saline-sodic concerns.

Soil colloids generally adsorb calcium and magnesium over sodium and this increases the salt content of the soil solution. Roots lose water because of osmosis and crops become stunted, develop chlorosis and necrosis, suffer from some form of nutrient toxicity like boron, and the crops ultimately die of water stress. Different crops, however, vary in their salt tolerance and they are usually classified as high, medium, and low tolerance to salt-affected soil conditions. In the Philippines, the agricultural utilization of saline-sodic soils are generally based on cultivation and breeding of salt-tolerant crop varieties. Investments for reclamation of saline-sodic soils for agriculture are uncommon.

Again, from the economic point of view, these are problem soils because we tend to look at our soil resources in terms of their agricultural productivity. The intangible ecological importance is now the subject of valuation by government statistical offices. From the ecological point of view, these are not problem soils but contribute significantly to a balanced ecosystem by acting as buffer zone between the land and the sea—protecting the coasts from erosion, absorbing sediments and pollutants; serving as breeding, feeding, and nursery grounds for estuarine and marine life; and providing sanctuary for migratory birds.

5.4.9 The Acid Sulfate Soils

The acid sulfate soils have sulfidic materials that accumulated under permanently saturated and generally brackish water conditions. Upon drainage, the sulfides oxidize to form sulfuric acid and the pH drops below 3.5 within 2 months. The soil also releases toxic levels of iron, aluminum, and heavy metals. This kind of soils forms when sulfate-rich sea water mixes with iron-rich coastal deposits and organic matter under anerobic (waterlogged) conditions resulting in the formation of pyrite or iron sulfides. Under natural conditions, these soils do not pose any agricultural production or environmental problems. But when drained and the pyrite reacts with oxygen in the air, sulfuric acid forms and we have the associated and related issues and concerns. Jarosite is the main product of pyrite oxidation and can be recognized by presence of yellowish precipitates /bright yellow or straw-colored mottles with dark-reddish streaks of iron oxide in the sulfuric horizon that form above the sulfidic materials.

Fig. 5.28 Most of the salt-affected soils in the Philippines are saline sodic in nature and located near seashores and mangrove areas. The rice grown in these areas are stunted, with reduced tillering, and characterized by whitish leaf tips

The areal extent of acid sulfate soils in the Philippines can be considered a subset of the mangroves, salt marshes, estuaries, or tidal lands (Fig. 5.28). Unless disturbed, it is quite difficult to assess the presence of acid sulfate soils as pyrite itself is not visible to the naked eye; and minimization of disturbance is the preferred management strategy for acid sulfate soils.

Singh (1981) quoting Tang (1979) estimated that at least 60 % of the fishponds in the Philippines are affected by acid sulfate conditions. His own survey is that about 15000–20000 ha of acid soils were in Panay island alone. Attanandana and Vacharotayan (1986) mentioned some 7,000 ha of Sulfic Tropaquepts, Sulfaquepts, and highly organic Sulfaquepts in Luzon and Mindanao.

The Recel (1989) estimate of 27,000 ha of acid sulfate soils in the Philippines is based on 7,000 ha of Sulfic Tropaquepts by Briones and IRRI (International Rice Research Institute 1979) and additional 20,000 ha of Sulfaquents by Briones (1982).

Attanandana and Vacharotayan mentioned that acid sulfate soils are generally unproductive due to soil acidity, salinity, aluminum toxicity, iron toxicity, low content of major nutrients, low base status, and hydrogen sulfide toxicity. They further discussed that for rice culture, the recommended amelioration measures are leaching and drainage, submergence, liming, manganese dioxide addition, nitrogen-phosphorus-potassium application including utilization of rock phosphate as phosphate source, and use of resistant varieties. For use as fishpond, Singh found out

Fig. 5.29 Acid sulphate soils that characterized many of the country's mangrove areas do not pose problems as long as the ecosystem is maintained. But when opened up for economic production, then environmental concerns ensued. When kept at reduced condition such as used for fishponds, fish or prawn owners complained that their fingerlings took long time, if at all, to grow to commercial size. When used for agriculture and the soil is exposed to air, the oxidation of sulphidic materials contribute to degradation of surrounding ecosystems

that large-scale liming to reclaim fishponds without tillage and flushing of the pond bottom is not effective to increase field yields. Even without liming, satisfactory fish yields were obtained after one season of tilling and flushing (Attanandana and Vacharotayan 1986).

Nevertheless, the disturbance of acid sulfate soils for rice culture or fishpond development and the consequent flush of acidic leachate could damage the aquatic ecosystem with the possible contamination of water by arsenic, aluminum, and other heavy metals. The degradation of surrounding water resources may eventually present risks to health (such as possible breeding ground for acid tolerant mosquitoes) and environment (such as possible stimulation of algal blooms).The economic and environmental cost of disturbing acid sulfate soils for productive use should be weighed heavily against economic gains.

The ecological and hydrological importance of acid sulfate soils should be appreciated in terms of the role that intertidal wetlands play. These are habitats for fish and other estuarine species and serves as buffer for tides and floodwater and stabilize the shorelines. Ecosystem restoration for disturbed or exposed acid sulfate soils should be considered as another management option. It should be understood that many of the traditional remediation techniques are not only expensive and environmentally intrusive but also ineffective to prevent continuing oxidation of sulfidic materials. The remaining option is to reinstate the reduced condition (Fig. 5.29).

5.4.10 Peat Lands

A peat land is an organic soil, or soils formed from the decomposition of organic matter. It contains high amount of organic matter originating from accumulated plant materials that thrived in the area, died, and decayed possibly thousands of years ago. Since ordinary biomass decomposes and converts back to a stable humus over time, these dead plants in peat lands are under unusual circumstance—generally under waterlogged or reduced conditions that prevent them from rapidly decomposing.

We can surmise that these were mostly mangroves in coastal or saline areas and in swamplands where we have freshwater sources (Fig. 5.30). Inlands, these could possibly be adjacent to lakes, or former forests that geologically subsided or sunk to become a lake. And with geologically active earth that we have, the lake either dried up and became shallower or it was uplifted to become swamplands. A peat land is a subset of poorly drained soils, but these are not mineral soils but organic soils. As these former lakes further dry up and the peat lands are exposed to scorching heat of the sun, the organic matter burnt up, and we have farmers talk of "smoking or burning soils". Some rural folks even use peat lands, especially those with partially decomposed plant materials, as fuel source to cook their food.

Peat lands may be problem soils because of huge investment required to drain and convert them to become agriculturally productive. And experiences showed that converting peat lands to agricultural land is rarely successful. As per Lantin (1990), most of the Philippine peat soils are cropped with rice and yields are low due to deficiencies of nitrogen, phosphorus, and zinc. Salinity is associated with coastal peats and iron toxicity with acid peats.

But beside from being a fuel source, peat lands have other economic uses. It is a habitat for a diversity of flora and fauna, and as such, this wildlife are food, timber, and clothing sources. In other countries, peat fiber is harnessed to produce wrapping paper; dried in blocks for use as a building material to construct traditional houses; and in more modern times, the activated carbon from peat is used in the chemical and pharmaceutical industries to absorb water and air impurities as a component of filtration and air purification systems. There are also some health resorts in European countries that use peat in baths as part of therapeutic treatments for a variety of illnesses.

But more importantly, and with global climate change as an issue, peat lands sequester carbon and serve as carbon sink. And hence, instead of economically converting our peat lands into economically profitable natural resource, it would be best to restore and preserve them as part of national patrimony we can bequeath to the next generation for a healthier, more sustainable, and ecologically balanced nation. The Protected Areas and Wildlife Bureau (PAWB) launched its Sustainable Use and Protection of Peat lands Project. There are two major peat areas in the country—the Sab-a Basin in the north coast of Leyte provinces and the Agusan Marsh. The National Action Plan for peat lands has been prepared to raise awareness on the value of peat lands, build capacity of local communities on peat land management, and protect the existing peat lands for their ecosystem values.

From the PAWB website, the Sab-a Basin has a total area of 3,088 ha, about 44 % already reclaimed for agriculture. The remaining unutilized peat land (1,740 ha) consists of small areas of swamp forest and sedge/grass peat swamp as per ADB 2000 report. There are two smaller peat basins in Daguitan (210 ha) and Kapiwaran (430 ha) but already converted to agricultural lands (Protected Areas and Wildlife Bureau Undated)

The Agusan Marsh, as per PAWB, is the largest peat land in the country but there is no reliable estimate of the area and distribution. The PAWB website mentions possibly additional peat lands in other areas of Mindanao, Western Samar, Southern Leyte, Northern Luzon, Surigao del Norte, Mindoro Oriental, and Pangasinan. Lantin (1990) stated that continuous tract of peat lands were surveyed in Tinanbulan in Cotabato, Basey in Samar, Sanchez Mira in Cagayan, and Sta. Fe in Leyte (70). Further quoting Rotor (1981), he mentioned that the largest peat area surveyed covered some 7,000 ha in Sta. Fe, Leyte. Smaller peat areas were found in Mindoro, Sorsogon, Quezon, Albay, Cebu, Misamis Occidental, Butuan, Laguna, and Rizal (Rotor 1981).

Recel (1989) reported 15,000 ha of peat lands in the Philippines. Surprisingly, the 1994 Soil Taxonomy Map of the Philippines estimates the Histosols or organic soils to mere 342 ha. Obviously, the analog map could not reflect a more accurate update of peat lands in the country owing to the limitations of the map scale. The BSWM digital soil map of the Philippines (2012) has no Histosol; apparently, this is included in the Unidentified Soils that total 960,935.15 ha. Again, the map scale limits further classification of these mapping units. Until we could have the final output of the BSWM-PAWB soil survey of peat lands concluded, we could not come up with an update. This may take longer than expected owing to funding availability and the current peace and order situation in many of these areas. It is just not possible for now for soil surveyors to conduct field soil surveys in many of these areas. From Chap. 1, we compute peat soils based on the soil series as in Table 5.7.

Table 5.7 Estimate of peat soils in the Philippines based on the soil legacy data

Soil series	Extent (ha)
Caimpugan peat	110,000
Cotabato *hydrosols*	76,875
Tinambulan peat	2,275
Dolongan series	3,357
Total	192,507

5.4.11 Mine Tailings

Mine tailings are the soil materials left over after the extraction of the mineral from the ore. These are distinct from the noneconomically important waste rock and the overlying soil (called the "overburden") that miners discard in the process of digging for the ore. The size and composition of the tailings vary and its disposal is the major environmental concern for everyone, including us who are outside of the mining industry. There are usually toxic chemicals used to extract the valuable mineral from the ore which remain in the tailings by the end of the extraction process. The waste rock dugged up to reach to the ore deposit naturally contains elements like arsenic and mercury that leach into the water system as these rocks are exposed to sun and rain. Furthermore, most of the chemical elements in the waste rock as well as in the minerals extracted from the ore are bound to sulfide compounds resulting into acidic wastes when these rocks and ore are exposed to the climatic elements. These wastes are referred to as the *acid mine drainage.*

The most common practices to dispose of mine tailings is in pits with natural or synthetic liners to prevent further leaching. Another practice is to put back the tailings to the original mining pit. There are other options for managing mine tailings, waste rock, and the overburden. But still, despite existing environmental and mining laws, mine tailings is a major source of contamination not only for our agricultural lands, but also pose health risks to many communities, and responsible for the destruction of coastlines and reefs. Most of the reported problems are in leakages of the mining pits, and direct disposal to the rivers and the sea.

We can mention for instance the 1996 Marcopper mine tailing incidence, and the battle between the mining company and militant environmentalist groups seemingly remain to these days, despite some estimates of as much as US$ 71 million already spent by the Marcopper's mother company, Placer Dome, on the environmental clean-up. In 1996, the valleys and coasts of the island of Marinduque suffered from the impact of mine tailings when a Marcopper Mine pit drainage tunnel, containing some 23 million metric tons of mine waste, leaked, discharging mine tailings into the 27 km long Makulapnit—Boac river system. The toxic spills flooded five villages, contaminated drinking water with zinc and copper levels beyond tolerable limits, and destroyed river biodiversity like fish and freshwater shrimp. It was estimated that some 200 million tons of toxic tailings were dumped into the shallow Bay of Calancan (OXFAM Mining Watch 2005). Silverio (2011) stated that the Marcopper Mining disasters (there are other similar incidents previous to this in 1991 and 1993) affected the municipalities of Sta. Cruz, Mogpog, and Boac who rely heavily on fishing and farming that were contaminated by the mine tailings. Quoting Mamerto M. Lanete of the Marinduque Council for Environmental Concerns, she further alleged that, "fifteen years after the Boac River Disaster, contaminated mine tailings still find their way into Tablas Strait which continuously threaten even the livelihood of the fisher folks in the nearby provinces of Romblon, Mindoro, Batangas, and Quezon". The Center for Environmental Concerns—Philippines (2011) had a full paper review of the three-phase 18 month US Geological Survey Study, entitled—"Engineering, Health, and Environmental issues Related to Mining on Marinduque" for more detailed summary of the impacts of mine tailings in the affected communities. There are other papers on the impacts of mine tailings on the environment, notably we have those of Marges et al. (2011) and Carr et al. (2000) relating to water and soil contamination.

An August 2012 news showed Philex Mining Corp. was plagued by leaking of containment dams spilling mine tailings to nearby creeks and river. The news filed by Cardinoza and Cabreza for *Inquirer News* reported that Philex faced an initial assessment of PhP326-million fine for discharging up to 6.5 tons of sediments containing cadmium, copper, lead, and arsenic on August 1 into the Balog River, a tributary of the Agno River which flows down to Pangasinan province (Cardinoza and Cabreza 2012). Heavy rains brought by the typhoons Gener and Ferdie caused the tailings pond to breach and leak into the Balog River. Some other environmentalist groups alleged that it was not just a breach but collapse of the tailings pond. The River flows to the San Roque Multipurpose Dam that straddles San Manuel and Itogon. Another report filed by Abano for *Business Mirror* stated that the Itogon local government imposed fishing ban on the waterway leading out of the Padcal mine site despite assurances by mining firm officials that the discharge was nontoxic (Abano 2012). The ban was eventually lifted within a month after fish samples were examined for heavy metal toxicity levels by the Bureau of Fisheries and Aquatic Resources. The fine, to be further assessed and imposed by the MGB is based on the Mining

Fig. 5.30 It might come as a surprise to many, but a number of mangrove areas in the country are actually peatlands. The underlying soils below consisted of organic materials from the mangrove species above that accumulated through the centuries. It could be surmised that most of the inland peatlands must have been lakes in geological past for organic matter to accumulate, and then geologically uplifted

Act of 1995 that stipulates a fine of P50 per metric tons of sediments spilled from a mine tailing facility. Additional violation of the Clean Water Act could be considered. Whatever final amount, it is expected that the mining firm will contest in the court huge fines on the basis of force majeure and its own assessment of the damages. A later news update by Gomez for the *Manila Standard Today* concluded that the mine tailings spill from the 92 ha tailings pond No. 3 could have covered as much as 30 ha (Gomez 2012). As the mining firm loses millions a day from this mine tailings spillage, and face a possible court battle raging for years and years, the affected communities around suffer. By the time court settlement comes most probably after decades, the affected land areas would have regenerated from this catastrophe as part of natural soil resilience from environmental stresses.

Other members of the big league, even the small players in the Philippine mining industry likewise suffer from oppositions from the environmentalist groups with regard to the impact of mine tailings on the downstream farming and fishing communities. It therefore appears that any comprehensive assessment to update the total volume of mine tailings would include not only a master list of the mining companies currently operating, their area of operation, the maximum volume of mine tailings in their containment dams but would also involve decommissioned mining sites with still active mining effluent containment dams, and the area coverage of the abandoned mine sites.

The Recel (1989) estimate of 22,223 ha (Recel 1989) is very much out of date. These figures are based on the affected irrigation systems as follows:

Bued Communal Irrigation System	1,193 ha
Amburayan River Irrigation System	4,430 ha
Agno River Irrigation System (ARIS)	16,600 ha

With open-pit mining, we need to estimate the total area affected as forests are cleared, the volume of the overburden or the soil stripped, the volume of the vegetation destroyed as this figure represents destroyed carbon sink. We should also add the block caving operations, which experiences have shown to have resulted in surface subsidence and ground collapse. River and coastline siltation are also serious problems resulting from mining operations. Expectedly, the website of the MGB has the estimated ore reserves of the country, the list of mining companies, their production output, and the contribution to the export income and labor force but mine tailing data are not included. Nevertheless, MGB has a Mining Environment and Safety Division that establishes the scientific and technological foundations to environmental guidelines and protocols and conducts environmental audits to ensure the compliance of mining companies to approved Environmental Protection and Enhancement Programs and their Final Mine Rehabilitation and Decommissioning Plans. The passage of a new mining law proposes not only to increase royalties to be paid to the government but also proposes to designate all mine waste and tailings as state property to enable the government to extract any remaining minerals. The objective is still economic profit by further exploiting the mine waste, not waste treatment for ecosystem restoration.

Do we have any area update?

From the paper by the Cordillera People's Alliance (2007), the province of Benguet alone has hosted 14 mining companies since 1903. Some have closed while others are still actively operating. Two of the large companies are Lepanto Consolidated Mining Company (operating for 70 years) and Philex Mining Corporation (operating since 1955). Benguet Corporation, the oldest in the country, abandoned its Benguet mines in 1997. The paper reported that the abandoned pit mine site, underground tunnels, waste dump sites, mill, diversion tunnels, and tailing dams in Itogon still remain today. New mining explorations in all 13 municipalities of the province number 138, and cover some 147,618.9 ha, about 55 % of the total area of the province. This province alone is covered by past, present, and future mining operations. Benguet Corporation has 5 tailing dams; Lepanto has 5 tailing dams, 2 of which collapsed; Philex has 3 tailing dams, 2 of which collapsed in 1992 and 1994 and another in 2001, not to mention the 2012 since the paper was written in 2007, bringing about devastating impacts on the environment and the agricultural livelihood of the people living downstream. The Philex open pit mine presently affects 98 ha of lands (Cordillera People's Alliance 2007). Briones (1967) discussed the quantity of mine tailings coming from individual mining companies, the river systems affected, and the provinces affected downstream.

As we move to other mining areas in other parts of the country, we can only look in awe at large-scale open-pit mining stripping our mountains and forests, destroying our coastal and fishing zones, and drastically reducing the productivity of our irrigated rice fields, threatening our core production and protected zones, encroaching on and depleting the communities' food and water supply as various mining companies leave behind millions if not billions of tons of mine tailings in their quest for mineral ore. This chapter is about the economic benefits of soils, and the economic and social costs of soil pollution. This is not about the volatile issues confronting the mining industry. We can only argue for the ecological services, and the cultural and social values of a balanced soil ecosystem by adopting a sustainable resource utilization approach, a rational and needs-based minerals management policy, and mining waste strategies that address if not improve the carrying capacity of affected and downstream ecologies. A fruitful dialog between the different mining stakeholders including the civil societies is important to address all the economic, social, and ecological issues raised by various sectors and reduce escalating tensions. Although a balanced soil ecological system has no monetary value, it is a vital factor for defining the quality of life.

We therefore restrict our problem soils area update on affected agricultural areas served by various river and irrigation systems and the coastal areas as these are affected by selected mine tailings in the Table 5.8. This is by no means exhaustive and does not include all mining operations in the country (Fig. 5.31).

5.4.12 Summary of Problem Soils in the Philippines

There are many ways of looking at problem soils, but from our point of view, we are considering those of agricultural use, and therefore, of economic importance. It should be reiterated that these are problem soils from the agricultural production point of view, as these soils, except for the mine tailings, have important ecological functions, despite their agricultural limitations (Table 5.9).

The current figure is lower than the 1989 Recel estimates because the extent of Oxisols (the low fertility acid soils) in the Philippines is not as much as it was originally thought. This is consistent with the Oxisol estimates in Africa and South America. The estimates for the coarse-textured soils also decreased based on digital data holding. The estimates for the heavy cracking soil is not considered statistically

Table 5.8 Selected agricultural and coastal areas affected by mine tailings

River system	Agricultural areas affected	Service area (ha)	Provinces
Agno	ARIS	26,850	Pangasinan
	Ambayaoan-dipalo river irrigation	7,600	Pangasinan
	ARIS extension	23,700	Pangasinan
Lower agno	Lower ARIS	12,650	Pangasinan
Bued	San fabian river irrigation system	2,288	Pangasinan/La Union
Amburayan	Amburayan river irrigation system	3,420	Ilocos Sur/La Union
Abra	Several irrigation systems	11,000	Abra/Ilocos Sur
Boac-Makulapnit	Agricultural areas along river banks	280[a]	Marinduque
Mogpog	Agricultural areas flooded in 1993	3,943[b]	Marinduque
Sipalay	Agricultural areas with tailing spillage	1,000	Negros Occidental
Sub-total for agricultural areas		92,731	
Coastal areas	*Landforms*	*Extent*	*Province*
Calancan Bay	Shoreline and tidal flats	8,000	Marinduque
Honda Bay	Peninsula built from mine tailings	3[c]	Palawan
Canal Bay	Shoreline affected by cyanide tailings	812[d]	Surigao del Norte
Sub-total for coastal areas		8,815	
Grand total		101,546[e]	

[a] As there is no reliable estimates on the extent of agricultural areas damaged from mine tailings, this is computed on the basis of 703,228 m^3 (the mine tailings estimate is down from original estimate of 1.3–3.5 m_3, Soriano 2001) and converting this to hectares at approximately 0.25 m deep

[b] There is no reported estimate on the volume of 1991 and 1993 mine tailings that devastated Mogpog River. The 1993 mine tailing flood inundated 21 of its 37 barangays burying them in mud and toxic floodwaters. The estimated agricultural area of Mogpog is 5,121 ha and assuming 23 % upland, we have 3,943 ha subjected to flooding hazards

[c] Palawan Quicksilver Mine produced about 2,000,000 t of mine-waste calcines from 1953 to 1976, and about half of these were transported to Honda Bay to construct a peninsula about 600 m long by 50 m wide, and used as an operational port for the mine (Gray et al. 2003)

[d] In July 1987, dam failure resulted in a spill of unknown quantity of cyanide tailings causing fish kill in Placer, Surigao del Norte. In September 1995, a dam foundation failure at tailing pond no. 5 released some 50,000 m^3 of tailings leading to coastal pollution (Wise Uranium Project 2012). In April 1999, damaged concrete pipe in tailings pond no. 7 occurred releasing 700,000 t (approximately 1.982 million m^3) of cyanide tailings (FAO 1976) or total of 2.032 million m^3 or about 812.8 ha at 0.25 m depth

[e] There are several other farming and fishing communities severely impacted by tailing spills in other areas. We have for instance the two 2005 mine tailing overflows due to continuous rainfall in the mining operations of Lafayette Philippines in Rapurapu Island that extended to the sea and municipalities in the adjacent island. But for the purpose of updating our mine tailing affected agricultural areas, we limit it to these figures

Fig. 5.31 Mine tailings that escape into the river systems eventually find their way into the irrigation systems affecting prime agricultural areas

Table 5.9 Problem soils of the Philippines

Problem soils	Recel (1989) (ha)	Carating 2013 (ha)
Steep slopes	8,903,262	10,439,006
Poor drainage	90,880	511,456
Coarse textured soils	482,849	174,653
Heavy cracking clays	765,388	733,117
Low fertility acid soils	12,243,314	8,153,375
Saline-sodic soils	400,000	521,391
Acid sulphate soils	27,000	27,000
Peat lands	15,000	192,507
Mine tailings	22,223	101,546
Total	22,949,916	20,854,051

different. The steep slopes, poor drainage soils, acid sulfate soils, saline-sodic soils, peat lands, and mine tailings have significantly increased in area estimates.

Mine tailings present a major challenge for all sectors of the society. The estimate is only for major mine tailing disaster incidents that impact agricultural production areas and coastal communities. This is certainly under estimated, despite almost 80 % increase over the Recel estimates.

5.5 Maximizing Economic Benefits from Soils Through Land Evaluation

5.5.1 Introduction

Land evaluation is assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate, and other aspects of land to compare promising kinds of land use in terms applicable to the objectives of the evaluation (FAO 1976).

Land evaluation is part of land use planning. Conceptually, land evaluation requires matching of the ecological and management requirements of relevant kinds of land use with land qualities (LQs) while taking local economic and social conditions into account. Our objective is to provide guides for recognizing soil attributes relevant for assessing soils for various human activities and recognizing natural limitations that constrain the sustainability of a particular land use undertaking.

Land evaluation is commonly undertaken in two phases—a biophysical resource survey and an agro-socioeconomic survey for broad development planning purposes. In many of the soil resources assessment, the sociocultural context of the proposed land use is often neglected resulting in many so-called white elephant projects which are physically existent projects but nonoperational because of certain reasons; most often cause is cultural disharmony. Why put up a piggery project in a Moslem-dominant community or a corned beef canning plant in a Hindu-dominant community? It may sound absurd for such obvious cultural uniqueness but at higher level land use planning, such issues may be unnoticed unless we consider the sociocultural input to the planning process. This is especially important if the project involves introduction of new crops for a specific market. We need to consider how receptive and ready are the project beneficiaries to the new farming technology being introduced. Value chain and market opportunities are now considered as part of any crop production feasibility studies. It is not only how much we could produce given the suitability rating, but how much could the market absorb.

Who should do the land use evaluation exercise? For development planning agencies at the national and local government level, as well as those with zoning mandate, land evaluation is an important input that is usually ignored. Corporate development planning departments working on business expansions should also do land evaluation to assess comparative suitabilities or fitness of the land resources for their various proposed agribusiness and agri-enterprise projects.

Physical planning for development purposes often neglects the issue of land evaluation. Planners normally discuss the available soil resources data as a chapter or a few paragraphs in a chapter in the development plan, the impact studies, the feasibility studies, or the project proposal being prepared. There is no effort at all to interpret the available data, or in the absence of data, produce the soil data.

Most of the suitability maps prepared by the BSWM are taken in toto, without regard to the original map scale versus the actual planning level being undertaken. Mostly, the development plan documents are focused on demand-supply situation, development or investment costs, project impact assessment in terms of vegetational or biodiversity losses. There are very limited efforts, even for many of the foreign-assisted projects proposed for funding, to evaluate the capacity of the land to absorb the planned undertaking. Basic is the lack of understanding of how soil resources are to be managed and the data to be interpreted. So what if the soil series where the project study is located belongs to Maahas clay? It is there and nothing could be done to change it to another soil series.

The soil is a continuum and geomorphic or physiographic delineation is used by soil surveyors to prepare soil maps but in the ground or in reality, one cannot really isolate one soil mapping unit from another soil mapping unit or even delineate the interphase with another soil mapping unit. So basic to land evaluation is to collect data and how to interpret the soil data and its relevance to intended land use.

Presence of acidic soils would not really matter if we are growing acid tolerant crops. Rice may be sensitive to nitrogen levels in the soil such that at certain minimum level as evidenced by the greenness of the leaves, optimum yield could no longer be attained and we have to resort to nitrogen supplementation. But even lower than this critical nitrogen level for rice is not vital for peanuts and mongo because they could synthesize their nitrogen requirements through a symbiotic nitrogen-fixing bacteria present in their root system. Lowland crops like paddy rice and gabi would be happy thriving in clayey soils characterized by poor drainage conditions. Obviously moisture sensitive crops like onions and root crops like sweet potato and cassava would be best in loamy or sandy soils. They would not thrive in fine-textured soils.

The land is fixed, the soil is fixed. There is nothing we can do to change it, unless we invest to undertake land improvement activities which could mean a considerable capital for the developer. We use the process of land evaluation so that we match the requirements of the proposed land use with the qualities of the land that we have. What if they don't match? Then look for another land use that is more appropriate to the land that we have. Thus, more than one land use is proposed. And to show the evaluation process that we did, even the "losing" proposed land uses are shown alongside with the "winning" land uses in comparative format during the reporting process.

The land evaluation process is really simple—we define the specific land use and the requirements of that specific land use to attain the optimum levels of outputs given the assumed inputs. Then we matched the land resources that we have. The more difficult work is defining the requirements of the specific land use. This requires a lot of research which this chapter cannot cover. There are millions of possible uses given a piece of land. These LURs will have to be translated into land use evaluation factors and a criteria set defined (or some books describe this as scaling the land use evaluation factors) so that we can rate for pass or for fail.

5.5.2 Principles of Land Evaluation

Land evaluation is founded on the following principles (FAO 1976):

1. *Land suitability assessment and classification is only meaningful with respect to specific kinds of land use*. The land itself and the proposed land use are equally essential to suitability evaluation. It is incumbent upon development planners to have initially identified the proposed land use prior to the conduct of evaluation. Worst is that land use change is implemented oftentimes without any suitability evaluation at all. There are actual cases of coconut areas converted to paddy rice only to discover later on that the soil water percolation is high and the land could not sustain a suitable level of water for paddy rice production.
2. *Evaluation requires a comparison of the inputs and the benefits based on the proposed land uses*. This means that we consider the level of technology that accompanies the land uses under consideration. That would include traditional approaches to farming, low, medium, or high level of mechanization and technology applications. Evaluators often overlooked that Filipino farmers have differing levels of agricultural competence and available capital that greatly influenced the adopted level of production technology since most of the available reference materials are written not specific to local conditions.
3. *Evaluation involves comparison of more than a single kind of land use according to the development envisioned*. Comparative analysis would mean that at the end of the evaluation exercise, the overall suitability of one proposed land use could be equal, more, or less than that of the other proposed for the area. Many development planners expect the Department of Agriculture—BSWM to automatically come up with suitability maps for major crops such as rice and corn without recognizing that they themselves as soil resources data users should be identifying not only the crop options but also the evaluation exercise itself to support their feasibility studies or their development proposals or their zoning ordinance for that matter.
4. *A multidisciplinary approach is essential*. Soil is only one aspect of the evaluation. Climate and availability of water resources is another important production factor. For example, old and leached red soils classified as Ultisols are only productive to acid tolerant crops under distinct wet and dry conditions. But under a climatic condition of even distribution of rainfall, such soils can be productively grown to plantation crops.
5. *Evaluation is made in terms relevant to the physical, economic, and social context of the area concerned*. Where labor cost is high and the youth prefer to migrate to the cities, low technology input may not be practical but individual investment in farm mechanization may also prove to be quite expensive. Cooperative access to farm machineries maybe introduced if this is not yet the practice. Assumptions vary as we conduct land resources evaluation in different areas and these should be clearly specified.
6. *Suitability refers to the sustainable land use and is assumed to have considered the relevant land degradation aspects*. While agriculture is a form of land exploitation, sustainable resource management practices are part of the technology assumption; defined or reiterated in the tabular conclusion for the evaluated mapping units. Usually, the limitations of land use are stated and the accompanying soil conservation and management practices are recommended.

5.5.3 Basic Land Evaluation Concepts

We have defined earlier land evaluation as assessing the fitness of the land for the proposed land use. So in land evaluation, we have two sides of the equation: the demand side represented by the proposed land use and the supply side represented by the land or the soil resources that we are rating.

5.5.3.1 Final Evaluation Results and Outputs

In land evaluation, we aim to find the fitness of the land for the proposed land use undertaking. Fitness would refer to the overall evaluation rating of the mapping units under consideration. In the United Nations Food and Agriculture Organization (FAO) land evaluation framework, there are two land suitability orders:

Order Suitable (S)—the land on which sustainable land use being considered is expected to yield benefits which justify the inputs, WITHOUT UNACCEPTABLE RISK OF DAMAGE to the land resources.

Order Not Suitable (N)—the land has limitations to preclude sustained use of the kind under consideration. Normally, to make the land rated not suitable to become suitable, the land is modified and additional investments are incurred to correct the limitations; the cost of which is oftentimes, no longer reasonable.

There are three classes recognized within the Order Suitable:

Class 1 or Highly Suitable (S1)—Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class 2 or Moderately Suitable (S2)—Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase the required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.

Class 3 or Marginally Suitable (S4)—Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

There are two classes recognized within the Order Not Suitable:

Class N1 or Currently Not Suitable—Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.

Class N2 or Permanently Not Suitable—Land having limitations which appear so severe as to

preclude any possibilities of successful sustained use of the land in the given manner.

5.5.3.2 The Demand Side

We have earlier stated that this represents the requirements of the proposed land use, or a million possible land uses, each with specific requirements. Where multipurpose land use is proposed, a compromise may be necessary in the development of the LURs.

Land utilization type (LUT)—based on the FAO definition, this is a set of technical specifications in a given physical, economic, and social setting. This can be a current or a projected land use. Attributes include the output, market, capital or investment requirements, labor intensity, power sources, technology and infrastructural requirements, land holding sizes, and income levels.

An example is rainfed annual cropping based on subsistence corn and diversified upland crops by small holder mountain settlers with low capital resources, and high labor intensity. Another example is commercial sorghum production on sloping area (15–18 % slopes) with medium and government-subsidized capital, community-shared mechanization and energy inputs, and medium requirement for labor.

For purpose of clarification, land evaluation can also be done for nonagricultural uses. How suitable is an abandoned geothermal exploration area for wildlife and forest recreation? Or an infilled localized valley for a housing project? An upper footslopes of a limestone hill for construction of an orphanage? A nearby collo-alluvial plain for a garbage landfill? A tuffaceous plain for an industrial estate?

LURs—This refers to the ideal conditions given the proposed land use or land utilization type. It should be noted that soil requirements may only constitute part of the over-all ideal conditions. Climate for instance, especially for agricultural land use, is a major factor. The water source is usually an important decision element.

An example of an ideal condition is one for mango, normally available in the worldwide web and in various books in libraries. The best Philippine mangoes are grown in areas of distinct wet and dry season, although the fruit grows on a wide range of climatic conditions including areas with even distribution of rainfall throughout the year. The fruit is also known to grow in subtropical regions. What is critical is a dry period of 3–5 months to induce maturity of vegetative parts and flowers as rains will wash off pollen. Optimum elevation is up to 800 m above mean sea level and ideal temperature is 21–37 °C. Soils preferred are deep loamy soils rich in organic matter with pH ranging from 5.5 to 6.5. Soils with high clay content or frequent water logging are not suitable for mango production. We will translate this later into LURs presented as a set of diagnostic criteria. For purpose of this exercise, we will assume a plantation-type mango production, not a backyard growing.

Because much of the framework of land evaluation has been developed for agricultural land use, the concept of LUR is taken for granted by many development planning officers, both in the government and in private, especially by those involved in land development. For example, what is the ideal condition for a housing subdivision? We can use the same principles in this framework for evaluating nonagricultural land utilization types.

It is important for development planners to specify the optimal conditions required for the proposed land utilization type. In the Philippines, there is hardly recognition by the general populace on what we call—the *land use limitation* or those land attributes that restricts the suitability of the land for the proposed land utilization type. Perhaps because we put so much trust and faith on engineering and technology to enable us to overcome the land use limitation. The very high investment cost to overcome the limitation and develop a non-suitable area into suitable area is no longer an issue because of the high resale value of the property once developed and made suitable. The general view is that developers can recoup their investments and even earn a high profit once a marginal area is developed. We rely on engineering solutions given the land use limitation.

But in certain if not most cases, these land use limitations have never been identified prior to project development; much more no engineering solutions were proposed nor constructed to respond to the natural restriction imposed for the specific land use to save on project development costs. How many housing subdivisions have been established in frequently flooded second terrace riverbanks; and in worst cases, houses were actually built on top of what were dried up creeks and streams. Landslides are now common occurrences in many hilly land and mountain land housing subdivisions originally rated as *Land Capability Class M* which are very steep to mountainous in slopes, excessively eroded or shallow for agricultural cultivation and recommended for pasture or forestry. With encroachment of urbanization in these Capability Class M areas, these development neighborhoods have been re-graded and recontoured as roads are opened up and the area made suitable for human habitation; all done without the services of a professional hydrologist to assist planners on drainage courses. As tragedies occurred decades later, and developers sued and blamed for the landslides, only then are more detailed geological, hydrological, or engineering weaknesses in the original design exposed. But what is worst, even after tragedies had occurred, there are instances that little correction on the land limitation is made and implemented; life would go on for the rest of the unaffected, until perhaps the next tragedy occurs.

What parameters are relevant to consider? Rossiter (1994) identified them as (1) importance for the use; if omitted, will greatly affect the rating; (2) existence of critical values; researches have been done and data are available to affirm the optimal conditions; (3) availability of project development data with which to match with the ideal and evaluate; and (4) availability of knowledge system with which to interpret and evaluate the observed data. Previously conducted researches and studies would be helpful in the design of the diagnostic criteria with which to evaluate the proposed land use.

5.5.3.3 The Supply Side

This refers to the properties of the land being considered. It could refer to the results of the laboratory analyses based on soil sampling conducted, climatic data averaged over period of time, other properties that can be measured using other instruments, or other observations and inferences. An example of an observation or inference is that where the soil is clayey, the water movement down the profile is expectedly slow; conversely, where the soil is loamy to sandy, the water percolation or the infiltration rate is expectedly fast. A unit clay, being greatly smaller than a unit silt or sand has more surface area; and thus, given a fixed volume, clayey soil is expected to have more cation exchange capacity and be more chemically active than a similar volume of silt or sand. Clayey and other fine textured soils would be able to hold more pollutants than coarse-textured soils.

Land characteristics (LCs)—This is an attribute of the land that can be measured or estimated using laboratory analysis or field instruments. Examples are slopes, rainfall, soil texture, water holding capacity, biomass, nitrogen level. Few land evaluators actually use LCs per se to evaluate the fitness of the land for the given land use. The major reason is the holistic nature of a land attribute. For example, erosion hazard is not measured by slope angle alone but greatly influenced also by the vegetation, rainfall intensity, permeability, and soil structure. Soil structure is affected by the amount of organic matter in the soil; and we have earlier mentioned that permeability is affected by soil texture or the percentage of sand, silt, and clay. Even where the slope is high and the soil texture is coarse, provided the vegetation cover is good and the soil structure is also good, the erosion hazard is low to medium.

FAO recommends that land evaluation be carried out based on LQs rather than on LCs.

Land qualities—These can be sometimes estimated or measured directly, but most often described by a set of LCs. LQs refer to the complex attributes that influence positively or negatively the suitability of the land for specific kind of use. We have earlier mentioned an example of a land quality—erosion hazard—which can be measured by slope angle, amount and nature of vegetation cover, rainfall intensity, permeability, and soil structure. LQs of relevance to agricultural production could include soil workability or factors affecting mechanization (the relevant LCs would include soil texture, soil moisture, and soil consistency), inherent soil fertility (important LCs would include the laboratory analyses for major and limiting minor nutrient elements), soil moisture content (which would be greatly influenced by soil organic matter, soil texture, and soil water holding capacity, other relevant redoximorphic features), proximity to input suppliers, availability of post-harvest facilities, and nearness to market. The soil as a platform of infrastructures would require different land qualities, notably low flooding risks, absence of shrinking–swelling clays, and a rocky substratum. The LQs related to forest productivity would include mean annual increments of timber species, absence of fire hazards, good site factors for the establishment of young trees. When used for grazing, LQs desired are resistance to degradation of vegetation, availability of drinking water, absence of toxic elements in the grazing land, and possibly presence of shade trees against climatic hardships that could affect the ruminants.

Other examples of LQs—conditions for seed germination (the LC would be soil hardness and usually measured by a soil penetrometer), resistance to soil erosion, absence of soil toxicity, occurrences of pests and diseases (important LC would be air humidity as in the case of spore-borne fungal diseases, and seasonal aridity and sandy soils as in the case of locust infestation).

There are situations when a land quality can be measured by a single LC. An example is "oxygen availability in the root zone". The nearest diagnostic criterion would be the measurement of redox potential (Eh) in the root zone no less than +200 mV. This type of data is not usually available and very seldom measured by soil surveyors in the field. The closest and most direct criterion would be a root zone that lies above the water table. The next question would be, how long could a root zone be under the water table and still have sufficient oxygen available for the plant roots?

It is LQs (the existing condition) that we try to match against the LURs (or the ideal condition).

5.5.4 Developing the Diagnostic Criteria

The results of laboratory analyses per se have no meaning unless interpreted or matched against the LURs. This becomes the basis for assessing the suitability of a given area for the proposed land use. Based on LURs, a critical value has to be set such that below or above this level is no longer suitable. As there are a thousand possible land utilization types, we should learn how to prepare diagnostic criteria. We will use our given example mango, and refer to the ideal conditions for mango production that we were able to research to set our diagnostic criteria.

5.5.4.1 Developing Diagnostic Criteria (LUR) for Matching with Soil Characteristics

So how long could a root zone be submerged by a fluctuating water table before oxygen is totally restricted? A 3–6 months could be considered moderate or medium for most diversified upland crops, up to 6 months could be considered low or severe conditions. A land evaluator could check for presence of mottles during field surveys, soil drainage class in the soil map, or the natural vegetation during project site inspection to assess the upper extent of water table fluctuation. Where only moisture loving crops grow, this shows very high water table and not appropriate for the proposed land use that requires oxygen availability in the root zone. Thus, the *land quality classes* or the *severity levels*, also called the *factor ratings* or the *degrees of limitation* in various land evaluation books are established or determined based on field observations or laboratory experiments. Where no data is available, the power of observation becomes crucial in the land evaluation. How long can a mango tree survive water logging as in the case of flooding? Ask the experts; maybe the 3–6 months we have earlier considered moderate for upland crops is just too long for mango trees. Or just use common sense—if the area is already regularly flooded even if it is just a matter of days, or the water table is high, why consider planting mango in the first place.

The severity levels for the soil characteristics will have to be established. Given the example for mango, the optimal soil pH level based on literature is 5.5–6.5 and soils evaluated for mango falling within this range would be rated optimal. Slightly below and slightly above this level would be medium for the growing of mangoes. Much lower and higher pH would be marginal or severe conditions for mango production. Take note that if we plan to grow coconut, which oftentimes line up seashores characterized by salinity conditions, the optimal pH level is far much broader at 5.0–8.0. Furthermore, coconut could tolerate temporary flooding. Coconut would be able to stand relatively more severe soil conditions than mango. Expectedly, palm oil would grow in similar conditions as do coconuts, but on the lower pH range 4.0–7.0; would also require good drainage and could likewise tolerate seasonal flooding. The point we are driving at is that in land evaluation, the optimal condition is defined by the land use type we are evaluating. Literature reviews and research may have to be done to establish the LURs; and based on the optimal conditions for the specific land use type, we can design the diagnostic criteria for the adequacy or optimal levels.

Since we have discussed earlier that LQs represent a set of LCs, we therefore reserve the factor ratings (highly suitable, moderately suitable, marginally suitable, and not suitable) to describe land quality classes. As a general practice among land evaluators, LC ratings are described as optimal or adequate, medium or moderate, and severe or low. The diagnostic criteria for soil pH for mango, coconut, and palm oil we have earlier mentioned would be a set of pH ranges for optimal or adequate, medium or marginal, and severe; and these pH ranges are expected to vary for the different crops.

5.5.4.2 Developing Diagnostic Criteria for Matching with Land Qualities

A major work in the design of the land evaluation process is the establishment of the diagnostic criteria for LQs for each of the land utilization types we plan for the development of the area. We have earlier defined LQs to be a set of LCs.

If we take our earlier example on a set of pH range for mango—5.5 to 6.5 as optimal for mango, 5.0–5.4 and 6.6–7.5 as moderate, and <5.0 and >7.5 as severe—we can use this as indicative for the availability of major, secondary, and minor elements needed by the crop. At lower pH, we have toxic levels of iron, manganese, zinc, copper, and cobalt but deficient levels of calcium and magnesium. At high soil pH, it is the opposite—we have high levels of calcium and magnesium and deficient levels of iron and other micro-elements needed by the plants. Nitrogen, phosphorus, and potassium are fixed and unavailable at low pH levels and generally more available at higher levels. Assessing the nutrient reservoir would be centered on organic matter (Table 5.10).

With only two LCs for this land quality, permutation is the best way to develop the factor rating for land quality on nutrient availability for mango, presented as in Table 5.11

Note that as we add more parameters, the permutation process becomes longer. But evaluators rarely permutate because basic principles could be gleaned from the above example. But before that, we have to clarify certain issues—is the limitation not that easy to correct and would require huge investment on the part of the developer to improve land condition? Or is the limitation correctable and easy to manage?

From the standpoint of cost given our example, soil pH is not that easy to correct because we have to purchase and apply lime and this requires considerable investment and monitoring; unlike soil organic matter improvement where we can just use farm wastes to compost and apply to the soil.

So rather than permutate because LQs consist of several LCs, evaluators determine LQ rating based on the following basic principles:

1. Where all LCs are optimal or adequate, and there is no limiting LC, the LQ rating is highly suitable (S1). Likewise, where all LCs are moderate, the LQ rating is moderately suitable (S2); and where all LCs are severe or marginal, the LQ rating is marginally suitable (S3).
2. Where we have more than two LCs to define the LQ and we have a mix of ratings that ranged from optimal to moderate to severe, the dominant or most number among the LC ratings dictates the LQ rating, with exception. If the limitation is not that easy to correct, even the presence of optimal condition for the other factors will downgrade the LQ rating to the level of the noncorrectable LC rating. Where the limitation is correctable, the dominant or most number of LC rating dictates the LQ rating.

Table 5.10 Mango LURs for LQ1: Nutrient availability for crop uptake

Degrees of limitation	Soil pH	Organic matter
Optimal/adequate	5.5–6.5	1.5–8 %
Moderate	5.0–5.4 / 6.6–7.5	<1.5
Marginal/Severe	<5.0/>7.5	(Organic soils, >8 %)

5.5.4.3 Designing the Land Evaluation Diagnostic Criteria Using Set of Land Qualities

Given again our mango LUT example, LQ1—nutrient availability for crop uptake is not all that could make a successful growing especially if we are considering orchard or commercial production. Back again to our LUR for mango, our literature review shows that a distinct wet and dry season is critical. The Philippines is divided into four climatic types by Corona Classification System; and a Corona Climatic Classification Map is available for reference to determine which areas fall under which type. The distinct wet and dry season required by mangoes would fall under Type I and these cover mostly the western part of Luzon down to the western halves of Palawan, Mindoro, Panay, and Guimaras islands (Table 5.12).

The other critical parameter based on our research is to make sure that the trees do not experience long water logging conditions. We have earlier discussed that we can substitute the most relevant laboratory measured parameter if this is not available with what can be inferred based on available data. The availability of knowledge system determines the LC to use to measure our LQ. We will use soil texture instead of actually measuring water percolation down the soil profile to establish our criterion. Percolation and infiltration rate data are very limited and not easily available in soil survey reports. It is not also easy to find in the scientific literature the best soil infiltration rate for the growing of mango to enable us to establish evaluation criterion. On the other hand, we can infer soil drainage properties from soil texture. Soil texture can be obtained in almost all soil survey reports and can be done right in the field by "feel" method. For the purpose of this example, we arrange soil texture from coarsest to finest, or from fast infiltration rate to slowest, as follows:

Sand (S)	Coarse
Loamy sand (Ls)	Coarse
Sandy loam (Sl)	Moderately coarse

(continued)

(continued)

Loam (L)	Medium
Silt loam (SiL)	Medium
Silty clay loam (Sicl)	Moderately fine
Clay loam (Cl)	Moderately fine
Sandy clay loam (Scl)	Moderately fine
Sandy clay (Sc)	Fine
Silty clay (Sic)	Fine
Clay (C)	Fine

We can see that for our purpose in determining good soils for mango from the point of view of soil drainage and water movement down the soil profile, from sandy loam to sandy clay loam soils would be best. Of course, the physiographic location of proposed mango orchard matters because this determines flooding risk. Generally, instead of physiographic location, evaluators assess slope and flooding risk. We will use in this example the flooding rating based on soil map (Table 5.13).

The other critical factor for mango production is deep soil. Our LQ4 is sufficient soil depth for root growth and development. We will just use a general soil depth criterion for tree orchard (not specific for mango). Our soil characteristics will be effective soil depth (Table 5.14).

Take note that we have done so far only the diagnostic criteria for the evaluation of mango LUT. We have earlier stated that a major principle of land evaluation is comparison of more than just one LUT. We have to repeat the process for the other LUTs considered. While we do know that coconut and palm oil (which we cited earlier as examples for possible comparison with mango LUT) would have different LURs, comparison cannot be effected if we design separate diagnostic criteria for coconut. So for our purpose of demonstrating how to do land evaluation, we will use the same LQs for mango for evaluating the suitability of the area for coconut. We can add additional LQs for critical factors that we failed to consider that is important for coconut but we did not consider for mango because it was not that essential.

For LQ1, coconut could tolerate far wider pH range than mango, we already clarified that earlier. Nutrient management of course for the mango and coconut differ, especially the critical elements. But for purpose of comparison, our concern is general availability of essential (not the critical) elements and we will use the same LCs. For LQ2, the distinct wet and dry season is not preferred by coconut; climatic type with even distribution of rainfall is best. For LQ3, the land must not be waterlogged but coconut could tolerate short-term flooding. For LQ4, both coconut and mangoes require deep soils.

5.5.5 The Land Evaluation Process

Summarizing what we have done so far, the land evaluation process begins with defining the land utilization types, which for the purpose of demonstration, we have selected commercial or plantation-type growing of mango (LUT1) and coconut (LUT2).

The second step is to define the LURs and the diagnostic criteria. Table 5.15 is a sample first of the "must" table that should appear in every land evaluation report:

The third step is to prepare a tabular summary of the Soil Characteristics for the different LQs of the areas we are evaluating. Table 5.16 is the second of the "must" table that must be prepared by the evaluator. The sample data illustrated in this table could be taken during actual field survey by the developer/proponent or we can use various reports available for the project site.

The fourth step is to compare the LURs with the LQs and LCs of the land mapping units or project site being evaluated. Table 5.17 is actually not a "must" table but presented here to show the evaluation process.

Before we go to the next step, let us reiterate our basic points on land evaluation proper:

(a) Land evaluation involves comparison of LURs based on the diagnostic criteria we have designed against land quality and LCs that we were able to gather about our proposed project site;
(b) For all purposes and intents, despite efforts to be as objective as possible, land evaluation is still a subjective exercise, as subjective as judging beautiful ladies in a Miss Philippines contest; but in this case, we evaluate project sites for suitability to LUTs instead of ladies in a beauty pageant; and thus, it is very important for the land evaluator to have seen the project area to make any sound judgment;
(c) The land evaluator can challenge what literature says about crop requirements as it applies in the local condition by actually validating the criterion in the field through farmer interviews and site inspection. Where the criterion appears in conflict with actual field conditions, common sense should prevail.

The fifth step is to summarize. Table 5.18 is the third "must" table that should be presented in the land evaluation report. Usually, land evaluators assign a symbol for the LCs so that it could be incorporated in the suitability class rating and makes it easily to identify the land limitation. For our given example, we will designate the following symbols:

Soil pH (p)
Soil organic matter (o)
Climatic type (c)
Flooding (f)
Soil texture (t)
Effective soil depth (d)

Table 5.11 Rating guideline given the LCs that constitute LQ1 for mango

LC Ratings	LQ Ratings
Optimal soil pH and adequate soil organic matter	Highly suitable for mango
Optimal soil pH and moderate soil organic matter	Moderately suitable for mango
Optimal soil pH and marginal soil organic matter	Moderate suitable for mango
Moderate soil pH and adequate soil organic matter	Moderately suitable for mango
Moderate soil pH and moderate soil organic matter	Moderately suitable for mango
Moderate soil pH and marginal soil organic matter	Moderately suitable for mango
Severe soil pH and adequate soil organic matter	Marginally suitable for mango
Severe soil pH and marginal soil organic matter	Marginally suitable for mango
Severe soil pH and marginal soil organic matter	Marginally suitable for mango

Table 5.12 Mango LURs for LQ2: favorable climatic condition

Degree of limitation	Corona climatic type
Optimal	Type 1, two pronounced season; dry from November–April, wet rest of the year
Moderate	Type 3, season not so pronounced, relatively dry from November–April and wet the rest of the year
Marginal	Type 2, no dry season, with maximum rainfall from November–January
	Type 4, rainfall more or less distributed throughout the year

Table 5.13 Mango LURs for LQ3: low risk from over wetness

Degree of limitation	Flooding occurrences	Soil texture
Optimal	None	Sandy loam, loam, silt loam, silty clay loam, clay loam, sandy clay loam
Moderate	Slight	Sandy clay, silty clay, loamy sand
Marginal	Moderate to frequent	Clayey soils, sandy soils

Table 5.14 Mango LURs for LQ4: sufficient soil depth for root growth/anchorage

Degree of limitation	Effective soil depth (cm)
Optimal (deep)	>100
Moderate (moderately deep)	50–99
Marginal (shallow)	<50

The sample illustration shows that none of the four project sites actually are highly suitable for LUT-1 mango and LUT-2 coconut and their specific limitations are identified. This means that pursuing the proposed endeavor would not bring in expected benefits unless efforts are made to correct the limitations. In actual land evaluation practice, a range of crops to include a mix of perennials and annuals are proposed depending on the planners' choice of LUTs, to provide a variety of choices with which to make the decision.

The fourth and last "must" table is Table 5.19 summarizing the proposed management recommendations to sustain productivity for the envisioned undertaking:

5.5.6 Sample Application of Land Evaluation: Updating the Strategic Agriculture and Fisheries Development Zones as the Agricultural Component of the Updated Comprehensive Land Use Plan

5.5.6.1 The CLUP and the CDP

The Comprehensive Land Use Plan (CLUP) is required under Section 20 of the Local Government Code of the Philippines or Republic Act 7160. The local governments are required to prepare a CLUP to be enacted through a zoning ordinance. In addition, there is also the Comprehensive Development Plan (CDP) required by Sections 106 and 109 requiring local governments to prepare a CDP and public investment programs. In the CLUP, the term comprehensive is understood to refer to its geographical territorial sense; while in CDP the comprehensive is understood in the sense of being multisectoral in development.

The CDP is the Action Plan used by every local administration to develop and implement priority sectoral and cross-sectoral programs and projects in the project locations to put flesh on the skeleton as it were, gradually and

Table 5.15 LURs per land use type

Land quality	LCs	LUT 1—Mango			LUT 2—Coconut		
		Optimal	Moderate	Marginal	Optimal	Moderate	Marginal
1. Nutrient availability for crop uptake	Soil pH	5.5–6.5	5.0–5.4	<5.0	5.0–8.0	pH 4.5–4.9	<4.5
			6.6–7.5	>7.5		8.1–8.5	>8.5
	Soil organic matter	1.5–8 %	<1.5 %	>8 %	1.5–8 %	<1.5 %	>8 %
2. Favorable climate	Corona climate type	1	3	2, 4	2, 4	3	1
3. Low risk from over wetness	Flooding	None	Slight	Moderate	None-slight	Moderate	Frequent
	Soil texture	Sl, L, SiL, SiL, Sicl, Cl	Sc, Sic, Ls	C, S	Sl, L, SiL, SiL, Sicl, Cl, Sc, Sic	Ls	C, S
4. Sufficient soil depth for root anchorage	Effective soil depth (cm)	>100	50–99	<50	>100	50–99	<50

Table 5.16 Soil characteristics of the different mapping units being evaluated (Sample data filled up for illustration purposes only. The data do not represent any specific areas in the Philippines)

Land Quality	LCs	Project site 1	Project site 2	Project site 3	Project site 4
1. Nutrient availability for crop uptake	Soil pH	6.0–7.0	6.0–6.1	6.5–7.1	5.5–6.0
	Soil organic matter (%)	1.3	1.3	1.5	1.8
2. Favorable climate	Corona climate type	1	1	1	1
3. Low risk from wetness	Flooding	None	Slight	Moderate	Moderate
	Texture	Clay loam	Silty clay	Silt loam	Loamy sand
4. Sufficient soil depth for root anchorage	Effective soil depth (cm)	83	122	>150	135

incrementally, until the desired shape or form of development is eventually attained over the long term. This is consistent with the public control of the pattern of development. This is the responsibility of the Local Development Council (LDC) as provided for under Sections 106 (Local Development Councils) and 109 (functions of LDC), and in essence represents the short-term development plans of the incumbent local government unit administrator.

5.5.6.2 The SAFDZ and the IDP

The *Strategic Agriculture and Fisheries Development Zones (SAFDZ)* as component of the CLUP is to be regarded as the plan for the long-term management of the local territory's agricultural resources. It is skeletal circulatory framework of the territory's physical agricultural development. It identifies areas where development can and cannot be located, and directs public and private investments accordingly. CLUP and SAFDZ are assigned to the Local Government Legislative Council as provided for in Sections 447 and 468 of the Local Government Code. The visions and programs as well as the projects in the CLUP/SAFDZ takes a longtime to carry out.

The agricultural chapter of the CDP can be regarded as the implementing instrument of the SAFDZ as component of CLUP and assures continuity, rationality, and stability of the local agricultural development efforts. This agricultural chapter of the CDP is referred to as the *SAFDZ Integrated Development Plan (IDP)*. It indicates priority areas and required investments to jumpstart the development of agriculture and fishery industry in the locality. It is required in each SAFDZ at the municipal, provincial, and regional levels. The SAFDZ must allow the aggregation of multi-location projects and programs that cross administrative and political boundaries. It may establish SADFZ Convergence Points to facilitate the integration of two more LGU's to adopt a common development plan and come up with a political mechanism for their joint implementation, containing the various strategic development plans that can be implemented by LGU's at various levels. The compilation of the IDPs at the provincial and regional level is referred to

Table 5.17 Comparison of LUR with LQ/LCs and final suitability rating

Land quality	LCs	Data	LUT 1: Mango	LUT 2: Coconut
			Rating	Rating
Project site 1				
1. Nutrient availability for crop uptake	Soil pH	6.0–7.0	Moderate	Optimal
	Soil organic matter (%)	1.3	Moderate	Moderate
2. Favorable climate	Corona climate	Type 1	Optimal	Marginal
3. Low risk from over wetness	Flooding	None	Optimal	Optimal
	Soil texture	Clay loam	Optimal	Optimal
4. Sufficient soil depth for root anchorage	Effective soil depth (cm)	83	Moderate	Moderate
Suitability Rating			S2[a]	S3[a]
Project site 2				
1. Nutrient availability for crop uptake	Soil pH	6.0–6.1	Optimal	Optimal
	Soil organic matter (%)	1.3	Moderate	Moderate
2. Favorable climate	Corona climate	1	Optimal	Marginal
3. Low risk from over wetness	Flooding	Slight	Marginal	Optimal
	Soil texture	Silty clay	Moderate	Optimal
4. Sufficient soil depth for root anchorage	Effective soil depth (cm)	122	Optimal	Optimal
Suitability rating			S3	S3
Project site 3				
1. Nutrient availability for crop uptake	Soil pH	6.5–7.1	Optimal[b]	Optimal
	Soil organic matter (%)	1.5	Optimal	Optimal
2. Favorable climate	Corona climate	1	Optimal	Marginal[c]
3. Low risk from over wetness	Flooding	Moderate	Marginal	Moderate
	Soil texture	Silt loam	Optimal	Optimal
4. Sufficient soil depth for root anchorage	Effective soil depth (cm)	>150	Optimal	Optimal
Suitability rating			S3	S3[c]
Project site 4				
1. Nutrient availability for crop uptake	Soil pH	5.5–6.0	Optimal	Optimal
	Soil organic matter (%)	1.8	Optimal	Optimal
2. Favorable climate	Corona climate	1	Optimal	Marginal
3. Low risk from over wetness	Flooding	Moderate	Marginal	Moderate
	Soil texture	Loamy sand	Marginal	Moderate
4. Sufficient soil depth for root anchorage	Effective soil depth (cm)	135	Optimal	Optimal
Suitability rating			S3	S3

[a] Although optimal is dominant rating, where the limitation is non-correctable, the final suitability rating is downgraded to the rating of the non-correctable limiting factor

[b] Note that the mango criterion for soil pH was exceeded by 0.1 but the evaluator, having seen the project site, still rated Optimal instead of Moderate because in his personal view, such small difference would hardly create an impact on yield. This tells you that despite efforts to make land evaluation as objective as possible, it can still be subjective. And despite everything else was Optimal except for flooding, since this is a non-correctable limitation, the evaluator's final rating was marginally suitable (S3)

[c] The land evaluator can actually challenge what the literature states about optimal conditions for coconut or for other LUTs for that matter. In this example, the evaluator could conduct field interviews and project site inspection to validate if the coconuts in the project site are marginal compared to those in other climatic types. If the validation shows that the growth and yield is just lower but still makes a profit for the coconut farmer, the rating could be improved from marginal to moderate; and the overall rating of the land is improved to S2 (Moderately Suitable) instead of S3. Where the criterion seems in conflict with actual field conditions, common sense should prevail. This is especially critical if the land evaluation report is designed to support a bank agricultural commodity loan and the final rating is used by the bank to determine if the loan can be paid

Table 5.18 Summary of the suitability classes and sub-classes for the LUTs considered

Land management utilization type	Project site 1	Project site 2	Project site 3	Project site 4
Mango	S2*pod*	S3*oft*	S3*f*	S3*ft*
Coconut	S3*ocd*	S3*oc*	S3*cf*	S3*cft*

as the Agriculture and Fishery Modernization Plan (AFMP) to provide the development framework, guidelines, and policies for modernization and to define the priority investment for infrastructure to ensure food security and alleviate poverty.

The CLUP should be completed ahead of the CDP. Likewise, SAFDZ as component of the CLUP should necessarily be completed ahead of the IDP as the agricultural chapter of CDP. Both SAFDZ and IDP should also be prepared ahead of CLUP and CDP for proper integration into the LGU's rural development plans and visions.

The question that is often raised by local development planners is how to keep the long-term agricultural development plan from being disregarded with every change of administration. This is the reason we have a separate CLUP/SAFDZ from a CDP/IDP. The SAFDZ once enacted becomes a law and remains in effect even after the term of the incumbent officials. SAFDZ as a zoning ordinance cannot be disregarded without going through the proper legislative procedures for repealing or amending the ordinance. The SAFDZ once in place belongs to the people and cannot be attributed to a particular political leadership.

With the CLUP/SAFDZ separated from the CDP/IDP, the review process by the Regional Land Use Committee is simplified. This Committee was established in 1993 by Executive Order 124 to prioritize and establish procedures in evaluating areas proposed for land conversion, tourism development areas, and sites for socialized housing. The Executive and Legislative Agenda (ELA) is a planning document covering 3-year period corresponding to the term of local elective officials that is mutually developed and agreed upon by both the executive and legislative offices. ELA is not meant to replace or duplicate existing planning systems in the LGUs; rather, it adds greater value to the CLUP/SAFDZ and CDP/IDP by moving them forward to getting implemented and monitored.

Both the CLUP/SAFDZ and the CDP/IDP are prepared in an iterative way. These should be updated on regular basis to reflect the dynamic dimension of planning. The updating of CLUP is anticipated and SAFDZ updating is necessarily done about two years before the CLUP updating. There are several reasons we need to update the SAFDZ on regular basis. For one, the needs and demand for competing land uses change; there are overlapping boundaries which includes public lands and not suitable areas initially overlooked, there are emergent issues such as threats posed by climate change which were not originally considered; and there are already new areas qualified for SAFDZ.

5.5.6.3 Module 1: Generation of the SAFDZ Planning Database

The most common perception is to generate the maps, statistics, and development indicators which include the results of the land evaluation as important element in SAFDZ delineation. Many of the failures of SAFDZ is the planning from top to bottom just to comply with the requirements of the law. Those in the agricultural sectors were not consulted in the SAFDZ preparation. But part of good governance especially for planning of sustainable agricultural land management is to harness community participation and consultation, especially as to the crops that must be promoted for which land evaluation is to be conducted. In SAFDZ planning, our goal is to attain sustainable agricultural development and conservation of natural resources by maintaining and enhancing productivity, reducing production risks, protecting our land and water resources from further degradation, and promoting good agricultural practices. Good and effective land use planning solicits the plans and visions of the farming community and matching these with the policy and institutional support coming from the local government and eventually translating these spatially into SAFDZ. Unless SAFDZ is coordinated and collaborated with the plans and visions of the farming community, we will not be able to harmonize the local government unit's development plans and efforts with those of its constituents and SAFDZ will be reduced to nothing but a component map merely to comply with the requirements of CLUP without political life and political will to implement its provisions.

There is so much focus on land evaluation in SAFDZ delineation when more important focus should be the plans and visions of the farmer/fisher-stakeholders, and how these can be translated into long-term plan for which SAFDZ is its spatial representation. It is not inevitable that marginalized small-scale farmers will ruin their natural resources for short-term gain but even under such difficult environments, sustainable land management is possible. Local farming communities can adapt indigenous and exogenous agricultural technologies to improve their economic lot and contribute to the national development goals with local government's support. Farmers can be harnessed as part of the solution by soliciting their participation and inputs in the planning process rather than just imposing on them through the SAFDZ, the rural development agenda of the incumbent political leadership. Such political agenda should be properly reflected on the CDP/IDP, not on the SAFDZ which represents the long-term visions and dreams of the agricultural and fishery communities.

Table 5.19 Summary of suitability ratings and management recommendations by LUTs

Land management utilization type	Moderately suitable (S2)		Marginally Suitable (S3)	
	Major limitations	Recommendations	Major limitations	Recommendations
Mango	Soil pH, organic matter, soil depth	Project site 1 is rated moderately suitable. The soil pH is slightly alkaline for mango but this can be easily corrected by using ammonium sulphate fertilizers; organic matter is very low and it is recommended to collect fallen leaves, shred, compost, and use as fertilizer. The soil is relatively shallow, a very important limitation especially where typhoons commonly occur. Insisting to use this for mango production may require support stand for mature trees to protect them from winds	Organic matter, flooding, soil texture	Project site 2 is marginal for mango production. It is recommended to improve the organic matter by collecting the fallen leaves, shredding, converting to compost, and use as fertilizer. Flooding slightly occurs and the soil texture is too fine to allow good drainage. Mango will be subjected to prolonged water logging. As these are limitations very difficult to correct, successful mango production will require ingenious drainage system of dikes and canals
	–	–	Flooding, soil texture	Project sites 3 and 4 are marginal for mango production due to flooding, flooding and soil texture limitations, respectively. Mango will be subjected to prolonged water stress. As these are very difficult to correct, successful mango production will require ingenious drainage system
Coconut	–	–	Organic matter, climate, soil depth	Project sites 1 and 2 are marginal for coconut production. The organic matter limitation is correctable with organic fertilization. However, the climatic condition is not suitable for growing of coconut unless these are grown under protective agriculture system for even distribution of moisture throughout the year. The soil is also too shallow for coconut and the trees are expected to easily fall down during typhoon events
	–	–	Climate, flooding, soil texture	Project sites 3 and 4 are marginal for coconut. The climate is not suitable, flooding commonly occurs, and the soil is too coarse to retain sufficient moisture especially between rain periods. Attempts to successfully grow coconut in the project site would require investments in the establishment of protective agricultural systems and improvement in the soil texture to improve soil water holding capacity

The participatory approach to SAFDZ planning and delineation fosters ownership of both resources and the process and thus increases the prospects for adoption. Participatory SAFDZ mapping involves (1) characterization of the area by collaborating with the community members on the location and main features of the area given the map of the area (2) assessment of existing situation, strengths, and weaknesses by determining the location of agricultural infrastructures and services that makes a particular area strategic (e.g., location of farm-to-market roads, markets, postharvest facilities, piers/airports, rural banks, abattoir, government agricultural offices, and laboratories, etc.); collection of essential information relating to various land uses and land-based problems, their causes, and the necessary sustainable land management interventions to address the issues. The outputs of this participatory SAFDZ mapping should include the land uses, the delineation of the watershed where the farming community is located, land degradation issues, and other wealth of information such as the updated agricultural profile of the area, the matrix of agricultural development indicators, etc.

We have Iligan City for our example, popularly known as the City of Majestic Water Falls. It is geographically located between 8°00′11″–8°19′27″ north latitude and

Fig. 5.32 Location map of Iligan City

124°04′52″–124°34′46″ east longitude, approximately 795 km southeast of Manila. It lies in the northern coast of Mindanao facing Iligan Bay (Fig. 5.32).

The city is bounded on the north by the Municipality of Luga-it, Misamis Oriental and the city of Cagayan de Oro; in the west by the Linamon River fringing the Municipalities of Linamon and Matungao, province of Lanao del Norte extending to Ilagan Bay; in the east bounded by Cagayan and Pigcotin Rivers, municipality of Talacag, province of Bukidnon; in the southwest by the municipalities of Balo-I and Tagoloan, province of Lanao del Norte; and in the southeast by Kapay River, municipality of Kapay, province of Lanao del Sur. Iligan City is politically and administratively independent from Lanao del Norte although it has strong economic linkages with the province. It also serves as a catchment and transhipment area for agricultural products from Central Mindanao and Zamboanga del Sur. It encompasses 44 barangays, 21 of which are considered urban and 23 are rural. The total land area surveyed is approximately 81,745 ha of which about a fourth (25.13 %) of the total land area of Lanao del Norte.

The city used to be home to a growing number of large industries: energy, cement, flour, baking additives, animal feeds, biscuits, lime, charcoal, pvc pipes and tubes, coco oil and pellets, electrochemicals and chemical products, carbon and acetylene black, pulp for specialty papers, builders' woodworks, metalworks, and steel, the largest in terms of investment and employment. However, when the 2003 SAFDZ preparation was conducted, the Asian financial crisis of 1997 had its worst impact and brought about unconditional closure of Iligan City's major industries such as the National Steel Corporation, the Marcelo Fertilizers, the Maria Cristina Chemicals, Inc. (MCCI) and many others. This restricted the city's continuing economic growth and prosperity affecting the needs of its burgeoning urbanized population. The consequent slowdown in economic performance highlighted the need to refocus development thrusts in agriculture to cushion the negative impacts of the downtrend in the industrial sector. At this time of SAFDZ planning, it was significant to revitalize the agricultural sector and open up agricultural development prospects to offer positive programs and livelihood alternatives that can uplift the plight of the city residents.

In this Module 1, several spatial data relevant for agricultural zoning purposes were gathered: elevation map, erosion map, soil map, land use map(Fig.5.33), land limitation map. Socioeconomic survey was also conducted.

The major agricultural crops grown by the city residents were coconut (14,312 ha), corn (5,305 ha), banana (635 ha), coffee (354 ha), and rice (270 ha). It was significant to note that irrigated paddy rice areas were extremely limited and there was no room for expansion, and it was a major decision for the city to content itself as a rice importing city. Oil palm (709 ha), abaca (310 ha), fruit trees (130 ha), mango (58 ha), diversified field crops which includes vegetables and rootcrops (50 ha) citrus (20 ha), and cutflowers (10 ha) were the other existing major land uses. Local consultations with the agricultural stakeholders showed desire to intensify crop production by improving cropping index, productivity, and reduced production costs, thereby improve farm profitability and the cushion economic impact and improve lot especially of those affected by industrial recession.

5.5.6.4 Module 2: Statement of Problem and Identification of Possible Solutions

According to the inputs of the stakeholders, the list of existing problems is drafted; the issues and concerns in the area are located on the map, prioritized and ranked. The map enables the stakeholders to understand the boundary of their community and provides a good tool to point out problem areas like denuded forest, landslide-prone areas, mining

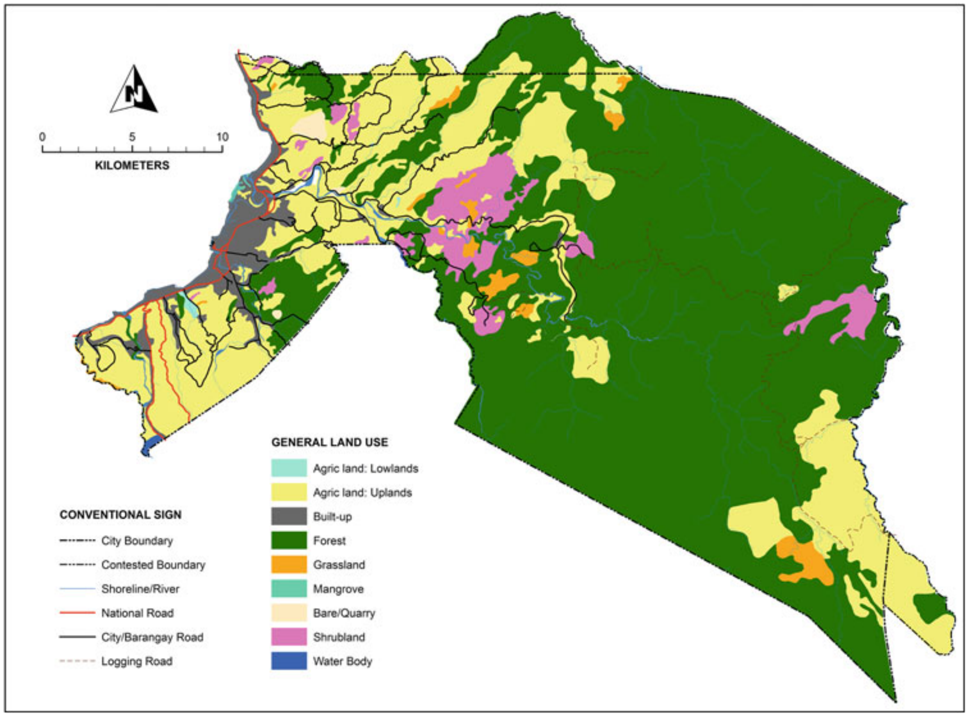


Fig. 5.33 The 2003 land use map of Iligan City (*Source* The Soil and Land Resources Evaluation for SAFDZ-CLUP Integration: Iligan City, BSWM)

sites—mining waste ponds—agricultural impact areas, presence or absence of agricultural infrastructures and services. It would be surprising for many communities to discover that political boundaries are not configured according to watershed and that critical food and water sources would most probably be located in the neighboring communities.

Given the issues and concerns, the concerned agricultural community assisted by technical team proposes solutions to the listed problems, discuss the feasibility according to the available resources, and develop priority interventions and implementation strategy. With these inputs, the Updated SAFDZ planning team can now reformulate goals or revalidate/revisit the existing vision statement. An important question for the agricultural community to answer is how does it foresee agriculture in the locality 10 or 20 years hence. The Module 2 exercise should be able to generate the revalidated/revised vision statement, the vision elements and their respective descriptors and success indicators, and the vision-reality gap, which will eventually be transformed into the agricultural sector's goals.

For our Iligan City example, the problematic statement is as follows: The Asian financial crisis brought unconditional closure of Iligan's major industries restricting the city's continuing economic growth and its capacity to absorb and provide for the needs of its urbanized population. It was vitally important to cushion the negative impacts of the downtrend in the industrial sector. It was significant to revitalize the agricultural sector and open up agricultural development prospects to offer positive programs and livelihood alternatives to uplift the plight of the affected city residents. A focus on agricultural development could be easier said than done. Later under Module 3, we would find out that a refocus on agricultural development had its limitations because there was not much agricultural area in Iligan City.

Second, in Iligan City, the significant SAFDZ areas to be declared were occupied by traditional crops (rice, corn, coconut) and much of the agricultural development planning would have to look into the scope of further development. The farm lands suffered from narrow economic base and would require reinforcing land use development.

Third, it was agreed that there was a need to introduce new crops to stabilize the agricultural ecology, and diversify income sources. Production technologies and farm products had to conform with the quality defined by the market and thus, capacitating farmers was a challenge to be competitive at the national and global agricultural trade scene.

The vision statement was: Iligan City able to cope with its limited agricultural land resource through crop diversification and sustainable agricultural management practices to cushion the economic impacts of the downtrend in the industrial sector.

5.5.6.5 Module 3: Drafting of the Updated SAFDZ

The SAFDZ identification process framework begins with the delineation of the Network of Protected Areas for Agricultural and Agroindustrial Development (NPAAAD). The NPAAAD areas as defined by Section 6.2 of the Agriculture and Fisheries Modernization Act (AFMA) are the agricultural areas identified in order to ensure sustained production of the country's basic agricultural and fisheries

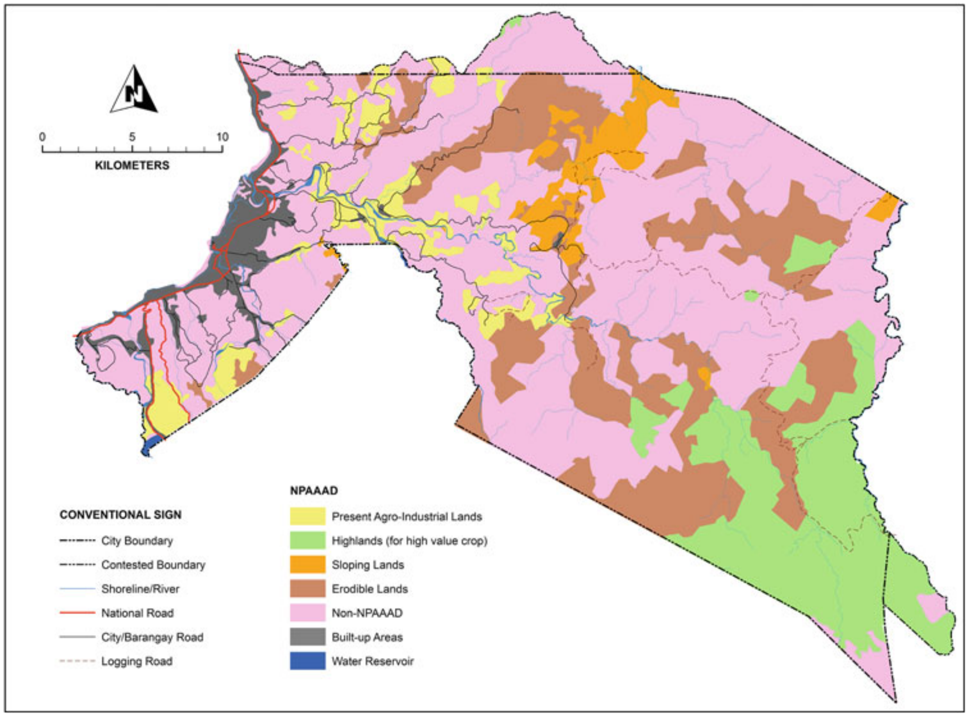


Fig. 5.34 NPAAAD Map of Iligan City

commodities through the stewardship and utilization of the most productive agricultural and fishery land resources for optimal production, processing, and marketing. These cover all irrigated areas, all irrigable lands already covered by irrigation projects with firm funding commitments, all alluvial plains highly suitable for agriculture whether irrigated or not, agroindustrial croplands or lands presently planted to industrial crops that support the viability of existing infrastructure and agro-based enterprises, highlands or areas located at an elevation of 500 m or above and have the potentials for growing semi-temperate and high value crops, all agricultural lands that are ecologically fragile, the conversion of which will result in serious environmental degradation and mangrove areas and fish sanctuaries, and all fishery areas as defined pursuant to Fisheries Code of 1998. Section 8 of AFMA provides for the BSWM to undertake the mapping of NPAAAD but as the original NPAAAD maps were lost in the haste to complete the first version of SAFDZ in 1998, LGU's can update their respective NPAAAD. In NPAAAD mapping exercises, the "base map" is the BSWM Slope Map.

Technical Phase of the SAFDZ Preparation

Step 1: Delineate, validate, and finalize the Network of Protected Areas for Agriculture (NPAA) which represents the prime agricultural lands in the area based on the *BSWM Slope Map*. The slope class delineations are: 0–3, 3–8, 8-18, 18–30 % slope. Areas greater than 30% slope are not considered. Locate the alluvial lands; locate also in the map the sloping uplands grown to various agroindustrial crops. It should be noted that alienable and disposable lands are below 18 % slope and under the mandate of the Department of Agriculture (DA). Above this slope are nonalienable and nondisposable lands and under the mandate of the Department of Environment and Natural Resources (DENR). Agricultural development of area above 18 % is a politically sensitive issue; and certainly not open for discussions since we are dealing with another government agency; unless there is a more recent policy change that will allow agricultural activities in areas above 18 %. Intrusion of people and communities on nonalienable and nondisposable areas are addressed through the social forestry programs and local governments wanting to improve the economic plight of these highland dwellers should be well aware to coordinate the agricultural component of their rural development programs with DENR.

Step 2: Identify and delineate all those irrigated areas, irrigable areas with funding commitments, and the nonirrigated lands in alluvial areas 0–3 % slope; the agroindustrial croplands served by agricultural infrastructure and supporting agri-based enterprises in the 3–8 and 8–18 % slopes; the agricultural highlands that grow semitemperate and high value crops, the ecologically fragile (erodible) lands, the grasslands (potential agro-industrial lands and agricultural expansion areas) in the greater than 18 % slopes; and all those mangroves, fishery areas, and fish sanctuaries. The final map output is the NPAAAD.

For our Iligan City example, Fig. 5.34 is the NPAAAD map and the results are summarized in Table 5.20 showing the extent of the prime agricultural lands from map legends A to E.

Table 5.20 The extent of NPAAAD areas in Iligan City (*Source* BSWM)

Mapping symbol	Description of NPAAAD areas	Areas	
		Ha	(%)
A	All irrigated areas	136.00	0.18
B	All irrigable lands already covered by irrigation with firm funding commitment	–	–
C	All alluvial plains highly suitable for agriculture, mainly non-irrigated areas	–	–
D	Agroindustrial croplands presently planted to industrial crops that support the viability of existing agricultural infrastructure and agro-based industries	2,494.00	3.28
E	Highlands or areas located at the elevation of 500 meters or above and halve the potential for growing of semi-temperate and high value crops	7,530.00	9.90
F	All agricultural lands that are ecologically fragile, the conversion of which to non-agricultural uses will result in serious environmental degradation, includes mangrove areas and fish sanctuaries	14,748.00	19.39
G	All fishery areas as defined by the fisheries code of 1998	353.00	0.46
	Sub-total of NPAAAD areas	24,908.00	33.21
Bu	Built-up areas	5,728.00	7.50
Fa	Forest/watershed areas	45,095.00	59.29
	Sub-total of non-NPAAAD areas	50,823.00	66.79
Grand total		76,084.00	100.00

Note Area distribution may not reflect the official area because of conflict in boundary and map scale limitation

Table 5.21 The Iligan City land resources problem-solution matrix based on the NPAAAD Map

Problem	Solution
Has very little areas for rice production	The city will have to content itself importing rice from neighboring municipalities and provinces
Has limited agroindustrial croplands	Farm diversification and intensification, introduction of other crops
Has vast highlands with potential for agriculture	Introduction of high value crops

From the NPAAAD Map and the accompanying tabular summary, Iligan City, our example, has only 10,160 ha of agricultural lands. Of these, 136 ha are irrigated, 2,494 ha are agro-industrial croplands, and 7,530 ha are potential areas for growing of semi-temperate and high value crops. From the NPAAAD map, the problem-solution matrix could be summed up as in Table 5.21.

Step 3: Validate and finalize the Bioeconomic Management Zones, which indicate the prime agricultural areas within NPAA that are adequately provided with support infrastructure such as farm-to-market roads, ports, credit/banking facilities, market, and urban centers. The resulting Bioeconomic Management Zone Map refers to physical aspect (landforms, land management units, soil and land use) and their economic characteristics such as presence of support services, growth centers, and diversified/intensified farming. The mapping unit legend are as follows: (1) *High agricultural production areas* which are economically productive units with optimum input usage, presence of postharvest facilities, credits, market centers, roads, farm-to-market roads, land use conversion activities, crop diversification, and crop intensification; (2) *Medium agricultural production areas* which are economically productive units with moderate input usage and postharvest facilities and minimum land conversion activities; (3) *Low agricultural production areas* which are economically productive units with low input usage, agricultural facilities and services, less crop diversification and intensification; (4) *Very Low agricultural production areas* which are low productive units with no growth centers, no markets, and no postharvest facilities, no crop diversification and intensification; includes areas under ecological rehabilitation; (5) *Non-agricultural production areas* which are the miscellaneous areas in the map.

Step 4: Overlay NPAAD Map with Bioeconomic Management Zone Map to come up with the initial SAFDZ Map. Section 4 of AFMA defines the SAFDZ's as areas within NPAAAD identified for production, agroprocessing, and marketing activities to help develop and modernize, with the support of government, the agriculture and fisheries sectors in an environmentally and socioculturally sound manner. In Section 6, the criteria for identification are: suitable for agroclimate and environmental conditions giving the area a comparative advantage in the cultivation, culture, and production and processing of particular crops, animals, and aquatic products; strategic location of the area

Table 5.22 Correlation of NPAA, NPAAAD, Bio-Eco Zone, and SAFDZ

NPAA		NPAAAD	BIO-ECOZONE	SAFDZ
Mapping symbol	Description			
1	Irrigated			
1.1 (0–3 % slope) 1.2 (>3 % slope)	Alluvial Lands Sloping Lands	a. All irrigated areas	1. High agri'l prod'n area	SAFDZ
2	Irrigable and efficient diversified agricultural lands			
2.1 (0–3 % slope) 2.2 (3–8 % slope)	Alluvial Lands Sloping Lands	b. All irrig'l land already covered by irrig project w/firm funding commitment c. All alluvial plains highly suitable for agriculture, mainly non-irrigated	2. Medium agri'l prod'n area	SAFDZ
3	Agroindustrial Lands			
3.1 (<18 % slope) 3.2 (8–18 %, Df + 18 % slope of 3.1)	Present agro-ind'l lands Potential Agro-ind'l lands	d. Agro-ind'l croplands or lands presently planted to ind'l crops that support the viability of existing agri'l infra and agro-based enterprises	3. Medium agri'l prod'n area	SAFDZ
4	Expansion Areas (Idle)			SAFDZ
5	Ecologically fragile lands			SAFDZ
5.1 (>500 masl, <18 % slope)	Highland (for high value crops)	e. Highlands or areas located at 500 m elevation or above and have potential for growing semi-temperate and high value crops.	4. Low agri'l prod'n area	Remaining NPAAAD
5.2 (18–30 % slope) 5.3	Erodible lands (for A.F.) Pasture Land	f. Agri'l lands that are ecolgl'y fragile (the conv of which to other uses will result in serious envit'l degrad'n) and mangrove areas and fish sanctuaries	5. Very low agri'l prod'n area	Remaining NPAAAD
5.4	Fishpond/saltbed	g. All fishery areas as defined in Fisheries code of 1998	6. Fishery prod'n area	SAFDZ

for the establishment of agriculture or fisheries infrastructure, industrial complexes, production and processing zones; strategic location of the area for market development and market networking both at the local and international levels; and dominant presence of Agrarian Reform Communities (ARC's) and small cultivators and other small farmers and fisher folks in the area.

The important attributes of SAFDZs are: best land and water areas that are *highly suitable* and are actively used for crops, livestock, fish production representing cluster of contiguous prime lands that can be consolidated as an Integrated Area Development Package for competitive advantage; general presence of roads, market centers, credit facilities, and other agri-support facilities; proximity to offshore marketing infrastructures like airports and seaports; proximity to urban and other growth centers; and presence of farmers and fisherfolks for equal distribution and access to benefits (Table 5.22).

The SAFDZ Map Legends are as follows:

1	Strategic Crop Sub-Development Zone
2	Strategic Livestock Sub-Development Zone
3	Strategic Fishery Sub-Development Zone
4	Strategic Crop/Livestock Sub-Development Zone
5	Strategic Integrated Crop/Fishery Sub Development Zone
6	Strategic Integrated Crop/Livestock/Fishery Sub-Development Zone
7	Strategic Integrated Fishery and Livestock Sub-Development Zone
8	Remaining NPAAAD
9	Agroforestry Zone
10	Watershed Forestry Zone
11	Built-up Areas
R/L	River wash/Lahar
EZ	Economic Zone
MR	Military Reservation
SD	Sand Dunes/Beach Area
NIPAS	National Integrated-Protected Areas System

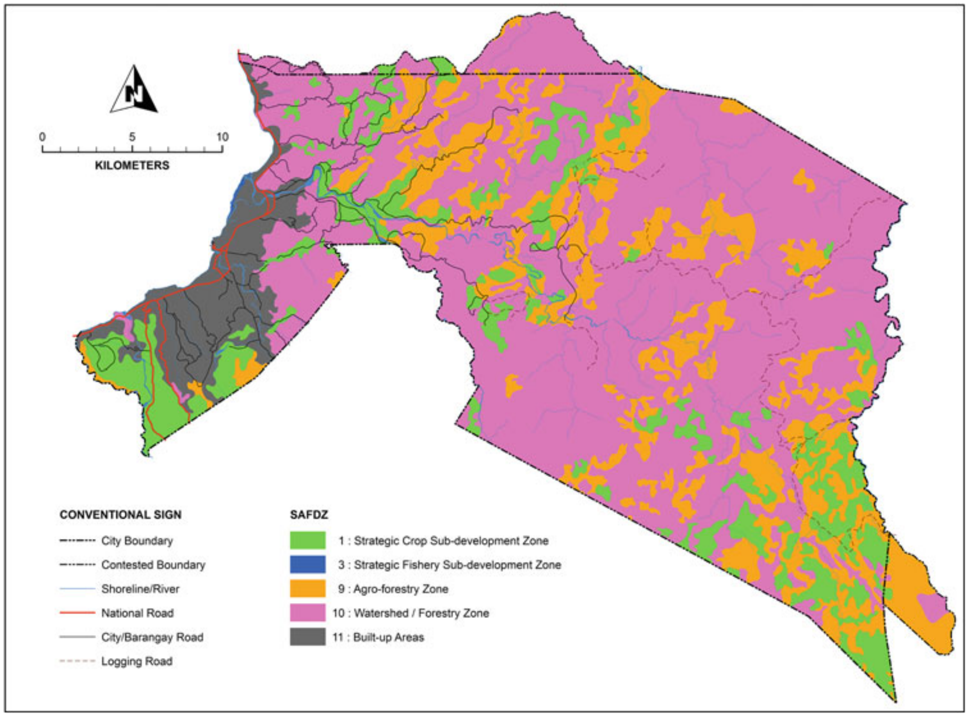


Fig. 5.35 The SAFDZ Map of Iligan City (*Source* BSWM)

To validate and finalize the initial draft of the SAFDZ Map, the additional guidelines are as follows:

1. Check the political boundaries, the names and locations of *barangays* to ensure that none is left out.
2. Check conflicting municipal boundaries and reflect the necessary correction.
3. Recheck to ensure that the SAFDZ's are in their proper location.
4. Delineate watershed protection areas that are sources of water for the major and potential irrigable areas and the recharge areas of major aquifers identified by DENR.
5. NIPAS, public and mineral lands with and without approved concession permit, industrial zones, risk-prone areas, built-up and agricultural areas with approved conversion certificates should be excluded from the municipal SAFDZ. To validate, overlay the draft SAFDZ map with the Land Classification Map (Source: NAMRIA), the Geo-hazard Map (Source: MGB), NIPAS Map and other Protected Area Maps (Source: PAWB), and other relevant spatial data such as Drought Vulnerability and Flood Vulnerability of SAFDZ areas to be able to address climate change issues.
6. Ensure the necessary map legends are consistent with the GIS Cookbook for LGUs, the guidebook published by the Housing and Land Use Regulatory Board (HLURB). Each of the SAFDZ numerical map legend has also a corresponding RGB code-assigned color.
7. Measure and determine area estimate for each *barangay* falling inside each SAFDZ mapping unit and fill up the table for SAFDZ listing and composition matrix for the municipality.
8. The Updated SAFDZ Map and Table for SAFDZ list and composition must be signed by the Municipal Agricultural Officer, the Municipal Planning and Development Coordinator, the major participants, and confirmed by the Mayor.

The outputs of the technical phase of Module 3 are the draft SAFDZ to be integrated into the CLUP, the policy maps to be printed at suitable scale, and the draft zoning ordinance.

For our Iligan example, Fig. 5.35 shows the SAFDZ Map of the city and Table 5.23 the extent of the subzones. The distribution of NPAAAD categories first presented in Table 5.20 is reprinted to show where the SAFDZ map units were obtained. Note that the areas are equal since SAFDZ was derived from NPAAAD.

Iligan City has very little agricultural areas, and the vision was to devote them all to crop production. In practice of course, some suitable areas can be devoted to livestock or integrated crop-livestock but without extensive pasture areas, livestock promotion would be limited to feed lots and backyard growing and only to a very limited extent to pasture. The city has no remaining NPAAAD or areas reserved for future agricultural expansion.

Political Commitment Phase

With the SAFDZ delineated, the LGU agricultural development planning team now generates spatial strategies and choosing the most desirable alternative; formulates the

Table 5.23 Comparative NPAAAD and SAFDZ areas (Note that they are equal because SAFDZ was based from NPAAAD)

Distribution of NPAAAD land categories				Extent of SAFDZ sub-zones			
Mapping symbol	Land category	Area (has.)	(%)	Mapping symbol	SAFDZ areas	Area (has.)	(%)
A	All irrigated areas	136	0.18	1	Strategic crop sub-development zone	10,160	13.35
B	All irrigable lands already covered by irrigation with firm funding commitment	–	–	2	Strategic livestock sub-development zone	–	–
C	All alluvial plains highly suitable for agriculture, mainly non-irrigated areas	–	–	3	Strategic fisheries sub-development zone	353	0.50
D	Agroindustrial croplands presently planted to industrial crops that support the viability of existing agricultural infrastructure and agro-based industries	2,494	3.28	4	Strategic integrated crop/livestock development zone	–	–
E	Highlands or areas located at the elevation of 500 m or above and halve the potential for growing of semi-temperate and high value crops	7,530	9.90	5	Strategic crop/fisheries sub-development zone	–	–
	Sub-total agricultural areas	10,160	13.35	6	Strategic integrated Crop/livestock/ fisheries sub-development zone	–	–
F	All agricultural lands that are ecologically fragile, the conversion of which to non-agricultural uses will result in serious environmental degradation, includes mangrove areas and fish sanctuaries	14,748	19.39	7	Strategic integrated fisheries/livestock sub-development zone	–	–
G	All fishery areas as defined by the fisheries code of 1998	353	0.46		Sub-total for SAFDZ	10,513	13.8
	Sub-total of NPAAAD areas	24,908	33.21	*Non-SAFDZ areas*			
Bu	Built-up areas	5,728	7.50	8	Remaining NPAAAD	–	–
Fa	Forest/watershed areas	45,095	59.29	9	Agroforestry zone	14,748	19.40
	Sub-total of Non-NPAAAD areas	50,823	66.79	10	Watershed/forestry zone	45,095	59.30
Grand total		76,084	100.00	11	Built-up areas	5,728	7.50
					Sub-total for Non-SAFDZ	65,571	86.20
				Grand total		76,084	100.00

policies on production, infrastructure, settlements, and protection areas consistent with the preferred strategy. It finalizes the implementation tool—the zoning ordinance.

For SAFDZ to become an amended zoning ordinance, the local legislative council (*Sangguniang Bayan*) has to come up with a resolution nominating and approving the list of *barangays* included in the SAFDZ, approving and committing local land resources for national agricultural and fisheries development programs. The approved-updated SAFDZ is incorporated as the agricultural component of the updated CLUP.

In our Iligan City example, the clustering of *barangays* into different growth areas to promote crop zonification and production areas based on the City's Flagship Program and the Safety Net Sub-Program is presented in Table 5.24. This represents the long-term strategy to attain the city's vision. It should be further noted that not all the 44 *barangays* that constitute the city are covered by SAFDZ. The city is divided into two growth centers and there are 13 *barangays* covered under the first growth area and 10 *barangays* under the second or total of 23 out of 44 *barangays.* The basis of the selection is the extent and coverage of the SAFDZ map.

5.5.6.6 Module 4: Preparation of the SAFDZ Integrated Development Plan

Modules 1 and 2 provide the planning input while Module 3 provides an assessment of the agricultural resources of the local government. We now have to match the visions and plans of the farming community and the local government with the resources that we have. This is basically what Module 4 is all about.

Table 5.24 Cluster analysis matrix by growth area, Iligan City (*Source* The Soil and Land Resources Evaluation for SAFDZ-CLUP Integration of Iligan City 2003)

Barangay	Flagship program		Safety net sub-program		
	Rice	Crop dev't	Orchard	Poultry/livestock	Inland fisheries
A. Growth area I					
Digkilaan	X		X	X	X
Sta. filomena	X		X		
Kabaksanan	X		X	X	X
Sta. elena	X		X	X	
Rogongon		X	X	X	
Kalilangan		X	X	X	
Lanipao		X	X		
Abuno		X	X	X	
Upper hinaplanon		X	X	X	
Mandulog		X	X	X	X
Panoroganan		X	X	X	
Tipanoy		X	X	X	
Buru-un		X	X		
B. Growth area II					
Bonbonon			X	X	
Hindang			X	X	
Bunawan			X	X	
Dalipuga			X	X	
Kiwalan			X	X	
Dulag			X	X	
Pugaan			X	X	
Ditucalan			X		
Upper Tominobo			X	X	
Mainit			X	X	

The outputs of Module 4 are the formulation of the agricultural sector's goals, objectives, and targets; the prioritization of the agricultural and fisheries programs, projects, and activities, the preparation of the agricultural development investment program, and the preparation of the capacity development program.

The major activity of Module 4 is to look into each of the SAFDZ mapping unit (the subdevelopment zones) to assess suitable crops and generate agricultural development programs, projects, and activities that conform with the agro-climate, the LCs and qualities of the area, the visions of the local farming community, and the rural development agenda of the political leadership.

It is here where the Land Evaluation exercise is discussed in this section and given the set of recommended crop commodities becomes an important decision tool. The recommended crop commodities must have the best comparative advantage (S1 or S2 in the land evaluation rating) and have the strategic accessibility and location in terms of agricultural and fishery infrastructures, production and processing zones, and market development and networking both at the local and international levels.

Guidelines in the updating of strategic crop sub-development zone

1. Based on consultation with the farming community, identify, conduct suitability evaluation, and rank according to importance at least 5 to 10 major commodities (including livestock and fisheries).
   For our Iligan City example, Fig. 5.36 shows the Oil Palm Suitability Map, one of the 15 crop commodities evaluated for suitability. The results of the suitability evaluation of the 15 crop commodities are presented in Table 5.25.
2. From the suitability studies, determine which of these crop commodities have the best comparative advantage in terms of suitability, available technology, and trained manpower.
3. Determine the extent to which the crop commodity can be expanded and where they are located; must include

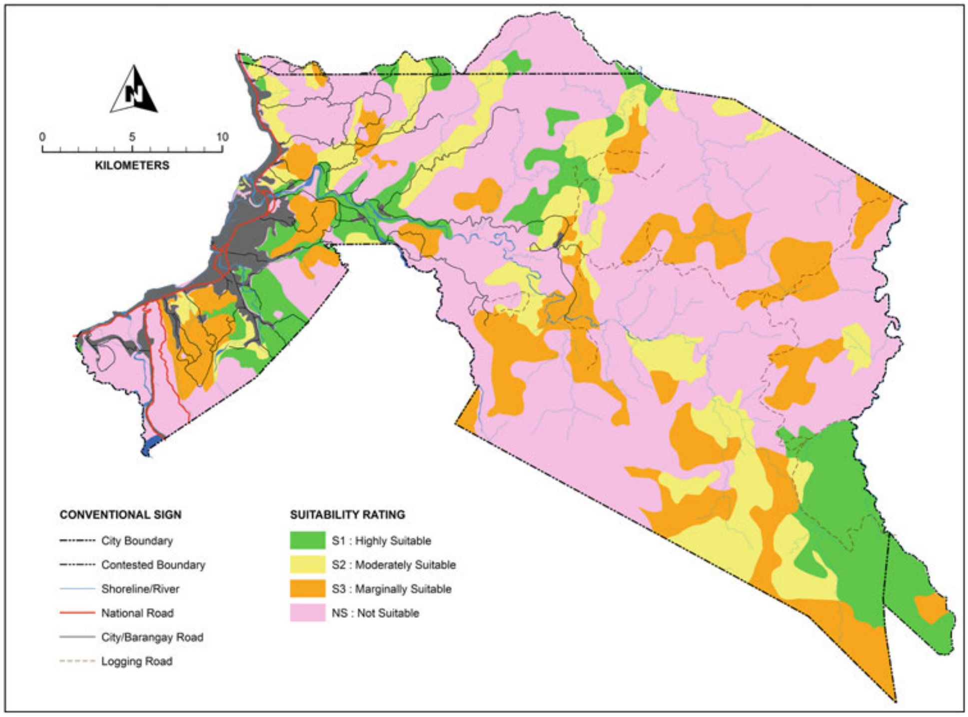


Fig. 5.36 The oil palm suitability map as part of the land evaluation study conducted for Iligan City (*Source* BSWM)

Table 5.25 Area of suitability classes by Land Utilization Types, Iligan City (*Source* BSWM)

Crop/land utilization type	Suitability Class (in ha)			
	S1	S2	S3	S4
Paddy rice				
Irrigated	1,795.7	40.0	–	79,909.3
Non-irrigated	1,343.7	492.0	–	79,909.3
Upland	1,435.7	10,676.2	11,831.8	57,801.3
Corn				
Wet season	3,895.7	21,622.5	9,463.9	46,762.9
Dry season	1,835.7	15,335.9	8,126.4	56,447.0
Banana	5,266.7	14,567.5	11,645.8	50,265.0
Abaca	3,831.0	24,165.8	8,795.5	44,952.7
Coconut	12,776.9	19,959.6	7,251.9	41,756.6
Coffee	2,552.0	24,516.2	10,742.7	43,934.1
Cacao	2,552.0	24,516.2	10,742.7	43,934.1
Oil palm	9,648.9	13,109.3	13,576.4	45,410.4
Root crops	452.0	6,727.5	28,262.6	46,302.9
Vegetables/diversified upland crops	452.0	6,727.5	28,262.6	46,302.9
Mango	8,034.7	17,752.9	14,200.8	41,756.6
Mixed fruits	6,755.7	21,693.5	11,788.7	41,507.1
Cutflowers	3,895.7	11,839.2	11,616	54,394.1
Forest trees	21,951.8	19,419.5	36,457.7	3,916.0
Fish pond—brackish	60.0	40.0	–	81,645.0

Note Areas are computer generated from ArcGIS and do not equal SAFDZ official figures list and areas of *barangays* and composition (activities and existing development structures) by delineating the S1 and S2 areas and the area estimate.

4. Assess the access to services, power, peace and order, and distance to the market centers. This criterion serves as basis to prioritize development of alternate and expansion areas.
5. Assess the production risks and hazards and propose the necessary sustainable land management practices to address the issues.

Guidelines in the Updating of Strategic Livestock and Fisheries Sub-Development Zone

1. Indicate on the map the location of the S1 and S2 areas for livestock and fisheries commercialization. Identify specific species that can complement and be integrated into the banner program.
2. Identify locations of areas and extent with best comparative advantage and which can be nurtured and developed as the cutting edge to pursue fisheries and livestock production in the locality.
3. Identify the status of support facilities and the other requirements to push for their commercialization.
4. Identify production risks and hazards and propose the necessary sustainable land management practices.

Guidelines in the Updating of Watershed/Forestry Zone

1. Delineate the watershed in the SAFDZ and assess the status of soils, vegetation cover (biodiversity), and water in terms of the degree of degradation (type, extent, severity), the driving forces, pressures, impact, and the necessary actions to improve the environmental value of the watershed.
2. Establish the formal working relationship with DENR to plan and implement programs and projects relating to the protection and conservation of the watershed.
3. Determine the presence of natural risks and hazards such as faults, landslide-prone areas, flooding, etc.

The Strategic Agriculture and Fisheries Development Zones Integrated Development Plan

The IDP indicates the priority areas and the required investments the development of agriculture and fisheries in the locality. This is required in each SAFDZ at the municipal, provincial, and regional levels. The SAFDZ allows the aggregation of multilocation projects and programs that cross administrative and political boundaries.

The IDP should be able to identify the specific crop, livestock, and fishery commodities to be developed; recognizing that commodity development allows the aggregation of multilocation programs and projects that cut across administrative and political boundaries. This is referred to as the SAFDZ Convergence Zones to facilitate the integration of two or more LGU's to adopt a common development plan and a common mechanism for their joint implementation in areas that have similar land use potential. It involves the various strategic development plans at various LGU levels. This type of planning aims to protect the farmers from market pressures and manipulations by the local traders.

The compilation and integration of various IDP's is referred to as the Agriculture and Fisheries Modernization Plan (AFMP) which provides the development framework and the priority investment plan for infrastructure to ensure food security and alleviate poverty. The priority Investment Program identifies the area coverage, the commodities, the objectives, and the nature and cost of investments to upgrade the productive capacity of the agriculture and fishery sector.

5.6 The Soil as National Asset: Soil Valuation and Accounting

5.6.1 The Soil as an Economic and Environmental Asset

The soil has always been traditionally looked up into as an agricultural resource. But biomass production is not the only role of soil. It serves also as a platform for human activities—and as such, engineering and architectural criteria have been established to ensure structural soundness and solid foundation of infrastructures and civil works. The soil also regulates atmospheric, hydrological, and nutrient cycles. The environmental role of soil is now considered an important component of the ecosystem and with the challenges of soil pollution, soil acidification/salinization/sodification, soil erosion brought about by human activities and its impact on the quality of human life, we have increasingly become aware of our soil resources as a very important patrimony of the nation, a national asset that needs to be utilized wisely if we are to achieve food security and provide a decent home for our families and communities.

For decades now, an emerging discipline is land and soil resources accounting, pioneered in the Philippines by the NSCB through its Environmental and Natural Resources Accounting (ENRA) Program. There are actually five resources covered—fishery, forest, land/soil, water, and minerals. The NSCB environmental accounting framework follows the United Nations System of Integrated Economic and Environmental Accounting (UN SEEA) methodology. It was developed to provide the mechanism for the integration of natural resources and environmental concerns to support the sustainable development thrust of the national government.

Our focus of course is on the land and soil resource account so that we could define research agenda to improve the estimation. The physical account of natural resources includes items such as the opening and closing stocks, other accumulation, and other volume changes. It is interesting that for land and soil resource, the opening and closing stocks refer to the quantity of land, specifically area measured in hectares in each land use category at the beginning and ending of an accounting period. The NSCB ENRA program is thus focused on the analysis of available data from various statistics-generating government agencies for the physical accounting, and from there, estimate the monetary value, in Philippine pesos. Volume changes in land area could be due to transfer from the environment (usually marginal lands) to economic use, or its reverse, from lands of economic use to revert back to environment (natural vegetation), changes in land use and land area due to natural, political, or other noneconomic causes, or due to land reclamation (in which case, this is considered increase in asset).

Quality changes (which refers to land degradation; the ENRA framework was begun in the early 1990s' while the Philippines had not yet acceded to the UN Convention to Combat Desertification which took place in May 2000) are not part of the asset accounts but are used to assess the cost of productivity losses. Currently, such land and soil quality changes consider soil erosion and its equivalent nutrient losses, and of course soil contamination which would include soil pollution, and other pedogeochemical transformations like acidification, salinization, and sodification.

As the framework is already established for which NSCB has to be commended for its pioneering efforts, it is therefore our objective in this book to provide the scientific support and basis to improve the estimation. We will review how the data was estimated or computed, and from a soil scientist' point of view, we will consider as research agenda the appropriate methodologies to enhance the assessment. Land and soil resources accounting is conducted to provide improved, timely, and relevant information on the allocation and use of land resources. The indicators used would be important input to policy makers and planners on the proper management, allocation, and use of our land and soil resources.

5.6.2 Physical Inventory of Soil and Land Resources as National Patrimony

The Soil Taxonomy Map of the Philippines (1:1,000,000, BSWM 1994) provides a good reference on the major classification and extent of Philippine soils. The classification is based on the USDA Soil Taxonomy System. The area coverage was measured using planimeter method (Table 5.26).

Table 5.26 Major soil orders and their extent of distribution based on soil taxonomy map

Soil order	Estimated area (ha)	Percent of total land area (%)
Inceptisols	14,652,684	48.8
Ultisols	8,113,453	27.0
Alfisols	3,973,611	13.2
Entisols	1,540,737	5.1
Mollisols	762,767	2.5
Vertisols	733,117	2.4
Oxisols	39,922	0.1
Andisols	39,854	0.1
Histosols	342	0.0
TOTAL	29,856,487	99.5

Soil resources, although dynamic with continuing soil formation and development and at the same time undergoes erosion and other geochemical transformations and processes, they follow geological time frame. And hence, in a sense, soils can be considered as finite resource. It would be unlikely that the soil map would have changed with the passing of years, except in the detail of information due to mapping scale.

Considering the high expense of field survey work, it could be seen that much of the additional work on the updating of physical inventory of our soil and land resources to improve data reliability would have to rely on advances on Geographic Information Science (GIS) and Remote Sensing (RS).

For the physical soil resources inventory agenda to be useful for national asset accounting purposes, there is a need for the BSWM, as the national soil resources mapping agency, to program the following research agenda.

5.6.3 Part 1: Soil Resources Inventory Research Agenda

1. Digitization of the Soil Taxonomy Map at Great Group level. The classification of Philippine soils is based on the USDA Soil Taxonomy System, a six hierarchical level of classification—Order, Suborder, Great Group, Subgroup, Family, and Series. Digitization would enable computer-assisted estimation of area coverage for each of the soil mapping units; and perform other analytical operations. There is a great need to recalculate area estimates per soil mapping unit.

Table 5.27 Area distribution by pedo-ecological zone (BSWM 1993)

Pedo-Ecological Zone	Definition	Area (M ha)	Percentage of total
Lowland	<18 % slope, <100 m elevation, >25 °C	6.583	22
Upland	<18 % slope, 100-500 m elevation, 22.5–25 °C or 8–18 % slope, <100 m elevation, >25 °C	6.836	23
Hilly land	18 % slope, <500 m elevation, <22.5 °C	7.863	26
Highland	>18 % slope, >500 m elevation, <22.5 °C	7.899	26
Miscellaneous	Built-up, river wash, plateau escarpment, etc.	0.837	3
Total		30.018	100

2. One example of what can be done with digitized Soil Taxonomy Map of the Philippines is to overlay the digitized map to the satellite images, adjust the boundaries, and reissue the soil taxonomy maps at national level; adjust delineations at regional levels to conform with land management units as basis for soil resource mapping and reissue the map at regional level.
3. Recompute areas at regional and national levels. While any office can do all these enumerated tasks given a digitized soil map, only BSWM can release official figures on areas of coverage for each major soil classification as the nationally mandated government agency on soil resources mapping. Without these official data on areas of coverage for major soil classification coming from BSWM, there is no way we can do soil resources accounting.

5.6.4 Part 2: Land Resources Inventory Research Agenda

The soil is only a component of land. Besides soils, land resources would include land cover, water resources, climate, people and their socioeconomic and cultural activities.

The country is reported to have 30 million ha. The percentage of area distribution by pedoecological zone is as in Table 5.27.

Based on land classification, the country had 47 % (14,207,582 ha) alienable and disposable lands and 53 % (15,792,418 ha) forest lands (National Statistics Coordination Board 2006; sourced from NAMRIA). Considering that only a major catastrophe such as crustal movement or archipelagic uplift could make possible a major depletion or accretion of land resources, we can physically account for our land resources in terms of utilization or land use.

A major source of information would be the official land use maps released by major government agencies like the forest cover data from the Forest Management Bureau (FMB) and the National Mapping and Resource Information Authority (NAMRIA) both under the Department of Environment and Natural Resources (DENR). It is also incumbent upon the Department of Agriculture (DA) through BSWM to come up with updated agricultural land use map. There are efforts toward this end using satellite imageries and funded under the Unified Enterprise Geographic Information System Project. The Land Use Maps of the two rural development departments should be harmonized; DENR providing the location and areas for alienable and disposable lands and for the nonalienable and nondisposable lands. DA should be able to detail for major and commercially important agricultural commodities the extent of agricultural land uses for those areas covered by alienable and disposable lands. The pending bill in the Philippine Congress for the enactment of the Land Use Act of the Philippines, once approved, should be able to provide not only policy directions but also major data input for an updated land use map of the Philippines. It could be seen that under present condition, NSCB used several data sources to generate their physical land resources inventory.

It is interesting that as part of the commitment of the Philippines to the UN Convention to Combat Desertification (UNCCD), BSWM has been approved by the Food and Agriculture Organization (FAO) of a technical cooperation for land degradation assessment (LADA, originally developed for dryland areas) using the Land Use System (LUS) approach. The project timetable coincides with the writing of this book, and initial output may be available by the time this book is off the press. This is a multi-agency collaboration that also involves the participation of NSCB. The output of this technical cooperation would enable the Philippine land degradation data to be in harmony with the global data and this Philippine LUS Map serves as another possible data source for the estimation of our stock inventory level. LUS Map differs from a Land Use Map in the interpretation of each of the mapping unit.

A *Land Use Map* is generated by a single government agency with a specific mapping mandate. It is frequently confused with *Land Cover Map* and they are often used interchangeably. Land use refers to how the land is used by humans and refers to economic use to which the land is put to use (as commercial, residential, industrial, agricultural, recreational, etc.). Land cover refers to the vegetation, structures, or other features that cover the land (grass, trees, water, etc.). Two mapping units or land parcels may have similar cover but different land use—an example is a grassland consisting of vegetation native to the area and another grassland that is used for pasture. An edifice of course could be a manufacturing plant (industrial use) or an office building (commercial use). Or we can have two mapping units or land parcels that have similar land use but different land cover. An example is a recreational land use such as a golf course with grass for a land cover and a sports arena (or building) as another example of land cover.

On the other hand *LUS Map* is a multi-agency output. A specific LUS is arrived at as an indicator of a land degradation issue, an output of several meetings and consensus among government data and statistics generators. As a land degradation indicator, it would have a definition, a position within the DPSIR logical framework (Driving Forces-Pressures-State-Impacts-Responses), target and political pertinence, methodological description and basic definitions, evaluation of data needs and availability, and the institutional data generator.

We leave it to the resource accountants whether to use Land Use Map or LUS Map for soil and land resources stock inventory. Whichever is chosen, there are still additional agenda that must be addressed:

1. Given the Land Use or the LUS Map, one could play with the spatial data by overlaying these with the soil map, and generate the area per land use per major soil classification per region or province depending on the detail of data extraction desired.
2. It is critical for BSWM to generate soil loss data per unit of major soil classification; or land degradation data per unit of major land use or major LUS. Existing erodibility or erositivity studies per major soil series has to be completed to reliably estimate stock changes. BSWM may also need to reassess its various erosion plot studies to estimate sedimentation rates for major land uses and major soil series and come up with official figures for soil loss estimation purposes.
3. Actually the major issue for land and soil resources accounting is the monitoring of the changes for each accounting period for the closing stock inventory. Without the regular monitoring, we would only have the opening inventory but no closing inventory. But considering the cost—whether by field survey or by use of satellite imageries, it may be more practical to do the land and soil resources accounting every 5 years; or the year prior to the development of the Medium-Term Philippine Development Plan (about 6 years interval) for this output to be of great use to planners and policy makers. Even at this large interval, each updating of spatial data is a major undertaking for which government financial resources would be needed. Without investments in data updating and acquisition, the core accounts of land and soil resources could not be reliably generated. We have to be realistic that reliable data costs money. Without the government providing funds for regular updating of land and soil resources inventory, or providing research funds to assess soil losses given a specific LUS, we cannot generate accurate and reliable data.

5.6.5 Monetary Valuation of Soil and Land Resources

We will leave it to the resource economists to undertake the soil and land resources valuation to estimate the equivalent monetary value. There are several resource valuation methods applicable for our concern—soil and land resources; but for the purpose of this book we will discuss briefly the asset valuation method applied by Francisco (1994) in resource assessment and accounting for soil depreciation of upland soil resources, and part of the ENRA study.

The asset value of the soil resource is estimated in terms of the present value of annual land rent over the accounting, T, plus the present value of the asset in the Tth year. Soil depreciation is subsequently computed as the yearly change in the value of the asset.

In equation format, the asset value which is referred to as the net present value (NPV) is as follows:

$$\mathrm{NPV} = \sum_{n-1}^{T} \frac{\mathrm{LR}n}{(1+i)^n} + K_T \tag{5.1}$$

where:

NPV present value of the asset at year n;
T length of the planning horizon/economic life of the resource
i rate of discount
LR land rent in year n; and
K land value at the end of year T

The economic depreciation is computed by Francisco as:

$$\text{Economic depreciation} = \mathrm{NPV}_{n+1} - \mathrm{NPV}_n \tag{5.2}$$

Francisco's valuation has the following assumptions:

1. Assumes constant prices. The observed changes in the value of the land rent can only be attributed to changes in the yield or productivity of the resource and in the time value of money.
2. The expected value of the resource at the end of the planning horizon is a constant amount, K, which is perceived not to influence the yearly changes in the value of the asset. This assumption is arrived at considering the difficulty in estimating the expected value.

3. Low and high discount rates were used. A low discount rate shows a bias in favor of future consumption while a high discount rate means preference for the present consumption over the consumption at some future time.
4. A reasonable allowance for return or profit on one's investment was assumed and included as part of the costs of production.
5. The variable T was assumed based on the usual length of the planning horizon for resource-based projects.

From Francisco's paper, the reported asset value was PhP242.28 billion using 10 % discount rate or PhP168.75 billion using 15 % discount rate over a period of 30 years for 7.4 million ha of agricultural lands in 1988. On per hectare basis, the asset value was about PhP32,778 or PhP22,830 using the same rates (Francisco 1994).

The resulting economic depreciation of upland soils in the Philippines, given on-site impacts of soil erosion, between 1988 and 1989 was estimated at PhP1.47 billion or PhP0.38 billion using 10 and 15 % discount rates, respectively. Francisco recommended to include the trend in land value to obtain more realistic figures of soil depreciation or appreciation over the years (Francisco 1994).

As Francisco's work was only one from a number of valuation options, a major input irrespective of resource valuation method used, was area distribution per major soil classification or area distribution per major land use or LUS. Physical inventory of our soil and land resources is an important undertaking for any realistic resource accounting. This is a major investment considering the cost of such undertaking but the consequent importance of the data and statistics generated far outweigh data generation costs. Good planning can only be the product of good data. Resource data and statistics generation is worth the investment.

5.6.6 Changes in Stock Inventory

5.6.6.1 Soil Losses

It could be seen that regardless of whether we are referring to physical inventory or to monetary equivalent, an important key data input is an improved estimate of soil losses.

For the Francisco (1994) studies, the extent of soil erosion in the Philippines was calculated using data on area distribution by land management unit and pedoecological zone and the rate of erosion by type of land use. The extent of watershed degradation was sourced from BSWM. Erosion rate for agriculture was estimated by getting the weighted average between upland agricultural lands and fruit trees. Francisco came out with a gross erosion estimate of 2.05 billion tons per year with grasslands as greatest contributor followed by agriculture, and least by woodland. The average rate of erosion is estimated at 80.62 metric tons per hectare per year. She used as standard 3–10 metric tons per hectare per year as the tolerable soil loss. The soil loss data were then converted into equivalent nutrient losses (nitrogen, phosphorus, potassium) and then to fertilizer equivalent. Francisco found the use of Universal Soil Loss Equation (USLE) quite frustrating resulting to widely varying rates of soil loss by land use. It is incumbent upon BSWM to improve the estimation methodology and come up with reliable figures by completing its erodibility studies for major soil series.

5.6.6.2 Soil Erodibility

The erodibility of soils can be described as the sensitivity to the effects of eroding factors like wind and water on the soil structure. It expresses the degree of soil's resistance to two energy sources—the impact of raindrops on the soil surface, and the shearing action of runoff between clods in grooves or rills (FAO 1996). This property is expressed as *erodibility index* defined as the potential soil loss, in tons per hectare per year. The erodibility index is determined by combining the effects of slope and soil type, rainfall intensity, and land use. This BSWM soil conservation research focuses on major soil series, use of rainfall simulator (varying rainfall intensities) under varying slope conditions, and soils sampled based on soil series classification and major land uses. But in the absence of such officially released data for national and spatial erodibility index mapping, studies using GIS and Remote Sensing tools can use spatial data on terrain morphology (for soils and slope; use of Land Management Unit is an alternative), mean annual rainfall, and broad land use patterns to generate estimates. Actually, it is still the amount of soil organic matter and soil texture rather than soil series per se that matters in erosion studies. The use of soil series as a major factor in the analysis of results may only be confusing rather than helpful. Note that in soil survey terminology, soil types refer to the soil series plus soil textural classification. We recommend soil types rather than soil series for erodibility mapping purposes. BSWM is expected to issue updated Regional Soil Series Map. This can be used directly or extract Broad Soil Texture Classification Map from this dataset for use by soil conservation staff in erodibility index mapping.

The Soil Organic Matter Map may not be useful for national erodibility mapping exercise because as a tropical country, the decomposition of soil organic matter is very fast. The organic matter content of Philippine soils ranges from about 1.3–2 %. Andisols or volcanic ash soils would have about 3–8 % and Andisols constitute mere 0.1 % of our total land area. At national level erodibility index mapping, the variation in soil organic matter may not be that statistically significant. The inclusion of soil types

Table 5.28 Summary of spatial and tabular data that must be generated by BSWM to improve soil and land resources inventory stock estimates

Spatial data	Tabular data
Re-issued *soil taxonomy map* (national and regional)	Recalculated area coverage/soil mapping unit (SMU)/region
Land management unit map (national)	Area coverage/LMU or terrain morphology
Agricultural land use map (national and regional)	Area coverage/agricultural land use/region
LUS map (LADA inter-agency output)	Area coverage/LUS; data definition
Soil erodibility index map (national and regional)	Soil loss in tons/hectare/mapping unit
Soil texture classification map (national)	Broad textural classes or clusters/mapping unit
–	Sedimentation losses/major land use/region

would improve the national erodibility estimates. Given the algorithm and the spatial data at national level, it would not even take an hour for computer-assisted national-level estimation using GIS tools.

Monitoring for closing stock inventory purposes would of course require review of the factors. Terrain morphology is constant and unlikely to change. So is the soil type. But mean annual rainfall and land use patterns will definitely change every accounting period. It may be basic upon BSWM to review if not conduct additional erosion plot studies and establish sedimentation rates for major land uses in the Philippines to improve our estimates for soil losses. For USLE to be applicable to Philippine conditions, we must establish the constant for each of the major agricultural land uses (vegetation factor in the equation), preferably by climatic group.

5.6.7 Summary and Conclusion

The agricultural statistics production is domain of the Bureau of Agricultural Statistics. As a member of the DA family, it would be difficult for BSWM to source research funds to generate what can be considered as data elements of environmental statistics. BSWM is clustered with the other research and development (R&D) institutions within the DA family. As a staff bureau, the focus of its soil inventory and soil conservation activities is to support the various national food production programs to attain national food security and self-sufficiency goals. R&D proposals relating to information generation are screened for compliance to thrust and marching orders relating to development of soil and water technologies for sustainable agricultural production.

Efforts to stress BSWM's soil conservation role rather than sustainable agricultural production role could be interpreted as leaning toward an environmental shift. In fact, from its establishment in 1951 as Bureau of Soil Conservation, it was renamed Bureau of Soils in 1964 and further reorganized as BSWM in 1986 to underscore that its soil conservation function is support to sustainable agricultural production. It is not the end but the means.

But the Environmental Management Bureau (EMB) of the DENR also looks to BSWM for the formulation of criteria and standards relating to soil and agricultural land resources conservation and wise utilization and their possible application to nonagricultural areas. EMB policies and regulations concern air and water quality, although quite lately, it has a program on soil quality. Despite BSWM's current program thrust on food security and self-sufficiency through development of sustainable agricultural land management technologies, many of the important soil quality parameters rest with the Bureau. For example, it is BSWM that will assess the extent of soil pollution from mine tailings especially as they affect agricultural areas. EMB will then enforce the soil rehabilitation efforts to mitigate and address the impacts on various affected ecosystems, including agroecosystems. The DENR Policy and Planning Service also looks to BSWM for policy directions on environmental goods relating to soil conservation that could be negotiated for tariff agreements with the World Trade Organization (WTO) members. BSWM is the national focal point of the UNCCD and coordinates all national efforts to address the issue of land degradation. As the mapping arm of the Department of Agriculture, only BSWM can release official data and statistics relating to the improvement of soil and land resources stock estimates. BSWM remains the sole-mandated national agency on Philippine soils.

In the light of these, part of its support to national policies would include these maps and statistics that can be considered as research agenda (Table 5.28).

5.7 Land Degradation Assessment

Land and water resources are the foundation for agricultural production, fisheries, and aquaculture that provide nutrition and income, together with other products for food, fuel, fodder, and building materials. Further, ecosystem services associated with land and water—including surface and groundwater restoration, regulation of extreme climatic events such as floods and droughts and maintenance of biological diversity—provide crucial benefits to both rural and urban populations. The environmentally fragile areas such as upland and mountainous regions where the majority of the poor and marginalized live, have faced deforestation and intensified cultivation leading to soil erosion and fertility losses, increased flood and drought incidents, and altered water flow patterns.

5.7.1 The Philippine Commitment to UNCCD

The quality and management of land resources in the Philippines has become a serious concern because of pressures of exponentially increasing population and the subsequent need to expand agricultural production to marginal areas while ironically converting prime agricultural lands to nonagricultural uses. Population increases and limited land resources are the two most important driving forces of land degradation.

The United Nations Convention to Combat Desertification (UNCCD) is a special United Nations (UN) agenda for poverty reduction in the dry, arid, semi-arid, and dry humid areas, particularly in the African Continent. It was adopted in Paris, France on June 17, 1994, this date being celebrated annually as the World Day to Combat Desertification.

Within the context of the Convention, desertification is defined as land degradation in arid, semi-arid, and subhumid areas resulting from various factors, including climatic variations and human activities. While the Philippines is not within the original geographic limits and do not have the conditions defined by the Convention, it was recognized that the country has become increasingly vulnerable to seasonal aridity, drought, and land degradation. Through the intervention of the Philippines lead by then BSWM Director Rogelio N. Concepcion, the emerging climate phenomenon attributed to the increasing recurrence of El Niño, was accepted in the Convention and was considered as the primary basis for the acknowledgement of desertification in the tropical monsoon countries. The Philippine Senate and House of Representatives jointly ratified the UNCCD on February 10, 2000 and the final accession came into full force in May 10, 2000.

As signatory to the UNCCD, the *Philippine National Action Plan*, the main instrument of the Convention, has done historical analysis of land degradation in the Philippines, identified the forms, causal factors, extent, and distribution of land degradation. There is so much to be desired, however, on the baseline data, and the need to integrate these figures with the global land degradation data. The Program Component 3 of the Philippine National Action Plan calls for database development and harmonization.

The BSWM tried to estimate the land degradation in the country using GIS and their erosion, slope, and land use data. The computer-assisted estimation of land degradation hot spots indicated 5.3 million ha of degraded lands. There is significantly gap compared with the global assessment data of 13.2 million ha for the country. Therefore, there is a strong need to verify and harmonize the Philippine land degradation data with the globally estimated data. Presently, the country has no integrated land degradation assessment information that would include estimates not only from BSWM but also from other resource management agencies like the Forest Management Bureau (FMB) and the Ecosystems Research and Development Bureau (ERDB) of the Department of Environment and Natural Resources.

The primary importance of identifying the degraded and vulnerable land areas is to provide accurate information for identifying unsustainable land use, inappropriate management technologies and sustainable land use planning and policy making.

5.7.2 The Philippine LADA Project

The aim of this initiative is to extend and apply the knowledge, tools and experiences created by LADA to the Philippines. LADA refers to the FAO *Land Degradation Assessment in the Drylands*, as LADA concepts, approaches, methodologies, and tools were originally developed for drylands. LADA started in 2006 with the general purpose of creating the basis for informed advice on land degradation at global, national, and local level. It was implemented in six countries—Argentina, China, Cuba, Senegal, South Africa, and Tunisia. FAO approved a 2 year technical cooperation project in the Philippines on capability building to test the applicability of LADA methodologies for a monsoon country. This is also to harmonize Philippine land degradation data with the global data.

There is so much for Filipino resource managers to learn in this LADA. Land degradation is no longer measured just by concepts relating to soil and productivity losses. The approach is more holistic and encompasses not only biophysical measurements but socioeconomic parameters, as well.

5.7.3 Basic Land Degradation Concepts

While LADA actually is the name of the project executed by FAO with funding from UNEP, GEF, and others; for our purpose *LADA* also refers to a specific set of methodology on land degradation assessment covered by several manuals developed by the project for global, national, as well as local land degradation assessment in *drylands*.

The LADA approach adheres to *DPSIR framework* (Driving forces, Pressures, State, Impacts, Responses). According to this framework, there is a chain of causal links starting with *driving forces* (economic sectors, human activities) through *pressures* (emissions, waste) to *states* (physical, chemical, and biological) and i*mpacts* on ecosystems, human health, and functions eventually leading to political responses (prioritization, target setting, indicators). The set of LADA Manuals for assessing land degradation actually revolves around this basic framework: The root causes and at the same time consequences of land degradation and desertification are often poverty and food insecurity combined with harsh climatic events such as drought, leading to excessive pressures on fragile ecosystems, the natural resource base, and the adoption of resource-depleting survival strategies by the poor.

LADA defines *land degradation* as the reduction in the capacity of the land to perform ecosystem functions and services that support society and development. For the soil ecosystem, these functions and services include biomass production (agriculture and forestry), as platform for human activities, and as regulator of atmospheric, nutrient, and hydrologic cycles.

Land use is considered the major driving force of land degradation. *LUS map* analyzes natural resources, land cover, and socioeconomic data using combination of spatial modeling and expert knowledge. The LUS map units also include other sets of biophysical and socioeconomic information of relevance to land resources and ecosystems degradation that provide a cartographic basis for national assessments. The development of the LUS Map of the Philippines as the means to achieve land degradation assessment at national level is the major output. A detailed land degradation assessment is initiated at the local level and governed by a separate manual.

The analysis of LUS is based on the Mapping Questionnaire (QM) developed by the Geneva-based World Conservation Approaches and Technologies (WOCAT) and is referred to as the *WOCAT QM*. A separate consortium of institutions on sustainable land management constitutes the Philippine Conservation Approaches and Technologies (PHILCAT). The analysis of LUS as land degradation assessment unit refers to set of questions in the WOCAT-QM to which the assessment units (LUS) are subjected to. Since this was originally developed for drylands, adjustments to encompass environmental conditions unique to the Philippines and definition of threshold levels for the required parameters necessitates the development of PHILCAT-QM to set the standard for detailed evaluation of LUS mapping units. The PHILCAT-QM covers only parameters and issues not addressed by the WOCAT-QM.

5.7.4 The Philippine Land Use System

As Party to UNCCD, the Philippines will have to report at this international body a regular assessment of the state of land degradation.

The LADA methodology is founded on the DPSIR Analysis—Driving forces of land degradation, Pressures, State, Impacts, and Responses. Land use change is seen as the most important driving force in land degradation and considered the most suitable units that capture the status and causes that influence land degradation and the appropriate sustainable land management interventions. This is the core database for LADA and used to link local to national to global land degradation assessments. In LUS, we consider not only the specific land cover but also the type of management and inputs. When linked with the ecosystem where they occur and with the prevailing socioeconomic context, what we have is not only a land use but also a set of attribute data that capture the driving forces, pressures, state, impacts, and responses in terms of sustainable land management interventions and policy options.

For preliminary analysis and stock taking and using ArcGIS 10, the 2003 Landsat-based Land Cover Map produced by the National Mapping and Resource Information Authority (NAMRIA) was used. This 2003 Philippine Land Cover Map by NAMRIA originally had 23 classes but based on LADA manual, was reclassified into 9 ecosystems based on land cover and these ecosystems were further classified into 14 major land uses.

Although the manual specified segregation based on livestock density, aggregations were made for the irrigated and rainfed areas because livestock is not really associated with wetland rice and upland crop production in the Philippines. Livestock is generally associated with backyard (domestic or household level of production) and pasture/grassland areas (commercial production). Table 5.29 presents the summary and the definition of the LUS classes. The definition takes into consideration the Forest Management Bureau (FMB)—International Tropical Timber Organization (ITTO) reference on standardization of forestry terms and terminologies. It should also be further noted that because the Republic Act 7586, also known as the National Integrated Protected Areas System (NIPAS) Act of 1992, which provides the legal framework for the establishment and management of protected areas in the Philippines, cuts across the LUS definitions, and many of these protected areas are not necessarily free of inhabitants (some of these are protected landscapes and seascapes), we have also parceled out the protected areas according to the LUS where it should properly belong. The Philippine LUS will be used to integrate Philippine data with the global data and appears to be the best data source for the most current official land use figures and can be adopted for major policy studies, especially those relating to land uses. Figure 5.37 presents the 2003 LUS Map of the Philippines.

Table 5.29 Summary of 2003 Philippine LUS (*Source* BSWM-FAO-LADA project, figures as of August, 2012)

	LUS Class	Technical Description	Area (ha)
1	Rice, irrigated	This covers irrigated agricultural lands. While the *Total Livestock Unit* was computed based on the LADA Manual, livestock raising is not really associated with irrigated agricultural lands. These areas are characterized by numerous small farms or field units (less than ±10 ha) in close proximity to rural population centers. Field units can either be grouped intensive or widely spaced, depending on the extent of the area under cultivation and the proximity to rural dwellings and grazing areas. Includes irrigated (i.e. mechanical or gravity-fed), multicropping of annuals, for either individual or local (i.e. village) markets. May include fallow and 'old fields', and some inter-field grazing areas (After WOCAT-QM manual, Liniger et al. 2008). These areas total to about 1.5 million ha. At the moment, about 1.2 million ha are in map form. The remaining 0.3 million ha represent an aggregation of small fields not captured in the current map scale. This LUS also includes 8,844.79 ha of protected areas under PAWB jurisdiction	1,272,283.18
2	Rainfed agricultural lands	This covers non-irrigated and rainfed agricultural lands. Although the *total livestock unit* was computed based on the LADA manual, livestock is not really associated with this LUS. Characterized by numerous small farms or field units (less than ±10 ha) in close proximity to rural population centers. Field units can either be grouped intensive or widely spaced, depending on the extent of the area under cultivation and the proximity to rural dwellings and grazing areas. Field units are rainfed, multicropping of annuals, for either individual or local (i.e. village) markets. May include fallow and 'old fields', and some inter-field grazing areas (After Liniger et al. 2008)	10,006,545.25
	2a-Rice and corn lands	Lowland and upland areas under rainfed/upland rice and corn-based cropping systems	(6,044,257.57)
	2b-Sugarcane lands	Lowland and upland areas under sugarcane-based cropping system	(374,996.77)
	2c-Coconut lands	Lowland and upland areas under coconut-based cropping system	(3,562,485.22)
	2d-Diversified upland crops and fruit orchards	Lowland and upland areas under a mix cropping system, both perennials and annuals	(24,805.69)
3	Forest, protected	National Parks, Provincial Nature Reserves, Bird Sanctuaries, Botanical Gardens, Conservation Areas, National Heritage Sites. Excludes private game farms, private nature reserves and state land. They are included in the related natural vegetation biomes. Also includes all forestlands under NIPAS and the expanded NIPAS covering 1,490,693.87 ha under PAWB jurisdiction (*Source* DENR)	6,286,312.17
4	Forest, plantations	Forest stands established by planting or/and seeding in the process of afforestation or reforestation. They are either : introduced species (all planted stands), or intensively managed stands of indigenous species, which meet all the following criteria: one or two species at plantation, even age class, regular spacing (*Source* DENR). Includes "Agroforestry" or areas of the Philippines classified as forest lands that are under some forms of Community-Based Forest Management Program. Includes 5,164.49 ha of protected forest plantations under PAWB jurisdiction	1,045,681.18
5	Grasslands, unmanaged	Natural grassland; No significant sign of human activity. Includes 171,120.65 of protected grasslands under PAWB jurisdiction	3,164,905.32
6	Grasslands with very low to low livestock density	Grasslands are defined as those areas where grasses dominate the vegetation and where woody plants are absent or rare; With low livestock density equivalent to TLU/km2 of 0.0–0.87 (After Liniger et al. 2008), Includes 115,289.76 ha of protected grasslands with very low to low livestock density under PAWB jurisdiction	1,526,856.43
7	Grasslands with medium to high livestock density	Grasslands are defined as those areas where grasses dominate the vegetation and where woody plants are absent or rare; With high livestock density equivalent to TLU/km^2 of 0.87–1.65 (After Liniger et al. 2008). Includes 5,320.47 ha of protected grasslands with high livestock density under PAWB jurisdiction	144,267.83
8	Shrubs, unmanaged	Refer to vegetation types where the dominant woody elements are shrubs i.e. woody perennial plants, generally of more than 0.5 m and less than 5 m in height on maturity and without a definite crown. The height limits for trees and shrubs should be interpreted with flexibility, particularly the minimum tree and maximum shrub height, which may vary between 5 and 7 m approximately (*Source* DENR). Includes 370,033.28 ha of protected shrubs-unmanaged under PAWB jurisdiction	5,009,810.86

(continued)

Table 5.29 (continued)

	LUS Class	Technical Description	Area (ha)
9	Forest, mangrove	The type of forest occurring on tidal flats along the sea coast extending along the streams where the water is brackish and composed of mainly Rhizopora, Bruguiera, Ceriops, and Nipa species (*Source* DENR). Includes 22,804.32 ha of protected forest-mangroves under PAWB jurisdiction	212,256.80
10	Wetlands, unmanaged	Refer to inland and coastal habitats linked by rivers and streams. These wetlands share common and important functions in river catchments by providing a regular water supply, by filtering the water naturally, by reducing the effects of floods and droughts, and by providing a vital wildlife habitat and ecotourism. Most wetlands are characterized by a high water table, water-carrying soil and hydrophytes (water-loving plants) (After Liniger et al. 2008). Includes 58,901.26 ha of protected wetlands-unmanaged under PAWB jurisdiction	154,405.32
11	Open water, inland fisheries, brackish water	Areas of (generally permanent) open water. The category includes both natural and man-made waterbodies, which are either static or flowing, brackish and salt-water conditions (After Liniger et al. 2008). Includes 3,443.54 ha of protected open water-inland fisheries-brackish water under PAWB jurisdiction	189,596.81
12	Open water, inland fisheries, freshwater	Areas of (generally permanent) open water. The category includes both natural and man-made waterbodies, which are either static or flowing, and freshwater condition. This category includes features such as rivers, major reservoirs, farm-level irrigation and stock watering dams, permanent pans, lakes and lagoons (After Liniger et al. 2008). Includes 41,696.82 ha of protected open water-inland fisheries-freshwater under PAWB jurisdiction	261,204.52
13	Bare areas, unmanaged	Also Barren land; Absence of vegetation, including area with less than 4 % vegetative cover; no significant sign of human activity. This includes bare rock and sand dune areas. Also includes 1,997.82 ha of protected bare areas-unmanaged under PAWB jurisdiction	99,783.41
14	Urban	Areas used for or covered with built-up elements of the residential, commercial, industrial, or institutional sector (Choudhury and Jansen 1998). Includes 6,233.12 ha of protected areas under PAWB jurisdiction	222,584.27
Total			29,596,493.35

5.7.5 Comparing GLC2000 Against GC2009

Originally, the plan was to compare NAMRIA Land Cover2003 against the downloaded GlobCover2009 (GC2009) data for the detection of land cover changes to derive the so-called hot spots for further detailed land degradation assessment. However, since the two datasets (2003 and 2009) were not sensibly comparable and that it was impossible to source out a more recent land cover data from NAMRIA, an earlier global cover data was sourced out to proceed with land cover change detection exercise.

GlobCover2008 which has similar geometric specifications with GlobCover2009 was downloaded; however, the detection of changes between the two imageries were very minimal, perhaps just pixels showing "noise". So the remaining option was to use another downloadable global data from the Global Land Cover 2000 (GLC2000) project (Joint Research Centre 2010). The imagery also presents land cover classes but the pixel resolution was 1 km by 1 km and coarser than GlobCover2009 which has pixel resolution of 300 m by 300 m.

5.7.5.1 The GLC2000

In collaboration with a network of international partners from around the world, the Global Vegetation Monitoring (GVM) unit of the Joint Research Center (JRC) compiled a harmonized land cover classification for the year 2000 using data acquired by SPOT4 Vegetation instrument covering 14 months of pre-processed daily global data (Joint Research Centre 2010). From this dataset, we obtained and processed the Philippine coverage into LUS Map following the same procedures for the 2003 NAMRIA land cover map. The Philippine coverage for the GLC2000 is presented as Fig. 5.38.

5.7.5.2 The GC 2009

The European Space Agency's (ESA's) 2009 global land cover map has been released and available online from the ClobCover website. The map was produced using 12 months of data from Envisat's Medium Resolution Imaging Spectrometer at a resolution of 300 m (European Space Agency 2011). The map legend uses the UN FAO Land Cover Classification System. The GC 2009 coverage for the Philippines is presented as Fig. 5.39.

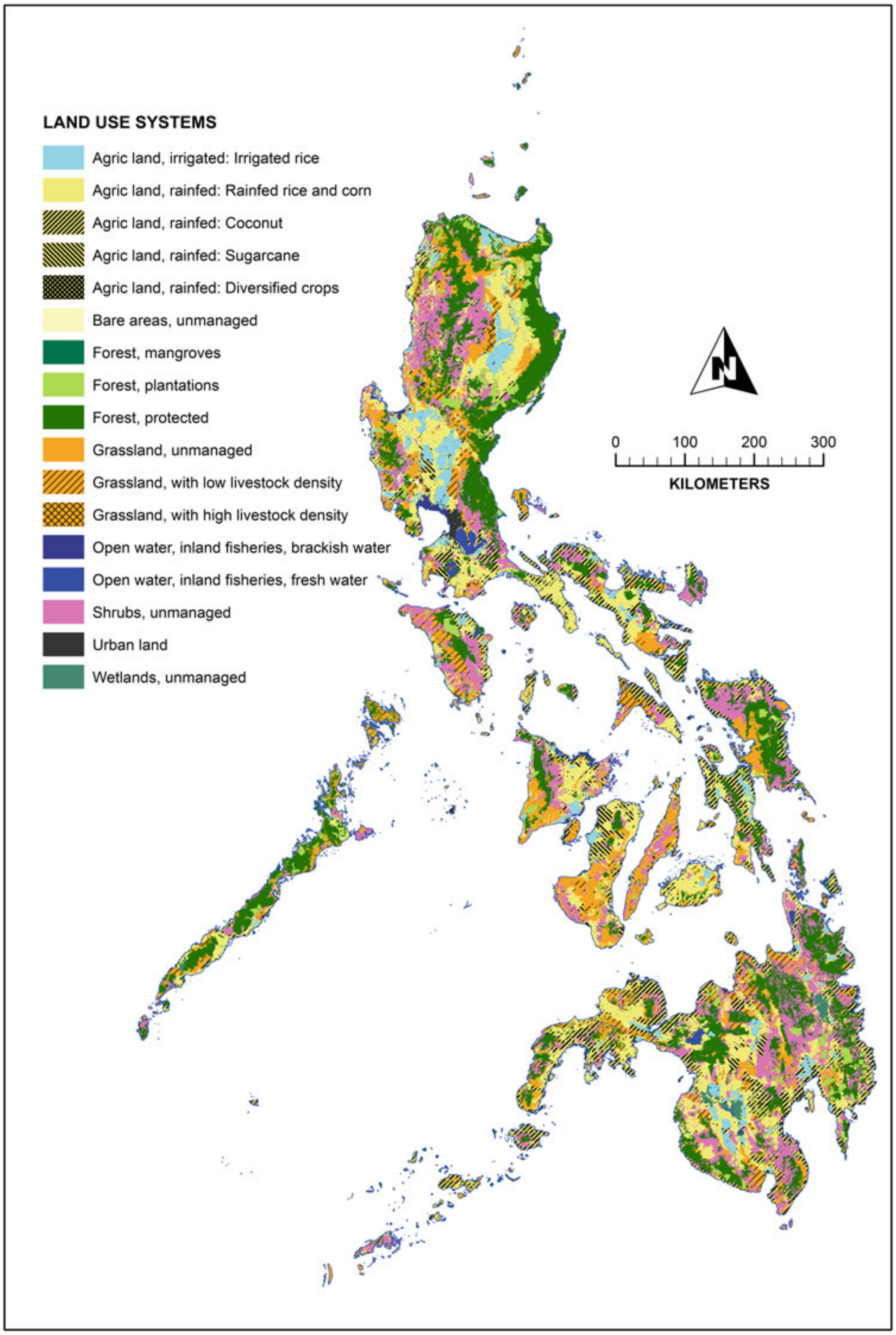


Fig. 5.37 2003 land use map of the Philippines

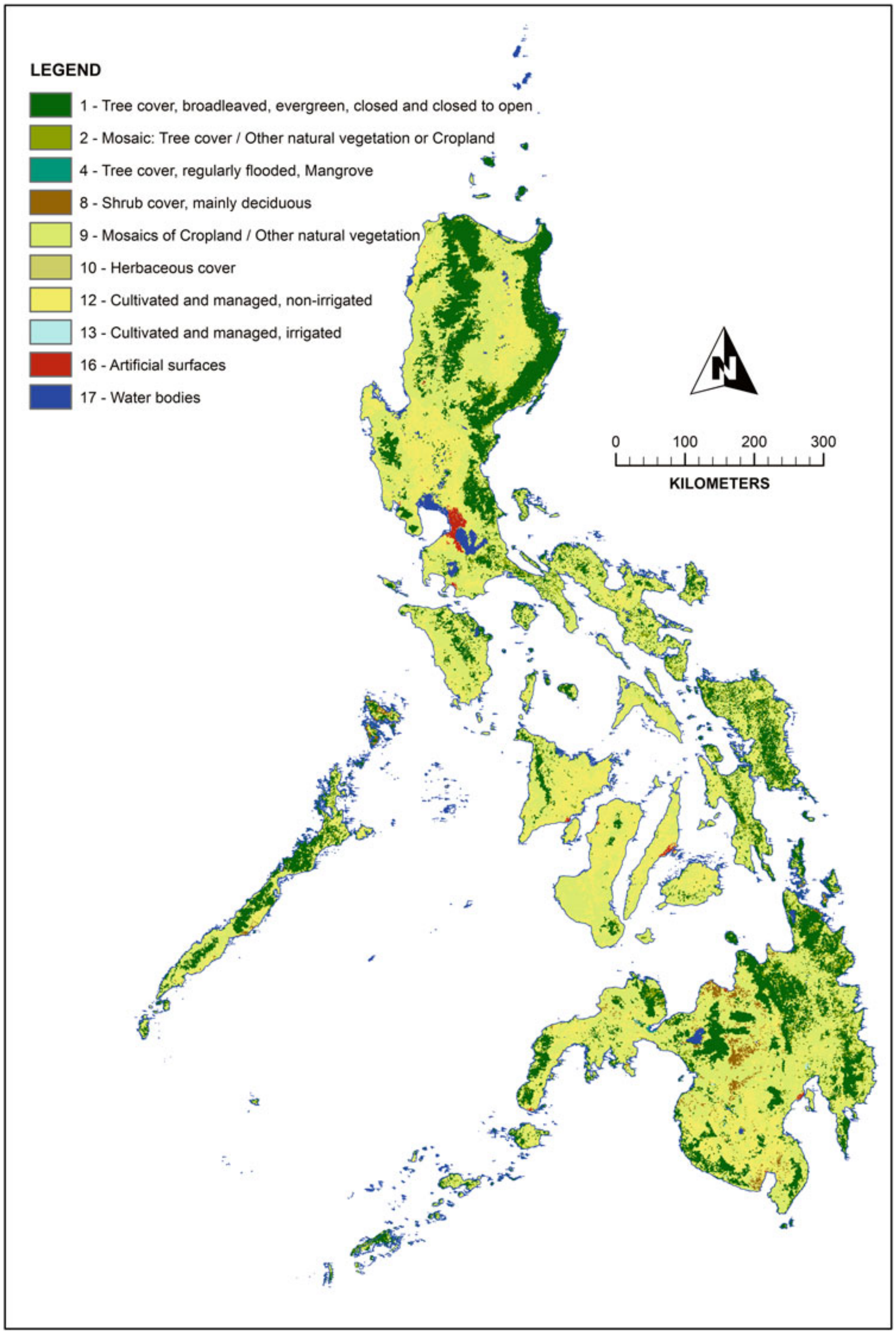
5.7.5.3 The GC2009 Overlaid on GLC2000

Figure 5.40 presents the results of the overlay. The red colored mapping units represent the change in land use. It can be seen that most of the forest edges have been encroached by other land uses.

Please note of inherent limitations of our change detection analysis particularly some unrealistic (not sensible) land cover changes which may be partly attributed to the following:

1. Errors due to different pixel resolutions: GLC2000 has about 1 km × 1 km while GC2009 has 300 m × 300 m, land cover that can still be discriminated into different classes by the 300 m × 300 m image would not be recognized by a 1 km × 1 km image. A number of examples can be illustrated by some known water bodies (lakes) that were not detected by GLC2000 but were clearly mapped by the GC2009. This

Fig. 5.38 Philippine land cover map based on GLC2000



would result into a detection of change from for example forest into water body or shrubs into water body or agricultural land into water body.

2. Spectral limitations of the imageries to segregate land cover classes: For example, the identification between forest and shrubs may be based on contiguity of canopies, thus shrubs that are clustered closely may be identified as forest. Thick vegetation along agricultural lands may also be identified as forest in the imagery which may only be closely clustered fruit trees on the ground. The difficulty in discriminating agricultural lands against shrublands and even grasslands may also be attributed to spectral limitations of the imageries.
3. Inter-seasonal variation: this is another limitation of the imageries being used, the production of GC2009 for example was mosaicked from a number of multitemporal datasets, hence cutting across different seasons. Imageries of the same area during the dry season would

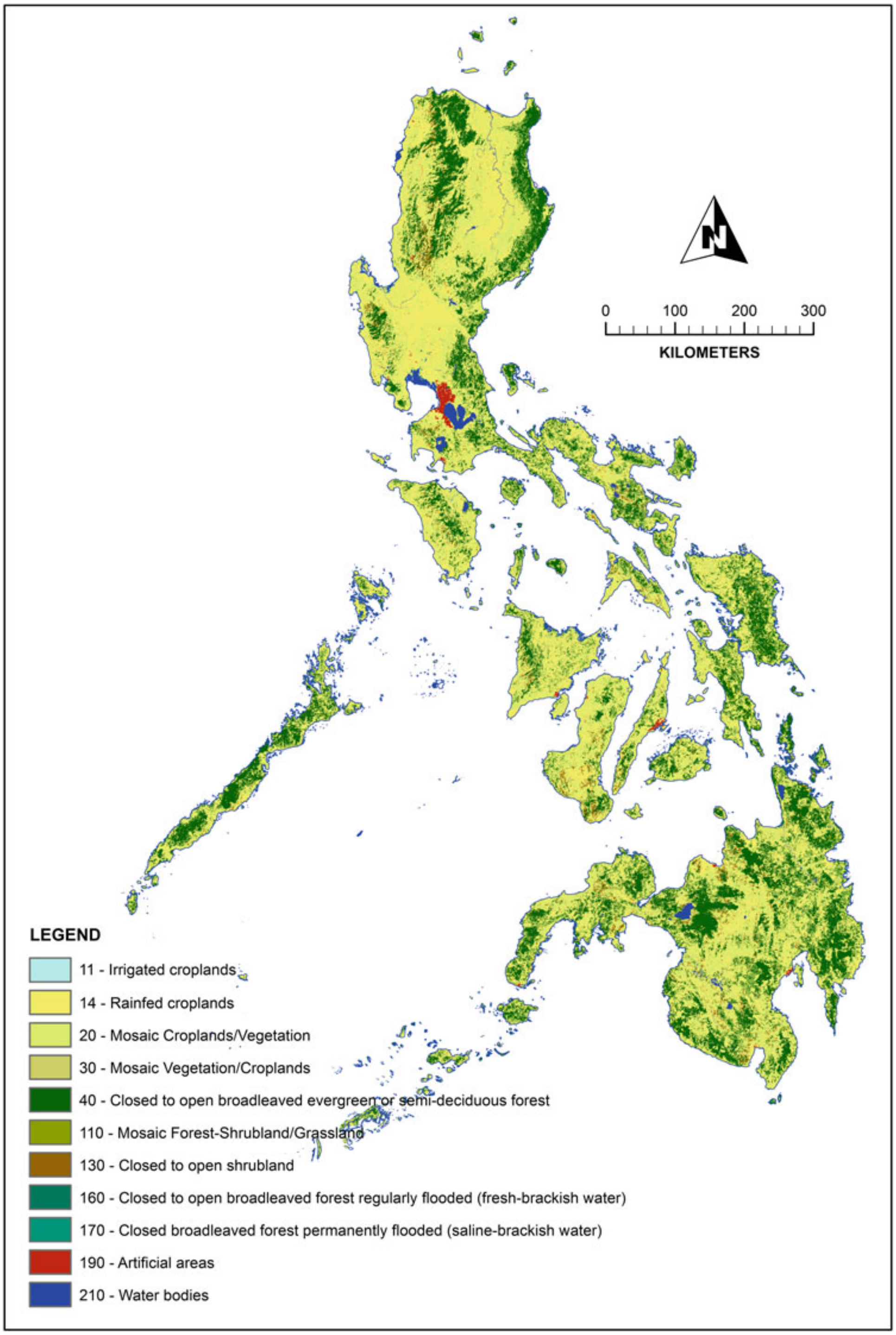
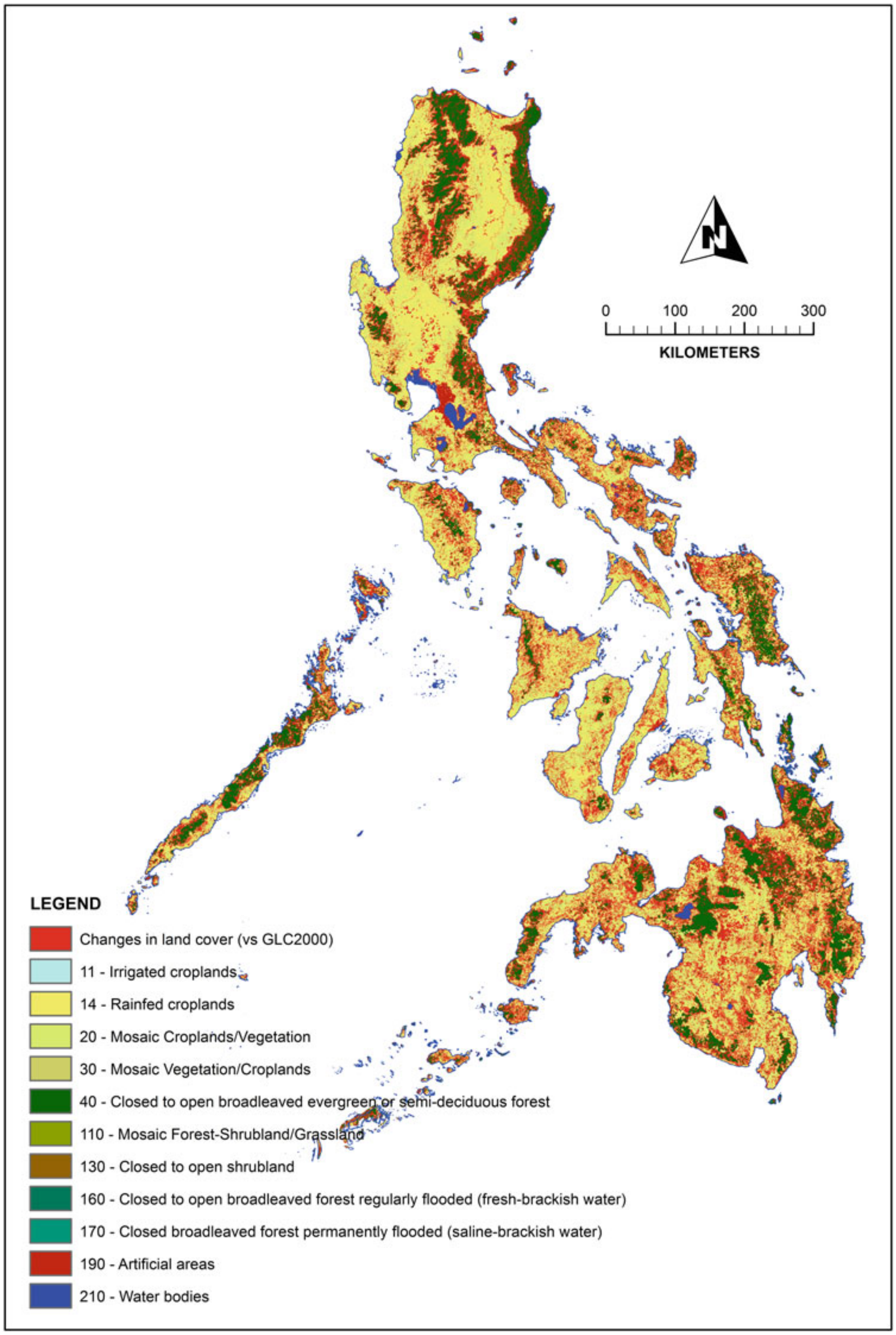


Fig. 5.39 Philippine land cover map based on GC2009

significantly be different during the wet season. Rice paddies for example may be identified as water bodies when waterlogged during the start of the wet season, while simply agricultural land or even grassland during the dry season. Shorelines of lakes are also affected by inter-seasonal variation, during the dry season lakes may have less water hence receding shorelines, and vice versa during the wet season. This may help explain some land cover changes that tend to show for example shrubs to water body or water body to agric land.

4. Intertidal variation: significant differences may also be identified when imageries are taken during high tide as against low tide. Some mangroves or other vegetation may disappear during high tide while detected as forest during low tide. Coastlines may also be significantly

Fig. 5.40 Results of overlay of GC2009 with GLC2000



different between high and low tides, resulting to significant land cover changes along the coasts.

5.7.5.4 Summary of GC2009/GLC2000 Land Use Changes

Despite the data limitations, the change detection exercise between GLC2000 and GlobCover2009 provided some reasonable areas of land conversions or changes in land cover which could be further pursued for a closer land degradation assessment at the national level. As could be seen, most of the forest edges have been converted from other land uses. The pixel-by-pixel comparison between GLC2000 and GC2009 do not make sense as the total areas for the LUS mapping units are far above national statistics.

As available global land cover maps could not be overlain on the official 2003 Philippine LUS Map since the earlier NAMRIA land cover maps (e.g., 1998 edition, or earlier) are not compatible for overlay using GIS softwares, we rely on official statistics to conduct our DPSIR analysis.

5.7.6 The Agricultural Lands

5.7.6.1 State of Irrigated Rice Lands in the Philippines

The 2003 Philippine LUS Map estimates irrigated lands at 1,272,283.18 ha. As per FAO report, close to 3.31 million ha are devoted to rice. But what is actually reported to FAO as correlated by the Bureau of Agricultural Statistics (BAS) report, is rice area harvested. Since we have two cropping seasons, the rice area is around 1.6 million ha. The Philippine has about 1.4 million ha of irrigated lands, the rest of the rice areas are rainfed, with more than half devoted to rainfed lowland (wetland rice) and the remaining are rainfed upland rice. Of the irrigated areas, only about a third constitutes large reservoir-backed national irrigation systems constructed in the 1960s and 1970s. By 1980s up to the present, the nature of capital investments in irrigation is for small communal irrigation systems. About two-thirds of the irrigated lands are too small to be reflected on national maps, farmer-operated and managed.

Around 1.27 million ha of National Irrigation Systems (NIS) service area as reflected in the PhilLUS are results of actual mapping by the National Irrigation Administration. We have additional paddy areas coming from the Communal Irrigation Systems (CIS) service areas that were not mappable. The total CIS areas could reach up to 500,000 ha but only presented as point data in the NIA map. The rest of the area devoted to rice is either under fallow, newly harvested, or yet to be planted, or under relay intercrop to catch the remaining moisture (usually onion, watermelon, etc.). The PhilLUS Map Version 1.2 gives us a real-time picture of the rice areas at the time the satellite image was taken.

We can conclude that as of 2003, the initial version of PhilLUS Map for irrigated rice tallies with national statistics. There has not been a significant decrease in irrigated rice areas considering that the FAO report quoted was published in 2010. This is a bright spot. But this does not mean there are no challenges and concerns to hurdle.

5.7.6.2 State of Rainfed Areas in the Philippines

The rainfed or nonagricultural areas in the Philippines based on the 2003 PhilLUS Map is 10,006,545.25. This is broken down as follows:

Upland rice and corn	6,044,257.57
Sugarcane	374,996.77
Coconut	3,562,485.22
Diversified upland crops and fruit orchards	24,805.69

The FAO (2010) report also mentions that we have an average 3.34 million ha for corn, 673,000 ha for sugarcane, 4.25 million ha for coconut, 591,000 ha for industrial crops, 148,000 ha for vegetables and rootcrops. Additionally, the cutflowers occupy about 133,000 ha. This totals 9,150,000 ha. There is another 2.20 million ha devoted to nonfood crops. Corn area, based on available local statistics, is reported just like rice, in terms of area harvested; and at two cropping seasons, the actual area coverage would be about 1.67 ha. The adjusted total for rainfed rice based on FAO estimate is 9.665 million ha. This is rather close to the PhilLUS estimate at 10 million ha.

This rainfed areas in the Philippines is also a bright spot. This of course does not mean that the rainfed agricultural sector is not beset by land degradation issues.

Total agricultural areas in the Philippines Based on 2003 PhilLUS Map, the total agricultural areas stand at 11,278,828.43 ha.

The adjusted FAO estimate for the total agricultural areas in the Philippines is 11.31 million ha. The estimate is significantly close to the 2003 PhilLUS Map.

The latest available statistics from the Bureau of Agricultural Statistics (BAS) is for the year 2002 at 9 million ha, and before that is 1998 census which placed agricultural lands at 11 million ha. This only shows that we were able to maintain our agricultural areas since 1998, and any changes reflects the dynamics of crop area production as affected by several factors. There are many literatures that cited the 2002 BAS statistics claiming that we now have only 9 million ha of agricultural lands. Based on the PhilLUS estimate, we have kept our agricultural lands at 11 million ha and the 2002 BAS statistics is part of the dynamics of agricultural economics and environmental production and represents the yearly ups and downs of agricultural production scenario.

Although we consider this as a bright spot, agricultural lands remain threatened by conversion to nonagricultural use. The total agricultural areas approved for conversion to nonagricultural uses from March 1988 to June 1995 from the Department of Agrarian Reform (DAR) is 14,739 ha. Region IV has the largest at 7,029 ha and Region III follows at 2,223 ha. The total applications received were 33,707 ha of which 17,348 ha were exempted through Department of Justice Opinion 44. These figures exclude unrecorded or illegal conversions.

Agriculture is also a threat to forest lands as opened up forest due to commercial and illegal logging are eventually converted to agricultural lands. Forests destroyed for mining purposes, however, are rarely converted to agricultural use.

5.7.6.3 Driving Forces

A driving force is a need. For irrigated rice, the need is for more living and working space. The primary driving force to convert irrigated rice lands is the competition for more economic gain from other land uses—primarily from housing, commercial, and industrial, as the country's population increases. It is no secret that so much rice areas adjacent to Metropolitan Manila and other highly urbanizing areas have been converted to nonagricultural uses. Bulacan and Pampanga in the north, Laguna and Cavite in the south, and Rizal in the east are the provinces that have received the brunt of encroaching urbanization.

For the rainfed agricultural areas, losses to nonagricultural areas are generally compensated by gains from forest lands as these are converted to agricultural uses. Of the 30 million ha that constitutes the Philippines, we have around 15.88 million ha as forest and considered non-alienable and nondisposable lands. We have 14.12 million ha as alienable and disposable, generally titled and privately owned. In the Philippines, forest is defined as areas with slopes higher than 18 %. The BSWM estimate for areas with slopes 18 % and higher is 15,182,432.93 ha and very close to the forest estimate. We therefore set 15 million ha as the threshold for ideal minimum forest cover. Lower than this figure means encroachment of other human activities on lands with higher than 18 % slopes. At current estimate of 7 million ha of forest lands, this shows that rainfed agriculture and other human activities have encroached on about half of our forest lands. This should also explain why studies based on satellite imagery affirm current agricultural area at 11 million ha despite significant losses to other nonagricultural uses. Although the GC2009/GLC2000 cannot be used for cell-by-cell analysis, this exercise remains useful because the overall picture shows that most of the forest edges were converted to other land uses in span of 10 years. The opening of forest for agricultural uses is basically hinged on socioeconomic forces as unskilled lowlanders are driven to the mountains for lack of economic opportunities. Demographic and economic factors are the driving forces for conversion of forest lands into agricultural areas.

5.7.6.4 Pressures

Pressures are driving forces that lead to human activities that exert stress on the environment; as a result of production or consumption processes which can lead to changes in land use.

For irrigated rice lands, the conventional thinking is the social and economic mood that convince rice land owners to convert their land holdings into residential, industrial, and recreational uses. There are now insights on essential element of politics of urban-rural relations that facilitated the conversion (Kelly 1998). As these former rice areas became export processing zones, hospitals and universities, residential subdivisions, golf courses, resorts and theme parks, we have a reworking of social and economic, as well as physical landscape, and we have less dichotomy between rural and urban setting, which from Kelly's studies is an intensely political process.

For the rainfed agricultural areas, declining productivity leads to agricultural expansion in marginal and forest lands. Poor agricultural intensification, slash-and-burn agriculture, and deforestation are the additional pressures to convert forest and other marginal and ecologically fragile lands to agricultural production. The lack of economic opportunities in the lowlands and the opening of forest lands through logging and other economic opportunities (such as geothermal plants, mountain resorts, etc.) provide incentives for road construction and eventual opening up of forest to local inhabitants. To prevent further expansion of agricultural areas into forest reserves, the improvement of agricultural productivity in existing rainfed areas and the generation of other income opportunities have to be addressed. But similar to irrigated rice lands, the opening up of forest lands for agricultural land use is run by power politics, and we could not ignore the influence of political power and vested interests.

5.7.6.5 Impacts

The decrease in area of our irrigated rice lands in favor of nonagricultural uses certainly impacts food security. The country is already a rice importer to tide the population over the next harvest season. Rice importation is also a means to stabilize the price of this staple food. But a huge food import exposes the country's vulnerability to global food supply and demand scenario. With limited rice areas, and insufficient rice harvests to feed the country's increasing population, the conversion of rice areas to nonagricultural uses exacerbates further the situation. But what is ironic is that owing to natural physiography, the soil properties of most of the rice areas are suited best for rice production, and conversion to nonagricultural uses has limitations since these areas are flood-prone and they are generally characterized by the presence of heavy cracking soils which have bearing on the quality of life of those who opted to live or work in these former rice areas. The additional civil works investment on flood control alone is gargantuan. Overcoming the cracking properties of soils is another financial drain for nonagricultural uses of rice soils. Just a look in the major highways alone, these former rice areas are repaired more often than the other portions, leading to national jokes that these parts of the highway are most probably subcontracted to corrupt Filipino engineering companies and those that withstand the test of time are subcontracted to Korean or Japanese companies. We have failed to realize that some of these are former rice paddies with soil properties best suited to the growing of rice and not for road, neither for home, much more for industrial nor commercial uses.

For the rainfed agricultural areas, the decline in land productivity because of unsustainable land management practices is the major impact. Agriculture is nutrient mining and should be considered exploitative in nature. Until we address this issue and promote sustainable land management practices, the continuing encroachment of rainfed agricultural areas in forest lands will be undeterred.

5.7.6.6 Responses

The national government recognizes the threat of continuing conversion of rice areas to non-agricultural uses and responds to avert further conversion of the remaining irrigated rice lands. There are both policy and productivity enhancement responses. Irrigated as well as irrigable lands cannot be converted to non-agricultural uses. Agricultural zoning is also mandated upon the local government units. The government food production program promotes productivity enhancing projects revolving the use of good seeds, fertilizers, irrigation, postharvest facilities, financing, and marketing. The national irrigation systems are handled by the National Irrigation Administration (NIA) while the Department of Agriculture supervises the National Rice Program for productivity enhancement.

To address further encroachment of rainfed agricultural areas into forest lands, reforms in the forestry policies will have to be coupled by the promotion of sustainable land management practices in existing rainfed areas. Currently, the government agricultural program for these rainfed areas are commodity based. The Philippine Coconut Administration (PCA) for example handles the sustainability and productivity improvement of coconut-based farming systems. The Sugar Regulatory Administration (SRA) is in-charge of the sugar industry. The Department of Agriculture handles the corn as well as the high value crops program.

5.7.7 The Forest Lands

5.7.7.1 State of Forest Lands in the Philippines

We have earlier established 15 million ha as the threshold for ideal minimum forest cover for the Philippines based on the forest definition as lands with slopes of 18 % or higher. From the 2003 PhilLUS Map the sum of the forest protected (6,268,312 ha) and the plantation forest (1,045,681 ha) which includes community-managed agroforestry plantations is 7,331,993 ha.

Actually, there is even an increase in forest if we consider that the published total forest area in the Philippines is 7,162,000 ha. However, we assume this forest data, obtained during the 2003 National Inventory, is also sourced from the same satellite imagery processed by NAMRIA, which is the base of the PhilLUS Map. The 2003 PhilLUS Map just affirms existing forest figures for the country at 7 million ha, and the two figures can be considered not statistically different.

The 1969 National Forest Inventory places the forest at 10.6 million ha while the 1988 Survey of National Forest Resources records 6.4 million ha. In effect, we have even increased our forest resources since the last forest inventory. This is certainly another bright spot for the country. It represents a positive impact of government efforts to address forest denudation. Nevertheless, if our threshold value for forest would correspond to the slopes higher than 18 %, which is 15 million ha, this is still a long way to recover the ideal area for forest cover. Whether the country will recover this original forest coverage is to be seen. Efforts are focused on conserving and preserving whatever is left of our forest resources.

5.7.7.2 Driving Forces

Increasing population is cited as one of the major driving forces for migration into the uplands which started at the turn of the century and turned for the worst in the 1960s when forest areas were opened up by logging and facilitated by establishment of logging roads. (Forest Management Bureau 2009). Quoting Sajise (1988), the FMB paper estimated that the upland population is more than 20 million people comprising of indigenous people and migrants. Of these, 11 million are estimated to be residing within the official forest lands (Cruz et al. 1992).

Others moved into the forestlands in search for lands to cultivate, burning the residual forest to clear the land for planting of short rotation crops with some perennials. Initially, the lands are fallowed but as the population increases and the competition for the land became intense, the fallow period became shorter and the land became degraded. Without an effective population program, even to the present as the legislative body still debates, lingers, and eventually enacted the Reproductive Health Bill, which the Catholic Church is vehemently against, the country's population continually expands to the forestland and the cycle of forest destruction—land degradation—and poverty will continue.

5.7.7.3 Pressures

The increasing intrusion on the country's forest lands diminishes its extent to barely half of the nonalienable and nondisposable area, and the number of qualified voters occupying forestlands is sufficient to exert political influence. In the Philippines, it appears that the presence of communities in forestlands is undeniable, and the only option is to face this fact squarely. Modern conservation philosophies promote the concept of harnessing the people as part of the solution. In the case of populated forestlands, participatory management options or provisions for tenureship through principles of forest co-stewardship is considered as part of the evolving policy shift on forest management. Nevertheless, the presence of communities in the forestlands highlight other issues like biodiversity, wood energy, land degradation, climate change, poverty.

Logging, whether legal or illegal certainly is pointed out as the major cause of deforestation, loss of biodiversity, and forest fires. Illegal logging has its economic roots compounded by weak governance and corruption.

Mining is another major economic activity that seriously affects the extent of forest coverage. Not only it destroys the forest, it strips also the land of its soil resources to obtain the precious ore leaving behind destructive mine tailings and overburden. The economic value of minerals is also an important pressure to consider that propels destruction of forest cover and bring about irreversible effects on communities and ecosystems downstream. Mining leads to direct forest losses due to the clearing of the land and the stripping of mountains. But as long as there are ores and minerals underneath the forest and the demand for metals and minerals remain economically attractive, it will inevitably attract prospectors and developers.

5.7.7.4 Impacts

The denudation of forest through logging and the cultivation of sloping lands bring with them increased erosion, sedimentation and siltation of river systems, landslides and avalanches, flooding, fish asphyxiation in rivers and lakes, loss of biodiversity and consequent species invasion resulting in choking of river outlets and increased pest and disease incidence in upstream and downstream communities.

Mining not only destroys the forest and bring about loss of wildlife and biodiversity, but also strip our mountains for ore and mineral resources leaving trails of destruction on environment, farmlands, coastal ecosystems like mangroves and corals which provide livelihood for already impoverished upland and lowland communities. The verifiable economic benefits from mining has to be reviewed in terms of environmental, social, cultural, and economic costs.

5.7.7.5 Responses

FMB, the Philippine forestry agency, strategies for effective governance in the forestry sector, includes stabilizing forest policies through effective implementation, a shift from a regulatory mindshift to a development mindshift, improving the investment climate in the forestry sector, and develop an effective and efficient system of environmental users' fees. The basic forestry policy is the Revised Forestry Code, Presidential Decree No. 705 issued in 1975 during the Marcos' Martial law regime. Additionally we have the National Integrated Protected Areas System (NIPAS) Law, and the Wildlife Conservation and Protection Law.

The Timber License Agreement (TLA) has been replaced by other forms of tenure that are consistent with the Constitutional mandate to access natural resources through joint venture or sharing agreements. Community-Based Forest Management (CBFM) is a paradigm that involves communities in sustaining forest through projects such as timber harvesting, agroforestry, and livestock raising, with varying levels of success. In addition to nationally funded social forestry projects, the Local Government Code of the Philippines provides that municipalities should implement community-based forestry projects, entering into Memoranda of Agreement with DENR.

Additional laws relating to decentralization of forest management include the Congressional enactment of Indigenous Peoples Rights Act of 1997 where indigenous peoples were given the right to have titles to ancestral lands and domains. About 5.9 million ha were covered by Certificates of Ancestral Land/Domain Titles. (Forest Management Bureau 2009). In addition, through Executive Orders, about 685,000 ha of forestlands were under the management of government owned or controlled corporations, mostly watersheds for hydropower, geothermal, and irrigation systems.

We also have the Philippine Mining Act of 1995, and the Executive Order No. 79 signed by President Benigno S. Aquino III in July 2012. There are the usual oppositions to the presidential issuance as inimical to the interest of the environment and the majority. The Executive Order is intended to harmonize mining policies and regulation and leaves it to the LGUs to decide for themselves whether or not to declare their respective areas of jurisdiction as mining free areas. Mining is also not allowed in areas in the National Tourism Development Plan, critical areas and island ecosystems, prime agricultural lands covered by Strategic and Fisheries Development Zones, declared fish refuge and sanctuaries, protected areas, and agrarian areas.

5.7.8 Mangrove Forest

5.7.8.1 State of Mangrove Forest in the Philippines

Manera (2006), pursuing a joint master in water and coastal management at the Universidde do Algarve had a poster on the State of Mangrove Forests in the Philippines (Manera 2006). His paper showed that the Philippines harbors at least 40 species belonging to 14 families of around 54 true mangrove species worldwide. Members of the genera *Bruguiera, Ceriops,* and *Rhizophora* and the families *Avicenniaceae* and Sonneratiaceae provide important resource base. The high diversity mangrove sites are located in Bohol

(26 spp.), Pagbilao Bay in Quezon province (24 spp.), Aurora province (23 spp.), Ibajay in Aklan province (22 spp.), Puerto Galera in Mindoro island (18 spp.) and Cebu (18 spp. as per Primavera, 2000). The Maneja poster discussed that an estimated 70 % of the original mangrove forest of the Philippines had been lost, from 500,000 ha in 1918 to only 120,500 ha in 1994 or a depletion rate of 3,700 ha per year from 1980 to 1991. Two-thirds of the remaining 20,000 ha old growth forests are found in Palawan and Zamboanga del Sur.

Melana et al. (2005) quoted Brown and Fisher (1920) for the 500,000 ha of mangrove forests in the early 1900s that line the 18,000 km of Philippine shorelines. The over-exploitation and conversion reduced the mangrove forests to 117,700 ha as per 1995 Philippine Forest Statistics (Forest Management Bureau 2010).

5.7.8.2 Driving Forces

Yparraguire et al. (2008) discussed that the relationship between population and the carrying capacity of the environment is a delicate issue and that when local population grows, there is lack of access to good residential lands, settlers tend to illegally occupy the foreshore areas that are deemed public lands. This situation puts them in conflict with the mangrove forests in the area. The diminishing mangrove stands were attributed to the conversion of mangrove forests for fishpond operations and residential areas of illegal settlers.

5.7.8.3 Pressures

The Manera poster discussed that brackish water pond construction for fish/shrimp aquaculture has been regarded as the major cause for mangrove loss in the Philippines (Manera 2006). Around half of the 279,000 ha of mangroves lost from 1951 to 1988 were converted into culture ponds. The accelerated fishpond development was caused by pro-aquaculture and antimangrove-biased policies of the government and the Shrimp Fever in the 1980s. The decline in municipal fish catch is linked with mangrove losses. Other issues contributing to mangrove destruction are over-exploitation by coastal dwellers, conversion to agriculture, salt beds, and settlements, and institutional factors as low economic rent, overlapping government bureaucracy and inconsistent policies, weak law enforcement, and lack of political will.

The Manera poster assertion on the antimangrove bias policies of the government seemed to have been concurred by Melana et.al. in their paper which stated that in the 1950s, vast tracts of mangroves were awarded to concessionaires and logged over for firewood and tanbarks as mangrove firewood was the preferred fuel source in coastal villages but a greater volume was exported to Japan (Melana 2005). In the 1960s, the government adopted a policy aimed at increasing fish production by converting large areas of mangroves into fishponds for culture of milkfish and prawns, and opening loan windows in government banks to finance fishpond development.

5.7.8.4 Impacts

Melana et al. asserted that as a consequence of these destruction of our mangrove resources, seagrass and coral reef ecosystems also deteriorated, destroying as much as 70 % of the coral cover with about 25 % in good condition and 5 % in excellent condition. It was estimated that there is a reduction of as much as 670 kg in fish catch for every hectare of mangrove forest that is clear cut. Aside from the decline in fishery, the paper also reported additional impacts like shoreline erosion especially in most of the typhoon-prone areas, and decline in forest structure and diversity of plant species in most of the remaining mangrove stand. The conversion of mangroves to fishpond resulted also in the decline of the ecological function of mangroves which are—as nursery grounds for fishes, prawns, crabs, and shellfishes; production of leaf litter and detritus material which provides a valuable food source for the marine animals; protection of shore and estuaries from storm waves and erosion; pollution sink for nearshore waters, wildlife habitat, and biodiversity. Fishponds are plagued with diseases, acid soil (exposure of acid soil forming jarosite minerals when mangroves are opened up), deteriorating water quality, seepage of water through dikes, and market fluctuations. Many shrimp ponds were abandoned because of low productivity. Rising incidence of "fish kill" and "red tide" were attributed to either total lost or insignificant functions of the remaining degraded mangroves aggravated by high chemical and fertilizer inputs from the neighboring agroecosystems (Melana 2005).

5.7.8.5 Responses

Melana et al. mentioned that it was only towards the end of the 1970s when the government realized the fishery value of mangroves. A National Mangrove Committee was formed in then Ministry of Natural Resources to formulate policies to conserve remaining mangrove forests in the country and a Mangrove Forest Research Center was created under the Forest Research Institute of the Philippines to generate rehabilitation technologies and develop sustainable management strategies (Melana 2005).

Melana et al. continued further: The 1980s and 1990s were marked with significant efforts to rehabilitate destroyed mangroves and related coastal resources. There were presidential proclamations to protect mangrove reserves. The Mangrove Forest Research Center was expanded in its concerns and coverage and became nation-wide in scope under the Freshwater and Coastal Ecosystem Section of the Ecosystem Research and Development Service. Not long after, the Coastal Environmental Program and the Coastal

Resource Management Project were launched by DENR in 1993 and 1996, respectively (Melana 2005).

The Manera poster asserted that there is no shortage of laws and policies to protect the remaining mangrove areas in the Philippines. Sustainable conservation and management relies on strict implementation. Zoning has also been recommended for the remaining mangrove forests, to be zoned as Protected forest. A buffer zone of 20–50 m along riverbanks and 50–100 m facing open seas as well as mangrove-friendly aquaculture technology are being promoted (Manera 2006).

The Melana et al. paper mentioned some success stories on mangrove management and development efforts. Cited were the Self-help Community-Based Mangrove Plantation of Banacon island, Getafe,Bohol, Contract Reforestation Project, Mangrove Tenurial Instruments (Nipa-Bakauan Special Use Permit and Community-Based Forest Management Program, Integration of aquaculture in mangrove management (a case of failure and a case of success were detailed) (Melana 2005).

The National Wetland Action Plan for the Philippines has specific set of activities to address the rehabilitation and conservation of mangrove areas under the Thematic Area 3. This was the output of the third Technical Working Group formed to review and consolidate the stakeholders' recommendations during their Conference on Wetlands, Climate Change Adaptation, and Biodiversity Conservation held in Dumaguete City in January 2009. The full paper forms the National Wetlands Action Plan for the Philippines, 2011–2016 (Protected Areas and Wildlife Bureau 2011).

Thematic Area 3: Coastal and Marine Wetlands

Strategy 1	Enhance baseline data on and conduct assessment and monitoring of coastal and marine wetlands (conduct inventory assessment and monitoring of priority areas, develop database)
Strategy 2	Rehabilitation of degraded coastal and marine wetlands (conduct workshops to review protocol on rehabilitation and restoration, issue directives to adopt protocol, conduct rehabilitation activities, establish Marine Protected Areas, conduct re-stocking, launch and implement "Adopt a Wetland")
Strategy 3	Promote ecotourism as a conservation strategy for coastal and marine wetlands (update list, conduct mapping, develop ecotourism plan, pilot ecotourism activities, conduct IEC, implement marketing activities to promote ecotourism)
Strategy 4	Implement sustainable aquaculture practices (promote appropriate aquacultural practices, conduct monitoring of aquacultural parks, compile documentation of best practices)
Strategy 5	Research and Development (conduct studies on carrying capacity of small islands, conduct vulnerability study on flora and fauna to sea level rise)
Strategy 6	Establishment of critical habitat for threatened/endangered species (assess and declare critical habitat areas of endangered species, develop and implement management plans in these established critical habitats)
Strategy 7	Coastal and Marine Law Enforcement (deputize wetland enforcement officers, organize and conduct training)

At any rate, these efforts to rehabilitate destroyed mangrove forests seemed to have gained a foothold and the reforested areas have stabilized. The PhilLUS 1.1c showed that we have 212,256 ha of mangrove forest as of 2003, quite an improvement from the earlier estimates of 120,500 in 1994. The government agencies behind the mangrove rehabilitation and conservation of existing ones should be congratulated, although we are not yet half-way if we will consider the early 1900 mangrove area estimate.

5.7.9 Wetlands

5.7.9.1 State of Wetlands in the Philippines

The 2003 PhilLUS Map estimates the wetlands at 154,405 ha. The ecological importance of wetlands and its stabilizing influence in the economy and contribution to the quality of life focuses on its role in flood control, ground water replenishment, sediment and nutrient retention, shoreline stabilization, and as host of a biodiverse flora and fauna which can be economically exploited if harnessed sustainably. Other ecological functions of wetlands include recharge of streams and aquifers, filtering of pollutants, and providing wildlife habitat.

In the Philippines, we have not only the PAWB taking responsibility for the protection and sustainable development of wetlands, we also have the Society for the Conservation of Philippine Wetlands, Inc. in the forefront for implementing the Philippine National Action Plan to promote and conserve the wetlands, including the coastal and marine wetlands.

The Society's website stated that the Philippines has five wetlands declared as Ramsar Sites (Society for the Conservation of Philippine Wetlands 2013). The Ramsar Convention, also known as the Convention on Wetlands of International Importance, is an international treaty for the conservation and sustainable utilization of wetlands. The initial convention was held in Ramsar, Mazandaran, Iran on February 2, 1971 and agreements came into force on December 21, 1975. The World Wetlands Day is celebrated on February 12. The five Ramsar Site Philippine wetlands are: Olango Island in Lapulapu, Cebu (5,820 ha which includes about 2,900 ha of intertidal flats), the Naujan Lake National Park in Oriental Mindoro (14,568 ha), the Agusan Marsh Wildlife Sanctuary (14,836 ha declared Ramsar Site but the whole marsh covers 89,359 ha; others estimate this to cover some 110,000 ha), the Tubbataha Reefs National Marine Park (33,200 ha), and the Puerto Princesa Subterranean River National Park in Palawan (22,202 ha). The total for the area declared as Ramsar Site is 90,626 ha. But including the non-Ramsar Site and excluding the Tubataha Reefs as well as the Puerto Princesa Subterranean River, the total is 110,015 ha.

In addition, we have other well-known big wetlands like the Leyte Sab—a Basin covering 90,000 ha of herbaceous swamp, the Liguasan Marsh (220,000 ha), the Candaba Swamp (32,000 ha). These total 342,000. The sub-total for these well-known wetlands (110,015 + 342,000) is 452,015 ha.

We also have not so well-known wetlands like the Cabusao Camarines Sur Wetlands (27,000 ha), Ajuy, San Dionisio and Sara, Iloilo Wetlands (45,000 ha), Buguey, Cagayan Wetlands (14,400 ha), Hinungan, Southern Leyte Rice Paddies (5,000 ha), Lalaguna, Quezon Marsh (300 ha during the dry season and can extend to 500 ha during the wet season). There are also smaller associated marshes and swamp forests in some major rivers and lakes. Just these mentioned wetlands total 91,300 ha.

This would put our threshold value at 543,315 ha for selected wetlands in the country as against the 2003 Phil-LUS of only 154,405 ha that the satellite image was able to detect. This clearly shows the intrusion of the agricultural sector on the freshwater wetlands. This is evident in the Candaba Swamp, the Liguasan Marsh, and the Agusan Marsh. The Candaba Swamp is usually flooded during the rainy season and the water is impounded and used as fishpond but as dries out during the dry season, the area is converted to rice fields. Cosio, et.al. of Pampanga Agricultural College reported in his paper that only 72 ha from its original area of 32,000 serves as home to migrant wild ducks and various birds that escape the winter winds from China and Siberia (Cosio et al. 2010). This reflects on the extent of human activities in this swamp.

Likewise, around 140,000 of Liguasan Marsh dry out during the dry season and are cultivated. Liguasan Marsh actually consists of two adjoining marshy basins—the Liguasan Marsh and the Libungan Marsh. This is about half of the total marsh area utilized for agricultural production.

Of the total 89,359 ha of Agusan Marsh, only 14,836 ha is declared under Ramsar Site, and 44,000 ha is declared Protected Areas. Besides agricultural encroachment by small settlers who drain the marginal areas for conversion to rice fields, fruit orchard, and palm oil plantation, the small-scale miners in Diwalwal, Compostela Valley threaten the marsh with 300,000 tons of mercury-rich mine tailings.

It appears from this LADA assessment, that the wetlands are among the ecologically threatened LUS mapping unit from the national perspective.

5.7.9.2 Driving Forces

The increasing population and the need to expand agricultural area to provide economic opportunities for the rural poor is a major driving force for the conversion of wetlands to agricultural lands. With no other means of livelihood, the rural poor have nowhere to go but exploit ecologically fragile areas which are marginal for agriculture. This means the wetlands were drained and the native vegetation was removed to enable agricultural production. These may no longer be wetlands and the difficulty in detecting the wetlands in the satellite imagery using remote sensing techniques.

The conflicting interest between ecological stability and economic opportunity for the rural poor is certainly highlighted by decreased area coverage of wetlands as detected by remote sensing techniques. Without public appreciation of the importance of wetlands and the need to provide livelihood means to the rural poor will continue to hound policy makers on what to do with our remaining wetlands. Policies on draining wetlands for agricultural production to ease rural economic issues have been the primary key driver in conversion of wetlands.

The anthropogenic driving forces are linked to population growth, socio-economic development, political decisions and governance to generate the *pressures* (direct causes) such as land use intensification and over-exploitation which for the Philippines, these wetlands are drained for agricultural and other purposes. We have a diversity of economic sectors desiring to have a pie in the utilization of wetlands—agriculture, tourism, industry, housing to cite a few. The increased human activities could also increase the vulnerability of wetlands to pollution.

The driving force of ecological origin would include climate change and possible rise in sea levels. Changes in climatic parameters—temperature, precipitation, relative humidity have been known to have effect on the area coverage of wetlands. Wetlands develop in low-lying areas in the landscape where water drains and collects. The shape of the landscape creates unique drainage conditions which influence the formation and characteristics of soils, usually classified as poorly drained and called *hydric* soils with the characteristic gleying and mottling. The wetland plants are called *hydrophytes,* adapted to wet anaerobic conditions. The circulation and distribution of water is the driving force behind the formation of wetlands and changes in the hydrology of the area would have impact on the wetlands.

The PAWB Philippines National Report on Wetlands identified indirect causes on the loss of wetlands: we have the socio-economic driving forces which include poverty, illiteracy, population, as well as national and local politics. The environmental and policy regulations include—limited if not lack of enforcement, where present it is bias towards development at all cost, subsidies provided to some economic activities sometimes lead to wholesale conversion of wetlands.

5.7.9.3 Pressures

The PAWB Philippines National Report on Wetlands provided a conceptual framework on the causes of the loss of wetlands. We have the direct pressures which include (Department of Environment and Natural Resources—Protected Areas and Wildlife Bureau 2005):

Resource use and overexploitation.

Habitat loss and deterioration from conversion of wetlands to other uses with perceived higher economic values, which sometimes become irreversible.

Introduction of exotic species and diseases leading to replacement if not extinction of endemic and native species.

Pollution and climate change from domestic, industrial and agricultural sources that lead to water quality problems.

5.7.9.4 Impacts

The agricultural development of wetlands increases the input of agricultural pollutants, decreases the wetland's natural filtering function, and certainly reduces other important ecosystem services. Where we have agriculture and nutrient mining, subsistence farmers eventually find themselves with declining productivity and the cycle of further expanding to other wetlands occur.

5.7.9.5 Responses

To address continuing decline and conversion of our wetlands, we need to come up with policies to manage wetlands for multiple ecosystem services, and in harmony with livelihood strategies, not necessarily to maximize both conservation and poverty reduction at the same time but to come up with a win-win scenario or compromise to ensure sustainability of the ecosystem services while allowing equally sustainable agricultural development.

The 2011–2016 National Action Plan details the core activities, targets and timetables, the implementing agencies, expected outputs, indicators, and means of verification (Protected Areas and Wildlife Bureau 2011). We will just go through the summary:

Thematic Area 1: Wetlands Policy

Strategy 1	Review of existing land use and management of wetlands (inventory and mapping of priority wetlands, review and cancelation of fraudulent titles and inappropriate tenure instruments, strict implementation of water users' rules and regulations, strict enforcement of easement and buffer zone regulations, resolve reclamation issues)
Strategy 2	Implement local management and economic measures to conserve wetlands (set users and service fees, induce resource valuation)
Strategy 3	Integrate climate change mitigation and adaptation measures in relevant plans and policies (review and adoption of relevant policies and legislations, assessment of vulnerability to climate change of priority wetlands

Thematic Area 2: Freshwater/Inland Wetlands

Strategy 1	Establish baseline data and conduct biophysical and sociocultural assessment and monitoring of freshwater wetlands (conduct inventory assessment and monitoring, review existing database)
Strategy 2	Preparation and implementation of management plans for priority freshwater wetlands in the country (prepare manual, conduct trainings on the use of manual)
Strategy 3	Rehabilitate priority freshwater wetlands (design scheme to manage settlements, implement community-based reforestation, implement bioremediation and phyto-remediation technologies, implement soil conservation technologies, address invasive alien species, launch and implement "Adopt a Wetland" project)
Strategy 4	Implement climate change mitigation and adaptation strategies (conduct vulnerability assessments, identify vulnerable species, monitor migration patterns of birds, formalize Philippine Bird Banding Scheme, hold national conference on Climate Change Adaptation and Population Health and Environment, adopt appropriate watershed protection and conservation management strategies, conduct conservation of peatlands, conduct R&D on specific climate change mitigation functions of wetlands, adoption of Green technology)

Strategy 5 Promote ecotourism as a conservation strategy (update list and profile of freshwater wetlands with ecotourism potential, conduct mapping, develop ecotourism plans)

Strategy 6 Implement sustainable aquaculture practices in freshwater wetlands (regulate aquaculture practices)

Thematic Area 3 (Refers to mangroves)
Thematic Area 4: Enabling Activities

Strategy 1 Compiling, organizing, and making available information on Philippine wetlands (establishment of metadata base, information dissemination)

Strategy 2 Knowledge management (replication of best practices)

Strategy 3 Preparing, adopting, and implementing the Communication, Education, Participation, and Awareness (CEPA) Action Plan (conduct CEPA action planning, upscale existing CEPA activities, establish wetlands information centers, develop framework for stakeholders' participation, hold a National Wetlands Conference every three years, provide incentives for wetlands conservation)

Strategy 4 Capacity development and enhancement (preparation of capacity development plan, conduct formal and non-formal education, strengthen institutional capacity. Build financial capacity)

Strategy 5 Development and implementation of innovative methods, tools, and technologies for wetland management (develop integrated wetland management framework, develop appropriate and cost-effective monitoring tools, apply management effective assessment, implement pilot rainwater harvesting facilities, come up with scheme to phase out aquaculture in NIPAS sites)

It is also important to note that the PAWB Philippines National Report on Wetlands has specific section on Society's response in the light of destruction and loss of wetlands (Department of Environment and Natural Resources—Protected Areas and Wildlife Bureau 2005):

1. Direct conservation actions (restoration of degraded habitats, reintroduction of local species, saving particular species and habitats in wetlands, coastal clean-up, prevention of projects that have implications and impacts on wetlands).
2. Scientific information and research (undertaking research activities to generate scientific information to serve as basis for sound management).
3. Environmental policy and legislation (crafting the passage of polices and legislation that will prevent further loss of wetlands and promote its wise use; development of appropriate protected area system at local, regional, and national level).
4. Education and capacity building (development and dissemination of educational materials and conduct of training programs for various stakeholders and levels).
5. Advocacy (lobby work with policy makers at local and national levels, the general public, and the private sector).
6. Funding (generate resources to sustain these activities to respond to the challenges).

Considering that the wetlands, unmanaged is the second of the hotspots at 154,405 ha recorded by PhilLUS 1.1c when the total just for the priority areas is 482,400 ha, it is more than timely that the Action Plan has been put in place.

5.7.10 Initial Conclusions from the LADA Study

The analysis of the LUS mapping units were initially done for Regions 3, 7, and 10 based on the LADA Questionnaire for Mapping Land Degradation and Sustainable Land Management prepared by the World Overview of Conservation Approaches and Technologies, hence the manual is known as the WOCAT-QM.

It should be noted that this manual was originally prepared to develop and test an effective assessment methodology for land degradation in *dry lands* initially involving six partner countries—Argentina, China, Cuba, Senegal, South Africa, and Tunisia. This is the first effort to apply the methodology in a monsoon country.

The WOCAT-QM basically directs users to set of DPSI questionnaires with which to analyze a particular LUS mapping unit. The type of land degradation pre-inputted in the manual are as follows:

- No land degradation.
- Soil erosion by water (loss of topsoil, gullying, mass movements/landslides, riverbank erosion, coastal erosion, offsite degradation effects such as siltation, downstream flooding, etc.).
- Soil erosion by wind (loss of topsoil, deflation and deposition, offsite degradation effects).
- Chemical soil deterioration (fertility decline, acidification, soil pollution, salinization/alkalinisation).
- Physical soil deterioration (compaction, sealing and crusting, waterlogging, subsidence of organic soils, loss of bioproductive functions).
- Water degradation (aridification, change in quantity of surface water, change in groundwater/aquifer level, decline of surface water quality, decline of groundwater quality, reduction of the buffering capacity of wetlands).

- Biological degradation (reduction of vegetation cover, loss of habitats, quantity/biomass decline, detrimental effects of fires, quality and species composition/diversity decline, loss of soil life, increase of pests and diseases).

Considering the absence of statistical data at regional levels and the limited available data at the national level, the project management is having difficult time establishing baseline data for each of the LUS mapping unit. And with the urgency to align the Philippine National Action Plan with the UNCCD's Ten Year Strategy, the pressure is even greater. The Philippine LADA output which is supposed to highlight the hot spots and the bright spots will be the basis for the re-aligned National Action Plan. And this pressure for the LADA output to be released soonest is compounded by the specific users for critical decision making of national economic relevance.

For example, President Benigno Aquino issued Executive Order No. 79 signed July 6, 2012 that expanded the "no-go" mining zones in the country to include 78 tourism sites and farms, marine sanctuaries, and island ecosystems in response to the public clamor to protect the environment from mining. This means that for LADA output to be relevant in this particular decision process, we have to include in the analysis of the LUS map the SAFDZ and further overlay the on-going mining sites; and thus, we could recalculate the extent of mine tailings and polluted agricultural and coastal areas (chemical degradation) by LUS and by region. For the proposed mining sites, we can predict the extent of the mine-tailing impacted agricultural and coastal areas given various scenarios assuming potential problems with waste management.

It can be concluded that by the time the Philippine LADA Project is completed, it has succeeded in capacitating the local staff for land degradation assessment. But the output is very qualitative and would not be able to highlight the desired hot spots and bright spots for the re-alignment of the Philippine National Action Plan and for the other data users until more specific post-LADA project studies are conducted such as those relating to extent of mine tailings, peatland conversion, soil fertility decline, etc. and LUS analyses are conducted with updated spatial data from collaborating agencies.

5.8 Sustainable Economic Use of Soil Resources

5.8.1 Sustainable Farming Philosophy Hinged on Nutrient Recycling

A healthy, well-balanced, high quality soil yields healthy crops. Healthy crops yield healthy citizenry.

Today's leading political personalities face a world of skyrocketing number of aging constituents besieged by every form of sickness and diseases with roots that can be traced to dietary habits – cancer, diabetes, arthritis, allergies, heart diseases, hormonal imbalances such as goiter, etc. coupled by unstable supply and demand scenarios of food crops brought about by vagaries of climate change, monopolistic cartels, and increasing prices of agricultural inputs. Recognizing that political dynasties could rise and fall at a spark of a food riot, government institutions consider every possible ways to provide food security to bring about political stability.

The Green Revolution of the 1960s resulted in the massive use of chemical fertilizers and pesticides and the significant decline of crop varieties used by farmers. Today, many farmers feel they could not survive without chemical pesticides and fertilizers. But it seems that intensive use of chemicals in agriculture is just the beginning. Not only are chemical pesticides expected to be used with greater efficiency and precision and chemical fertilizers to become more refined and powerful through computer-aided remote sensing and geographic information system, there is thrust towards chemical control of plant growth processes such as root initiation, regulation of germination, branching and leaf orientation, time of flowering and fruit set, and control of fruit ripening. In fact it is now common practice in Philippine mango production to chemically control the onset of flowering. In the livestock industry, livestock raising is envisioned in controlled environments, synchronized estrus, and regulated ovulatory rates, and artificial insemination is already a common practice. Recycling of animal wastes as reconstituted foods for livestock, poultry, and fisheries is another trend. The outbreak of "mad cow" disease shows the consequence of this practice. In the current news is the commercialization of genetically modified crops and livestock as well. The Mendelian breeding philosophy is being set aside in favor of DNA mapping and transplant to alter the genes of the crop. We also have Severe Acute Respiratory Syndrome (SARS) and avian flu outbreaks in epidemic proportions traced to cooping up of thousands of chickens in small cages so that they can be automatically and efficiently fed and watered, resulting in close human-avian interaction.

With the increasing cost of fossil-based fertilizers beyond reasonable levels and the development of pest resistance to agricultural chemicals emerged the rise of alternative agricultural technologies, the so-called sustainable farming technologies or the organic agriculture option. The whole sustainable farming technology options and the gamut of various agricultural production ideologies associated with it—natural farming technology system, biodynamic farming system, quantum agriculture system, system of rice intensification, etc. need to be properly founded on the proper understanding of the soil. The soil after all, is the foundation of agriculture.

Cocannouer (1971) stated, "Man may sense but he probably never will discover the secret of organic life. Nature in her wisdom will not grant to man that last revelation, for to do so would mean man's annihilation. Nature never destroys; she ever constructs".

He continued, "To build and maintain a complete soil, a soil with actively functioning fertility chain, is one of nature's greatest assigned tasks. Yet, strangely enough, nature as a rule does not reach her goal" Cocannouer (1971).

The first agricultural production philosophy we need to understand therefore is farming with nature calls for one important objective: to build soils to a complete balance in the shortest possible time, something nature working alone, is rarely able to do (Cocannouer 1971).

What is soil? Most books discuss that it is composed of six parts: (1) air (2) water (3) solid minerals (4) dissolved minerals (5) organic matter or dead remains of plants and animal wastes, and (6) a vast community of living organisms—all working together. In proper balance, these provide a place for plants to grow and give us food. The last component of the soil—the soil biota—is little considered. Maybe because most are microscopic. Only earthworms and other soil fauna can be seen. There seems to be a dichotomy between soil fertility which focuses on physical and chemical features, and soil biology, when the truth is, the presence of soil biota is one of the indicators of soil fertility and one way to attain soil fertility.

The soil is not, as many suppose, a dead, inert substance which merely supplies mineral elements to plants and gives them a place to anchor their roots. A healthy soil is vibrant and alive and dynamic. It teems with bacteria, fungi, molds, yeasts, protozoa, algae, worms, insects, and other minute organisms which live mostly in its top few centimeters. This hive of living creatures in the soil, the eaters and the eaten, adds up to incredible numbers.

The organic matter is obtained from living and dead plants and animals, plant roots, green manure crops, animal manure, crop residues. The organic matter is broken down and decayed through the action of the complex mass of soil macro and microorganisms, producing organic acids which make minerals soluble. The most important product of this process is humus which improves the physical condition of the soil, supports soil organisms, increases permeability for water, improves aeration, stabilizes the soil's temperature, improves water holding capacity (sponge effect) and serves as storehouse of plant nutrients. Humus is the stable compound resulting from organic matter decomposition in the soil. It consists of insoluble humic acids that tightly bind to clays and greatly resistant to further decomposition.

Serious depletion of organic matter and humus, termed as dehumification, is due to improper cultivation practices, unchecked erosion, continued monoculture, and failure to restore to the soil what the preceding harvests have taken from it.

There is no artificial fertilizer that can supply a completely balanced diet for plants in the way that humus-rich soil can. Chemical fertilizer companies blend and formulate mixtures to supply major nutrients needed by the plants but they simply cannot mechanically formulate humus. While it is true that plants could not differentiate nitrogen from an inorganic and from an organic source (although organic adherents disagree), plants were not designed to get their nutrients by being force-fed. Forcing upon the plants immediately available food in the form of water-soluble chemicals, which they cannot reject but must absorb, constitutes a bypassing of the soil's extremely important functions in relation to plant life. As crops are grown in humus-deficient soils with the aid of increasing quantities of chemical fertilizers, they become susceptible to insect pests and diseases.

The second important agricultural production philosophy is that to be able to build soils and raise healthy crops, we need to enhance soil life and improve soil humus (Cocannouer 1971).

Fertile topsoil is, by far, man's most valuable and indispensable natural resource. It is about 10–15 cm deep but can go deeper, as much as 25 cm in some areas. Within this very thin surface of the earth lies the difference between success and failure in agriculture. It stands between man and famine. And what it takes nature many years, decades, and centuries to build, can be easily lost in a matter of minutes if we do not know how to take care of our soil resources. What is removed by erosion is the best part of the topsoil, the surface portion, which contains health-producing microbes, humus, and available plant food. Each ton of lost soil through erosion could provide food for many people for many years.

Soil humus is decomposed organic matter, not organic matter itself which is in the process of decomposition. Humus is a complex brown to dark amorphous substance resistant to further decomposition. Humus production begins with the decay of crop residues. Until the final stage of decomposition, nutrients in the organic matter are not available to the plant. Micro and macro organisms like earthworms along with proper climatic conditions are vital to complete the decomposition to produce humus.

Carbon constitutes about 50 % of the humus itself and used by the various soil microorganisms in their metabolism such as fermentation and respiration, converting it to energy values for plant growth. Humus, as a concentrate of carbon and energy aids soil microorganisms survive extreme conditions such as excessive moisture, as well as cold and dry conditions enabling soil bacteria for instance to carry out their antibiotic effects in the soil and relate with plant roots for nutrient exchange.

Humic acids, carbonic acids, and carbon energy are activated through association of properly digested organic residues or from a balanced decay of crop residues. Humic acids control many vital processes in the soil.

The third important agricultural production philosophy rests on proper care and maintenance of the soil. The soil building process is not a one-time exercise, but continuing.

A fourth important agricultural production philosophy is to consider the whole agro-ecosystem and the important roles of insect pests, diseases, and weeds in nature. That these are not our enemies but essential components of a balanced soil ecosystem. Furthermore, a balanced soil ecosystem is able to store and hold water to meet crop needs.

It is unfortunate that weeds, from the agriculture point of view, are defined as unwanted plants. But like insects, pests, and diseases, weeds have important ecological functions. In his book *Weeds, Guardians of the Soil* by Joseph Cocannouer (1950) listed the following purposes of weeds: (1) They bring minerals, especially those which have been depleted up, from the subsoil to the topsoil and make them available to crops. This is particularly important with regard to trace elements. (2) When used in crop rotations, they break up hard pans and allow subsequent crop roots to feed deeply. (3) They fiberize and condition the soil and provide a good environment for the minute but important animal and plant life that make any soil productive. (4) They are good indicators of soil condition, both as to variety of weed present and to condition of the individual plant. Certain weeds appear when certain deficiencies occur. For instance, cogon grasses grow in burnt forested acid soils. As “pioneer” plant species, they lower soil temperature, prevent erosion, and pumped up nutrients to enable series of plant successions for the burnt forest to regrow. (5) Weeds are deep divers and feeders, and through soil capillarity, they enable the less-hardy, surface-feeding crops to withstand drought better than the crop alone could. (6) As companion crops, they enable our domesticated plants to get their roots to otherwise unavailable food. (7) Weeds store up minerals and nutrients that would be washed, blown, or leached away from bare ground and keep them readily available. When weeds therefore become so abundant that they interfere with crop production, it ought to be recognized that the cause of the problem is not the weeds, but the depleted soil which the weeds are trying to protect and build up. Instead of destroying such weeds with herbicides while our soil continues to be degraded, we need to get busy and build up the soil so the weeds will naturally reduce themselves (Cocannouer 1950).

Water is essential to all organic life. And with seasonal aridity occurring in the country, the competition for water use from industrial, agricultural and residential users will worsen in the years to come. To re-echo the words of Cocannouer, will expensive dams and reservoirs revive springs? Will they put humus back into our famished farms? Will they repair broken water cycle? While the controversy rages, the ravages go on. But the natural fact is unequivocal: the only way to bring back the spring is to rebuild the soil segment where the springs existed. Legions of ponds dotting the land would go far in lifting the water tables in all parts where they have dropped so low. But even with great numbers of artificial lakes and ponds, we would still be far from sponge-filled soil. Land that contains a good sponge structure to considerable depth will store up much of the excess water and then return it to the surface soil later by means of upward capillarity. Indeed, a soil that is organically balanced has the power to regulate soil moisture. When the organic stuff is almost completely broken down, much capillary water is stored in it and later released for the use of plants. The secret of an efficient soil sponge is that water is quickly absorbed as it falls; excess water is sent on down to the water table; a reserve supply is held by the sponge. We should realize that even if nature alone could ultimately rebuild ravaged segment, our civilization constantly imposes obstacles to that accomplishment. Nevertheless, there is truth to the saying that a springless region is a dying region (Cocannouer 1971).

5.8.2 Translating Agricultural Production Philosophies into Policy Advocacies

1. To build the soil and restore its balance should be a primary concern of every farmer, encouraged and assisted by government agencies. The government should promote agricultural waste recycling program as well as the development of soil-enriching biota. The current thrust is on profit-generating technologies without concern for the building of soil life. If an agricultural project cannot generate immediate income for the farmer, it has no room in government project funding. There should be a reversal of policy that favors only projects with visible impacts that can be credited to the government efforts to improve farmers’ plight. The government should also embark on nonvisible, nonvote getting and long-term programs relating to sustainable land management such as soil erosion management and fertility rehabilitation.
2. Corollary to the first, research on commercialization of soil conditioners and biofertilizers that enhance soil life

and fertility should be promoted and supported. Of course, if the nation will concentrate on soil building program resulting in healthy crops, this will bring into disarray the fertilizer and pesticide industry. But then if we understand that healthy soils bring in healthy crops, there would have been no room for these industries in the first place.

3. Intensify soil conservation awareness for upland and hillyland farmers; and disseminate soil conservation and management strategies. There should also be efforts to reforest or afforest denuded mountains.
4. There should be a continuing program on soil conservation, e.g. funds should be allocated for the development of Soil Conservation Model Farms. Farmer incentives (such as awards or grants or tax discounts) should be given for farmers who have successfully restored the balance of nature in their farms from originally barren and sick soil condition. We are yet to hear of a farmer awarded because he practiced soil conservation. In the Philippines, outstanding farmers are selected on the basis of economic or profitable success of the farming endeavor regardless of whether the farming technology is sustainable or not.
5. Encourage the development of small but sustainable farms instead of promoting and giving incentives to corporate farms that are on monoculture. The Department of Agriculture should have the political will to accomplish its vision of being committed to small farm entrepreneurs contributing to national development instead of favoring mostly big corporate farms. The *Bahay Kubo* (My Nipa Hut) folk song that is about a diversified household-level farming system has intrinsic centuries-old farming wisdom relating to soil fertility and pest management handed to us by our forebears.
6. Promote sustainable agricultural production systems based on diversified farming schemes, a holistic approach that integrates crops, livestock, poultry, and fisheries, and with provisions for agri-waste management and recycling. The objective is for a small-scale farm to be able to feed a family with surpluses to trade for non-farm household needs. A farm providing all the food needs of a family rather than generating cash in an inflated economy will be able to survive economic crises better. But this requires value and norm transformation considering the profit and money-orientation of our society. Our society is presently consumer-goods oriented, and without the cash, it will be difficult to acquire manufactured goods. It is sometimes ironic that even in the most depressed homes, there are modern household gadgets to rival those of the rich homes. And thus, presently, our limited agricultural resources are prioritized to grow fertilizer-dependent cash crops for exports to get foreign currencies. It is even an accepted fact that because of trade liberalization under the General Agreement on Tariff and Trade (GATT), several Asian countries now self-sufficient in rice are finding it profitable to import rice in exchange for diverting production resources to more remunerative activities. Meanwhile, the people suffer from high cost of locally available food and relatively cheap imported and mass-produced (under the guise of economics of scale) fertilizer- and pesticide-laden food. Why sacrifice quality for quantity when we can have both if we only learn to work harmoniously with nature?

5.8.3 The Battle Against Flood: An Ignored Lesson from Social Studies Classes

5.8.3.1 Floods Renew the Soil

Floods are a serious problem in many river basins throughout the world, particularly in the monsoon and typhoon areas of Southeast Asia. Floods destroy about 4 million ha of crops every year. In recent years, floods seem to be very much more destructive than usual. There are many record-breaking floods as they become more frequent and destructive.

Yet, it was taught as early as elementary, in social studies classes, that for centuries, the renewal of rich flood sediments from the flooding of river systems is a major component for natural renewal of productive agricultural areas. In fact, the large part of arable lands on earth is around the largest river systems on earth—the Nile River, the Mississippi River, the Tigris and Euphrates Rivers, the Yellow River, the Amazon River, the Ganges, the Rhine, and the Mekong River. Actually, these productive agricultural lands have been formed from the sediments left by those rivers in geological times. When the flood comes over spilling its banks, and the water eventually recedes, what is left behind is rich silt. This silt provides excellent fertilizer for crops. Even if the land is over farmed and all the nutrients are depleted from the soil, the land renews its fertility when new deposits of silt arrive following the next flood. It was the flooding of the Nile that sustained ancient Egypt for thousands of years. They even created a science to predict the arrival of the floods, although they couldn't predict the extent of the flooding.

The strategy to decrease agricultural impact of flood is to fallow the land when the flood season comes. Silt does affect soil permeability, especially hardened silt. Plant roots from surviving crop will die of not being able to respire. The silt deposited when flood waters recede restricts oxygen supplies, especially on newly planted seedlings. Roots must also contend with toxic compounds carried by the flood waters as by-product of anaerobic (without oxygen) decomposition of dead plant materials. Even trees will show evidence of stress such as yellowing of leaves, crown dieback, and peeling bark. The flooding impact on agriculture is an issue because we rely on our modern technology of overcoming nutrient mining by chemical fertilization; and thus, we go to the extent of three cropping season per year. Not only this brings about stress to the agricultural land, we also expose our crops to vulnerability when the flood season comes. An excellent cropping calendar is the planting of the main crop, followed by the relay or intercrop, and then fallow.

5.8.3.2 Controlling the Flood

Flood control projects and dams may increase human comfort and provide water as the need arises, but it causes substantial adverse impact in the renewal of the arable land. Goldsmith and Hildyard discussed the myth of flood control (Goldsmith and Hildyard 1984).

The main methods used today for controlling floods are building of embankments to contain flood waters within rivers and construction of reservoir where flood waters can be impounded before being released at a rate which is sufficiently slow to prevent destructive flooding downstream. Embankments, dams, and other similar devices are referred to as structural controls (Goldsmith and Hildyard 1984).

The historical experience with such controls show how ineffective these are. The inhabitants of China's Yellow River Basin have built barriers to control the course of the river and its tributaries since time immemorial. These barriers have not prevented the Yellow River from flooding surrounding villages and the agricultural lands. Despite the record, the Chinese government, and like many other governments throughout the world, continues to rely on embankments to control floods. Yet, the floods continue to occur (Goldsmith and Hildyard 1984).

The problem of controlling floods by structural means is compounded by the widespread deforestation. A forested watershed will release about 1–3 % of the total rainfall. By contrast, a deforested watershed releases as much as 97–99 % of the rainfall to the river system. The pressure on existing embankments is tremendous. Another impact of deforestation is on the weakening of the soil structure and the decrease of organic matter. The soil becomes vulnerable to erosion. Such silting also increases the pressure on the embankments whose heights must be continually raised to prevent flooding (Goldsmith and Hildyard 1984).

Where dams are used to control floods, the problem of management are exacerbated by the desire of the politicians to make the maximum use of the waters in the dam's reservoir. For flood control purposes, the water level in the reservoir must be kept as low as possible; for the purpose of generating hydroelectricity or for irrigation, it is the opposite. More often than not, the latter uses have priority. Goldsmith and Hildyard quoting Widstrand (1980) stated that the short-term value of water for irrigation or hydropower would be too strong an argument not to sacrifice some flood-mitigation benefits in favor of increased supply benefits (Widstrand 1980). Such trade-off could be disastrous, especially in eagerness to generate maximum amount of hydroelectricity, the dam's authorities could maintain the reservoir full even during rainy months. How many times are Bulacan and Pangasinan farmers affected when the Angat and San Roque Dams release water during heavy rains, the reservoir is full, the river's floodwater could not be contained behind the dam. Usually, the dam gates are opened too late for basically politico-economic reasons.

Goldsmith and Hildyard further quoting Arnold (1976), asserted that too often, flood policies and programmes are based on the assumption that flood disasters result from nature's actions, not man's. But Arnold pointed out that in actual fact, the misery and damage are mostly caused by human error, especially by poor land management and myopic flood control strategies. People in trauma, those affected by flood, want immediate action, which means dealing with the effects rather than the cause. This includes building structural controls rather than adopting real long-term solutions to flooding (Arnold 1976).

5.8.3.3 Addressing the Issue of Flooding on Long-Term Basis

With several extremely devastating floods experienced by the country the last five years like the ones brought by Typhoon Ondoy in 2009 in Metro Manila, Typhoon Sendong in Cagayan de Oro in 2011, the perennial Cotabato flooding along the flood plains of Rio Grande and Tamontaka River, the perennial flooding and landslide in Tacloban, and several more other cases from north to south of the archipelago being reported in the mass media every time the rainy season comes; in fact, Campostela Valley is in the news for several weeks as this book is being written, when Typhoon Pablo drowned communities as rainwater accumulated on the mountain top and burst down the villages—it is indeed worth taking a look at what are our options with regards to flood.

Vohra (1980) as quoted by Goldsmith and Hildyard couldn't put it more succinctly, the only way to tackle the growing menace of floods, is to control deforestation, denudation, and soil erosion in the watersheds of rivers (Vohra 1980). Goldsmith and Hildyard also emphasized that any long term solution to the problem of floods must undoubtedly go further than simply halting deforestation. (Goldsmith and Hildyard 1984). We certainly need to reforest denuded mountains, abandon those communities established in the forest, and afforest these areas with slopes greater than 18 %. It is very evident that the 7 million ha of current extent of our forest is simply not enough to bring about ecological stability in the archipelago. We should close the gap between the current forest statistics at 7 million ha and extent of the non-alienable and non-disposable lands at 15 million ha; and stop making political accommodations to these settlers of ecologically fragile lands. We need a lot of political will to enforce logging ban, prevent human intrusions into our forest lands, and prevent conversion of cleared forests into mountain resorts and exclusive residential villages that afford scenic views of the metropolis.

Goldsmith and Hildyard further cautioned on replanting our forest with fast growing species with very shallow root system because they have minimal capacity to retain water or to bind soils within their roots. Often, these kinds of trees are chosen because there is already a ready market for the timber. They advocated for a mix of native trees so that the new forests will resemble as closely as possible those that previously grew in the area (Goldsmith and Hildyard 1984).

And as we go down the flood-prone areas, we should realize that these are the best agricultural lands, the fertility of which is annually renewed by the floods. As we want to keep our forests intact, we need also to prevent further urban development of flood plains. Arnold (1976) as quoted by Goldsmith and Hildyard pointed out that flood plains provide key links in many food chains. They are the habitat of numerous birds and other wildlife. They support a vast diversity of plant life, they also provide some of the most fertile land and best-watered land for growing crops (Arnold 1976). These are our best agricultural lands; and being regularly flooded, not really suitable for residential or commercial use. It should not be surprising then that of the worst flood damage in terms of human lives and property in the Philippine history: the 1991 Typhoon Uring Ormoc flood and the 2011 Typhoon Sendong Cagayan de Oro flood took place in Isla Verde and Isla de Oro, respectively, both delta of alluvial deposits formed by accumulation of river silts; both islets were heavily populated by low income families prior to the flood and the residents living in these deltas and on the river banks, together with their properties were decimated as rampaging flood water literally erased the communities.

As for those in the higher river terraces, it is about time to rethink of the wisdom of our forebears who built their houses on stilts. There are still many traditional Filipino houses in Metropolitan Manila along this architectural style. We have been westernized in our thinking that we tend to ignore our traditional way of life with its centuries of accumulated experiences and wisdom; maybe believing that technology and modernization could overcome many of the challenges they used to face. We should realize that many of our agricultural researchers are looking back to the wisdom of our traditional agricultural practices and adapt them to modern times for sustainable land management. Maybe it is about time also to review and look back at our traditional way of life for the wisdom it brings, especially on how to deal with floods. It is just as simple as building our houses on stilts as our forebears and grandparents centuries and decades before us did.

As Goldsmith and Hildyard concluded, we need a completely new attitude towards the problem of flood control. We must abandon the illusion that floods can actually be eliminated. Regardless of the brilliance of our scientists, the ingenuity of our engineers, and the generosity of World Bank to loan us interest-bearing funds for flood control projects, floods will continue to occur. But they need not be disasters. On the contrary, throughout history, floods have been made use of by populations inhabiting river basins to irrigate and fertilize their fields in a perfectly sustainable manner. If floods can be brought once more under the joint control of the forests and the flood plains, we too might learn to live with floods and derive from them still more sophisticated benefits (Goldsmith and Hildyard 1984).

With population and economic pressures facing political leaders, making forests, first river terraces, deltas, former tidal flats, and other ecologically fragile ecosystems off limits to human and economic activities may be easier said than done. But the lessons on flood by Isla Verde and Isla de Oro and the lessons on landslides by St. Bernard-Southern Leyte and those of Compostela Province should make it clear that we cannot win any battle against nature. Until we learn the lesson, nightmarish floods and landslides will continue to hound us.

5.8.4 A Sample Political Platform Hinged on Sustainable Agricultural Philosophy

5.8.4.1 A Political Leader with Sustainable Agricultural Philosophy

Mayor Nacianceno M. Pacalioga, Jr. of the Municipality of Dumingag, province of Zamboanga del Sur in the southern island of Mindanao won the third One World Award (OWA) Laureate, an international competition sponsored by the International Federation of Organic Agriculture Movement (IFOAM) and the Rapunzel Naturkost, one of the biggest organic foodstuffs manufacturers in Germany and founded by Joseph Wilhelm. The awarding ceremony was held in Legau, Germany in September 14, 2012. The award was given to individuals who promoted globalization in a manner that is not oriented towards profit maximization but rather, on the three pillars of sustainability: ecology, social aspects, and economic welfare. For a prize, Mayor Pacalioga received 25,000 euros and a beautiful statuette named Lady OWA. a female torso to represent Mother Earth with a centrically penetrating flat relief of earth, designed by a

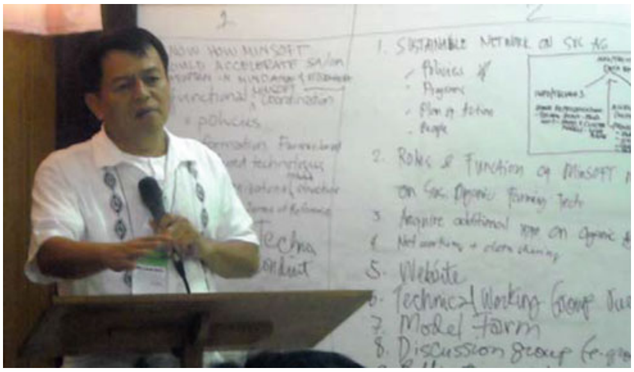


Fig. 5.41 Mayor Nacianceno M. Pacalioga, Jr. of Dumingag, Zamboanga del Sur, enunciated his organic agricultural platform during the formation of the Mindanao sustainable organic farming system and he eventually hosted a congress for organic practitioners as a major activity of this network of networks

Taoist free lance artist Dao Droste. Mayor Pacalioga bested four other finalists—Premanjali Rao, a Caribbean island teacher-founder of a school for impoverished fishermen families and members of the underprivileged castes; Nazmi Ilicali of Turkey who organized farmers in Eastern Anatolia on organic dairy farming; Elba Rivera Urbina of Nicaragua who is considered an organic activist; and Humberto Rios Labrada who is a scientist-artist from Cuba. Earlier, in 2010, the municipality of Dumingag was awarded one of the Top Ten Most Outstanding Local Government Units in the Philippines by no less than President Benigno Simeon C. Aquino III (One World Award 2013) (Fig. 5.41).

5.8.4.2 The Municipality of Dumingag

Dumingag is a second class municipality politically subdivided into 44 barangays or villages, of which 33 are uplands and 11 are lowlands. It is a landlocked municipality, quite far from the sea. There are no mining, nor logging, and marine resources. As per 2007 census, it has a population of 46,039 people and 8,017 households. Some of the villages were quite remote and the inhabitants belong to indigenous tribes called Subanan. About 90 % of the people lived below the Philippine poverty level. The people relied mainly on agriculture for their livelihood. About 84 % of the farmers had no sufficient production and income to support the basic needs of their family. Poverty was widespread (Pacalioga 2011).

When Mayor Pacalioga first ran for the office of the mayor in 2007 after serving as vice mayor for nine years, his political opponent was involved in the agro-chemical industry. From the very start of his campaign, his political platform was hinged on sustainable organic agriculture. It was a tight election as Mayor Pacalioga won by a narrow margin (One World Award 2013).

The political platform of Mayor Pacalioga was dubbed as the "Genuine People's Agenda". It was the product of collective discussions of the leadership with the local residents as to their direction and future. From the onset, he espoused participatory approach to rural development planning. His strategy was called Social Preparation and Strengthening People's Participation. Through this, the communities were able to diagnose their social problems, identify priorities, and plan out doable solutions to address their problems (Pacalioga 2011).

Mayor Pacalioga has three basic thrust to establish the local economy and address widespread poverty in the municipality: (1) the promotion of sustainable organic agriculture by launching the Food Sufficiency Program; (2) the promotion of household approach to farming as opposed to corporate farming; and (3) the people empowerment through capacity building and community participation in decision making and governance. The municipality's vision is to make Dumingag the Organic Capital of the Philippines (Pacalioga 2011).

5.8.4.3 Promotion of Sustainable Organic Agriculture

Through sectoral consultation and strategic planning with different stakeholders, the municipality was able to craft its Masterplan on Organic Agriculture. Dumingag's sustainable organic agriculture program focused on providing profitable and stable farm income and promote stewardship on natural resources. Best practices relating to crop rotation, crop diversification, nutrient recycling, biological pest control, and integrated farming systems that combine tradition, innovation, and science were upheld to enhance ecological processes and functions and biodiversity.

Rice-duck farming was launched especially for those farms that have adequate supply of water.

Inland fisheries were developed in partnership with the Mindanao State University. From less than 5 ponds in 2007, there are 264 ponds to date.

Most households were trained on organic feed formulation to raise native chicken organically. The chicken raisers were formed into cooperatives for stable market access.

The organic growing of cassava was promoted. From 350 ha in 2007, there are now more than 2,000 ha of cassava plantation. The hole-method of planting was introduced for bigger yield. This method was also applied for other crops like bananas. The municipality has tied up with San Miguel Corp for marketing of cassava products.

From 5 ha of abaca in 2007, there are now more than 500 ha. The farmer holding is generally less than 2 ha of abaca farm. More than 100 farm workers make a living in the abaca farm, ushering the abaca handicrafts industry increasing the work force from 4 to 60 women providing income and stimulating further the local economy. The municipality has tied up with NewTech Pulp, Corp. for the marketing of abaca products.

From less than 10 ha of rubber, there are now 1,100 ha and this figure is still increasing. Dumingag looks forward to the additional jobs that will be generated to process the rubber latex right in Dumingag.

Less than 5 ha of falcata plantations existed in 2007. There are now more than 200 ha, harvestable in seven years. The municipality had tie-up with Novawood Industries for the marketing of falcata

Vermicomposting facilities were established to address farm waste, nutrient recycling, and humus-build-up.

Integrative medicine was identified as the best approach to deal with health problems. The municipality has established partnership with Damayang Pilipino sa Nederlands and with the Jobs Education for Peace to assist on issues relating to women empowerment, social enterprise, and integrative medicine.

The development of organic model farms were established through the JH Cerilles State College, transforming 100 % of the 43 ha of rice fields owned by the school into an organic farm.

The local government also established the Dumingag Institute of Sustainable Organic Agriculture to train farmers and their children on organic farming principles and technologies. But in addition, all the public and private school teachers in the municipality were educated on sustainable organic agriculture.

5.8.4.4 Promotion of Integrated and Diversified Household-Level of Farming

Organic agriculture is generally considered to be part of sustainable agriculture. But organic agriculture can also be unsustainable such as those produced on large corporate farms, and those on uncertified organic farms that utilize methods that are not considered integrated and diversified to be sustainable on long-term. There is an argument that for organic farming in the Philippines to be economically profitable, an organic farm has to produce in-house its own fertilizer and pesticide concoctions rather than purchasing commercially produced organic fertilizers, pesticides, and other ameliorants such as soil conditioners.

Dumingag farmers are taught on principles of Natural Farming System that originated in Korea. The farmers rely on indigenous microorganisms (IMO), oriental herbal nutrients (OHN), fermented plant/fruit juice (FPJ/FFJ), fish amino acids (FAA), lactic acid bacteria serum (LAS), and a host of several other practices where the farm inputs are produced by the farmers themselves. Former high-yielding mono-cropped and chemical-based farmers who have converted to sustainable organic farming principles have two to three rice lines in their rice paddies, legumes, and companion plants.

Furthermore, participatory plant breeding enable national organic farming networks with foothold in Dumingag to teach local residents to develop their own rice varieties using traditional varieties and farmers' expertise to select the best materials adapted to their locality. The germplasm collection is enhanced by exchange with other networked farmers in other organic farming communities in Mindanao. Scientists worked with farmers to enhance the municipality's rice genetic pool, and liberated the farmers on dependency to multinational seed companies.

The number of organic farming practitioners increased from less than 20 farmers in 2007 to 438 farmers and the number is still increasing. Labor-sharing scheme (called *hunlos* in the local dialect) was introduced especially for those whose farms are adjacent.

Dumingag generates and stores its own seed varieties of rice and they are no longer at the mercy of the giant seed companies nor of the big agrochemical firms.

5.8.4.5 Promotion of People's Participation and Empowerment

The heads of offices and the different stakeholders had to immerse themselves in all the 44 villages to campaign for the economic program centered on sustainable organic farming. The Livelihood Development Coordinators were organized as the direct arm of the mayor in community organization work. An elected councilor from each village was also designated as the focal person for the agricultural program. Furthermore, an Organic Farming Team was organized to implement the organic farming program, especially the component on education and advocacy. This enabled the mayor to dialog with the people at the grassroots level in all stages of planning, implementation, and evaluation of the Genuine People's Agenda.

An integral part of the empowerment was cooperative development through the Dumingag Organic Farming System Practitioners Association, with active set of officers and members. The cooperative is engaged in micro-finance to provide production loan, share cost of farming failures due to calamities, and assist members in marketing.

For capacity building, the municipality sent seven students to the Southeast Asia Rural Social Leadership Institute (SEARSOLIN) at Xavier University for 1-month training on organic agriculture. Additional three delegates were sent to South Korea for three-month course on Natural Farming Systems. Series of trainings on organic vegetable farming were conducted among farmers. The municipality is also on third phase of the process to acquire capability to certify its agricultural products in compliance with the international organic standards through the Organic Certification Center of the Philippines (OCCP).

Networking with the academe, the various national government offices, and with the provincial government to keep up with the scientific developments and to avail of national programs relating to organic agriculture was established and maintained. This includes membership in IFOAM through the endorsement by the Sustainable Agriculture Center of the Xavier University College of Agriculture.

5.8.4.6 Impact on the Municipality as a Whole

The local government income has increased. The average income before 2007 was about PhP 2.9 million and steadily increased to PhP4.5 millionin 2007, PhP5.7 million in 2008, PhP 12.5 million in 2009, and about PhP13.5 million in 2010. There were only 180 businesses in 2007 but as of 2010, there were about 324 business establishments. The municipality has risen from third class when the mayor assumed office, to second class. Since the municipality income is sourced from taxes paid by the residents, this reflects also on the increased income and improvement of economic well-being of the residents.

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6 Soil Issues and Challenges

Abstract

Soils impact our daily lives in many ways and in many uses. And it is because of these many ways and many uses that we are faced with soil issues and challenges which can only be properly addressed in terms of what is the best of the options. So this chapter culls out a sample soil series from a lowland, upland, or highland soils in Chaps. 2, 3, or 4 and pairs with a specific topic on the economic use of soils discussed in Chap. 5. Quite repetitive, but unless we view the soil in its landscape setting and reinforce the best scientific approach to the issue, we sometimes fail to realize that the most logical response was already tackled in previous chapters and the basic principles taught as early as during elementary education. We should realize and understand that true science works in harmony with nature. This chapter looks into land use competition, land use conversion, climate change and carbon sequestration, corporate farming and monoculture, research direction, and researchable areas for rice soils, flooding, and soil renewal, land degradation, soil productivity enhancement, soil pollution, the role of soil ecology in development planning in the Philippine context, how our industrial crops can compete in a global trading scenario where trade barriers and other protective mechanisms are being removed, and the problems associated when we open for economic use a mangrove area with acid sulfate properties. Repetition reinforces knowledge and understanding and shows how this book could be useful not only to soil surveyors but also to those who have interest and stake in soil resources management given a specific local condition. Finally, we sum up the whole book which started with the geological history of the country that defined the properties of its soils, and with the history of the Philippines that defined its agricultural geography, the two forces that catapulted us to where our agriculture is now. We close the *Soils of the Philippines* with the Filipino folk song that sums up the centuries of agricultural wisdom and the agricultural heritage of our forebears; the folk song is about crop diversification and multiple cropping in a backyard home gardening setting that reinforces the concept of food sovereignty.

6.1 Quingua Series and a Flood-Free Home

Food and shelter are human rights. Article 25, paragraph 1 of the Universal Declaration of Human Rights states, "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing, and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age, or other lack of livelihood circumstances beyond his control" (United Nations 2013).

But what happens when a piece of land is both suitable for the growing of crops and for human habitation at the same time?

A river levee is associated with man-made dikes to prevent the flooding of country sides. There are ancient levees that date back to the Mesopotamian and ancient Chinese civilizations which show that engineering

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techniques required to build a levee are known since the beginning of human civilization.

But there are also natural rivers or coastal levees. Rivers have the ability to carry sediments; and it varies with speed. When a river floods over its banks, the water spreads out, slows down, and deposits its load sediment. With time, the river's banks are built up above the level of the rest of the floodplain. These resulting ridges are called natural levees.

In the Philippines, soils associated with river levees are classified as Quingua series.

The Quingua series is a member of fine clayey, mixed, isohyperthermic family of *Typic Tropudalfs*. They are very well-drained soils occurring on level to nearly level (0.0–2.0 % slopes) of river levees of the alluvial landscapes. These soils have characteristically brownish color throughout the profile.

Surface horizons are brown to dark brown silty clay loam with yellowish brown and grayish brown mottles. The soil structure is friable, consistency is sticky and plastic. The argillic B-horizons are grayish or dark grayish brown with mottles. The soil structure is moderate to strong subangular blocky; consistency is sticky and plastic. The C-horizons that occur mostly below 150 cm are brown to dark brown, yellowish brown with yellowish red mottles (Soil Survey Division 1987).

The Quingua series is closely associated with the San Manuel series. Soil surveyors are normally confused which is which when faced to face with a soil profile. The Quingua series has an argillic B-horizon which is characterized by increase in clay content of the subsurface horizon and is certainly deeper than the San Manuel soils. Hence, Quingua soils belong to soil order Alfisols, the geologically mature soils. The San Manuel soils do not have argillic horizons or increase in clay content at the subsoil; but these are characterized by fine loamy texture throughout the profile underlain by stratified sandy materials. San Manuel Series are classified as *Fluventic Eutropepts* or belonging to soil order Inceptisols, or young soils with limited profile development. From the geological time point of view, the Quingua soils are older than the San Manuel soils.

The Quingua series are among the most productive agricultural soils. These are well-drained soils, and traditionally grown to orchards, paddy rice, and a variety of upland crops.

An example of Quingua soil series is Quingua silty clay loam, 0.0–2.0 % slopes covering approximately 2,242.91 ha in Laguna province. The mapping unit occurs on or near the border of San Cristobal and San Juan Rivers with the largest mapping units in barrios of Linga and Banadero. Extensive areas are also distributed by patches along the rivers of Sta. Maria, Tungkod, Macasipac, and Mata at barrio Coralan. Small portions are found in the western part of Lumban town just along Pagsanjan River. Some areas are scattered at the eastern part of Sta. Maria cemetery and at the base of a hill adjoining Mabitac town.

Certainly, the agricultural use of Quingua series competes with human settlement. To the people residing in the area, the choice of a natural river levee as a human habitation is hinged on it being flood-free. As naturally elevated, residents get close to a water source without having to worry about floods when the rainy seasons come. As well-drained loamy soils, river levees could provide a good foundation for structures. Without natural wetness, it is suitable for building site development. The hydraulic conductivity is moderately slow and the basic infiltration rate is moderate.

The food versus shelter issue is just a recent challenge as human population increases while our total area remains constant. For centuries, the use of natural river levees for human habitation has not affected significantly the agricultural production. But with rising population and a constant area, our best agricultural lands are giving way to housing developments. Debates will continue as our best agricultural areas give way to this intrusion of urban development. The importance of a decent house in a healthy environment is equally essential to nurture and mold our citizens as it is to feed them.

The Philippine legislature enacted the Agriculture and Fisheries Modernization Act (AFMA) and the consequent delineation of Agriculture and Fisheries Development Zones (SAFDZ). Still, zoning is a mandate vested with the local government that is elected every 3 years. Political and economic considerations, more than technical and ethical considerations, become a deciding factor in land conversions. Laws and technical guidelines for land conversion decisions are without teeth unless there is a political will to implement them.

It would not be surprising if the agricultural use of Quingua soil series will continue to give way to housing projects. The publication of the *Soils of the Philippines* might even provide the key in identifying best soils for human habitation, and increase their real estate value. For now, the demand and supply situation between food and housing will ultimately dictate the winner. Or the government can opt for a policy compromise of mix land use. Whatever the final fate of Quingua soil series, it remains a fact that in the quest for prime agricultural lands, the Quingua series is certainly on top of the list.

6.2 A Plush Subdivision in a Heavy Cracking Clay Soil

Vermont Royale Executive Village in Cainta, province of Rizal is a plush executive housing village. It is along Marcos Highway and very near malls, schools and colleges, and other city amenities. It stands among other housing subdivisions in the area—Mountain View Village, UE Village, Saint Gregory Village, to cite a few of the nearby plush villages. A three-story 4-bedroom house on a 174 m^2 lot area and with a garage for two cars could fetch as much as PhP7,200,000.00 or something like PhP41,000/m^2 (Sulit.com.ph 2013). The low-lying portions of the subdivision were top-of-head flooded during the height of Typhoon Ondoy; obviously those in the higher portions were not.

Typhoon Ondoy referred to the devastating typhoon that hit Metropolitan Manila in the last week of September 2009 that brought about massive flooding especially in the low-lying parts of Marikina-Cainta vicinities. Typhoon Ondoy's 9 h of rainfall brought an equivalent of 1 month rainfall, reputedly the worst in 40 years (Ramos et al. 2009). It was one of the worst flooding experiences; many residents were trapped to their rooftops for as much as 18 h due to rising flood waters. It left many residents traumatic and living in fear every time the rain comes.

But more than the slightly and moderately flooded rating of this subdivision that makes this housing village in the list of being in the worst flooding scenarios in a once-in-forty-years event. Vermont Royale homes is the epitome of land conversion in the Philippines, as food production areas compete with the demand for more living spaces. The soils of the subdivision belong to Marikina soil series. The typical pedon that represented Marikina soil series was taken at an empty lot in this subdivision during the field soil survey work. It is a Vertisol and dominated by swelling–shrinking clays. It could have been a rice field sometime in the past, its best land use given the soil properties. The area has given way to advancing urbanization of the metropolitan suburbs.

The Marikina series is a member of the fine, mixed, isohyperthermic family of *UdorthenticChromusterts*. The soils are deep, somewhat poorly drained occurring on level to nearly level (0.0–2.0 % slopes) minor alluvial plain. The A-horizon, not more than 30 cm thick, is gray, light gray to gray, greenish gray clay with strong brown yellowish red, brown to dark brown mottles. Mottling is an indication of fluctuating water table. The cambic B-horizon is yellowish brown, dark yellowish brown, brown to dark brown, grayish brown clay with distinct clear gray, dark gray, light olive gray, or yellowish brown mottles. Few thin continuous and discontinuous slickensides commonly occur. Few soft iron-manganese concretions and highly weathered tuffaceous fragments occur with increasing depth. The C-horizon below 100–150 cm depth is dark yellowish brown or yellowish brown clay. There are also mottles here, brown, dark brown, strong brown, or gray in color. Few small iron-manganese concretions and highly tuffaceous fragments can be found. Few thin discontinuous slickensides sometimes occur in the C-horizon (Soil Survey Division 1989).

The Marikina series is associated with Pinagbuhatan series. Both are derived from alluvial deposits and they both occur on level to nearly level minor alluvial plains. Marikina soils, however, is somewhat poorly drained or have lighter color (high chroma) while Pinagbuhatan soils are poorly drained and have darker B-horizon (low chroma). Pinagbuhatan soils have higher cation-exchange capacity and base saturation percentage compared to Marikina soils.

Since Marikina soils have slow permeability, the external drainage is poor and the internal drainage is somewhat poor. This property makes it perfect for the growing of rice.

Marikina clay, 0.0–2.0 % slopes, no flooding, in the province of Rizal covers around 1,482 ha and is mapped in Barrio Burgos, Montalban towards Ampid and Nangka of San Mateo, Rizal. A small portion is found north of Taytay town proper. Included in this unit are small soils with shallow solum and soils found in geomorphologically slightly depressed areas. The soils are planted with paddy rice and at the time of soil survey in 1989, some are used for urban expansion.

Marikina clay, 0.0–2.0 % slopes, slightly flooded covers 1,684 ha. It occupied mostly barrios of Bayanbayanan and Sto. Niño of Marikina. Some areas are found north and south of Marikina town near the Marikina River. At the time of the survey, these soils are devoted to paddy rice but some parts are converted to urban and commercial expansion.

Marikina clay, 0.0–2.0 % slopes, moderately flooded occupy about 340 ha and mapped in Barrio Sta. Elma and San Roque, Marikina. The soils, at the time of the survey, is primarily devoted to paddy rice. Marikina City is highly urbanized these days, and hardly is there a rice field in the area.

Indeed, there is hardly any soils belonging to Marikina series in the province of Rizal devoted to rice production these days, except perhaps in the remote areas of Montalban and San Mateo. Even Marikina has ceded from Rizal Province as early as 1975 to become part of the Metropolitan Manila (National Capital Region). It became a chartered first class city in 1996 under Republic Act 8223 (Wikipedia 2013a). Most of the Marikina soil series originally described in the soil survey report are now extinct, buried under housing subdivisions and urban expansion.

But how suitable are Marikina soil series for urban development? The central concept of Vertisols, the soil order under which Marikina soil series is classified, is that these soils have high content of expanding clay and that at some time of the year, they have deep wide cracks. They shrink when dry and swell when wet. The clay content is high, greater than 30 % to at least 50 cm from the surface. When these soils in dry state have cracks at least 1 cm wide and reach a depth of 50 cm or more, these soils are also called heavy cracking soils (Pourch 2011).

Vertisols owe their specific properties to the dominance of swelling clay minerals, mainly montmorillonite (Greenfield 2004). When dry, the soils contract resulting in deep cracks. The cracks close after rains when the clay minerals swell. During expansion of the clay minerals, high pressures are developed within these soils causing a characteristic soil structure with wedge-shaped aggregates in the surface soil and planar soil blocks in the subsoil. The slippage of one soil block over the other leads to the formation of typical polished surfaces, "slickensides" on the blocks (Greenfield 2004). Expansion and contraction also cause the formation of microtopographic features known as "gilgai", a distinctive microrelief of knolls and basins that develop by internal mass movements in the soil and heaving of the underlying material to the surface (Greenfield 2004).

Vertisols are generally found on sedimentary plains, both on level and in depressions. Vertisols are hard to work with—very hard consistence when dry and very plastic and sticky ("heavy") when wet. The workability of the soil is often limited to very short periods of medium or optimal water status (Greenfield 2004). Tillage operation is normally done in the dry season with heavy machinery; mechanical tillage in the wet season causes serious soil compaction. Wet Vertisols are impassable (FAO 1993). These soils are imperfectly to poorly drained; leaching is limited, and hydraulic conductivity is very low. Because of this, clay dispersion accompanied by clay movement, the normal consequence of high sodium saturation in saline or salt-affected soils, cannot take place in Vertisols. Flooding is a problem in areas with high rainfall.

Vertisols are chemically fertile and capable of sustaining continuous cropping. The structural stability is rather low and these soils are susceptible to water erosion. They do not necessarily require fallow period because pedoturbation brings subsoil to the surface. These soils are excellent for rice production and for animal grazing but create serious engineering problems if the agricultural land use is converted to housing subdivisions or industrial estates.

Structures standing on Vertisols would see brick cracks, sticking doors and sheet rock damage, separation of expansion joints, diagonal cracks above or below windows, visible cracks of foundation slab, cracking or waving of floor finishes. There is a feeling of walking up or down hill as one walks across the room. As the clay expands during wet season, the structure and the foundation moves up and down. As long as the movement of the foundation is not great enough to damage the house, it may not pose much of a problem (Flori-tex 2009).

Soils dominated by swelling–shrinking clays present hazards to structures built on top resulting from differential vertical movement that occurs as clay moisture content adjusts to changed environment. In a highway pavement, differential movement of 0.4 in. within a horizontal distance of about 6 m (20 ft) is enough to pose an engineering problem (Integrated Foundation Solutions 2013). Buildings are capable of withstanding even less differential movement before structural damage occurs. But the greatest damage on small buildings are impacted on those constructed when clays were dry followed by soaking rains that prompt swelling of clays (Integrated Foundation Solutions 2013).

Design and construction of structures that ignore the existence of swelling–shrinking soils can worsen a manageable situation and can result to improper structural design (improper foundation loading, improper depth or diameter of drilled pier, insufficient reinforcing steel, and insufficient attention to surface and underground water), faulty construction, inappropriate landscaping, and long-term maintenance practices unsuited to the specific soil conditions (Integrated Foundation Solutions 2013). These would be continuing and costly problem.

But in an ever expanding metropolis, where the land is prime, and real estate costs escalate to a market value attractive to land speculators and investors and housing developers, urban encroachment even to soils where the best use is so specific to the growing of rice, it is science-technology-engineering that is looked up to in order to overcome land use limitations. Developers can scrape off the soils with vertic properties, or bury the soil beyond the reach of the structure's foundation. But whether man can triumph in the battle against nature is yet to be seen.

Meanwhile, regular floods that revisit the flood plains to renew the soils with silt depositions as part of nature's soil formation and development cycle, become a nightmare for the residents. The soil enriching silt left behind goes to waste as residents clean up and start their life anew. At the same time, in another part of the metropolis, untouched by flood, the residents practicing urban agriculture put fertilizers to grow their crops, spending a sizeable amount of money and effort to enrich their soil and improve productivity. Ah, this is life; this is the irony of life.

6.3 Soil Carbon Sequestration and a Look at Organic Soils

Our modern society is a high energy consuming society. Our huge consumption of fossil fuels and the widespread deforestation transformed large pools of carbon into atmospheric carbon dioxide causing global warming and consequently inducing climate change.

In the Philippines, the per capita consumption of energy in 2005 is estimated at 3.4 barrels of fuel equivalent, computed as the ratio of total energy consumption over the estimated population on that year (Virola 2013). Generally, we use electricity for lighting and for home recreation such as television and radio. Other types of fossil fuel use include

Liquefied Petroleum Gas (LPG) and kerosene for cooking. The Philippine energy supply is a mix of indigenous and imported energy. The energy that fuels our nation does not come without a price. Not only it contributes to economic drain on scarce foreign exchange resources, the use of fossil fuel also contributes significantly to the release of carbon dioxide to the atmosphere, and be a factor to global warming.

In gasoline alone, carbon represents about 84 % of the weight. A gallon (about 3.8 L) of gasoline could release as much as 20 lbs (or about 9 kgs) of carbon dioxide (US Energy Information Administration 2013). Globally, the burning of fossil fuels releases an estimated 21.3 billion tons of carbon dioxide per year (Karoly 2013). Studies of Dr. Jarl Ahlbeck indicated that about 50 % stayed in the atmosphere, 5 % is absorbed somewhere based on constant airborne fraction rule, and 45 % is absorbed according to partial-pressure-controlled mechanism (Ahlbeck 1999).

Plants absorbed man-made emissions. But agriculture and forestry biomass waste exposed to sunlight easily breaks down to return carbon dioxide to the atmosphere. If not, then aerobic bacterial will release large amount of carbon dioxide back into the atmosphere. It is said that next to coal-fired electricity generator, farms and the transport system are the largest carbon emitters.

It is estimated that agricultural soils contain more than three times the amount of carbon in the atmosphere based on the 2,200 billion tones of carbon estimates by Batjes (1996). However, most agricultural soils have lost their original soil organic carbon pool when it was yet in a natural ecosystem, and prior to agricultural land use. This is because soil organic matter decomposes when the soil is disturbed following tillage practices. Soil organic matter declines after conversion of primary forests to plantation and cultivated lands.

In agricultural systems, capturing and restoring atmospheric carbon in crops and soils is dependent on how the soil resource is managed. Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately re-emitted (Sundermeier et al. 2013). A stable soil organic matter is being looked into to offset the emissions of combustion engines powered by fossil fuels—a means that both enhances soil quality and at the same time contributes to long-term agronomic productivity (Sundermeier et al. 2013).

Soil carbon sequestration techniques in agricultural soils are focused on management systems that add high amounts of biomass to the soil (example is promotion of organic agriculture), cause minimal soil disturbance (promotion of zero or minimum or conservation tillage), conserve the soil and water (promotion of cover cropping and crop rotation), improve soil structure, and enhance soil faunal activity (Ecological Society of America 2000). Considering current standard tillage practices to puddle rice soils in the lowlands, it is actually the upland and hillyland soils that would be able to contribute significantly to carbon sequestration.

Carbon is a key element in soil organic matter, as much as 57 %. Soil organic matter is created by the cycling of plant and animal detritus by soil organisms. A well-decomposed organic matter forms humus, a dark brown porous and spongy material that provides a carbon and energy source for soil and plant microorganisms. Humus, the advanced form of soil organic matter, has a buffer property, reducing fluctuations in soil acidity and nutrient availability. A soil with high organic matter is more productive than the same soil where much of the organic matter is removed by burning and other poor soil management practices. Once sequestered, carbon remains in the soil as long as restorative land use and other good management practices are followed.

How much organic matter do Philippine soils contain? On the average, between 1.3 and 1.5 %. A soil with organic matter at 2 % is rather high for an average Philippine soils. Volcanic ash soils (those classified as Andisols) could have 3 to as high as 8 % organic matter. Do you think this is significant enough to sequester atmospheric carbon? The Philippines is in the tropics. Warmer climate increases rate of biomass decomposition and soil carbon turnover, resulting in a positive feedback on atmospheric carbon dioxide as this is released from soils at increasing rates. It is unlikely that even at continuous and decades of organic fertilization that soil organic matter percentage can be further improved.

How about organic soils, or soils classified as Histosols? How much carbon could they sequester?

By definition, organic soils consist chiefly or at least 30 % of organic matter. Peat soils and muck soils are examples. Peat is an accumulation of partially decayed vegetation and formed in marshy areas, inhibited from decaying fully by acidic and anaerobic conditions. In many parts of the world, peat soils are generally used as a fuel source by nearby communities, functioning just like fossil fuels, and contributing to carbon dioxide emissions to the atmosphere.

Muck is made up primarily of humus from drained swamplands. When the water dried up, what was left was vegetation and decaying trees. Crops would require high levels of phosphorus and potassium. Magnesium is highly exchangeable and will have to be added as the soil ages. The long-term continued use of organic soils for agriculture requires good water table control and soil management practices. Organic soils subside at a steady rate due to oxidation of the soil organic matter, soil shrinkage, wind and water erosion, and the fluctuating height of water table.

Dolongan series is an example of an organic soil in the Philippines. It is classified as a *TypicTropohemist.* Dolongan series is found on estuarine plain, level to nearly level, no flooding nor erosion hazards. There are no rock outcrops.

The soil is poorly drained, the parent material is organic materials. The typical pedon herein described is collected at Bgy. Dolongan in Basey, Samar. The soils are planted to vegetables and fruit trees.

The A-horizon is up to 7 cm deep, black, moist, loam, no mottles, weak to moderately fine granular structure, nonsticky, nonplastic, friable, common fine roots, clear wavy boundary. Right below is the organic horizon (designated as **O**) with highly decomposed organic material (designated as **a**) or at intermediate state of decomposition (designated as **e**). The Oa1 horizon that extends to 26 cm is dark reddish brown, moist, the texture cannot be determined in the field, no mottles, moderate fine granular structures, nonsticky, nonplastic, friable, common very fine tubular pores, many highly decomposed organic materials interspaced with few (1–3 mm in size) fibers, few fine roots, gradual wavy boundary. The Oe horizon that extends to 38 cm is red and dark reddish brown, undecomposed organic materials, moist, nonsticky, nonplastic, friable, clear wavy boundary. Below is the 2Oa1 horizon up to 56 cm, the 2Oe1 horizon that extends up to 90 cm, then the 2Oe2 horizon up to 112 cm, and the 3Oe1 horizon up to 131 cm.

It is interesting that for organic soils, the definition is at least 30 % organic matter but in the case of Dolongan soil series, the highest laboratory analysis obtained is 23.9 % at 2Oa1 horizon. The topsoil has 9.09 % organic matter, a little bit higher than the average for volcanic ash soils, but certainly quite very low for organic soils. The organic matter analysis shows how fast organic matter decomposition occurs under tropical condition; so fast that even organic soils would have difficulty qualifying as organic soils if we use international definition of at least 30 % organic matter. Can organic soils provide a pool of sequestered carbon under Philippine conditions? If these organic soils are even poorly managed, they would even contribute to the release of greenhouse gases to the atmosphere.

To sum up, it can be seen that as much as Philippine agricultural soils can contribute to carbon sequestration, it is itself a major contributor of greenhouse gases, owing to rapid organic matter decomposition under tropical conditions. Significant attention on soil carbon sequestration for a tropical country like the Philippines would have to be focused on forest soils, not on agricultural soils. Most of the studies on carbon dioxide balance in tropical rainforests are centered on those emitted by the rainforest vegetation. Perhaps our soil researchers could spotlight their studies on the dynamics of soil organic carbon under natural forest, secondary forest, pasture, and organic soils. We need to generate more data to acquire a clearer picture of soil carbon sequestration under Philippine conditions.

Nevertheless, agricultural soils will be able to contribute significantly to carbon sequestration provided our current farm management practices are revised with the objective of diminishing the rate of soil organic matter decomposition under tropical conditions. It is time to teach our farmers new farming techniques adapted to climate change.

6.4 A Loophole in the Agribusiness Enterprise Development Planning

The Iwahig Prison and Penal Farm was established in 1902 by the United States to originally house prisoners who had fought against the American colonizers during the American-Filipino War. It is in the island province of Palawan, south of Puerto Princesa. Presently, it is one of the seven operating units of the Bureau of Corrections under the Department of Justice. It is unique among penal institutions because of minimum security despite the presence of more than 2,000 inmates convicted of homicide. Vocational activities are available which includes farming, fishing, forestry, and carpentry. Just to imagine how vast this penal farm is, in the late 1950s when part of the colony was distributed to deserving colonists, Iwahig was subdivided into four districts—the Central subcolony with 14,700 ha, Sta. Lucia with 9,685 ha, Montible with 8,000 ha, and Inagawan with 13,000 ha (Wikipedia 2013b).

But Iwahig is but just one of the seven penal colonies maintained by the government. The Sablayan Prison and Penal Farm is on a 16,190 ha of government land in the province of Mindoro Occidental, established in 1954 (Bureau of Corrections 2012a). San Ramon Prison and Penal Farm is sprawled within 1,414 ha property in Zamboanga City, built during the Spanish era in 1869 (Bureau of Corrections 2012b). The Davao Prison and Penal Farm in Santo Tomas, Davao del Norte, built in 1932, is sprawled on 5,212 ha of the vast Tadeco Banana Plantation (Wikipilipinas 2008).

It is this vast agricultural areas and literally free manpower that have made these prison farms attractive to agribusiness development planning to be part of the mainstream food production program of the national government. Assured foreign market for high value crops at least contribute to national food self-sufficiency; if we consider the domestic market only, farm management can be professionalized, income for the inmates assured, and government funds utilized in a more worthy and sustainable endeavor—the development of penal farms for agribusiness is seriously being considered by the national government. This means public investments such as the inclusion of provisions for irrigation facilities, agricultural credit, and other infrastructural projects and services such as improvement of farm-to-market roads, delivery of farm machineries, and the like. And this is certainly a positive development and a worthy initiative.

High value crops, from the point of view of Republic Act 7900 or the High Value Crops Development Act, refers to nontraditional crops which include but not necessarily limited to coffee and cacao, fruit crops (citrus, cashew, guyabano, papaya, mango, pineapple, strawberry, jackfruit, rambutan, durian, mangosteen, guava, lanzones, and watermelon), root crops (potato and purple yam), vegetable crops (asparagus, broccoli, cabbage, celery, carrots, cauliflower, radish, tomato, bell pepper, and patola) legumes (pole sitao, snap beans and garden peas), spices and condiments (black pepper, garlic, ginger, and onion), and cutflower and ornamental foliage plants (chrysanthemum, gladiolus, anthuriums, orchids, and the likes) (Congressional Oversight Committee on Agricultural and Fisheries Modernization (COCAFM) 2012).

Singling out the Iwahig Prison and Penal Farm as our example, the soils of Iwahig belongs to Guimbalaon clay. The Guimbalaon series are primary soils developed in place from the weathering of underlying rocks, mainly basalt and andesite. These are red soils or acidic. The external drainage is fair to excessive while the internal drainage is fair. The soils have slopes up to 25 % with moderate to severe erosion if left unprotected. The uncultivated areas are generally grasslands and the cultivated areas are planted to coconuts, upland rice, diversified upland crops such as legumes, and fruit trees such as the acid-soil loving cashew trees. Liming would be needed to utilize productively this soil to high value crops and soil conservation practices have to be employed.

Matching, therefore, the clayey soil characteristics and the crop requirements, eliminating already those that would not meet the climatic requirements, it appears that pineapple, coffee, and cacao could be grown commercially in the Iwahig Penal Farm. Cashew is also acid loving but since it requires well-drained sandy loams, the development of drainage system needs to be given extra consideration. Black pepper is not sensitive to soil acidity but requires well-drained soil conditions and like cashew, the establishment of a drainage system would be an added investment. The soil texture would suit onion, citrus, pole sitao, snap beans, papaya, and chrysanthemum but these are rather sensitive to soil acidity. The soil requirement of the other crops could not be met by the soil conditions prevailing in the farm; either the soil texture is heavy for the crop or the acid condition could not be tolerated or both. Guava can tolerate many soil conditions, and the tree is often regarded as a weed. But in the Philippine context, commercial guava production is generally perceived as referring to guapple, the nonseasonal extra large fruit which would require well-drained clay loam to sandy loam rich in organic matter.

The active promotion of free trade has spurred newly industrialized economies like the Philippines to focus on export of agricultural products. Government investments for the conversion of idle or underutilized government lands into a viable agribusiness enterprise is considered important to attain food security and improve our balance of trade with other countries. To be globally competitive is the name of the game.

The major mistake in the preparation of the feasibility studies and business proposals is to pattern government agribusiness enterprise development similar to those of the multinationals operating in the country. To be competitive and gain significant market share, the focus is on crop commodities with comparative advantage in terms of quality and production costs. One town, one product is a priority government program to promote entrepreneurship by providing a comprehensive assistance package that encompasses identification, development, and market of a distinctive product or service. While this is a worthy project and deserves success, policy planners miss one point when considering an *agricultural commodity* for agribusiness enterprise development.

So what is wrong with following the multinationals in their agribusiness endeavour? The answer is in monocropping. Given the crop suitability for Guimbalaon soils that constitutes the Iwahig Penal Farm, a singular crop is expected to be focused for agribusiness development. Maybe cashew. Or maybe coffee and cacao. Or maybe black pepper. Expect the feasibility study to be focused on one or two of these suitable crops. This violates the very first principle of a balanced ecosystem—*unity in diversity*. Nature in her wisdom will not allow the dominance of a single species in an ecosystem. A natural dominance of a single species such as dominance of cogon in a newly burnt *kaingin* is an indication that the soil is healing itself. Cogons are deep rooted and can get their nutrients down the profile; and in time, as the soil temperature goes down and the degraded biomass adds to the soil humus to enrich the soil, other pioneering plants will grow.

Few development planners realize the magnitude of challenges that face multinationals engaged in monoculture. Not only does it require great management skill, the environmental instability created has brought about capital intensive technology, and the reliance on agricultural chemicals to keep the system productive. Altieri (2000) enumerated the first wave of environmental problems at the ecotope level—erosion, loss of soil fertility, depletion of nutrient reserves, salinization and alkalinisation, pollution of water systems, and eventual loss of fertile croplands to urban development. At the bioceonosis level, we have loss of crop, wild plant, and animal genetic resources, elimination of natural enemies, pest resurgence and genetic resistance to pesticides, chemical contamination, and destruction of natural control mechanisms. Altieri further stated that intensive management oftentimes results in the amount of energy invested to produce a desired yield, surpassing the energy harvested (Altieri 2000).

In the second wave of environmental problems, Altiere noted the emergence of biotechnology but it followed the same paradigm of addressing challenges associated with monoculture, or continuing defiance of the law of nature. The resulting environmental risks linked with genetically engineered crops were mentioned such as—condition for genetic uniformity making a single cultivar very vulnerable to a new matching strain of a pathogen or pest; promotion of genetic erosion, unpredictable ecological effects such as possible creation of super weeds and possible transfer of virus-derived transgenes into wild relatives (Altieri 2000).

Not even the best minds with the best plans, the best managers, the substantial government investment, and the assured foreign market can sustain these one crop, one town agribusiness enterprise efforts after the incumbent's political term for the simple reason that nature will not allow monoculture or the dominance of a single plant species in an ecological system. Few people are aware of the huge cost in crop protection that multinational companies invest to keep the productivity of their monocropped plantations. As most of these are under contract growing, eventually when the lease is finished and the lands are returned to the farmers, the lands are generally no longer productive because of long-term use of environmentally destructive agricultural chemicals. Unless the government is willing to match the investments of multinationals in crop protection, it would be difficult to keep up with their production pace.

But with the expected political pressures from elected officials, bureaucrats and technocrats need to come up with economically viable and truly productive farms that can be shown to the ordinary people, at least until the elected official's term ends. We tend to forget such simple wisdom as *unity in diversity* we learned as early as elementary science, hoping that technology would bail us out of what monocropping brings. But what the computers and spreadsheet softwares cannot provide policy planners is the desired *sustainable* increase in farmer income beyond the elected official's term.

It is recognized that an agroecosystem is a young ecosystem, and thus, inherently unstable. To attain a certain degree of complexity and stability, the strategy is to approximate a mature ecosystem such as a forest ecosystem. Obviously, in crop diversification and crop integration planning, we have to include perennials like fruit trees which would take more than an elective official's term to be fruit bearing and income generating. Timber trees would take even a generation to be harvestable. And with the political pressures for the development planners and policy makers to have tangible outputs in time for the next election, development programs are generally short-sighted. Agricultural programs are designed to provide the greatest political exposure with visible-tangible-vote getting strategies and impacts such as dramatic increase in crop yield and farmer income, infrastructural development like farm-to-market roads and water impounding projects, agricultural information portals that can be accessed and understood by ordinary farmers, and the likes.

Government projects are therefore generally perceived by the public to be but for a show. Who would admit these monocropped lands are highly infested ecological nightmares since crop protection strategies are considered vital part of every crop production technology? When the next set of elected officials come, who knows, maybe the focus is on logged over forests that have become grasslands; the vast idle prison lands already eyed for privatization to raise much needed revenues to sustain government spending. Prime military lands were already sold. Government schools in prime urban commercial areas were already sold. Anyway, such agricultural development of prison lands would have been credited to the predecessor and better left to its deteriorated state for even greater political impact in favor of the incumbent. If not sold, these already developed government agricultural lands would most probably be left to succumb to the powerful forces of nature. And agricultural development planners are back to square one to look for new agricultural development target areas under the new administration.

6.5 A Second Look at a Typical Rice Soil: Are There Still Researchable Areas?

The San Manuel series is classified as fine loamy, mixed, isohyperthermic *Fluventic Eutropepts.* These are deep soils, well-drained on nearly to gently sloping river terraces or levees of minor alluvial plains. The soils are brown to dark brown, dark yellowish brown friable to firm clay loam, silty clay loam, silty clay, or silt loam. Inherent fertility is generally very high for paddy rice production with adequate organic matter but moderate for upland crops, where the organic matter can be considered deficient. The cation-exchange capacity and the base saturation percentage are both adequate. The soil reaction is likewise adequate with pH ranging from 6.2 to 7.6. These soils are subjected to flooding by seasonal river overflow. San Manuel series is considered an important rice soils but in areas near highly urbanized cities like Metro Manila, this soil series is commonly grown to diversified upland crops.

Increasing the productivity of rice soils is at the forefront of every administration's agricultural program. The focus is generally on the development of high yielding varieties and provisions for irrigation, credit, and postharvest facilities.

But soils, given appropriate management techniques, can also significantly contribute to improving productivity. But what is pathetic is that given limited resources, the research and development program of the national government and those of the local government units are generally focused on applied research. For agricultural programs as well as agricultural researches to pass through approval stage and evaluation by policy makers, the basic question to answer is the impact on farmers' income by looking at profitability criteria. Authorities generally demand from bureaucrats projects and researches that address directly the needs of farmers, or at least impact them in a positive way. Hence, most of the soil-related studies are fertility experiments, looking for that optimal fertilization rates given a specific crop commodity. There is hardly any basic research conducted in most government agricultural research institutions; simple quest for knowledge for knowledge sake. Knowledge products, being intangible, are hardly given premium priority.

Are there still researchable areas in rice soils?

Stresses on our fragile rice soils are often human-induced. Fertilizers and pesticides applied in our rice fields contaminate the soil and groundwater systems. Garbage landfills are sources of hazardous chemicals, which contrary to general perception, is not just limited to the landfill vicinities. The unsaturated zone between the soil surface and the groundwater is a research area to come up with management technologies to prevent or remediate pollution problems. Van Genuchten (1994) proposed measurements and modeling of unsaturated zone flow and transport processes, not only with downward, but also with upward flow especially for soils with shallow water table, which is a characteristics of most rice soils. His paper was a literature review of conceptual issues on vadose zone flow and transport modeling to analyze specific experiments on water and solute movement. From limited field studies, Van Genuchten extrapolated information for different soils, crops, and climatic conditions, as well as for different tillage and water management schemes, for evaluating the comparative effects of alternative soil and water management practices and chemical application technologies on crop production and groundwater pollution (Van Genuchten 1994). Given the limitation of models, he nevertheless argued that they provide a means for organizing and integrating our knowledge and understanding of the soil processes and provide guidance to experimental research programs (Van Genuchten 1994). The several models he discussed in his paper can be tested for various Philippine rice soil conditions. What such studies cannot provide research evaluators and policy makers is how much incremental increase in farmer income could be made when the results are available; a major criterion to fund deplorable agricultural researches in the country.

Despite never-ending soil fertility experiments at national, local, and academic research stations, the chemical and physical degradation of rice soils remain a major issue and concern. Nutrient depletion of rice soils as an issue seems at first glance quite contradictory to efforts of the national government to promote organic agriculture to wean farmers away from heavy dependence on expensive and excessive use of agricultural chemicals. The only explanation is that rice farming is nutrient mining. The initial efforts to address nutrient mining and degradation of rice soils through chemical fertilization during the decades of the Green Revolution did not sustainably address the issue but brought with it other environmental concerns. With the exigency of feeding the country's burgeoning population and having reached the limits of expanding our cultivated areas, the government looks at other crop management options.

And hence, the Philippine Organic Agriculture Law was enacted. And this should provide new areas of research. Besides the traditional soil erosion and soil nutrient flow and balance studies, multidisciplinary soil ecological research would provide a fresh accent on better understanding of soil biological processes in addition to the usual focus on the physical and chemical properties and processes of soils to attain sustainable productivity.

We need soil biologists to conduct sampling and enumeration of major decomposition organisms in rice soils—the food webs, spatial and temporal patterns, interactions and relationships, and their roles in nutrient cycling. It may be necessary to use stable isotopes to estimate the trophic positions of soil fauna, and coordination with the Philippine Nuclear Research Institute would be appropriate. We need studies that address rice soil health issues—the development of key concepts, and in measuring and monitoring which would necessarily update existing soil test programs. The emphasis could be on soil management practices that promote soil health such as fallow periods, rice straw management, crop rotation, use of commercial soil health products which would relate not only to the use of organic fertilizers and biofertilizers to boost nitrogen sources, but could also introduce Vesicular ArbuscularMycrohrhiza (VAM) in our rice production systems for phosphorus and zinc sources.

We have not done studies on soil compaction, usually consequence of farm mechanization such as use of tractors and an important parameter in land degradation and soil health studies. Most of these studies are baseline data generation in nature and would not be able to provide research evaluators and policy makers with how much incremental increase in farmer income when results are available. We desire to imitate the mechanization in advance countries but we have not realized the environmental consequences they have to pay.

The current soil survey methodology is based on the classic concept of soil—landscape relationship. Considering that the delineation of San Manuel series were done several decades back, we need an update to cope with technological progress and the digital spatial data requirements of the Information Age. An ordinary rice farmer, given an appropriate computer resource, can nowadays access simple and easy to navigate satellite imagery such as what we have in Google Earth. There are emerging technologies such as SoLIM (University of Wisconsin-Madison 2002) which represents soil spatial variation by pixels as vectors of similarity values, uses Geographic Information System (GIS) techniques and automated fuzzy inference scheme, and extracts and stores soil-landscape relationships. There are other soil survey and mapping technologies such as the use of remote sensing with gamma ray spectrometry (McKenzie et al. 2008) although some of the techniques are still in their infancy. Nevertheless, digital soil mapping and pedometrics is certainly here to stay. This is also a primary data generation activity and a map output could not contribute directly to incremental increase in farmer income for a research proposal to be attractive to project evaluators and policy makers. How relevant is the quote from R. S. Smith way back in 1928, then director of the Illinois Soil Survey who responded to the inquiry of the Comptroller of the University of Illinois as to the estimated cost of completing the State's soil survey. He said, "I cannot conceive of the time when knowledge of soils will be complete. Our expectation is that our successors will build on what has been done similarly as we are building on the work of our predecessors" (USDA—National Resources Conservation Service 2013).

With elections regularly held and how to attract votes a primary consideration in our democratic processes and governance, it would certainly take a long time for *quest for knowledge for knowledge' sake* to come into the fore. The political agenda will impact decision powers in every areas of governance including research policies and directions. Meanwhile, our neighboring countries will continue to make significant progress in their agricultural sciences in their efforts to be globally competitive. But for us here, without even basic soil knowledge, it is not surprising that we lag behind.

6.6 A Lost Step in Soil Renewal Cycle in the Quest for Economic Progress

Typhoon Frank (international code name Fengshen) that passed by Iloilo province in 2008 made news impact. It not only flooded rice areas but also submerged about 42 towns of the province, with many residents spending the night in their rooftops or on tree tops. It was the worst flood experienced in Western Visayas in memory. Roads were impassable as trees and giant billboards fell, electricity and communication lines were cut off, houses and vehicles were swept by rampaging waters. Even a ferry boat capsized in between the seas of the neighboring island. Standing crops were damaged, and several lives were lost. The province was declared to be in a State of Calamity. The most affected towns were Oton, Miag-ao, Leganes, Pavia, Zaraga, Leon, Janiuay, Pototan, Dumangas, Barotac Nueva, Ajuy, and Carles. The agricultural damage alone was placed at PhP555 million as the typhoon affected 246,441 ha of farmlands in Western Visayas, Eastern Mindanao, and Calabarzon. The floods left a thick layer of mud all over the city and in most of the affected municipalities of the province (Burgos and Nestor 2008).

Flood is certainly a major threat in river basins throughout the world and much more for a monsoon country like the Philippines. This Typhoon Frank alone was reported to have affected some 242,213 ha of rice lands, 1,064 ha of corn areas, and 3,164 ha of areas planted to vegetables and high value commercial crops in the affected regions (Corporate Network for Disaster Response 2012).

Sta. Rita series is the most important flood plain soils of Iloilo province, occupying level lands from Tigbauan at the west to San Miguel, Janiuay, and Pototan at the north, and Barotac Nuevo and Dumangas at the east. It is developed from alluvial deposits as most of the big rivers such as Iloilo, Aganan, Jaro, and Jalaud Rivers naturally drain this area. The surface soil is black to dark brown with moderate coarse granular structure; highly plastic and soft when wet, shrinks and cracks and becomes very hard when dry. There are no stones, gravels, or pebbles. The drainage is generally poor because of its topography and the heaviness and compactness of the surface soil and the subsoil.

When floods such as this brought about by Typhoon Frank covers the rice areas, the rapid water movement and silt left behind have destructive effects. Crop survival depends on tolerance to the duration of the flooding condition. As the flood water recede and the silt left behind dries, crusting of the surface layer follows, restricting gas exchange in the root zone. Standing crops that survived the forces of water movement and prolonged anaerobic condition would die for lack of oxygen in the root system and for the toxic metabolites from anaerobic decomposition.

Despite the awesome and destructive power of floods, the mud and silt left behind is the much needed renewal of agricultural lands, providing excellent fertilizers for crops. In fact, these flood plains, as these areas regularly visited by floods are called, were historically formed from the flood sediments. Even if the land is over farmed and all the nutrients are depleted from the soil, the land renews its fertility when new deposits come after the next year's flooding season.

It was taught as early as elementary social studies that the flooding of the Nile was used by the ancient Egyptians to their advantage until 1970 when the Aswan Dam was constructed. Developing their science to predict the flooding of the Nile, the ancient Egyptians would know when the flood would come, but they could not determine how high the flood would rise to irrigate their fields. "Nilometers" were built into the river's banks to measure the flood and assess the taxes that would be paid by the farmers the succeeding year (Wikipedia 2012a).

It is inconceivable not to associate the rise of civilizations to rivers and the importance of the annual flood season to sustain the populace. The Yellow River watered the cradle of Chinese civilization and the floods attributed to the river have been oftentimes catastrophic, making most people refer to it as "China's Sorrow" and "The Ungovernable" (Wikipedia 2013b). It is the river silt that makes North China fertile and sustains its huge population through its thousands of years of history. Another of Asia's ancient civilization, India, is known for its Ganges River sourced from the Himalayas. It is not only a source of life, but also a place of death where Hindus bring their deceased. The most sacred river of the Hindus is lined up with fertile delta; and despite destructive floodings at times, the regular annual flooding is considered vital to those in the flood plains where the farming season is centered on the floods, with rice as their main crop. Thailand's Chao Phraya River forms the rich alluvial plains in the center of the country, and despite occasional ravaging floods that destroy lives and property, the annual flooding brings with it sediments that richly benefit agricultural productivity. It is further recognized that the Thai traditional housing architecture is designed to suite flooding condition because flood as part of living in the flood plain is a fact of life. Of Southeast Asia's rivers, the longest is the Mekong River that cuts across several countries. From its origin in China's Qinghai Province near the border with Tibet, it flows to South China Sea passing by Yunnan Province in China, Myanmar, Laos, Thailand, Cambodia, and southern Vietnam (Wikipedia 2013c). Of its monsoon flooding, the Tonle Sap in western Cambodia is well known as it engorges to become largest fresh water lake in the region. The trapped sediments, with its nutrients, is considered vital to maintain the area's long-term sustainability.

The taming of the Yellow River started as early as the Qin Dynasty in 246 B.C. (Cowen Undated), and the Han Dynasty followed to promote large flood control, irrigation, and navigation projects (Cowen Undated). The river has 26 major changes in its course in the past 2000 years that it was not until 1905 that a permanent bridge was built across it (Cowen Undated). Through the centuries, several strategies were attempted, ranging from a "Confucian" solution of discipline and order imposed upon nature to a "Taoist" solution of allowing the river a more natural course with lighter constraints (Cowen Undated). Current efforts to tame the river emphasize modern technology and skills; and bring about more benefits besides flood control and year-round navigation such as electric generation and general water management ability.

Nevertheless, barriers like dikes and dams have not prevented rivers from overflowing and flooding the surrounding villages and agricultural lands. Floods will continue to occur, but need not be at calamitous magnitude. With only half of the original forest that we used to have, the destructive floods we now experience seemingly every rainy season is the cost we pay and the consequences of our past collective actions. Any long-term solution to destructive flooding necessarily begins at the source. We have to stop deforesting our forest and reforest the deforested. The destructive Iloilo flooding experience resulting in heavy agricultural damages, repeated in many other places of the country almost every time we experience heavy rains, has its roots in our deforested forest. As long as our mountains are denuded, we would continue to experience this destructive type of flooding.

Goldsmith and Hildyard contented that we need to abandon the illusion that floods can actually be eliminated. To quote them, we might as well learn to live with floods and derive from them still more sophisticated benefits (Goldsmith and Nicholas 1984).

A destructive flood is compounded by the economic pressures and consumer orientation of our society and the desire of farmers to improve their economic plight. Our farmers try to come up with as much as three cropping seasons in a year to cope up with the economic pressures. What should have been a main crop–relay crop–fallow cropping pattern is now main crop–main crop–main crop planting. We rely on technology such as fertilization, hybrid variety, and irrigation to transcend what we perceive as low yielding traditional farming system despite the centuries of wisdom imbedded in these traditional agricultural practices. We want to be modern as the other advanced countries are, we want to be efficient, we want to be more productive. So we plant rice even in just decades ago, the land was supposed to be fallowed. And we take pride in it. In our quest for economic progress, we ignore an important soil renewal process—the flooding season to renew the fertility of our land.

And thus when the floods come, it is like a curse upon the land.

And this is where the irony is. We pay dearly in terms of lives lost and property destroyed. Floods that should have been a blessing, that should have been an important opportunity for soil renewal in the soil development cycle, have become a feared and traumatic experience for many. Good forest cover and reserving our flood plains for crop production rather than for urban development, as well as letting the agricultural lands fallow when the flood seasons come are good policy objectives for rational flood control strategies.

6.7 Crop Production Sustainability for Intensively Used Soils

La Trinidad, Benguet is considered the country's major vegetable-producing area. This place is also noted for strawberries and cutflowers. The municipality itself is quite big, some 8,237 ha consisting of 16 barangays, with agricultural area about 1,351 ha (Wikipedia 2013e). The valley proper that is most familiar to many is an intermountain basin surrounded by mountain ranges of 1,500 meter class with an area of about 290 ha. As per report of the National Water Resources Board based on JICA-funded water usage study (NWRB 1987), the Balili River takes its course at the eastern side of the basin flowing in the south–north direction. The foot of Mount Pico is drained by springs that give rise to the Bayabas, Pico, and Puguis creeks which merge to form the Bolo Creek and empties into the Balili River. The basin has an elevation of 1,320 m and slopes from 0 to 3 degrees (National Water Resources Board 1987).

The soils of this basin belong to La Trinidad series. These soils are brown to dark brown silty loam and loamy sand extending over the flat gently flat lands, deep and well-drained; although the lower areas are oftentimes affected by flooding. The area is widely grown to vegetables, strawberries, and cutflowers. Strawberries occupy about a third of the agricultural production area and the main vegetables grown are legumes such as string beans, garden peas, leafy vegetables such as Chinese cabbage, pechay, cabbage, lettuce, celery, green onions, cauliflower, broccoli, asparagus, fruit vegetables such as cucumber, eggplant, tomato, sweet pepper, and tuber crops like white potato, radish, taro, sweet potato, and carrots. The main cut flowers produced are roses, gladioli, chrysanthemums, dahlias, and anthuriums.

It is interesting that La Trinidad used to be known as the Salad Bowl of the Philippines because of the significant vegetable production volume. But through the years, yield declined due to depletion of soil nutrients. Most of the farmers are heavily dependent on chemical fertilizers and the use of pesticides. This massive dependence on agricultural chemicals lead to soil acidity, soil compaction, and increased resistance to pests and diseases. With increased prices of chemical inputs but erratic trend in the selling prices of their produce, agricultural production has become of late an extremely challenging endeavour.

Calderon (2010) in her studies of the La Trinidad's agricultural production practices as slowly being undermined by ecological challenges, employs NiklasLuhmann's social system theory and argues that there is no point-for-point communication between the system of agriculture and its environment. It is only when agriculture perceives ecological dilemmas as threats to its operation that it begins to rethink its relationship to nature and attempts to change its modus operandi to address such dilemmas. Calderon further stated that ecological disasters can only produce "too little resonance" within the system of agricultural production. But once ecological problems become visible to agriculture and are consequently translated into its communicative processes, thereby triggering agriculture's self-critique and self-transformation, it creates disturbing conflicts within the system itself. Thus, La Trinidad's agriculture is changing. The salad bowl phenomenon that drew huge sums of money to the town's coffer has begun to reevaluate its commercial practices. The social fissure is divided into continuing with the non-organic practices or going into organic. There are those who are not convinced to abandon their commercialized agrochemical intensive processes of production, there are those who are for gradual conversion, and there are the organic proponents. But it is already recognized by farmers that the excessive use of synthetic fertilizers and chemical biocides as problematic at present and consider these as threats to secure their future. It is interesting that part of Calderon's conclusion for La Trinidad's interviewed farmers is that even as agriculture prepares for the future, it finds the future unable to begin.

An understanding of the soil and the agroecological system as a whole should be able to provide insights on how to rehabilitate intensively cropped lands. The soil is defined to be the top layer of the earth's surface consisting of mineral layer (sand, silt, and clay which are the unconsolidated products of rock weathering), with its void spaces filled up by air and water. Another important soil components are the organic matter and the vast soil biota or living organisms with their important role of nutrient cycling. These microorganisms decompose organic matter into various stages which are important in maintaining a healthy and balanced soil. Organic matter that has reached its climatic phase and a point of chemical stability in the soil is termed *humus*. Soil humus would not go any further decomposition.

Humus serves not only as a storehouse for essential plant nutrients but has many other functions in the soil—it improves the physical condition by contributing to soil aggregation and structural stability thereby enhancing soil internal drainage and aeration; it improves water holding capacity; through its chelation effect, it prevents leaching losses and binds toxic chemicals; and it acts as buffering agent against adverse soil conditions such as sudden changes in soil acidity or alkalinity. The natural process of humus production starts with decomposition of plant and animal residues through the action of soil macro and microorganisms. Man can enhance this process through introduction of plant biomass (such as farm wastes—rice straws, corn stubs, leaves, etc.), enhancement of decomposition actors (e.g., application of animal manures, introduction of vermiculture and fungi decomposition activators, etc.), and application of beneficial soil microorganisms themselves (such as use of fermented fruits, plants, seaweeds, etc.). To restore degraded soils, agricultural practices will have to hasten natural processes such as soil humus production that nature by itself, will take a long time.

Any sustainable land management practices necessarily begin at improving or restoring soil humus. Fertility amendments such as application of inorganic fertilizers will increase nutrient availability, but without soil humus, unused fertilizers will leach out of the system and contribute to environmental problems like soil acidity and algal blooms. Most soil fertility and soil chemistry experts just look at the nutrient balance. The soil after all, is not just a medium for plant growth. Without the soil biological component, it is difficult to integrate introduced nutrients into the soil system and attain a balanced and healthy soil. The theoretical framework of modern organic agriculture movement was laid down by Sir Albert Howard whose 1943 work, *An Agricultural Testament*, dedicated much of his time to produce high quality compost as humus-enriching amendment (Howard 1943). He argued that a soil supplied by humus provides all the fertility needed by the crops. Synthetic fertilizers, nevertheless, could be used within a sustainable farming system, as long as the importance of humus is equally emphasized.

Weeds are defined as unwanted plants from the agricultural point of view; and weed control is considered part of the modern farming system. Agricultural chemical companies promote the use of weedicides and herbicides to boost agricultural productivity. Weeds are looked up to as harboring pests and diseases and that they compete with the crop for soil nutrients. However, if we consider the agroecosystem as a whole, there is really no such thing as unwanted plants because weeds also have their role to play. Weeds provide cover to otherwise bare soil and prevent soil losses. Rather than compete with the crop for nutrients, weeds store these nutrients in their biomass and prevent them from leaching out of the system. The diversity of the weeds is also a good indicator of the condition of the soil. Of course weeds should not be allowed to go rampant and take over the farms and gardens, unless the soil is in a fallow period and allowed to be restored naturally. Cocannouer (1950) argued that a balanced soil will not sustain weeds. In the farm, weeds can be allowed to grow in-between plots as soil cover to prevent soil erosion; and when plucked out, can be added to the soil biomass for composting.

As for crop pests and diseases, healthy soils bring in healthy crops. Sir Howard's classic work summarized his research findings: Insects and fungi are not the real cause of plant diseases but only attack unsuitable varieties or crops imperfectly grown. He further argued that their true role is that of nature's censor, pointing to us crops that are imperfectly nourished and unfit for human consumption. He viewed that protecting crops from pests and diseases merely preserves the unfit and obscures the real problem of how to grow healthy crops. From his several studies that started years before the outbreak of the Second World War, he concluded that fertile soils yield crops resistant to pests and diseases. Worn-out soils, even when stimulated with inorganic fertilizers would need insecticides and fungicides to be productive (Howard 1943).

Definitely, soils cannot be continuously cropped without undergoing degradation. A fallow period will allow regeneration of nutrients and rebuild soil fertility. If we rest our machineries and equipment in a factory for annual maintenance and check-up, why can't we do so for a soil resource? Since the present economic system will still tax idle agricultural lands and the farmer needs to earn cash to sustain the needs of the farm household, it may be prudent to set aside a percent of the total farm area for fallow rather than fallow the whole agricultural land as they did in Biblical times. Some go for a 5 year fallow cycle; and still others would opt for a 7 year cycle. A longer cycle means smaller area is fallowed and greater percentage is devoted to crop production. Some fallow the land for at least a cropping season but the standard practice is for at least a year or two cropping seasons. Our government should consider giving agricultural tax incentives to fallow practice and soil conservation measures to promote good agricultural practices.

Resting the land revitalizes the soil and will restore productivity to degraded agricultural lands. In modern fallow practices, the soil is further enriched by green manuring using leguminous species or nitrogen-fixing plants. The biomass is plowed over or deeply incorporated into the top soil as the land is prepared for the next planting season. In monocropped production system which is not far-fetched in La Trinidad, the land degradation is so severe; and this is normally indicated by nematode infestation. Not even fallowing the land could reduce the pest population. Important keys in eradicating nematodes in the production system is to practice crop rotation and crop diversification, increased organic matter through compost and mulch, promotion of soil biodiversity like introduction of earthworms and beneficial fungi.

How to rehabilitate the overworked and degraded La Trinidad soil series? Give it a rest and rebuild its soil humus and when it is time to replant, practice crop diversification and crop rotation.

6.8 Improving Productivity of Acid Uplands and Hillylands

Barangay San Roque in San Jose del Monte City in the province of Bulacan is a hilly and grassland community at the foot of the Sierra Madre Mountain Range. This is a logged-over area, quite a contrast to the highly urbanized neighboring barangays that can be considered a spillover of the emerging megacity that is Metropolitan Manila.

In the land cover map, the barangay is classified as Grassland/Shrubland. Of the total 10,738 ha that constitute the 59 barangays of the city, San Roque occupies about 3,500 ha or about 31 % of the total land area. The local farmers grow fruit trees, corn, banana, root crops, and vegetables. Grasses usually occupy the undulating to hilly areas and portion of the ridges while shrubs are usually found on the rolling to steep slopes and on the gullies along rivers and creeks. It is a warm–cool upland on 100–300 m above sea level and with temperature ranging from 22.5 to 25 °C.

The soils are dominated by Sampaloc series consisting of deep, well-drained soils formed on nearly level to gently sloping volcanic plain and residual terraces, undulating to rolling low andesitic hills and rolling to steep high andesitic hills. These soils are classified as fine, kaolinitic, isohyperthermic *Typic Hapludults*. The inherent fertility is low, the soil suitability for various crops is marginal. The Sampaloc series is a typical red soils in the country.

Since this barangay is right at the very footslopes of the Sierra Madre Mountain Range, one can imagine that even as late as the 1950s and 1960s, this barangay must have been a lush forest. In fact, during the Japanese occupation, the hilly and wooden terrain is an ideal hiding place for the guerrillas. And after the war, the area provided an excellent niche for the insurgents. But being at the very rim of urban settlement and megapolis, demographic and economic pressures contributed significantly to deforestation. And since the soil belongs to Soil Order Ultisol, the once lush forest was totally dependent on inherent nutrient cycling. When deforestation occurred and nutrient cycling was cut off, no secondary forest ever developed, only grasslands and shrublands. And thus this classification in the Philippine land cover map remains to this day.

A ground validation will show that with continuing population influx, the dominant land use is changing again to that of agricultural. While the very few remnants of the once forest can still be seen, the transformation from forest to grassland and shrub land to agricultural is visible and certainly significant. Just outside the barangay is the huge metropolitan market that can absorb the barangay's agricultural produce. And with proximity to Metropolitan Manila, literally just a stone's throw away, Barangay San Roque provides an ideal place for quiet and peaceful living, with the majestic Sierra Madre Mountain at the background and the twinkling metropolitan cities at night in the foreground. Today is agricultural, maybe tomorrow is residential? Housing subdivisions have already sprouted like mushrooms in nearby barangays. This should explain how the remaining 58 barangays of the city contended themselves with the 69 % of the total land area.

At any rate, the significant evolution of Barangay San Roque from forest to grassland/shrub land to agricultural faces a lot of challenges. For one, how to bring water from the brook to the hill tops to irrigate the surrounding crops has been hurdled with small water impounding projects and the use of solar pump and ram pump. The latter is a cyclic water pump powered by continuous water from the brook, taking in water at a certain pressure and flow rate, to deliver later at a higher pressure and lower flow rate, enabling water to be lifted higher than where it started. The local farmers certainly learned the strength of cooperative work to get leverage from local politicians and national government agencies in order to have this water resources development project.

Good seeds and planting materials were sourced from the Office of the City Agriculturist. Accelerated soil erosion that comes with agricultural development is addressed by Guided Soil Conservation Planning, through the services of the Soil Conservation and Management Division of the Bureau of Soils and Water Management. Based on the topographic surveys of individual farm cooperators, site specific soil conservation strategies were designed for each of the farms; basically hinged on terracing and use of hedgerows, alley cropping, contour plowing, crop rotation and crop diversification, mulching, minimum tillage, and a mix of other soil and water conservation approaches and technologies. The farms in the rolling hills of Barangay San Roque are certainly a soil conservationist's haven and a source of pride for the community and the local and national government technicians working with the farmers.

But what is seen as the most difficult for farmers to hurdle is maintaining soil productivity considering the fact that we have red soils belonging to Ultisol soil order. These are acid soils, geologically old and bereft of soil nutrients needed by the crops, most of the bases having leached out of the ecosystem. The reddish color is the result of the accumulation of iron oxide, the most resistant of the soil minerals; and this is what is left out in the soil when the other minerals are gone. Acid soils are characterized by aluminum toxicity, calcium, and magnesium deficiency. Many soil fertility experts recommend liming to increase soil pH and the use of fertilizers to improve soil fertility. Such solution is very short term because the dominant clay mineral in Ultisols is generally kaolinite. This type of clay has good bearing capacity and no shrink-swell property.

Certainly, for civil engineers, Barangay San Roque is perfect for urban development and expansion. But for agriculturists who know what dominance by kaolinitic clay means, we have soils with low cation-exchange capacity or poor ability to retain nutrients. Adding fertilizers will not solve soil fertility problems because the soil has very low absorption capability to retain the added fertilizers for crop use on long-term basis. For Sampaloc series, our sample Ultisol soil that used to be forest that became grasslands and now being utilized for agriculture, the cation-exchange capacity of the topsoil is about 20 %, and the base saturation is about 13 %. To think that the top soil organic matter at these levels, is already 1.15 %. And as we go to the subsoil, the organic matter suddenly shrinks to 0.5 %.

No wonder, when this area was deforested and the nutrient cycling was cut off, the land could not sustain a second growth forest. It remained grasslands which improved the fertility of the top soil to sustain the current agricultural activities. But this is a fragile ecosystem, and soil management is certainly challenging if we are interested to sustain agricultural productivity. Again, the farmers here seemingly have gone into right approach to pursue the organic alternative. But without understanding of nature of their soils and what organic agriculture is all about, even the best of their current organic practices may not be sufficient to pursue this land use change from grasslands/shrub land to agriculture on long-term basis.

So we go back again to the fact that we have an Ultisol, a red soil, an acidic soil, a soil that is dominated by kaolinitic clay. A forest soil that is very low in cation-exchange capacity and base saturation. Most farmers of the area pursue agriculture using the organic approach by applying organic fertilizers. These are marginal farmers unable to buy inorganic fertilizers. For those who could afford to buy inorganic fertilizers, it is certainly an issue how long they could have an economically viable farming operation. With escalating prices of agricultural chemicals, it would not be surprising if their farms would be the first to yield to urban expansion in the future.

The improvement of the productivity through optimal liming and fertilization rates for various crops grown in Ultisols have been the subject of hundreds if not thousands of studies in local agricultural research stations and state colleges and universities, some dating back when these were still schools of arts and trades. In the same way that soil surveyors have their secret list of crop requirements so that they could match with results of field survey and soil laboratory analyses for land evaluation later on, and in the same way that soil chemists have their secret crop nutrient uptake list for fertilizer recommendation computations when the laboratory results are released, most agricultural extension workers worth their salt have their secret list of recommended fertilization rates for various crops relevant to their localities based on these hundreds of soil fertility studies and the successful local farm adaptations and farmer experimentations. These rates would include sometimes a mix of organic and inorganic fertilizer sources. A soil fertility approach to addressing soil productivity problems associated with Ultisols and other low activity clay soils such as Oxisols, is at best short term. A more holistic approach is needed for more long-term results.

It is surprising that in interviews with farmers who are long-term adherents of organic agriculture, they generally fail to explain the science behind the multitudes of their strategies—vermiculture, use of fermented fruit and plant juices, and a host of other practices based on Japanese and Korean *Natural Farming* philosophies as adopted in a tropical farm. If we are to address the low cation-exchange capacity of Ultisols because of the dominance of kaolinitic clays through the organic approach, we need to increase soil humus, that stable but complex compound after series of organic matter decomposition. It is so complex that many soil organic matter chemists and specialists get lost in the labyrinth of their studies. Humus is not only an important source of primary, secondary, and even tertiary nutrients considered essential for crop growth. As colloid, it can improve the cation-exchange capacity of the soil, or its ability to hold nutrients (Wikipedia 2013f). Such colloidal property can also bind toxins and other pollutants. Humus also has a buffer capacity against adverse acid or alkaline soil conditions. Humus can hold almost its equivalent weight in moisture improving the soil water holding capacity and crop ability to withstand drought conditions. Humus also improves soil aggregation and structure-enhancing aeration and capillary movement of water within the soil. It is also known that high humus soils destroy harmful nematodes (EarthWormDigest.org 2007). Humus enhancement can be achieved by promoting the recycle of farm biomass residue and enriching the soil biological activities.

Phosphorus precipitates in acid soil condition. The soil is not necessarily deficient of phosphorus; it could just be unavailable for crop uptake. Liming practice should be pursued when practicable to improve soil pH. Others recommend supplemental application of rock phosphates. The growing of acid-tolerant cultivars is another option. Other strategies mostly focus on improving the soil organic matter and include the use of legume cover crops, promotion of agroforestry or the planting of permanent crops which would include both fruit-bearing trees and timber trees, intercropping, multi-story cropping, and crop rotation.

So how do we know that the reddish Sampaloc soil series is responding well to our organic amendments and improving its agricultural production capacity? Humus-rich soils are usually dark brown to black in color, light, and retain moisture. The color is due to abundance of carbon, the stuff that makes life. Soil chemists generally further analyze humus to consist of humic acid, humic acid of low molecular weight called fulvic acid, and humins. It should therefore not come as a surprise that humus-rich soils are on the acidic side. We expect the same suitable (acid tolerant) crops to grow; but one of the most amazing fact about Ultisols is that when properly managed, these soils can be productive; in fact most commonly used for the growing of plantation crops.

Managing Ultisols or tropical red forest soils for long-term agricultural productivity requires a lot of investment in time and biomass to build soil humus, the stable product or final step in the decomposition of organic matter. But for a nation in a hurry, faced by demographic and economic pressures, the use of chemical fertilizers seems to provide immediate economic returns to the farmers. Most of the experiments are conducted to obtain the optimum lime and fertilization rates given highly weathered and highly leached soils and their associated properties. The philosophy is plant and fertilize. But how long can the soil withstand this stress?

A soil with low inherent fertility and low nutrient carrying capacity that it could not even regenerate the forest it used to have, is continuously being cropped. Despite soil degradative processes, there is no more turning back. The forest is gone and unlikely to come back. Slowly the grasslands that took over would soon be gone, too. It is now slowly being transformed into agricultural land use. Hopefully with soil conservation and organic agriculture thrust of the government, these could carry us through the end of the day. Maybe tomorrow, this would be residential. What is the best land use anyway for acid hillylands?

6.9 Soil Pollution Coming from Organic Fertilizers?

The Lapaz soil series, originally described in the province of Tarlac, has been traditionally grown to vegetables. This soil series is quite extensive as well in the other neighboring provinces of the Central Plain of Luzon. The soils are classified as sandy, mixed, isohyperthermic *Typic Tropoaquents*. As a typical soil grown to vegetables, the Lapaz soils have moderately thick gray fine sandy loam Ag horizons and very deep gray stratified fine sand Cg horizons. These soils are formed in broad flats and in slightly depressed landscapes in very deep stratified fine sandy alluvial materials on weakly dissected continental terraces above the main river flood plains.

A diversity of vegetables are grown in the Philippines, not only in this Lapaz soil series, but in many other soil series where vegetable production is highly suitable. The most commonly grown vegetables in the highlands are white potato, cabbage, sweet pepper, broccoli, cauliflower, lettuce, and tomato. In the lowlands, those most commonly grown are solanaceous, cucurbits, root crops, and legumes.

Since part of good vegetable production practice is fertilization, various kinds of farm animal manure are increasingly being utilized as organic fertilizer. It is said that when it comes to manure as a vegetable garden fertilizer, the most desired is the chicken manure with its very high nitrogen content, and good amount also of potassium and phosphorus. Chicken manure is generally applied not as fresh amendment, but as properly composted organic fertilizer. Otherwise, fresh chicken manure contains pathogenic bacteria like salmonella (Fredericksen 2011), emits ammonia and hydrogen sulfides (Grace Communication Foundation 2013), attract rodents and flies (WSU Extension Master Gardener Program Undated). Poultry manure processing sometimes entails addition of compost activators or indigenous beneficial microorganisms to hasten decomposition and conversion to organic fertilizer. Considering that commercial poultry and egg producers abound in the Central Plain of Luzon, the source should not be a problem. In fact, vegetable producers would find themselves competing with fishpond operators for chicken manure since this is also used in aquaculture to fertilize the fishponds and increase algal productivity.

It is quite surprising that among the pure-organic agriculture practitioners in the Philippines, they shun the use of poultry manure coming from commercial growers for their vegetable farms. The general belief is that the state of commercial poultry management in the Philippines today is heavily dependent on the use of chemical boosters, anti-stress drugs, vaccines, antibiotics, and premix vitamin, and mineral supplementations. Even at composted state, chicken dung from commercial poultry growers is being questioned as an organic fertilizer because of the presence of endocrine disrupting compounds and antibiotics. As the most progressive type of animal enterprise in the country, even relatively small backyard poultry businesses are quite impressive because most of these are part of an integrated contract farming operations and provided with complete financial, technical, processing, and marketing support by the multinational corporation that engaged the services of the contract poultry raisers. Since native and free range chickens are not really produced in large scale for any practical collection of manure, livestock provides the most common preferred source of animal manure for organic fertilizer production over that of commercial poultry.

The challenge on the consequent soil pollution using poultry manure as a source of organic fertilizer seems to have some basis, with great socioeconomic implications, especially for vegetable-producing farmers where the use of chicken manure is very popular. In vegetable producing municipality of Tublay, Benguet alone, close to 50 trucks deliver daily some 10,000–50,000 kilo-bags of chicken manure (Cariño 2009) and sold to farmers from P900 to P1,200 per sack.

Concern on the use of antimicrobials to minimize disease and improve growth and feed utilization is focused on possible development of resistant strains of microbes that could directly impact human health and the negative impacts associated with their excretion in the environment (Poultry Cooperative Research Centre 2013). Organic agriculture proponents argue that we should not underestimate the potential problems associated with various pharmaceutical preparations in the soil despite efficacy tests for the target animal because we have not studied well how they affect a wide range of microorganisms once they find their way into the soil system when used as source of organic fertilizers. These poultry pharmaceutical preparations can cast effects on soil microorganisms well below the concentrations that are used in safety and efficacy tests. We have not done studies relating to their degradation fates in the soil—what are the soil microorganisms involved, what are the degradation processes, and what are the subproducts of their degradation, and how these move from the soil to the groundwater, and to the lakes and bays. Their persistence and possible entry into the human system through the underground water have to be researched yet. Little is actually known about the environmental fates of these poultry as well as livestock chemicals and their impacts on the Philippine soil ecology.

The heavy use of antibiotics in the poultry industry and their eventual entry into the human system is being attributed to potentially deadly and drug-resistant strains of *E. coli*, Campylobacter, Salmonella, and a host of other growing number of bacteria now threatening human health. Despite antibiotics inactivation in soils through adsorption by clay minerals and their microbiological degradation, the persistence of antibiotics in soils remains a major concern in terms of impact in the soil microbial population and the consequent nutrient recycling processes and humus build-up, as well as possible impact in seed germination, root and shoot growth, and more importantly, translocation to stems and leaves for human absorption.

Another concern on the use of poultry litter as fertilizer is the contamination of aquatic environment via agricultural runoff through the release of steroid hormones in the litter, polluting the water with endocrine disrupting compounds (UM Aquatic Pathobiology Centre and UM Department of Epidemilogy and Preventive Medicine Undated). The majority of the estrogens excreted by poultry are estriol, estradiol, and estrone. Other contaminants found in poultry litter that have the potential to pollute the water systems are trace metals, pesticides, and antibiotics (UM Aquatic Pathobiology Centre and UM Department of Epidemilogy and Preventive Medicine Undated).

It is indeed paradoxical that what should have been the best source of animal manure for organic fertilizer production is increasingly being avoided by pure organic farmers because of possible adverse rather than positive environmental impacts. The dependency of commercial poultry on various pharmaceutical preparations is raising great concern as to the manure's value as a source of organic fertilizer. In the same way that the agricultural production system is being polarized between organic and the conventional with its heavy reliance on the use of agrochemicals, it appears that the poultry industry is facing self-examination as to the value of its management practices in the light of their human and environmental impacts. For now, the livestock industry in the Philippines is not faced with similar situation compared with the poultry industry because livestock production in the country is usually backyard level to be a significant market for pharmaceutical preparations. Until perhaps a more acceptable nonpharmaceutical-dependent poultry health practices are promoted, there will be increasing nonacceptance and isolation of poultry manure in the local organic agriculture scene aggravating the issue on how to dispose great volume of poultry fecal wastes.

6.10 Soil Ecology and the Watershed as Unit of Rural Planning

Development planning in the Philippines is extremely parochial because it is focused on the political agenda and platform of the elected officials. As such, the unit of development planning, whether at local or national level is the political boundary. And it is usually short, at most medium-term since any long-term planning in terms of objectives and focus, would most probably be changed, not just reviewed and updated, when a new set of elected officials come to power. Perhaps this is one of the costs of a democratic political system, as against that of a totalitarianism.

But as we come into the Information Age—the era of computers, digital data, and internet—we have instant access to a barrage of information, previously impossible to obtain in a short period of time. The Information Age thus ushers in desktop publishing, Geographic Information Science, spreadsheets, geostatistics, statistical modeling, photo editing, and innumerable applications not only relating to scientific and engineering but also to finance, trade and commerce, entertainment, and practically every aspect of human life. But back to planning, just for a simple view of the target area, one can access Google Earth and zoom in at the satellite imagery of the place, at a cost included in the monthly internet connection. Such convenience, such ease of data access, and how cheap. One can imagine how far much more sophisticated the planning tools are, especially for resource management and development purposes. One can project three-dimensional look of the area and rotate the image, input point data and interpolate spatial distribution, extract scenarios as specific parameters are theoretically changed. Of course, even the most sophisticated computer tool would have its crippling limitation—garbage in, garbage out. Any modeling and envisioned scenarios we come out with depend on the integrity and dependability of our data set. The general practice is to review and evaluate available data, and conduct a survey to update as well as collect new data set.

The watershed as the basic unit of planning provides a holistic way to integrate the multitude of data and advance computer tools now available to characterize existing conditions, prioritize problems, define objectives, develop strategies, and adopt selected actions. Watershed refers to a basin-like landform (Pennsylvania Environmental Council Undated) bounded by a topographic divide (Watershed Management Department, National Power Corporation 1982), and encompasses the hydrologic system where all the water from within this area drains towards the major tributary or common body of water. Since all living things depend on water, including the growing of food and fiber to sustain the communities within the watershed, our development plans need to be inextricably linked with the watershed-carrying capacity for sustainability. But because our development plans are not linked to watersheds, our urban expansion and development are skewed towards services or the tertiary industries, dependent on imports from adjacent cities and provinces and neighboring countries for our basic needs in food and water, and we have diminishing primary and secondary industries. In delineating new political boundaries for new municipalities or provinces, the basic considerations are generally the income from taxes to be able to operate independently and the demography, most especially the voters' profile. The justification in creating a new municipality or province is to limit the land area to a manageable level, and dividing is the natural course to improve the pace of development in a focused area. The watershed is hardly considered as a factor and tool for delineation. But we should consider the fact that without a water source, a community will not flourish.

But if we look at the watershed that constitutes a political boundary, we will see how vulnerable we are to simple basic needs such as source of water for our political constituencies. We will also be able to assess how much self-sufficient we could be in cereals and other essential food items. Demographic and social pressures are driving forces to plan for economic development without little consideration on the carrying capacity of our land resources. Having irrigable agricultural areas is not all there is to agricultural development planning for example. In some unique cases, even if we are just planning for small communal irrigation system, the water source or the headwater for irrigation is in the next municipality. Or vice versa—we have water sources but they all go to the next municipality. Or the municipality is importing rice from the other provinces, and there is hardly enough areas for the growing of rice and whatever suitable areas left are encroached by urbanization. Our political boundaries are not configured according to watershed boundaries.

A watershed approach to development planning necessarily protects the community's most vital resources—soil and water, and provides focal points for the community's planning efforts to enhance the services and benefits derived therein. Watershed education and stakeholders' involvement are vital when we consider the watershed or the subwatershed for that matter as a management unit. By looking at the watershed, we can assess current land use and redirect development towards protection of ecologically fragile or sensitive areas. All local government units are required by law to come up with Comprehensive Land Use Plans (CLUPs) and all relevant zoning activities as provided by law such as the Strategic Agriculture and Fisheries Development Zones (SAFDZs) are to be integrated to the CLUP. In almost every CLUPs, conservation and enhancement of ecosystem services are deliverables by the environmental management component and has a parochial point of view. Most of the social and economic development targets are achieved by facilitation of commerce and trade, or imports of goods and services from neighboring communities especially for highly urbanizing areas. It is truly exceptional that local economic development is achieved through exploitation of local resources within the watershed. Philippine communities just mirror the interdependence of nations and increasing trade complexity at the global scale. But since watershed as an important community resource has not been taken into account in the delineation of the political boundary, the national government economic development thrust is one product—one town. With parochial interests in the municipal CLUPs, provincial CLUPs are just municipal summaries, not really integrated; and when taken as a whole, it has its own political life and agenda apart from the individual municipal plans. Municipal CLUPs are generally prepared and developed independently from each other to fulfill a requirement from the national government.

But there are a number of local communities, with assistance from national government offices, local government units, and nongovernment organizations that pioneer the watershed approach to development planning. One example we can cite is the Carood Watershed, spanning six municipalities in the eastern side of the island province of Bohol: Candijay, Ubay, Pilar, Guindulman, Mabini, and

Alicia (Environmental Science for Social Change 2010). Assisted by the ESSC, this is a Jesuit research institute that promotes environmental sustainability and social justice through the integration of scientific methodologies and social processes. Carood Watershed covers some 20,500 ha, with about 10 % under forest cover and thousands of household communities (Environmental Science for Social Change 2010). Originally requested by the Department of Environment and Natural Resources (DENR) to assist in the implementation of the Community-Based Forest Management Program (CBFM), the Ubay-Mabini-Alicia SubProject was established and ESSC was among the local non-government organizations requested to assist in the implementation. Based on watershed planning tools, the major challenges were identified by the communities within the watershed and many of the problems were linked with the state of the watershed—soil erosion, downstream flooding, coral reef destruction, unproductive lands, and grassland fires. Educating and mobilizing the stakeholders, an integrated watershed management plan that addressed the issues and challenges was carried out, harnessing the communities themselves to be part of the solution. It is interesting to note that looking back, ESSC mentioned that the most critical issue was coordination between government agencies and local government units and that linking these different administrative institutions and development agencies was a difficult task (Environmental Science for Social Change 2010). There was also the need to harmonize the various local government units' development plans and community resource management plans (Environmental Science for Social Change 2010). Community empowerment was important to sustain watershed management efforts once the external project funding was completed. The tasks of watershed management was anchored on community mobilization as a voluntary collective action, weaved by traditional bonds and driven by common interests (Environmental Science for Social Change 2010). Other pioneering programs in other watershed areas are expected to yield similar experiences in terms of strengths and weaknesses of this watershed as a unit of development planning. The ESSC experience is typical.

As can be seen from the ESSC experience, a watershed plan is iterative and adaptive; it is a holistic process; geographically defined; and it is collaborative and participatory (Environmental Protection Agency 2008). We need to characterize the watershed. It is important to build the community as partners in the planning process, set goals, and identify solutions. Designing, implementing, and monitoring to measure progress and make necessary adjustments are important steps (Environmental Protection Agency 2008).

So where does the soil come in? This will be an important input in resource mapping and accounting as we go about with watershed characterization. The ability of water to move through the ground, the ability of various types of vegetation to flourish in the area, and the potential for development are dependent on the soils. Soil classification and pedogenic data that formed a catena or topographic sequence are essential inputs as we assess the sustainability of various economic activities from the forests up in the mountains, to the agroforestry activities on the footslopes and hills, to the agricultural and other commercial land uses in the uplands and lowlands, to the fisheries and other economic uses of our coastal lands, wetlands, and fresh bodies of water. Soils greatly affect land use and water quality in streams and rivers. We can delineate where are the prime agricultural lands to support the population; the stony and gravelly soils (mostly located in the municipality of Alicia) might as well be limited to perennials such as fruit orchards and timber trees; soils with multiple limitations such as those relating to slope, wetness, and depth and thus, classified as marginal, might as well be restricted to wildlife and forest reserve. Impervious areas where rain water collects can be reserved and developed for aquatic habitats, maintain stream flow, improve water quality, and recharge groundwater. These wildlife and forest reserves as well as wetlands perform not only environmental regulation function for air and water but could also be economically harnessed for ecotourism purposes. The delineation and safeguard of these so-called "Green Infrastructure" or "Protected Areas" are important community programs. By knowing the soils that constitute the watershed, we can conduct crop suitability evaluations and assess soil fertility. Watersheds with highly erodible soils are vulnerable to erosion and consequent sedimentation of water tributaries. This calls for best management practices especially in the upland and hillyland agricultural areas (e.g., minimum tillage, cover cropping, field strips, etc.), and further calls for buffer planting with trees the stream and river banks. The change in land use is internationally considered as the major driving force in land degradation and many of the flood disasters that plague urban areas can be attributed to diminishing forests and wetlands, the shallowing of water bodies, and the urbanization of flood plains. By studying the soils as they occur in the toposequence, and as part of watershed characterization, we will be able to identify the best land use, the limitations, and the vulnerabilities.

So where is the challenge to soil scientists? Soil science is traditionally offered in agricultural colleges and universities, and thus, has an agricultural orientation and application. The traditional concept of the soil is primarily focused on its role as a medium for crop production. But as we expand our planning and management unit to encompass the watershed, we necessarily have to expand our perspective and knowledge of soils to encompass the whole gamut of soil ecology, or a look at the soil as a component of a natural system, not just that of an agricultural production ecosystem. From a reductionist philosophy, the trend now is towards integrative and holistic approach.

Soil organisms interact in various ways in their abiotic environment, and these interactions could range from very simple to very complex. The basic nature of an ecosystem is to recycle most of the building blocks of life—nutrients, energy, and water. As a monsoon country, we need to have better understanding of key players in soil microbial communities and their spatial heterogeneity, the roles of soil microorganisms in the energy and matter fluxes, and their transformations, plant-microorganism relationships, the soil food web, effects of pesticides, herbicides, and fertilizers, These we cannot do without conducting researches on the activities of heterotrophic organisms in soils involved in primary and secondary production processes, understanding food webs specifically detritivory and microbivory in soils, and linking our understanding of various soil processes to soil biodiversity.

Community and farm waste disposal and nutrient recycling have to be linked with the regenerative capacity of soils from the exploitative activities of agriculture, pasture, forestry, and other economic activities. We need more studies on soil-borne contaminants and pathogens for urban soils, or soils located in human settlements and commercial areas which are usually established without regards to soil quality and their impacts on human health, and we need continuing studies on remediation of problem soils. We need to conduct studies on succession of plant communities in response to land use changes.

Development planning based on political boundary is very parochial and at best would only provide palliative solutions. But to go into community-based watershed planning for long-term solutions and sustainable development is certainly very challenging but has been done. For soil scientists in the Philippines, we need to come out of our reductionist background towards more holistic approach to soil issues and challenges.

6.11 Soils and Global Competitiveness of Our Industrial Crops

The agreements establishing the World Trade Organization (WTO) calls for a single institutional framework encompassing the General Agreement on Tariffs and Trade (GATT), as modified by the Uruguay Round, all agreements and arrangements concluded under its auspices, and the complete results of the Uruguay Round. Its structure is headed by a Ministerial Conference Meeting held at least once every 2 years. A General Council oversees the operation of the agreement and acts as Dispute Settlement Body and as a Trade Policy Review Mechanism. The WTO framework ensures a "single undertaking" approach to the results of the Uruguay Round. Thus, membership in the WTO entails accepting all the results of the Round without exception (World Trade Organization 2013a). The Philippines has been a WTO member since January, 1995.

World Trade Organization negotiations produce general rules that apply to all members as well as specific commitments of member governments, listed in documents called "Schedules of Concessions". Tariffs on all agricultural products are now bound. Almost all import restrictions that did not take the form of tariffs, such as quotas, were converted to tariffs, a process known as "tariffication" (World Trade Organization 2013b).

Previously more than 30 % of agricultural produce faced quotas or import restrictions. These were replaced by tariffs that represented the same level of protection. Then over 6 years, from 1995 to 2000, these tariffs were gradually reduced. The market access commitments on agriculture also eliminate previous import bans on certain products. In addition, the lists include countries' commitments to reduce domestic support and export subsidies for agricultural products (World Trade Organization 2013b). Thus, the WTO agricultural package provides for commitments in the area of market access, domestic support, and export competition.

Four countries used "special treatment" provisions to restrict imports of particularly sensitive products during the implementation period—Japan, Republic of Korea, and the Philippines for rice, and Israel for sheep meat, whole milk powder, and certain cheeses. The Republic of Korea and the Philippines extended their treatment for rice and new WTO member, Chinese Taipei, gave special treatment also to rice in its first year of membership in 2002 (World Trade Organization 2013c).

There are sectors in the Philippine economy that are not in favor of the Philippines becoming a WTO member and its implementation of trade agreements under the multilateral trading system. The major argument is the displacement of significant local production by cheap entry of agricultural products into the country. Bello (2003) discussed its negative impact on the Philippine production of rice, corn, meat, poultry, vegetables, tuna, and bananas and the disturbing new market restrictions imposed by the agricultural superpowers on the entry of Philippine agricultural products in defiance of WTO rules as well as the failure of the safety net program supposed to be addressed by the Agriculture and Fisheries Modernization Act.

At any rate, the basic argument of the pro-WTO advocate is for the country to fill production niches in agricultural commodities where the Philippines has a "comparative advantage", which the anti-WTO supporters claim can only be achieved through significant outlays in technical support and research and development. By allowing the entry of cheap agricultural commodities, anti-WTO advocates also perceive a seeming bias against small-scale producers in favor of large corporate farms considering economics of scale.

Such emphasis on corporate monoculture by concentrating agricultural production on commodities where the country has comparative advantage is a policy that would lead to unsustainable agricultural program and eventual ecological ruin. It is a disaster for the country to follow those leads. All the policy makers need to look into is the state of contract farms where the lease by local farmers to multinational agricultural corporations already ended. These agricultural lands are ecological ruins. Despite the sophistication and technological developments of these monoculture corporate farms, there is no way for man to win the battle against nature, specifically on the basic principles of fertilization and on the principles of crop protection.

Can an average Filipino farm compete against the entry of cheap agricultural commodities from abroad considering their economics of scale, technology available to big corporate farms in terms of varietal development and mechanization, capitalization, and government support and subsidy to their farmers?

It might be unheard of in the Philippines but agricultural subsidy is direct government payment to farmers to supplement their income, manage the supply of agricultural commodities, and influence the cost and supply of such commodities (Wikipedia 2012b). In 2010, the European Union spent €57 billion on agricultural development of which €39 billion was spent in direct subsidies to their farmers, the largest of which is the Single Farm Payment (Wikipedia 2012b). United States pays $20 billion per year to farmers in direct subsidies as "farm income stabilization" (Wikipedia 2012b). Japan paid US$ 46.5 billion in subsidies to its farmers (Wikipedia 2012b). Opening up the domestic economy to such cheap agricultural imports will grant local consumers with cheaper food cost but this serves as disincentives for local producers who could not compete on equal terms. This is disastrous for the country in terms of food security because there is no motivation to be self-sufficient on food production and greater reliance on cheap food imports. Haiti was one time self-sufficient in rice but following advice to liberalize its economy by lowering tariffs, domestically produced rice was displaced by cheaper subsidized rice from the United States (Wikipedia 2012b). For the Haitian farmers without access to subsidies, the removal of barriers to trade and the simplification of tariffs and the consequent downward pressure on prices lead to decline in profits; making it difficult for the Haitian farmers to compete; and they preferred instead to migrate to urban areas in search of better economic opportunities (Wikipedia 2012b). The question is, after dismantling our agricultural structures and just relying on cheap imports to feed our populace, how sustainable is this scenario? Monocultured grown, heavily fertilized, heavily laden with pesticides, cheap agricultural imports are not here to stay for good for the simple reason that their agricultural practices are unsustainable. The cost of fuels and agricultural pesticides are escalating to a point beyond the reach of average farmers and corporate farmers survive only because of the principles of economics of scale. No technology that is against natural law, no matter how advanced and sophisticated, can win the battle completely against nature when it comes to soil depletion and crop infestation. In literary terms, the super efficient and mass production philosophy of corporate farming is a Goliath. We need not be a Goliath to compete and lose against stronger Goliaths. We can be a smaller but smarter David and win this economic battle.

Can the Filipino farmers compete with the farmers in the developed countries? Yes of course, but not on equal terms with the farmers of advanced countries who practiced unsustainable agriculture and are dependent on government subsidies to keep them afloat. To be a David in this economic battle, the key is to practice sustainable agriculture, bid for your time, and then make the kill. Sooner or later, unsustainable agricultural practices will collapse. Why would it be called unsustainable in the first place if this is here to stay for good?

Let us take a look at our sugarcane farmers and the sugarcane soils. Silay sandy loam is typical of soils in Negros Occidental grown to sugarcane. This soil series is found in Talisay, Bacolod, and Abuanan. The topography is almost flat and the external drainage is good; however, the internal drainage is poor. Being sandy, the soil is easy to work with and cultivate either dry or wet. The surface soil extending down to 25 cm is poor in organic matter (Alicante et al. 1951). Sugarcane occupies the land for nearly a year before harvesting and there is not enough time to grow green manure crops before the next planting season. But Silay sandy loam has low productivity, and unless fertilized, no substantial returns can be obtained. In 1951, ammonium sulfate was the common fertilizer used at the rate of 300 kg/ha, with yield of about 100–150 piculs of sugar per hectare (Alicante et al. 1951). The use of ammonium sulfate left the soil acidic as residual effect, at about pH of 5.5. For favorable sugarcane growth, the soil pH has to be from 6.2 to 7.8. Current fertilization practices have surely changed. The Sugar Regulatory Administration—La Granja Agricultural Research and Extension Center (SRA-LGAREC) reported that for Negros and Panay, the 2006 average fertilization rate was 165-85-105 kg/ha (Bombio and Tahum 2008). Fertilizer cost could take up almost 40 % of the total production cost (Bombio and Tahum 2008).

Filipino sugarcane farmers are faced with low productivity brought about by use of old varieties, high cost of starting capital, and increasing cost of production inputs specifically fuel and fertilizers, dependency on rainwater, among many other concerns that plagued the sugar industry (Department of Agriculture, Regional Field Unit 5 2013). We should also consider the social and ecological problems associated with monoculture sugarcane production. When the sugar industry collapsed in the 1980s, thousands of sugarcane workers starved. Today, much of the landscape of Negros Occidental remains in monoculture sugarcane production controlled by wealthy plantation owners. Some of these sugarcane hacienda lands are being dismantled under the Comprehensive Agrarian Reform Program (CARP) and the lands are distributed to hacienda workers and their families. This means smaller sugarcane lands making it even more difficult for the local farmers to compete against big-time sugarcane farmers in developed countries.

In any warfare, most especially as it concerns agricultural produce traded domestically and the main issue at stake is national food security, the most important winning factor is strategy. We need to plan for long-term ecologically sustainable agricultural production practices that can withstand the test of time, reduce costs (such us the farms producing in-house its fertilizer and pesticide requirements) so that our products can compete against cheap imports, have room for maneuver (in short, diversify) to tide us against vagaries of climate and market ups and downs, and strengthen our networking and collective efforts (*bayanihan* spirit) because in unity there is strength. Once we have fortified our defenses, it is time to make our offenses—position our product in the global market through the promotion of cultural activities and participation in international trade fairs to raise consumer awareness. Finally, we have to understand the dynamics of the commodity demand and supply scenario so that we can time our planting just when the supply is high and harvest when the supply is low.

It is difficult to discuss of theories and principles when the economic battle is here with us now and there is no time for experimentation and trials. We will therefore cite positive transformation of the Flora Community near Kabankalan in Negros Occidental, one of the beneficiaries of the national government's CARP involving 76 hacienda workers and their families, approximately 375 people in all (Resource Efficient Agricultural Production—Canada 2013). They were awarded 87 ha of former sugarcane plantation divided into individual farms of 0.82 ha plus a collective farm of 17.7 ha (Resource Efficient Agricultural Production—Canada 2013).

The Paghidaet sa Kauswagan Development Group Foundation, a non-government organization based in Kabankalan City, facilitated the land transfer and community organizing. Partnerships with REAP-Canada and MASIPAG were forged to initiate development programming activities. The concept of Agro Ecological Village Model was introduced to address the concerns associated with conventional monoculture farming and to promote ecological sugarcane farming (Resource Efficient Agricultural Production—Canada 2013). Recycling farm biomass was an important key concept promoted to improve soil organic matter, reduce nitrogen fertilizer application, control weeds, preserve soil moisture, minimize erosion, and protect the canes from lodging during the typhoons. Another important concept introduced was the selection of outstanding varieties with self-detrashing capacity, drought resistance, ratooning capacity, adaptability to low fertility soils, biological nitrogen fixation potential, lodging resistance, and high tonnage and sucrose content. Adaptability trials were conducted. Furthermore, the cultivation practices were modified, sustainable practices and diversified agricultural production were introduced, and more economic opportunities relating to seed collection, planting, marketing, and value-added processing were promoted. Although the Ecological Village is still evolving, this holds promise as a development strategy for communities dependent on monoculture agriculture systems (Resource Efficient Agricultural Production—Canada 2013). The principles can also be adopted on commercial scale.

Monoculture, or the growing of the same crop on the same area on repetitive basis year in and year out is unnatural ecological occurrence. Its only advantage is the economy of scale and the ability to sustain the raw material requirements of our factories to manufacture processed goods. But this type of farming is biologically unstable and the farms are inherently susceptible to infestations. Nature will not allow the dominance of a single species in an ecosystem. Nature works under the principle of unity in diversity. Replacing diversity with a single cultivar and genetically identical crops is defiance of natural laws and the farm is very vulnerable to a host of crop failures. Despite monoculture's association with industrialized economies and the association of diversified farming with subsistence agriculture, the latter provides ecological stability and economic buffer against the dynamics of market forces.

The Philippines can compete against cheap entry of agricultural produce by coming up with an arsenal of ecologically sound agricultural practices hinged on nutrient recycling, crop diversification and crop rotation, and other sustainable agricultural practices. When we have other countries with limited resources also doing this, such as the hill tribes of northern Thailand with their organically certified and commercially grown highland agricultural produce penetrating the international market, we can say that the economic playing field is leveled; and this is truly the battle and survival of the fittest.

6.12 Prawns that Just Grew to Shrimp Size

The economic life of the province of Negros Occidental from after the war to the 1980s depended mainly on the sugar industry. However, when the sugar industry made a nosedive in the 1980s due to low world sugar prices in the mid-1970s followed by worst sugar prices that hit rock bottom in 1985, many of the Filipino sugar barons in Negros Occidental diversified their agribusiness interests to other agricultural commodities like fruits, vegetables, and also livestock.

One of those agribusiness endeavors that became popular was prawn farming. Many sugarcane planters shifted their capital to purchase acres of brackish shoreline to produce high value prawns, plantation-style. The large-scale prawn farms ranged from 16 to 25 ha plots, with production technology imported from Taiwan. Productivity was high and return on investment was reported to be as much as 42 % during the first year (Scott Michael 1987). Negros became known not only for its sugar industry, but also for its prawn industry.

These were the years when policy makers never appreciated the ecosystem value of mangroves. Primavera (2000) reported that the national policy encouraging brackish water pond culture has been premised on the belief that mangroves and other wetlands are wastelands. Carbine (1948) was quoted to having described the Philippine milkfish industry as important "because it makes use of otherwise practically valueless (mangrove) land." Oshima (1973) was further quoted to have likewise declared that "undeveloped" mangrove forests extending everywhere along the Philippine coastline were available for aquaculture. The increase of brackish water ponds and the increase in the aquaculture's contribution to the Philippine economy also meant the decrease of mangrove areas, and eventually, the decrease of fish caught near the seashore as the years went by. In the years that followed, the monoculture lead to the outbreak of luminous bacteria in Western Visayas affecting the volume of production and the importance of the prawn industry in the Negros economy.

But back to the early years when prawn production and export prices attracted the Negros *haciendero*s. It was not all profits and smiles for these sugar barons, especially the unfortunate ones who opened up mangrove areas characterized by presence of acid sulfate soils. Their prawns never grew up from their fingerling sizes as growth was stunted. The soils of their prawn ponds belong to Sicaba series.

The *Sicaba* tide water soil series was originally mapped in barangay Sicaba, Cadiz City, Negros Occidental. It belongs to coarse, loamy isohyperthermic *Haplic Sulfaquents*. These are poorly drained soils of fluvio-marine parent material. Sulfaquents have strong clay component, rich in organic matter from rotting wetland vegetation, and have high mineral content, primarily iron. These tidal marsh soils are anaerobic and contain sulfur-reducing bacteria which turn the sulfates in the sea water into iron sulfide or pyrite and release sulfuric acid, creating the distinct smell of a salt water marsh at low tide. The Sicaba soils are very acidic, pH of 3.2. This is a typical acid-sulfate soil in the Philippines. The topsoil is about 30 cm deep, very dark gray, sandy clay loam. A transitory AC-horizon to 50 cm depth is observed, similar to the A-horizon but has partially decomposed plant remnants. The substratum is dark gray sandy loam; and reaches to 120 cm. This series covers 89,568 ha for the whole country.

Pyrite forms when bacteria reduce sulfate (from sea water) to sulfide in the presence of iron and decomposing vegetation. When the mangroves are cleared and the soils exposed especially when the tides recede, these acid sulfate soils generate sulfuric acid. Aside from the destructive impact of sulfuric acid on the pond itself, the prawn health is certainly affected. The sudden pH change may cause mortalities because of damage to grills (Simpson and Pedini 1985). Where the impact is not really lethal, acidified water can cause "soft shell syndrome" or "no moult disease". The probable causes are the loss of calcium from shrimp shells and the loss of alkalinity during the neutralization of acids (Simpson and Pedini 1985). Outside of the prawn pond, the environmental impact of acidification would be seen on corrosion of affected infrastructures and on the decline of the species in the estuarine habitats.

The most common recommendation is to neutralize the acid such as the use of lime. The major issue is how much lime to apply and the cost of such rehabilitation which may not be that practical. There is need for more research and long-term monitoring of acid sulphate soils converted to prawn ponds. One example is the need for further studies to assess the effectiveness and feasibility of capping or lining to reduce if not minimize the movement of the oxidation products.

For now, the most practical is the abandonment of area and to consider alternative land use. Returning it back to its mangrove status would not be that easy as we have to replant with acid-tolerant mangrove species. As it were, a Pandora's box was opened and any rehabilitation efforts to address further environmental degradation would be arduous, costly, and long-term. In its original state as virgin mangrove forest, acid sulphate soils do not pose any environmental concerns. So we could say that in the first place, we should have not opened these mangrove areas but rather conserve them in their original land use as mangroves. Estimating the extent of acid sulphate soils remain an enigma because until we open up the mangrove and look at the soils, we would not know it has acid sulphate properties.

Since we also need to feed our increasing population, the best compromise is for our aquaculture and marine scientists to come up with community-managed, mangrove-friendly aquacultural practices.

6.13 Last Words: Today's Battle Cry is No Longer Food Security but Food Sovereignty

6.13.1 Food Security

The Philippine food production objective aims to attain food security for its people. Food security refers to the availability of food and one's access to it (Wikipedia 2013g). It is for this reason that production and prices of staple food and other essential food commodities are closely monitored by the national government. The Bureau of Agricultural Statistics (BAS) was established separate from the National Statistics Office (NSO) to collect, compile, and release official agricultural statistics to enable the country's policy makers make sound judgment especially on issues relating to food trade and importation. Food security is generally measured in terms of self-sufficiency and external dependency (Wikipedia 2013g). With Philippine population projected to have reached 105.72 million in 2013, the twelfth most populated in the world, it is indeed a huge challenge for the national government to feed, house, educate, and provide for other basic needs of its citizenry.

With a limited agricultural areas that are also competing for other land uses, and crop harvest figures that plateau when the optimum conditions are reached, the issues are further complicated by land degradation, water crisis, climate change, and land tenurial issues; and thus, the country's agricultural development programs to boost productivity remain a national priority.

A household is defined to be food secure when its occupants do not live in hunger or fear of starvation (Wikipedia 2013g). At the national level, that means importing from other agricultural producing nations a sufficient buffer stock to tide the nation over until the next harvest comes. At regional and provincial level, that means importing food commodities from other regions what are not locally produced. At the household level, that means having sufficient income to purchase what one does not produce. That translates to a regular trip to the wet market and the groceries; and stock on supplies. Would it not be better if the household produces much of its food requirement and the trip to the wet market and groceries are limited to those items the household could not produce?

Despite seeming complacency of our neighborhood households with this market routine, our agricultural system is actually threatened by global trade scenario dominated by big and efficient players; and they are changing the game. At the household level, not only big supermarkets and hypermarkets in city centers exist but medium supermarket franchises are mushrooming in communities enticing the regular customers of the small neighborhood retailers and squashing these small-time neighborhood retailing businesses (called *sari-sari* stores in vernacular). At the regional and national level, cheap food imports are coming in, making it difficult for the local farmers to compete. This is part of our national commitments to the World Trade Organization, as a member in good standing of a global community. Under these circumstances, the food is available and accessible, and we have food security. But we are slowly losing our farmers as they migrate to urban areas in search of better economic opportunities because of unprofitability of their farming operations. We have food security but decreasing self sufficiency and increasing external dependency. From a strategic point of view, the policy perspective that favors big time and efficient players over the small-time farmers and traders will be disadvantageous to the country in the long-run. Statistics will be deceiving because we have available food at affordable prices but in the city neighborhoods and in the rural areas, poverty is increasing. Our farmers and small-time traders and retailers are unable to compete against more operationally efficient big players and multinational corporations.

So while the government at national, regional, and local levels continue to use food security terminology in its white papers, the battle cry of non-government organizations operating in the Philippines is altogether another term—food sovereignty.

This concept views the business practices of multinational corporations as a form of neocolonialism; and contended that these multinational corporations have the financial resources to buy up the agricultural resources of impoverished nations, particularly those in the tropics have the political clout to convert these resources to the exclusive production of cash crops for sale to industrialized nations; and in the process to squeeze the poor of the more productive lands (Wikipedia 2013g).

6.13.2 Food Sovereignty

Food sovereignty asserts the right of people to define their own food systems; and it puts individuals who produce, distribute, and consume food at the center of decisions on food systems and policies rather than the corporations and market institutions they believe to have come to dominate the global food system (Wikipedia 2013h). This term was coined in 1996 by members of Via Campesina, a coalition of over 148 organizations, advocating for family-farm-based sustainable agriculture (Wikipedia 2013h).

Food sovereignty is defined as "the right of peoples, communities, and countries to define their own agricultural labor, fishing, food, and land policies which are ecologically, socially, economically, and culturally appropriate to their unique circumstances. It includes the true right to food and to produce food, which means that all people have the right to safe, nutritious, and culturally appropriate food and to food producing resources and the ability to sustain themselves and their societies" (Sivakumaran 2012).

The framework is structured around the following key principles (Sivakumaran 2012):

1. *People-centered approach to food*: The right to food is people-sensitive; the food available must be safe, sufficient, nutritious, and culturally appropriate. Food should be considered as more than just a commodity.
2. *Food providers*: Producers of food who cultivate, harvest, and process food are central to agricultural policies. Regardless of the size of their production and contribution they should be valued and consulted in plans on agricultural reform. Food sovereignty urges communities to invoke and exercise their right to produce their own food. Local food producers should also have sovereignty over natural resources with emphasis on the equitable sharing of natural resources between local communities. Privatization of natural resources and patenting of essential products are contrary to food sovereignty.
3. *Local food systems*: Food sovereignty emphasizes the local over the international in food systems. Food markets should be dependent on local food producers and the local markets should not be subject to dumping of excess foods from heavily subsidized food production. This approach will cut down pollution and waste from transporting food across long distances and over-processing food to make it more convenient and appealing to foreign consumers. It will also ensure the availability of culturally acceptable and nutritious food. If the large scale production of foods for export and biofuels (generally monoculture in concept) is replaced by multicropping of local foods, there would be sufficient foods for local needs.
4. *Agroecology*: Food sovereignty emphasizes sustainable agricultural production and processing methods which optimize production in a positive ecological system and improve resilience and adaptation to climate change. It also emphasizes the importance of building on local knowledge and skills to improve sustainable agricultural techniques that are ecofriendly.

Food sovereignty does not favor large-scale, industrialized corporate farming based on specialized production, land concentration, and trade liberalization but supports the small farm holders and collectively owned farms and serves as a platform for rural revitalization, farmer control over seeds, and productive small-scale farms that supply consumers with healthy and locally grown foods (Wikipedia 2013h).

6.13.3 Food Sovereignty and the National Food Production Policy

Actually, the Vision-Mission Statements of the Department of Agriculture do not depart from this concept, and there seems to be hardly an item to change to attain food sovereignty—*(Vision): A modernized smallholder agriculture and fisheries; a diversified rural economy that is dynamic, technologically advanced and internationally competitive. Its transformation is guided by the sound practices of resource sustainability and the principles of social justice, and a strong private sector participation. (Mission): To help and empower the farming and fishing communities and the private sector to produce enough, accessible, and affordable food for every Filipino and a decent income for all* (Department of Agriculture 2012).

The handicap is that in carrying out its Vision-Mission Statements, like other government agencies elsewhere in this world, it is derailed by multinational business interests; by the lure of foreign investments; by the pressure to attain food security because of increasing population or else be evicted from power by food riots; by political lobbying; by interdepartmental cross-cutting policy decisions from above and from the Legislative Branch oftentimes to meet short-sighted political agenda; by the urgency to modernize agriculture and failure to appreciate agricultural heritage systems; and of course, by the consumer (cash)-orientation of society where program success is measured in terms of increased farmer income. Producing one's food and selling the excess to be able to procure goods and services that the farm could not produce will not bring in the cash, the indicator with which program implementation success is measured by agroeconomists. Farmers are generally considered as producers of goods (not as self-sufficient producers of food) that they sell to traders to generate cash to provide for all their needs. And hence, they are treated similar to other producers and processors in the other economic sectors. Agricultural programs being promoted are on per commodity basis—the Rice Program, the Corn Program, the High Value Crops Program, the Livestock Program, and the support services like irrigation, fertilizers, seeds, postharvest facilities, and credit. There is no integrated and diversified sustainable farming program that recognizes the importance of small-scale food producers working in harmony with the agroecology in order to fulfill the Vision-Mission Statements. It is even alleged that there are farm-to-market roads constructed that ended in the political leader's farm. The perception is that references to the small farmer is nothing but rhetoric for political gain.

We should also consider the agricultural geography of the Philippines that explains why we are where we are. Despite decades of political independence from the colonizing western powers as well as decades of land reform program, agricultural exports, and hence large tracts of agricultural lands, remain devoted to plantation crops. When the Philippine revolution leadership against Spanish colonial rule changed hands from a plebian to an *ilustrado*, political science commentators noted that the leadership usurpation was to protect the interest of the Filipino elite. Dismantling of huge plantation estates never took place after the revolution; hence, the development of small-scale farming systems remained neglected, and the government focus has always been on our export commodity crops, the plantation crops. We are indeed in a paradox of importing food to attain food security, but at the same time we export plantation crops and their derivative products to earn foreign exchange.

On the part of consumers, patriotism and value reorientation to patronize local goods are much needed. Food dumping by industrialized nations and the flooding of supermarkets by cheap imported food would not be an issue if Filipinos would not buy them in the first place. But this is not the Filipino psyche. Filipinos in general favor the imported over the locally produced if given a choice. The Filipino National Hero Jose Rizal in his novel *Noli Me Tangere* (Touch Me Not) epitomized this character trait through the colonial mentality of Doña Victorina. For the former colonial powers to keep the Philippines atuned to its culture is certainly effortless, especially with modern mass communication and information technology. Slowly, ethnic, indigenous, and traditional way of life is fading, all in the name of modernization and because of availability of cheap but imported (not locally developed) technology. Locally produced goods are generally franchises or licensed by the international monopolies. Importers can import as much as they want in accordance with the global trade liberalization thrust, but if nobody buys them despite being cheap, easily available, and with heavy investments on advertising, multinationals and big agricultural players will not be able to make inroads in the Philippine consumer market scene. The problem is, there is hardly locally produced consumer goods; an ultranationalistic Filipino will find himself simply frustrated.

As long as we allow ourselves to be deceived by advertisements by these multinationals and big players; as long as we continue to patronize cheap imported foods and processed foods; as long as supermarket chains and convenience stores are filled daily with patrons who purchased foods dumped to us by industrialized nations; as long as we prefer to be domestic helpers abroad than teach our younger generation about Filipino values, customs, and norms (most Filipino domestic helpers abroad are school teachers); as long as we measure success in terms of how much money we make; food sovereignty will remain as illusory as the prosperity we seek for every Filipino.

6.13.4 Food Sovereignty: The Simple Case of a Woman Rice Farmer in Visayas

The non-government organization *Magsasaka at Siyentipiko para sa Pag-unlad ng Agrikultura* (MASIPAG), which can be translated as Farmer-Scientist Partnership for Development, has its roots in May, 1986 during the national convention of rice farmers and pioneered in teaching farmers rice breeding techniques to allow them to select the parent materials based on desired plant characters at zero chemical inputs. Subsequently, several projects emerged. MASIPAG can be considered the pioneer of reemergent organic agriculture in the Philippines.

Lydia Macaya, who lives in one of the isolated villages in the island of Panay, is one of the women rice breeders trained by MASIPAG. This is from the MASIPAG website and written by Dr. Sarah Wright in 2004 for the MISEREOR Lenten Campaign in Germany (MASIPAG 2012):

Lydia Macaya is only 35 years old but she is already addressed with the respectful "Nang" (added before a name) by her villagers. Nang Lydia is a community leader, rice breeder and trainer in organic agriculture. On her ½ ha plot she is developing a new strain of pest resistant, high yielding, locally adapted rice. She is also testing a new method of growing organic rice, trialing 60 different varieties, and growing enough food to feed herself and her extended family. Nang Lydia travels throughout the island of Panay and to different islands in the Philippines to give training to other small farmers on breeding and sustainable agriculture. All this from a woman who was forced to leave school at 12 years old because her family did not think she could use an education.

Nang Lydia was born in the isolated mountain village of Dao in the Philippines. The community has no electricity or telephones and is not accessible by road during the wet months of the year. As a child, life was not easy and she had to shoulder her share of responsibility for the family from a young age. She saw education as a way to make a better life for herself and her family but, unfortunately, she was not given the opportunity to go to high school.

"During elementary school, I would wake up at 4 am to prepare breakfast, to do some weeding on the farm, feed the animals and gather firewood and vegetables to give to the family to eat. I would leave to go to school at 6 am. It was a two and a half kilometer walk through the mountains that would take about an hour. During that time, I was so eager to go to school, even if there was a typhoon or lots of rain I

would want to go. I had to miss days sometimes if my parents asked me to do something like baby-sit my younger sisters and brothers or to take the carabao out to the farm to let it eat grass. Also we were the ones who did the plowing, so on plowing time we also had to miss school."

She left school after elementary because her parents would not let her continue. "I had to help out the family and my parents thought it would be a waste for me to get more education," she said. "They thought I would just get married and be of no more help to the family." In addition to continuing her schooling, Lydia wanted to manage their farm but for the time being she needed to go to work to help support the family. Nang Lydia went to Manila in 1988 to look for a job. She especially wanted to make sure her younger sisters had the opportunity to finish high school and college. In 1994, after her younger sister had finished high school, she moved back to the community and began working on the farm. It had long been her dream to come back to the community. "It was my will to work on the farm," explains Lydia.

In the Philippines it is unusual for the farm to be managed primarily by a woman. Although women play a major role in agriculture, mostly as unpaid family workers or self-employed farmers, they rarely hold the ultimate authority on the farm. Women's work managing budgets, ensuring food security for the family and planting, weeding, harvesting, threshing and processing, and are critical but often unrecognized.

For many years, women have been sidelined by official agricultural extension programs and other farming programs. When chemical farming and high yielding varieties came to the villages, they were based on western assumptions about women. The assumption was that women are housewives and therefore the major services extended to them have been through home management technicians and Rural Improvement Clubs. As men got access to new knowledge not available to women, their decision-making power on the farm increased.

Nang Lydia explains that when a farm is planted ½ to MASIPAG and ½ to conventional high-input agriculture it is almost invariably the woman who is behind the MASIPAG. "This is because if the husband was behind the MASIPAG, the whole farm would be planted to it because he has the say. If it is the wife, she has to negotiate and the husband may let her trial it on some portion of the land. But it usually only stays like that for a season or two. Eventually it gets resolved and the whole farm goes to MASIPAG."

MASIPAG organizers try to ensure that their programs ensure the full participation and empowerment of women and that women's contribution to the farm is recognized and supported. In Nang Lydia there is a gentle determination and enthusiasm that transcends ordinary boundaries. Supported by MASIPAG, her courage and vision has allowed her to become a leader, trainer, organizer and farmer-scientist in her own right.

Nang Lydia started using MASIPAG seeds in 1997 when she was given some seeds to try by the MASIPAG organizer Joemarie who was at that time working for the outreach unit of a local college. At this stage she didn't realize that the seeds were part of a broader farming system, supported by the MASIPAG organization, or that adoption of the seeds would lead to a new life.

At first her family, and the rest of the village, couldn't accept that she was using the MASIPAG technique. "They thought that it was the work of crazy people," said Nang Lydia. "For example, in the trial farm period, I planted out the farm with 20 varieties all in small patches in order to test which were the most locally adapted and pest resistant." This was a big risk to take considering she only have ½ ha to grow enough rice and vegetables for the whole family for a year.

Nang Lydia said, "It was difficult but ultimately I didn't care what people said. As long as it would benefit my family and the community in the long run. That is all I cared about." Although she was ridiculed at first, the community kept a close eye on Nang Lydia's output and, when they liked what they saw, they too began to use MASIPAG. Now in Nang Lydia's village of Dao with 78 households, 24 grow organically using the MASIPAG technique, and the method has spread throughout the area with adapters in all seven nearby villages that make up the Seven Cities area. Nang Lydia's sister, Estilita, speaks highly of the change, "We would be nothing without it. It makes us feel informed and empowered. We have had access to new information, met different people and learned so much. Nang Lydia even went to a conference of small farmers in the United States."

The Macaya family has ½ ha of land. ¼ of it is planted to rice and ¼ to a diversity of vegetables. "MASIPAG has big impact on the family because it reduces expenses and leads to a healthier life," she says. The family has not experienced a food shortage for many years now because they can grow three crop rotations in one year and they have cut expenses. Most families cannot afford the cost of inputs such as fertilizer and pesticide and MASIPAG is valued because it reduces crippling costs that lead to debt and to hunger. The positive health impacts of the organic rice, and the organic methods of farming are also highly valued.

"Since I started growing organically, the sickness in the family has gone down so much. Before we had more colds and flu, headaches and my grandmother had arthritis. We often had to go to the hospital. Now these problems have nearly gone away."

After her initial successes growing MASIPAG-bred rice, Nang Lydia began to get more involved in the organization *and expanded her role to become a trainer and a breeder. In the community she is looked at with respect as a leader. The training work allows her to spread the news about the benefits of organic farming and MASIPAG to other farmers. She has conducted trainings on basic orientation on sustainable agriculture, rice breeding, corn selection, corn breeding, trainers training, and Masipag orientation.*

"I enjoy conducting trainings because I like to empower fellow small farmers. At first I felt shy but now I enjoy it if I can give some benefits to others."

Two years ago, Nang Lydia also started breeding. She is breeding a new variety for MASIPAG, M143-1. Her new variety will have increased resistance to pests, increased length of seeds, increased number of tillers, be well adapted to the local soil and of a medium height. She is also breeding it for eating quality and aiming for a tasty variety with a good aroma. She is up to the fifth generation and variety will be soon ready for mass production. Nang Lydia enjoys the breeding, it helps with self esteem especially when the breeding process succeeds.

"I breed to increase the number of seeds that are available," says Nang Lydia. "It increases diversity and also means I am looking after the welfare of MASIPAG. I enjoy seeing the success of the effort I have put in. It is a good feeling to create something new, something that helps out MASIPAG as well as hopefully other farmers."

Nang Lydia currently grows 60 different varieties of rice in her trial farm which she uses for ongoing experiments checking adaptability and other characteristics of the different varieties.

Throughout the world, rural women historically have played, and continue to play an important role in rice farming systems. Women's role, however, is often viewed as a support role and their contributions are sidelined. Worse, the agricultural support and extension services offered, often exacerbate gender inequality. Nang Lydia is an example of the enormous contribution that can be made by women if their knowledge is recognized and supported. Although not given the option of going to high school, the training and knowledge she has acquired through her years of farming and with the help of MASIPAG have allowed her to make a significant contribution to her community and to other farmers in the region. Even her father now recognizes that he should have allowed Nang Lydia to go to school.

"I'd like to thank the German people for giving their support to the MASIPAG program," says Nang Lydia. "I want them to know that our lives have changed for the better, and the community is a healthier and improved place. It has a good effect on the lives of the people and I have gained knowledge that I have been able to share with other farmers and the community."

6.13.5 Food Sovereignty: The Sample Cases of Diversified Farmers in Visayas and Mindanao

These case studies were culled from Report on Organic Farming in the Philippines by Jacob Lundberg and Fredrik Moberg, produced with financial support from Sida, and published by the Swedish Society for Nature Conservation (Lundberg and Fredrik 2010):

The sacada (sugar plantation) worker

Elpidio "Jojo" Paglumotan used to be a plantation worker without any land of his own. At the sugar plantation, he earned around roughly US$ 3 per day for approximately eight months per year. For the rest of the year, the family had no income.

After a long-running conflict with the authorities, the members of his farmers' association on the island of Negros obtained the right to own their land. A number of the farmers ended up in prison before they finally won their rights from the government.

Today, Jojo owns half a hectare of land, half of which he used for rice cultivation and the other half for vegetables. In addition to this, he has 8 goats, 16 hens, 2 water buffaloes, 3 turkeys, and 8 ducks.

Jojo is one of the MASIPAG's 65 farmer-researchers who are breeding new varieties of rice for the organization. He is able to choose the varieties he wants to develop. He uses simple but effective method to keep pests in check without having to spray his plots with expensive and environmentally destructive agro-chemicals. One of the main problems for rice growers in the country is apple snail (Pomacea canaliculata), but Jojo has had no major problem since MASIPAG recommended that he allow his duck to wander around the rice fields. They eat the snails and also restrict the amount of weeds. Jojo's rice fields have numerous dragonflies, the natural enemy of a number of insect pests and these are example of beneficial insects that is strikingly absent in crops treated with chemical pesticides.

Eyes damaged by pesticides

Eugenio "Euni" Geraldo is a diversity farmer in Mindanao. After losing his wife in childbirth, Euni single-handedly raised his six children on 5 ha of land. Until 1999, he sprayed his rice and vegetable crops with chemical pesticides to protect them against insects and diseases. He damaged his eyes and lost some of his sight because of using pesticides.

However, after going on a course organized by MASIPAG, he began to grow organic crops. Not only because he partly lost his sight, the pesticides also affected the natural *pest control system and resulted in the disappearance of beneficial insects and birds. He wanted also his children to enjoy more nutritious food.*

MASIPAG trains him in the use of new cultivation techniques and rice breeding which he then shares with other farmers. Euni has a great ecological knowledge and a well-planned schedule on how the farm should be managed so that the nutrients can be recycled in the best possible way. His diversity farm includes rice, corn, sorghum, and bananas, as well as vegetables such as haricot beans, aubergines, and tomatoes. He also has half a hectare of forest.

"The forest is a source of water for my crops, while also promoting the natural enemies of pests. From it, I also get coconuts that we can eat or sell in the market."

On the hills around the rice fields, he grows the madre de cacao, a nitrogen-fixing and deep rooting tree that can extract nutrients from deeper soil layers. He uses the leaves as fodder and the branches for firewood. His cropping system also includes ducks which he rears on crop trash. He also has fishponds where he keeps tilapia and sells some at the market in the neighboring village.

6.13.6 Summary and Conclusion

To sum it up, we have sufficient natural resources to meet the needs of Filipinos, but a lot of rural-based Filipinos live in poverty. What we have is a crisis of ignorance to manage well our resources, and the crisis of moral depravity and lack of political will to pursue what is right rather than succumb to the external foreign interests that have enslaved us as a nation since the time when Rajah Soliman III lost in the Battle of Bangkusay.

Agriculture as a young ecosystem is inherently unstable and to attain a certain degree of stability we need to diversify and practice multiple cropping and crop rotation. We also have to return back to the soil what we got through composting. Sustainable agricultural practices lead to food sovereignty and food security through increased self-sufficiency and decreased external dependency. Many small-time farmers assisted by non-government organizations have overcome grinding poverty by managing their agricultural resources well. They may not have as much income as conventional farmers have, but they are assured of food in the home. Their family members do not go hungry and the excess farm outputs are marketed to generate cash to purchase essential nonfarm produce.

Our foreign colonizers may have left our country decades ago, but *neocolonialism* remains a powerful force to reckon with that it would take a collective and a unified stand to hurdle and overcome in order for us to pursue what is the best for our country. Until we regain our national pride from centuries of foreign domination, until the local producers and the local consumers unite to overthrow these so-called neocolonial interests, the concept of food sovereignty at the national level, maybe but just a dream.

It is a fitting end to this book, *Soils of the Philippines* to reiterate the Filipino folk song, *Bahay Kubo,* which sums up centuries of agricultural heritage and wisdom of our forebears, the very essence of what food sovereignty is all about:

Bahay Kubo	**My Nipa Hut**
Bahay kubo, kahit munti,	My nipa hut, even just small,
Ang halaman duon ay sari-sari;	But therein are variety of crops;
Singkamas at talong,	Turnips and eggplants,
Sigarilyas at mani,	Wingbeans and peanuts,
Sitaw, bataw, patani,	String, hyacinth, and lima beans,
Kundol, patola,	White gourd melon, loofah,
Upo't kalabasa,	Bottle gourd and squash,
At tsaka meron pa,	And there are more,
Labanos, mustasa,	Raddish and mustard,
Sibuyas, kamatis,	Onions, tomatoes,
Bawang at luya,	Garlic and ginger,
At sa paligid-ligid ay puno ng linga.	And all around abound sesame seeds.

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Authors' Biography

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The Soils of the Philippines senior author Rodelio B. Carating is Senior Science Research Specialist at the Bureau of Soils and Water Management (BSWM), Elliptical Road, Diliman, Quezon City, Philippines. Unlike his two co-authors who came from rural farm, the senior author grew up in Tondo, Manila. He obtained his B.S. Agriculture Major in Soil Science degree from the University of the Philippines, Los Baños (UPLB) in 1978. He is assigned at the Geomatics and Soil Information Technology Division and supervises various Geographic Information System (GIS) studies such as those relating to land degradation assessment, crop yield assessment using remote sensing techniques, and various land resources assessment projects for delineation of Strategic Agriculture and Fisheries Development Zones (SAFDZ) and integration with the local government's Comprehensive Land Use Plan (CLUP). He is also involved with other projects such as the Korean-funded Asian Network on Sustainable Organic Farming Systems (ANSOFS), the FAO-funded Land Degradation Assessment (LADA), and the DENR-implemented Globally Important Agricultural Heritage Systems (GIAHS). Mr. Carating also manages the BSWM Homepage (http://www.bswm.da.gov.ph) and the SOILSCAPE Quarterly Technical Bulletin of the bureau.

Mr. Carating is concurrently the Technical Assistant to the BSWM Director and supervises the Planning, Monitoring and Evaluation Group which prepares the BSWM medium-term plans (2011–2016 and 2017–2022) and the structure of the BSWM Strategic Performance Management System for the semestral performance appraisal of the bureau staff. He also oversees the management of the BSWM Client Center and the BSWM Dormitory. He is a member and currently serves as the Vice-Chair of the BSWM Bids and Awards Committee. He represents the Director who is the Vice-Chair in the National Convergence Initiatives (coordination of the rural development projects of the Department of Agriculture, the Department of Environment and Natural Resources, and the Department of Agrarian Reform), and represents also the Director who is the alternate of Undersecretary Sigfredo R. Serrano in the Steering Committee of the National Mapping Resource Information Authority (NAMRIA's) *The Philippine Geoportal: One Nation One Map Project*.

As for other project involvements and professional affiliations, Mr. Carating is a member of the Technical Working Group of the BSWM Agri-Pinoy Corn Program, Chairman of the Secretariat of the Philippine Conservation Approaches and Technologies (PhilCAT) which is the local consortium of the World Conservation Approaches and Technologies (WOCAT), member of the BSWM technical working group of the Philippine interagency consortium that updates the Philippine National Action Plan, the

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implementation instrument of the UN Convention to Combat Desertification and Land Degradation (UNCCD). He served as the Secretary and later on as the Public Relations Officer of the Philippine Society of Soil Science and Technology (PSSST), 2001–2005, capping his stint by serving as Secretary General and the lead personality in organizing the seventh East and Southeast Asia Federation of Soil Science Societies (ESAFS) International Scientific Conference held at the BSWM Convention Hall, 1–5 June 2005. He has organized many other BSWM-hosted regional and international conferences. His most recent involvement is with Global Soil Partnership—Asia Soil Science Network and the GlobalSoilMap.net East Asia Node. This book The Soils of the Philippines is part of the national efforts to consolidate the Philippine soil heritage data to facilitate the country's share in the exchange of global soil data.

Mr. Carating has authored several scientific papers dealing with soil survey and soil suitability mapping, isarithmic mapping of soil chemical properties using geostatistical techniques, the BSWM soil information system, classification and mapping of Taal and Pinatubo volcanic ash soils, and the BSWM Soil Museum Collection for various local and international scientific conferences. A number of his papers received the Best Paper Award in the in-house research review and in the PSSST annual meetings. His other publications are the BSWM Citizen's Charter (2009), the BSWM Soil Survey Manual (2009), and the BSWM Manual on Map Standards and Symbols for Soil and Water GIS (2010). He has just released the Philippine Land Degradation Assessment Report which highlighted the major outputs of the FAO-funded technical cooperation on land degradation that was completed in December, 2013. He has co-authored and edited several soil and land resources reports for the last two decades.

Raymundo G. Galanta

Raymundo G. Galanta is Supervising Agriculturist at the Soil Survey Division, Bureau of Soils and Water Management (BSWM), Elliptical Road, Diliman, Quezon City. He is a very experienced soil surveyor and has either been a member or a team leader in several provincial soil survey and classification work across the country. A native of Candon, Ilocos Sur, noted for the growing of tobacco, he finished his B.S. Agriculture major in Soils from the Gregorio Araneta University Foundation in Victoneta Park, Malabon City in 1968. The university had its humble beginning as an agricultural school at Hacarin Dairy Farm in Hacienda Carmelita, San Jose del Monte, Bulacan until it transferred to its present location in 1947. In 2002, it was fully integrated with the De La Salle University System and since then and until now, the university is known as the De La Salle Araneta University.

Mr. Galanta further received Diploma in Geomorphological Survey and Applied Geomorphology using aerial photography and other remote sensing techniques from the International Institute for Aerial Survey and Earth Sciences (ITC) in Enschede, The Netherlands, in 1977. He has many more trainings on aerial photo interpretation, remote sensing, and multispectral image analysis for agricultural applications such as those conducted by University of the Philippines Natural Science Research Center in 1979 and by the UNDP in Tokyo, Japan in 1980.

Among the soil survey, classification, and mapping projects he has participated in are those of Pangasinan Integrated Area Development Project, Panay Upland Area Integrated Development Project, Bicol River Basin Project, and the Pampanga Land Reform Priority Area. The list of provincial soil survey, classification, and mapping projects he has been involved with are quite innumerable—Bukidnon, Marinduque, Surigao del Norte, Pangasinan, Davao del Norte, Davao del Sur, Bontoc-Mountain Province, Benguet, Ilocos Norte, La Union, North Cotabato, Maguindanao, and Lanao del Norte. Of this list, seven provinces are located in the island of Mindanao making Mr. Galanta a noted and eminent authority of the soils of Mindanao.

He is married to the former Lourdes Salvador Santillan and they have a son. After making his share of the book, The Soils of the Philippines, Mr. Galanta retired from government service in June, 2011. He started his stint in government service in 1969; and thus, he spent 42 years of his best life pursuing the survey and classification of Philippine soils. The senior author is certainly honored to have the distinguished Filipino field soil surveyor, Tatang Romy Galanta as a co-author of this book.

Clarita D. Bacatio

Clarita Dizon Bacatio, PhD., is Supervising Agriculturist at the Soil Survey Division, Bureau of Soils and Water Management (BSWM), Elliptical Road, Diliman, Quezon City. She hailed from Cabiao, Nueva Ecija, a rice-growing province. Ms. Bacatio obtained her B.S. Agriculture from then Gregorio Araneta University Foundation (now De La Salle Araneta University) in Victoneta Park, Malabon City in 1978, her M.Sc. Soil Survey from International Institute of Geo-Information Science and Earth Observation in Enschede, The Netherlands in 1992, and her PhD. in Soil Science from the De La Salle Araneta University in 1997.

Ms. Bacatio is an experienced soil surveyor and she has been involved with the soil survey, classification, and mapping of the provinces of Rizal, Nueva Ecija, Nueva Vizcaya, Isabela, Tarlac, Davao del Sur, Davao Oriental, San Jose Del Monte City-Bulacan, Narra-Palawan, Quezon, Eastern Samar, Leyte, Marinduque, Laguna, Aurora, Negros Occidental, Iloilo, Antique, Aklan, and Bohol. She is certainly one of the respected and well-experienced soil surveyors in the Philippines, a rare and vanishing breed of professionals today.

Despite her hectic and frequent out-of-town soil survey schedule, Ms. Bacatio has two published papers in refereed Journal in 2005. The first one is "The Characterization of Marginal Soils of Three Techno-demo Farms in the Philippines" co-authored with Hideo Kubotera of the National Agricultural Research Center for Kyushu Okinawa Region, Masami Nanzyo of Tohoku University, and Ichiro Yamada, JICA Team Leader at BSWM which appeared in the Pedologist Volume 49, No. 2 and published by the Japanese Society of Pedology. The second one is "Partial Rejuvenation of the Soils in Intavas Techno-demo Farm, Bukidnon, Mindanao, Philippines by Volcanic Ash Materials" with the same co-authors which appeared in the Journal of Integrated Field Science, Volume 2 (JIFS, 2:19–27, 2005) and published by the Field Science Center, Graduate School of Agricultural Science, Tohoku University.

Ms. Bacatio is active in the Philippine Society of Soil Science and Technology and was elected to the Board of Directors serving in various capacity from 2002 to 2009.

Ms. Bacatio has just been widowed by Florencio P. Bacatio, Jr. whom they have been blessed with two sons and a daughter. She decided for an early retirement in December, 2013 to avail of the benefits offered by the national government's Rationalization Plan. Coming to the bureau in 1974, "Claire" as she is fondly called by friends has accumulated 38 years of wisdom and knowledge about soils that she shares in this book.

Soil Series Maps of the Philippines

Legends of Maps 1–3

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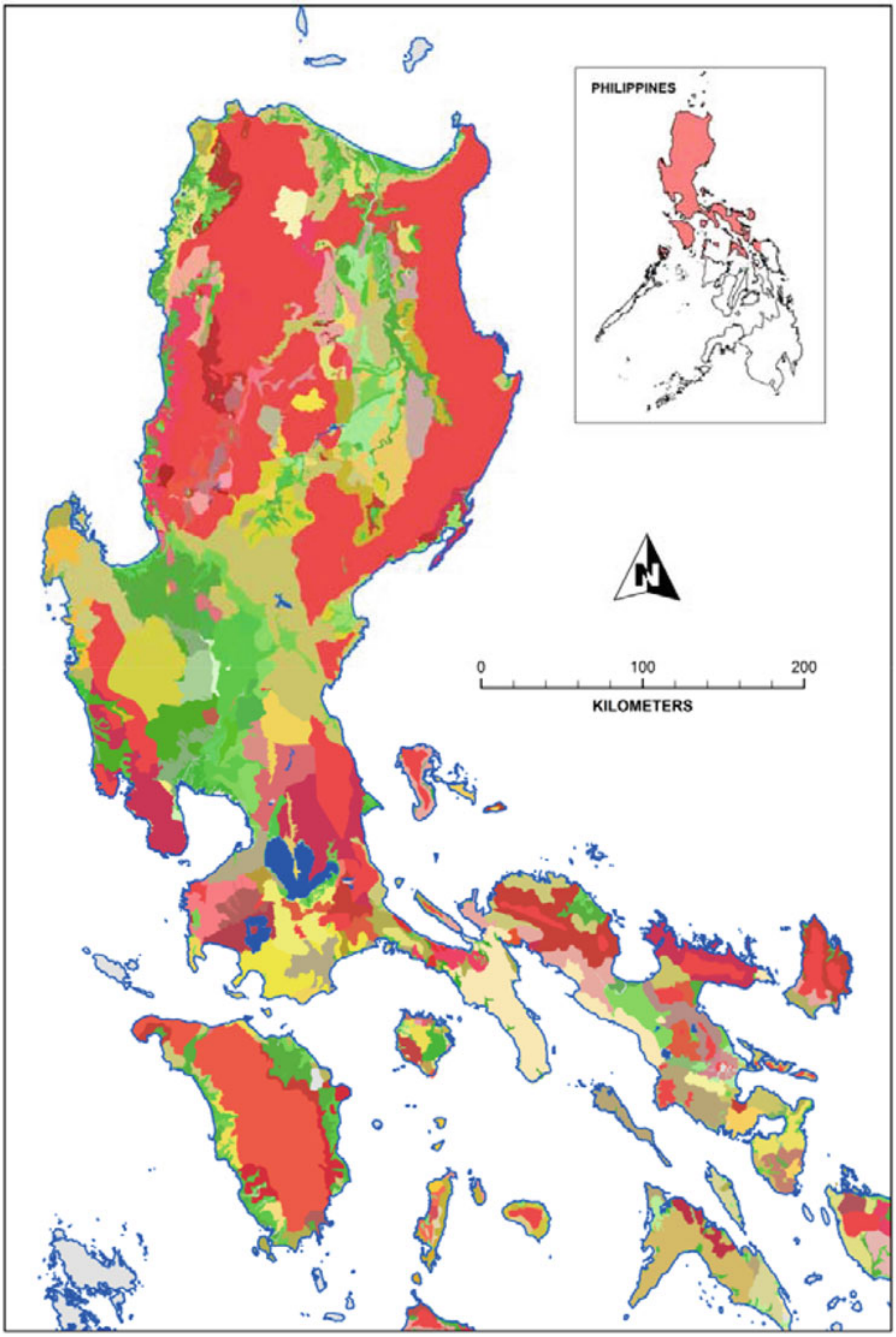
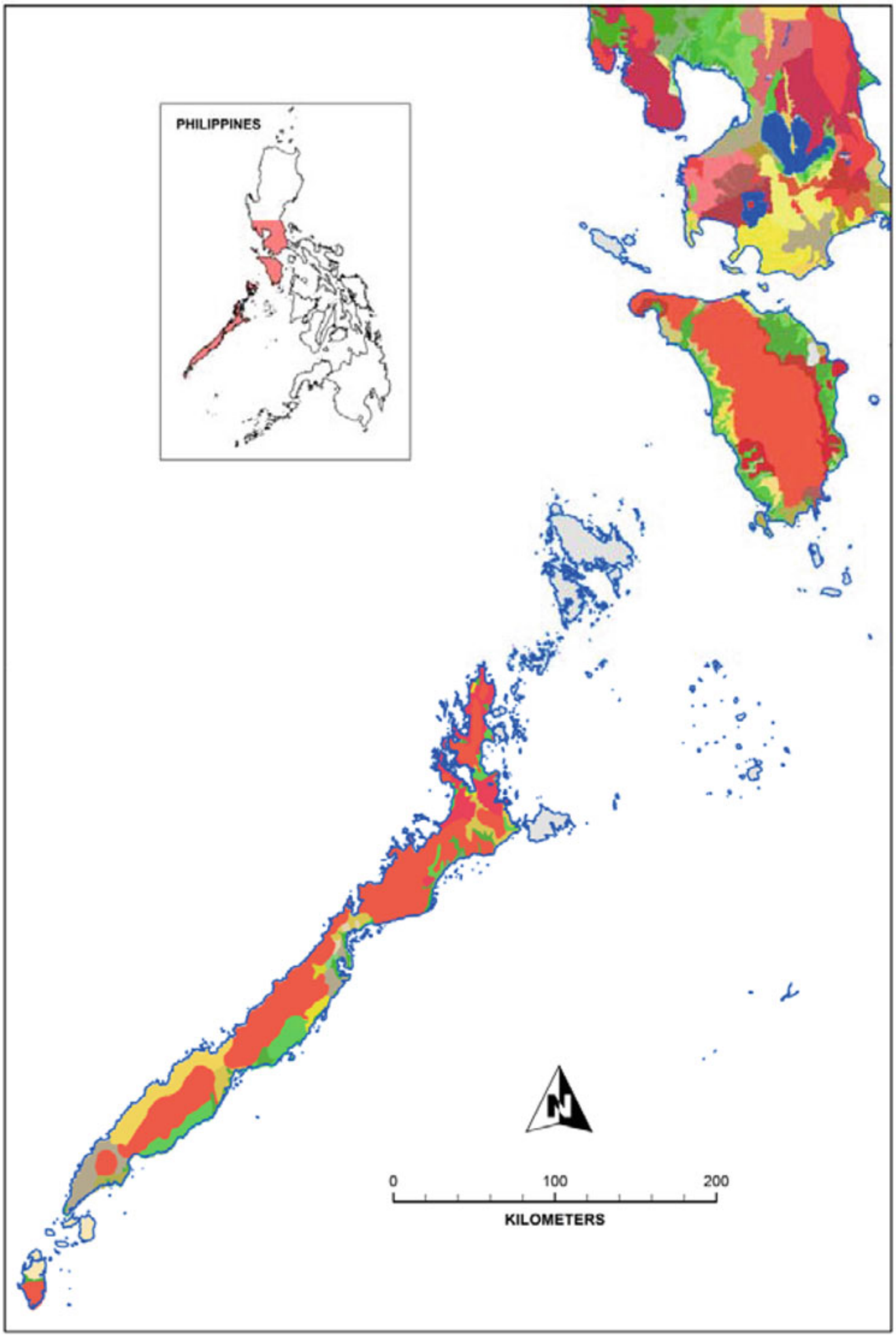
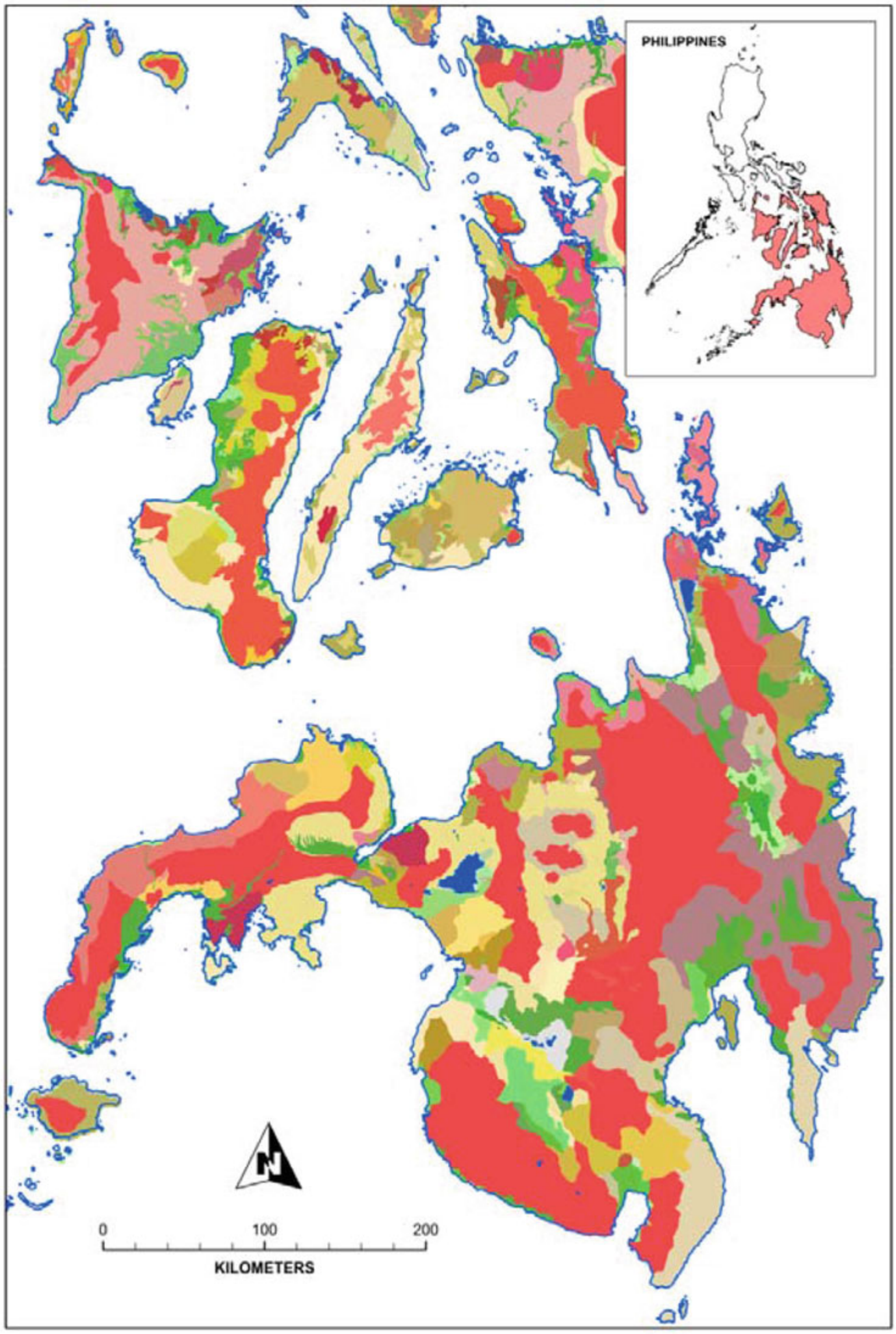
Map 1—Luzon



Map 2—Palawan



Map 3—Visayas and Mindanao



Appendix A
Major Rice Soils of the Philippines

The Bantog soil series (Plate 1A, Fig. A.1)	
Location of typical pedon:	Bulacan
Physiography:	Level to nearly
General description:	
Parent material:	Recent alluvium, recent coastal
Solum thickness:	100–150 cm
Drainage:	Poorly drained
Special features:	Surface crack at 5–10 cm wide, common distinct discontinuous intersecting slickensides; very few soft and hard spherical black manganese concretions
Mineralogy:	Very fine, montmorillionitic,
Constraints:	Cracks
Fertility:	Ranges from low to high
Major land uses:	Lowland rice, upland rice, corn, sugarcane, vegetables, root crops, coconut, and perennial trees
Total area:	142,812 ha
Distribution based on reconnaissance soil maps (ha):	
Bantog sandy loam	
Ilocos Norte	106
Bantog silt loam	
Ilocos Norte	361
Bantog clay loam	
Bulacan	8,550
Catanduanes	5,366
Ilocos Norte	2,285
Iloilo	1,478
Isabela	4,748
Leyte	399
Nueva Ecija	37,383
Pampanga	3,855
Sulu	330
Bantog silty clay loam	
Ilocos Norte	1,679
Bantog silty clay	
Ilocos Norte	351
Bantog clay	
Bohol	1,834
Capiz-Aklan	25,137
Ilocos Norte	1,913
Mindoro	2,217
Misamis Occidental	5,215
Misamis Orienta	5,045
Surigao	6,628
Zamboanga del Sur	3,438
Bantog-Malalag Complex	
Mindoro	3,127

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Fig. A.1 Landscape view of Bantog series

Fig. A.2 Landscape view of Bigaa series

The Bigaa soil series (Plate 1B, Fig. A.2)	
Location of typical pedon:	Bulacan
Physiography:	Broad nearly level slightly dissected alluvial terraces
General description	
Parent material:	Recent alluvium
Solum thickness:	100–150 cm
Drainage:	Moderate
Special features:	Fine thin, thick, and coarse slickensides; very few to few small and medium soft Mn concretions
Mineralogy:	Very fine, montmorillonitic
Constraints:	Cracks
Fertility:	Moderate to very high
Major land uses:	Lowland rice, upland, coconut, root crops, corn, vegetables, and sugarcane
Total area:	83,971 ha
Distribution based on reconnaissance soil maps (ha):	
Bigaa sandy loam	
Samar	1,074
Bigaa loam	
Quezon	3,584
Samar	16,144
Bigaa sandy clay loam	
Abra	3,220
Bigaa clay loam	
Bulacan	17,550
La Union	1,216
Pampanga	8,959
Bigaa silty clay loam	
Abra	519
Bigaa clay	
Abra	1,630
Cagayan	1,024
Isabela	29,087

The Butuan soil series (Plate 1B, Fig. A.2)	
Location of typical pedon:	Las Navas, Agusan del Sur
Physiography:	Level to nearly level
General description	
Parent material:	Limestone, shale–sandstone, sandstone, shale–sandstone–limestone
Solum thickness:	100–120 cm
Drainage:	Somewhat poorly drained
Special features:	Few, small, soft iron–manganese concretions at the depth of 70 below
Constraints:	None
Mineralogy:	Fine
Fertility:	Moderate
Major land uses:	Lowland rice, corn, coconut, vegetables, perennial trees
Total area:	98,162 ha
Distribution based on reconnaissance soil maps (ha):	
Butuan loam	
Agusan	74,010
Butuan clay	
Masbate	19,464
Surigao	4,688

The Candaba soil series (Plate 1C, Fig. A.3)	
Location of typical pedon:	Candaba, Pampanga
Physiography:	Level to nearly level
General description	
Parent material:	Recent alluvium
Solum thickness:	90–100 cm
Drainage:	Poorly drained
Special features:	Presence of few soft black manganese concretions
Mineralogy:	Very fine, mixed
Constraints:	Poor drainage, flooding, and zinc deficiency
Fertility:	Moderate to very high
Major land uses:	Lowland rice, vegetables, sugarcane
Total area:	15,487 ha
Distribution based on reconnaissance soil maps (ha):	
Candaba silt loam	
Pampanga	3,963 ha
Candaba clay loam	
Pampanga	11,524 ha

Fig. A.3 Landscape view of Butuan series

Fig. A.4 Landscape view of Candaba series with the dominating background of Mt. Arayat

The Isabela soil series (Plate 1C, Fig. A.4)	
Location of typical pedon:	Negros Occidental
Physiography:	Level to nearly level broad alluvial plain
General description	
Parent material:	Recent alluvium, old alluvium, recent coastal deposits
Solum thickness:	80–150 cm
Drainage:	Somewhat poor to poorly
Mineralogy:	Fine, montmorillonitic
Constraints:	Cracks at some period
Fertility:	High to very high
Major land uses:	Lowland rice, upland rice, corn, sugarcane, coconut, root crops, vegetables, perennial trees
Total area:	69,816 ha
Distribution based on reconnaissance soil maps (ha):	
Isabela sandy loam	
Negros Occidental	1,163
Isabela loam	
Agusan	3,110
Isabela clay loam	
Lanao	1,855
Isabela clay	
Agusan	823
Cagayan	15,560
Kalinga-Apayao	2,138
Negros Occidental	29,682
Negros Oriental	13,110
Zamboanga del Norte	1,250
Zamboanga del Sur	1,125

Fig. A.5 Landscape view of Isabela soil series taken in Negros Occidental

The Maligaya soil series (Plate 1D, Fig. A.6)	
Location of typical pedon:	Nueva Ecija
Physiography:	Level to nearly level broad alluvial plain
General description	
Parent material:	Recent alluvium
Solum thickness:	100–150 cm
Drainage:	Somewhat poorly drained
Special features:	Few thin slickensides
Mineralogy:	Very fine, montmorillonitic
Constraints:	Poor drainage
Fertility:	Moderate to high
Major land uses:	Lowland rice, corn, sugarcane, vegetables, plantation crops
Total area:	57,282 ha
Distribution based on reconnaissance soil maps (ha):	
Maligaya silt loam	
Nueva Ecija	9,729
Maligaya sandy clay loam	
Abra	3,180
Maligaya clay loam	
Laguna	4,656
La Union	3,996
Nueva Ecija	10,834
Nueva Vizcaya	8,355
Zamboanga del Norte	438

Fig. A.6 Landscape view of Maligaya series taken in Nueva Ecija

Fig. A.7 Landscape view of Prensa series taken in Nueva Ecija

The Prensa soil series	
Location of typical Pedon:	Bulacan
Physiography:	Level to slightly rolling
General description	
Parent material:	Residual soils from volcanic tuff
Solum thickness:	50–150 cm
Drainage:	Fair
Special features:	Presence of manganese concretions
Mineralogy:	Fine, mixed
Constraints:	None
Fertility:	Low
Major land uses:	Lowland rice, upland rice, corn, sugarcane, perennial trees
Total land area:	64,623 ha
Distribution based on reconnaissance map (ha):	
Prensa sandy loam	
Nueva Ecija	16,005
Prensa silt loam	
Nueva Ecija	16,456
Pampanga	1,592
Prensa clay loam	
Bulacan	17,250
Rizal	2,090
Prensa silty clay loam	
Bulacan	10,230

The Quingua soil series (Plate 1F, Fig. A.8)	
Location of typical pedon:	Bulacan
Physiography:	Level to nearly level upper river terrace/levees
General description	
Parent material:	Recent alluvium, recent coastal deposits
Solum thickness:	100–150 cm
Drainage:	Well drained
Special features:	Very few to few patches of clay skin in between ped faces
Mineralogy:	Fine, mixed
Constraints:	None
Fertility:	Moderate to very high
Major land uses:	Lowland rice, corn, sugarcane, vegetables, plantation crops, root crops, upland rice, coconut
Total area:	373,693 ha
Distribution based on reconnaissance soil maps (ha):	
Quingua sand	
Nueva Ecija	5,025
Quingua sandy loam	
Bulacan	3,750
Cavite	876
Isabela	1,142
Laguna	2,038
Mindoro	3,483

(continued)

(continued)

The Quingua soil series (Plate 1F, Fig. A.8)	
Nueva Ecija	1,296
Rizal	2,220
Quingua silt loam	
Agusan	4,391
Bulacan	20,850
Cagayan	4,504
Camarines Sur	620
Kalinga-Apayao	2,205
Mindoro	9,222
Misamis Occidental	1,918
Nueva Ecija	72,274
Nueva Vizcaya	9,725
Pampanga	21,569
Quezon	7,168
Zambales	7,767
Quingua loam	
Mindoro	2,615
Sulu	420
Quingua sandy clay loam	
Quezon	2,270
Quingua clay loam	
Cagayan	39,172
Kalinga-Apayao	7,650
Mindoro	38,433
Nueva Ecija	29,659
Palawan	8,200
Samar	6,983
Sulu	4,730
Zamboanga del Norte	2,865
Quingua silty clay loam	
Bontoc	500
Isabela	17,608
Kalinga-Apayao	1,620
Sulu	3,361
Quingua silty clay	
Mindoro	4,948
Quingua clay	
Mindoro	6,457
Samar	4,297

Fig. A.8 Landscape view of Quingua soil series

The San Fernando soil series (Plate 1F, Fig. A.9)	
Location of typical pedon:	Pampanga
Physiography:	Broad alluvial plain
General description	
Parent material:	Recent alluvium
Solum thickness:	100–130 cm
Drainage:	Poor to very poorly drained
Special features:	Few to common continuous slickendsides
Mineralogy:	Fine, mixed
Constraints:	Cracks
Fertility:	Moderate to very high
Major land uses:	Lowland rice, sugarcane, corn, vegetables, perennial trees
Total area:	28,231 ha
Distribution based on reconnaissance soil maps (ha):	
San Fernando sandy loam	
Ilocos Norte	404
San Fernando clay loam	
Ilocos Norte	2,370
Pampanga	6,362
San Fernando silty clay	
Ilocos Norte	701
San Fernando clay	
Cagayan	6,438
Ilocos Norte	9,384
Pampanga	2,527

Fig. A.9 San Fernando soil series utilized for growing of corn

The San Manuel soil series (Plate 1F, Fig. A.10)	
Location of typical pedon:	Tarlac
Physiography:	Nearly level river terraces
General description	
Parent material:	Old alluvium, recent alluvium, recent coastal deposits
Solum thickness:	100–115 cm
Drainage:	Well drained
Mineralogy:	Fine loamy, mixed
Constraints:	Slight to moderate flooding
Fertility:	Moderate to high
Major land uses:	Lowland rice, upland rice, corn, coconut, vegetables, sugarcane, root crops, perennial trees
Total area:	1,080,726 ha
Distribution based on reconnaissance soil maps (ha):	
San Manuel undifferentiated	
Leyte	10,623
San Manuel sand	
Ilocos Norte	170
La Union	1,635
Pangasinan	8,852
San Manuel loamy sand	
Mindoro	1,148
San Manuel sandy loam	
Abra	795
Bataan	234
Cagayan	10,168

(continued)

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The San Manuel soil series (Plate 1F, Fig. A.10)	
Cotabato	1,125
Ifugao	284
Ilocos Norte	4,251
Isabela	1,047
Leyte	5,671
Marinduque	2,219
Mindoro	23,234
Misamis Occidental	108
Negros Occidental	2,218
Negros Oriental	4,370
Nueva Vizcaya	4,443
Pangasinan	23,871
Pangasinan	42,026 (fine sandy loam)
Quezon	2,150
Samar	8,326
Sulu	152
San Manuel sandy loam, gravelly phase	
Zamboanga del Sur 500	
San Manuel silt loam	
Bontoc	125
Bukidnon	4,756
Cagayan	44,972
Camarines Sur	9,964
Ilocos Norte	6,217
Ilocos Sur	27,056
Kalinga-Apayao	1,022
Lanao	7,421
La Union	13,854
Leyte	45,925
Mindoro	53,435
Nueva Ecija	3,224
Nueva Vizcaya	3,470
Pangasinan	65,219
Surigao	45,000
Tarlac	15,466
Zamboanga del Norte	13,875
Zamboanga del Sur	32,562
San Manuel loam	
Agusan	21,727
Antique	3,565
Camarines Norte	75
San Manuel loam, gravelly phase	
Cotabato	4,375
Cotabato	41,250

(continued)

(continued)

The San Manuel soil series (Plate 1F, Fig. A.10)	
Ilocos Norte	9,597
Isabela	7,812
Kalinga-Apayao	135
Leyte	1,278
Mindoro	13,656
Misamis Oriental	13,463
Negros Occidental	14,146
Negros Oriental	5,380
Samar	18,129
San Manuel sandy clay loam	
Abra	4,532
Capiz-Aklan	3,542
Ilocos Norte	446
San Manuel clay loam	
Agusan	22,368
Camarines Norte	20,469
Capiz-Aklan	15,448
Catanduanes	1,375
Ilocos Norte	1,647
Kalinga-Apayao	1,260
Mindoro	10,924
Palawan	27,250
Samar	5,506
Zamboanga del Norte	9,000
Zamboanga del Sur	8,062
San Manuel silty clay loam	
Cotabato	41,875
Davao	134,855
Ilocos Norte	914
Kalinga-Apayao	2,632
Pangasinan	17,895
San Manuel silty	
Ilocos Norte	1,488
San Manuel clay	
Agusan	1,647
San Manuel-Taal Complex	
Negros Oriental	4,460

Fig. A.10 Landscape view of San Manuel soil series taken in Tagum City, the capital of the province of Davao del Norte

Appendix B
Major Soils Grown to Economically Important Crops

The Adtuyon soil series (Plate 2A, Fig. B.1)	
Major land uses:	Upland rice, corn, coconut, vegetables, plantation crops, root crops
Total area:	552,369 ha
Distribution based on reconnaissance soil maps (ha):	
Adtuyon loam	
Lanao	40,975
Misamis Occidental	6,299
Zamboanga del Norte	563
Zamboanga del Sur	1,750
Adtuyon loam, stony phase	
Lanao	8,998
Adtuyon clay loam	
Misamis Occidental	29,630
Sulu	31,270
Zamboanga del Norte	7,125
Zamboanga del Sur	49,938
Adtuyon clay	
Bukidnon	205,124
Adtuyon clay, stony phase	
Bukidnon	3,642
Lanao	87,160
Misamis Occidental	25,019
Zamboanga del Norte	312
Adtuyon-La Castellana Complex	
Lanao	13,368

Fig. B.1 Adtuyon series taken in Iligan City

The Alaminos soil series (Plate 2A, Fig. B.2)	
Major land uses:	Upland rice, lowland rice, coconut, root crops, sugarcane, corn, vegetables, perennial trees,
Total area:	428,090 ha
Distribution based on reconnaissance soil maps (ha):	
Alaminos undifferentiated	
Pangasinan	52,910
Alaminos sandy loam	

(continued)

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(continued)

The Alaminos soil series (Plate 2A, Fig. B.2)	
Pangasinan	16,482
Zambales	397
Alaminos loam	
Cagayan	18,972
Kalinga-Apayao	6,840
Pangasinan	63,400
Alaminos loam, degraded phase	
Pangasinan	6,680
Alaminos clay loam	
Cagayan	51,114
Isabela	6,911
Kalinga-Apayao	56,722
Mindoro	2,850
Nueva Vizcaya	7,625
Alaminos silty clay loam	
Mindoro	21,097
Alaminos clay	
Camarines Norte	58,668
Quezon	38,108
Zambales	19,314
Alaminos-Antipolo Complex	
Zamboanga del Sur	159,000

The Alimodian soil series (Plate 3A, Fig. B.2)	
Major land uses:	Upland rice, corn, coconut, root crops, perennial trees, sugarcane
Total area:	786,629 ha
Distribution based on reconnaissance soil maps (ha):	
Alimodian undifferentiated	
Iloilo	45,367
Alimodian sandy loam	
Bontoc	438
Kalinga-Apayao	34,200
Quezon	51,727
Alimodian silt loam	
Iloilo	5,464
Mindoro	3,246
Alimodian loam	
Agusan	14,271
Alimodian sandy clay loam	
Abra	3,100
Catanduanes	15,644

(continued)

(continued)

The Alimodian soil series (Plate 3A, Fig. B.2)	
Alimodian clay loam	
Abra	675
Camarines Norte	2,319
Camarines Sur	77,545
Capiz-Aklan	145,585
Iloilo	183,304
Kalinga-Apayao	32,198
Misamis Oriental	9,730
Zamboanga del Sur	26,438
Alimodian sandy clay	
Antique	105,992
Bontoc	1,875
Kalinga-Apayo	8,685
Alimodian clay	
Abra	3,100
Bukidnon	15,726
Alimodian-Barotac Complex	
Capiz-Aklan	13,391
Iloilo	8,593
Alimodian-Bolinao Complex	
Antique	3,379
Alimodian-Castilla Complex	
Zamboanga del Sur	7,812

Fig. B.2 Soil profile of Alimodian series

The Angeles soil series	
Major land uses:	Vegetables, lowland rice, corn, sugarcane, root crops, upland rice, perennial trees
Total area:	111,142
Distribution based on reconnaissance soil maps (ha):	
Angeles coarse sand	
Pampanga	8,161
Tarlac	5,377
Angeles sand	
Pampanga	11,609
Tarlac	2,495
Zambales	23,333
Angeles fine sand	
Pampanga	32,279
Tarlac	4,685
Zambales	13,893
Angeles sandy loam	
Tarlac	6,699
Zambales	2,611

The Annam soil series (Plate 2A, Fig. B.3)	
Major land uses:	Upland rice, lowland rice, corn, coconut, plantation crops, root crops, vegetables, perennial trees,
Total area:	666,655
Distribution based on reconnaissance soil maps (ha):	
Annam silt loam	
Quezon	11,946
Annam loam, gravelly phase	
Nueva Ecija	95,572
Annam sandy clay loam	
Kalinga-Apayao	3,128
Nueva Ecija	8,327
Annam clay loam	
Albay	40,846
Benguet	7,159
Bontoc	1,062
Camarines Sur	30,646
Ifugao	521
Ilocos Norte	5,388
Kalinga-Apayao	23,872
La Union	7,520
Nueva Ecija	157,228
Nueva Vizcaya	100,434
Pangasinan	52,052
Quezon	67,496
Sorsogon	15,710
Annam clay	
Bohol	37,140
Kalinga-Apayao	608

The Antipolo soil series	
Major land uses:	Upland rice, lowland rice, coconut, plantation crops, corn, vegetables
The Antipolo Soil Series	
Total area:	525,951 ha
Distribution based on reconnaissance soil maps (ha):	
Antipolo, undifferentiated	
Bataan	37,372
Laguna	14,792
Rizal	63,925
Zamboanga del Sur	8,750
Antipolo clay loam	
Laguna	198
Rizal	8,680
Zamboanga del Sur	65,375
Antipolo sandy clay	
Quezon	85,534
Antipolo clay	
Bataan	72,630
Laguna	10,622
Lanao	48,823
Rizal	51,540
Zambales	57,721
Antipolo-Alimodian-Luisiana Complex	
Camarines Sur	96,726
Antipolo-Bolaoen Complex	
Zamboanga del Sur	54,062

The Bantay soil series (Plate 2A, Fig. B.3)	
Major land uses:	Upland rice, corn, sugarcane, vegetables, root crops, fishpond
Total area:	198,780 ha
Distribution based on reconnaissance soil maps (ha):	
Bantay sandy loam	
Abra	1,670
Bantay loam	
Ilocos Norte	2,434
Iocos Sur	15,529
Bantay clay loam	
Cagayan	45,655
Ilocos Norte	40,470
Kalinga-Apayao	1,125
Negros Occidental	55,826
Quezon	14,216
Bantay silty clay loam	
Bontoc	19,375
Bantay clay	
Sulu	2,480
Bantay-Bauang Complex	
Nueva Vizcaya	3,382

Fig. B.3 Landscape view of Bauang series taken in Candon, Ilocos Sur

The Bauang soil series (Plate 3B, Fig. B.3)	
Major land uses:	Upland rice, lowland rice, vegetables, perennial trees, root crops
Total area:	224,016 ha
Distribution based on reconnaissance soil maps (ha):	
Bauang clay loam	
Abra	13,557
Ilocos Sur	57,439
Kalinga-Apayao	38,182
Quezon	32,494
Zamboanga del Sur	3,375
Bauang silty clay loam	
Abra	993
Bauang clay	
Abra	15,146
Capiz-Aklan	7,874
La Union	54,956

The Bolaoen soil series	
Major land uses:	Upland rice, lowland rice, sugarcane, vegetables, root crops, corn, coconut, plantation crops, perennial trees
Total area:	146,461 ha
Distribution based on reconnaissance soil maps (ha):	
Bolaoen sandy clay loam	
Zambales	12,038
Bolaoen clay loam	
Mindoro	8,985
Zamboanga del Sur	125,438

The Bolinao soil series (Plate 2B, Fig. B.4)	
Major land uses:	Upland rice, lowland rice, coconut, root crops, plantation crops, corn, vegetables
Total area:	843,352 ha
Distribution based on reconnaissance soil maps (ha):	
Bolinao silt loam	
Agusan	19,989
Bolinao loam	
Ilocos Norte	2,859
Sulu	15,920
Bolinao clay loam, deep phase	
Batanes	4,952
Cagayan	9,349
Ilocos Norte	14,315
Kalinga-Apayao	1,170
Lanao	3,369
Mindoro	10,410
Nueva Vizcaya	729
Pangasinan	25,144
Quezon	37,869
Sulu	43,380
Surigao	109,500
Zamboanga del Sur	22,250
Bolinao silty clay loam	
Mindoro	9,143
Bolinao clay	
Abra	2,663
Batanes	613
Bohol	55,871
Bukidnon	10,296
Cebu	58,575
Davao	106,721
Ilocos Norte	671
La Union	1,761
Leyte	2,236
Marinduque	694
Masbate	6,636
Mindoro	13,824
Misamis Oriental	23,953
Negros Occidental	8,496
Negros Oriental	18,740
Palawan	10,000
Samar	73,052

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The Bolinao soil series (Plate 2B, Fig. B.4)	
Sorsogon	3,450
Surigao	42,575
Bolinao clay, steep phase	
Cebu	23,500
Negros Oriental	4,490
Surigao	19,625
Zamboanga del Norte	13,250
Zamboanga del Sur	11,312
Bolinao-Pasonanca-Dahinub Complex	
Zamboanga del Norte	39,251

Fig. B.4 The soil profile of Bolinao series taken in Mindoro Oriental

The Camansa soil series	
Major land uses:	Corn, coconut, upland rice, plantation crops, root crops
Total area:	806,192 ha
Distribution based on reconnaissance soil maps (ha):	
Camansa sandy loam	
Agusan	38,926
Camansa loam	
Lanao	17,254
Camansa sandy loam	
Agusan	18,114

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The Camansa soil series	
Davao	535,132
Camansa clay loam	
Agusan	160,829
Surigao	33,312
Zamboanga del Sur	2,625

Fig. B.5 The soil profile of Camansa series taken in Butuan City, Agusan del Norte

The Catbalogan soil series	
Major land uses:	Upland rice, lowland rice, corn, sugarcane, coconut, plantation crops, root crops
Total area:	434,013 ha
Distribution based on reconnaissance soil maps (ha):	
Catbalogan clay loam	
Samar	434,013
Catbalogan-Tingib Complex	
Samar	4,834

Fig. B.6 The shallow phase of Catbalogan series showing the underlying shale material that is diagnostic for this soil series

The Coron soil series (Plate 3D, Fig. B.6)	
Major land uses:	Upland rice, root crops, perennial trees
Total area:	194,811
Distribution based on reconnaissance soil maps (ha):	
Coron silt loam	
Sulu	12,311
Coron clay loam	
Palawan	182,500

The Faraon soil series (Plate 2C, Fig. B.7)	
Major land uses:	Corn, sugarcane, coconut, plantation crops, vegetables, root crops2C
Total area:	1,012,836
Distribution based on reconnaissance soil maps (ha):	
Faraon sandy loam	
Negros Occidental	468
Zamboanga del Norte	9,375
Faraon clay loam	
Ilocos Norte	5,441
Zamboanga del Sur	22,000
Faraon sandy clay	
Palawan	27,000
Faraon clay	
Albay	1,548
Batanes	1,555

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The Faraon soil series (Plate 2C, Fig. B.7)	
Bohol	56,536
Bukidnon	1,952
Cagayan	1,024
Camarines Sur	48,139
Capiz-Aklan	10,900
Cebu	40,435
Cotabato	124,375
Davao	3,492
Iloilo	11,721
Lanao	1,793
Marinduque	3,783
Masbate	8,800
Misamis Oriental	5,265
Negros Occidental	9,846
Negros Oriental	22,880
Nueva Vizcaya	66
Quezon	204,160
Samar	79,095
Zamboanga del Sur	2,375
Faraon clay, steep phase	
Cebu	87,516
Leyte	42,490
Negros Occidental	115,026
Negros Oriental	63,730
Faraon-Bolinao Complex	
Leyte	559
Faraon-Pasonanca Complex	
Zamboanga del Sur	2,375

The Guimbalaon soil series (Plate 2C, Fig. B.8)	
Major land uses:	Upland rice, lowland rice, corn, coconut, plantation crops, root crops
Total area:	311,481 ha
Distribution based on reconnaissance soil maps (ha):	
Guimbalaon sandy loam	
Negros Occidental	7,908
Guimbalaon loam	
Negros Occidental	22,401
Guimbalaon loam, gravelly phase	
Negros Occidental	7,908
Negros Oriental	3,180
Guimbalaon clay loam	
Isabela	8,052
Misamis Occidental	25,519
Guimbalaon clay loam, stony phase	
Misamis Occidental 540	
Nueva Vizcaya	49,908
Guimbalaon clay loam, gravelly phase	
Ifugao	189
Nueva Vizcaya	18,367
Guimbalaon clay loam, eroded phase	
Nueva Vizcaya	19,251
Guimbalaon sandy clay loam	
Quezon	9,676
Guimbalaon clay	
Leyte	53,113
Negros Occidental	71,366
Palawan	4,800
Sulu	8,020
Guimbalaon-Annam Complex	
Benguet	2,616
Nueva Vizcaya	19,937

Fig. B.7 Soil profile of Faraon series taken from Manukan, Zamboanga del Norte. Faraon is classified as black limestone soils

Fig. B.8 Soil profile of Guimbalaon series taken at Iligan City, Lanao del Norte

The Ilagan soil series (Plate 3D, Fig. B.8)	
Major land uses:	Upland rice, root crops, corn, vegetables
Total area:	160,284 ha
Distribution based on reconnaissance soil maps (ha):	
Ilagan sandy loam, eroded phase	
Cagayan	41,287
Ilagan loam	
Isabela	118,997

The Kidapawan soil series (Plate 3E, Fig. B.9)	
Major land uses:	Upland rice, corn, coconut, root crops, vegetables, perennial trees
Total area:	260,581
Distribution based on reconnaissance soil maps (ha):	
Kidapawan loam	
Agusan	59,099
Kidapawan sandy clay loam	
Cotabato	48,125
Kidapawan clay loam	
Bukidnon	139,189
Cotabato	8,125
Davao	5,346
Lanao	697

The Lugo soil series	
Major land uses:	Upland rice, lowland rice, corn, sugarcane, coconut, root crops, perennial trees
Total area:	171,649
Distribution based on reconnaissance soil maps (ha):	
Lugo clay loam	
Samar	12,891
Lugo clay	
Bohol	11,713
Cebu	98,321
Leyte	39,615
Mindoro	1,029
Negros Oriental	8,080

Fig. B.9 A more reddish soil profile of Kidapawan series in Barangay Upper Dulag, Iligan City compared to Plate 3E

Fig. B.10 Soil profile of Lugo series

The Luisiana soil series (Plate 3E, Fig. B.10)	
Major land uses:	Upland rice, lowland rice, corn, vegetables, root crops, sugarcane, coconut, perennial trees
Total area:	514,737 ha
Distribution based on reconnaissance soil maps (ha):	
Luisiana loam	
Iloilo	4,602
Luisiana sandy clay loam	
Quezon	40,020
Luisiana clay loam	
Camarines Sur	42,559
Capiz-Aklan	18,717
Catanduanes	55,552
Ilocos Norte	6,270
Laguna	27,152
Mindoro	24,422
Nueva Vizcaya	8,841
Zamboanga del Sur	4,250
Luisiana clay	
Albay	3,700
Batanes	975
Camarines Norte	94,020
Leyte	27,235
Mindoro	21,057
Negros Occidental	23,564
Samar	67,143
Sorsogon	1,210
Sulu	26,420
Zamboanga del Norte	18,938
Luisiana-Annam Complex	
Nueva Vizcaya	1,127
Luisiana-Jasaan Complex	
Zamboanga del Norte	4,376
Zamboanga del Sur	59,212

Name of soil series:	Malalag series (Plate 2D)
Major land uses:	Upland rice, corn, plantation crops, perennial trees
Total area:	414,720 ha
Distribution based on reconnaissance soil maps (ha):	
Malalag silt loam	
Agusan	38,350
Malalag loam	
Cotabato	40,625
Davao	302,370
Suriago	20,125
Malalag clay	
Palawan	6,750
Malalag-Faraon Complex	
Romblon	8,844

The Sevilla soil series	
Major land uses:	Upland rice, corn, coconut, root crops, sugarcane, vegetables, perennial trees
Total area:	193,842 ha
Distribution based on reconnaissance soil maps (ha):	
Sevilla sandy clay loam	
Abra	5,605
Sevilla clay loam	
Nueva Vizcaya	6,034
Quezon	3,345
Sevilla clay loam, stony phase	
Sulu	2,040
Sevilla clay	
Abra	3,538
Albay	66,108
Bohol	25,906
Masbate	57,416
Sorsogon	23,850

The Sibul soil series (Plate 2F)	
Major land uses:	Upland rice, corn, sugarcane, lowland rice, plantation crops, perennial trees
Total area:	195,260
Distribution based on reconnaissance soil maps (ha):	
Sibul undifferentiated	
Bulacan	40,680
Sibul loam	
Batangas	9,370
Sibul clay loam	
Batangas	15,030
Sulu	270

The Tupi soil series (Plate 2F)	
Major land uses:	Upland rice, corn, coconut, vegetables, plantation crops, perennial trees
Total area:	144,402
Distribution based on reconnaissance soil maps (ha):	
Tupi sandy loam	
Cotabato	62,500
Negros Occidental	7,564
Negros Oriental	4,300
Tupi silt loam	
Negros Occidental	30,417
Negros Oriental	26,340
Tupi loam	
Romblon	13,281

The Ubay soil series	
Major land uses:	Upland rice, coconut, root crops, sugarcane, vegetables, plantation crops, perennial trees
Total area:	338,441
Distribution based on reconnaissance soil maps (ha):	
Ubay sandy loam	
Bohol	36,142
Masbate	29,532
Ubay clay loam	
Bohol	26,272
Samar	1,074
Sorsogon	10,120
Ubay clay	
Bohol	79,644
Masbate	86,273
Ubay clay, steep phase	
Masbate	69,384

The Umingan soil series (Plate 1G, Fig. B.11)	
Major land uses:	Corn, vegetables, lowland rice, coconut, sugarcane, perennial trees
Total area:	207,161
Distribution based on reconnaissance soil maps (ha):	
Umingan sand	
Nueva Ecija	5,395
Pangasinan	4,842
Umingan sandy loam	
Albay	1,500
Antique	10,861
Benguet	571
Capiz-Aklan	1,965
Ilocos Norte	224
Iloilo	19,317
Kalinga-Apayao	3,938
Leyte	479
Nueva Ecija	10,834
Pangasinan	10,558
Quezon	2,987
Umingan silt loam	
Marinduque	119
Nueva Ecija	17,511

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The Umingan soil series (Plate 1G, Fig. B.11)	
Pangasinan	16,186
Umingan loam	
Batanes	444
Ilocos Norte	5,091
Ilocos Sur	1,432
Kalinga-Apayao	2,745
Mindoro	7,481
Misamis Oriental	5,577
Nueva Vizcaya	2,166
Quezon	12,663
Samar	2,686
Umingan loam, deep phase	
Nueva Ecija	8,590
Umingan sandy clay loam	
Cagayan	955
Zamboanga del Sur	5,438
Umingan clay loam	
Agusan	2,197
Antique	7,018
Ilocos Norte	2,933
La Union	6,157
Leyte	20,766
Misamis Oriental	2,502
Negros Occidental	1,323
Umingan silty clay loam	
Ilocos Norte	1,711

Fig. B.11 Soil profile of Umingan series taken in Zamboanga Sibugay province. A distinguishing characteristic of this soil profile is a distinct layer of river-washed stones and gravels in the lower subsoil, below which is a stone-free layer

Glossary

Acid sulfate soils Soils under waterlogged conditions mostly those in the mangrove areas containing iron sulfide minerals, dominantly pyrite, generally stable or benign in undisturbed state but when the soils are drained for economic use, the sulfides react with oxygen to form sulfuric acid resulting in several adverse environmental impacts.

Acidic soils Refer to low fertility acid soils, classified in *Soil Taxonomy* as Ultisols and Oxisols, kaolinitic mineral clays most dominant in the exchange complex.

Aeolian soils Soils that developed from wind erosion such as the sand dunes of Ilocos Region.

Agglomerates Soil parent material formed by accumulation of large blocks of rock fragments associated with lava flow ejected during explosive volcanic eruptions. In contrast to conglomerates which are sedimentary, agglomerates are pyroclastic igneous rocks of angular or rounded lava fragments of varying shapes and sizes.

Alluvial plain, broad alluvial plain A flat landform created over long period of time by the deposition of sediments coming from the highland regions from which the alluvial soils formed.

Alluvial soils Soils formed from the deposition by water such as rivers which carry large quantities of soil materials.

Alluvial fan This is a fan-shaped landform, evolved through deposition of sediments consisting of gravels, sand, and other smaller materials by streams and coming from a single source, at the upper portion of the fan, spreading out into the flat land.

Anthropogenic soils These are soils disturbed from their natural setting because of long-term human activities.

Aquic soil moisture regime Soils are under water most of the time and chemically under reduced condition.

Argillic horizon A diagnostic horizon criterion used for soil classification characterized by illuvial accumulation of silicate clays by at least 20 % over the eluvial horizon.

Associations Consist of two or more named dissimilar taxa or miscellaneous areas occurring in a known and definable pattern and can be mapped at scale of about 1:24,000.

Azonal soils Soils that are not fully developed and lacking in well-developed horizons, evolved from factors other than local climate and vegetation and considered to be of more recent origin. *Zonal* soils are mature soils and have distinct profiles developed by the influence of local climate and vegetation while *intrazonal* soils have well-developed profiles due to parent materials, relief, and other factors of soil formation.

Barangay The smallest administrative and political unit in the Philippines; the local term for village or neighborhood. The term originated from *balangay* a kind of boat used by Austronesian people when they migrated to the Philippines.

Base map The map with the essentials or basic elements (usually boundaries, river systems, road network, institutional edifices) onto which additional geographic features (such as the soil mapping unit delineations) are added.

Base saturation The proportion of the cation exchange sites in the soil that are actually filled with cations such as hydrogen, calcium, magnesium, and potassium; normally presented as percent (saturation of the cation exchange capacity).

R. B. Carating et al., *The Soils of the Philippines*, World Soils Book Series,
DOI: 10.1007/978-94-017-8682-9,

Basin Refers to a drainage basin, the area drained by a river system and its tributaries. It would necessarily have a source, a mouth (the end of the river), tributaries, watershed (the topographic divide or boundary), estuary. The river would have a channel, bank, and bed.

Bouyoucos method Also known as the *Hydrometer* method of soil texture determination; the percentage sand, silt, and clay composition of a clay sample is ascertained by the principle that sand will settle down in about 40 s, silt for the next two hours leaving behind clay as the only particle to contribute to the density of the suspension and measured by a hydrometer calibrated to read in grams of solids per liter. The method is based on Stoke's law governing the rate of sedimentation of particles suspended in water.

Buried soil Defined in *Soil Taxonomy* as surface mantel of new soil material at 50 cm or more.

Caldera Refers to a large volcanic crater formed by a major eruption that culminated with the collapse of the volcanic cone.

Carbon sequestration The process of capturing atmospheric carbon dioxide and storing it for long-term as in forest and in peat lands.

Catena The sequence of soils from the hilltop (summit) to backslope to footslope to toe slope, and finally to the valley floor. Soils at top, middle, and lowest catenal drainage refers to the top, middle, and lowest river or lake terrace physiographic position.

Cation exchange capacity (CEC) The maximum capacity of total cations available for exchange that the soil is capable of storing at a given pH value; normally expressed as milliequivalent of hydrogen per 100 g of dry soil or as centi-mol per kilogram soil.

Compaction Soil hardness, soil density is increased due to tillage practices.

Complex (soil complex in the soil map) Consists of two or more named dissimilar taxa or miscellaneous areas that occur in defineable pattern and cannot be mapped separately at 1:24,000.

Collo-alluvial deposits Soil parent material originating from sediment transport from the upper portions of the landscape and brought down by both water and gravity.

Colluvial soils Soils formed from the deposition of soil and weathered materials coming naturally down from upper regions by gravity.

Columnar structure The peds are longer than they are wide; the soil aggregation is bounded by flat or slightly rounded vertical faces, quite common for soils of high sodium content and those heavy cracking soils rich in smectites and halloysites.

Concretions Also referred to as concentrations in soil survey manuals, these are small, hard local concentrations of materials such as calcite, gypsum, iron oxide, or aluminum oxide which vary in shape from spherical to irregular. There are also biological concentrations which are accumulated by biological processes such as insect casts and fecal pellets that can be found in the soil.

Conglomerates In rocks, consist of individual clasts within a finer grained matrix that were cemented; sedimentary if the clasts are rounded and breccias if the clasts are angular. In soils of colluvial, alluvial, or collo-alluvial origin, used to describe parent material of heterogeneous sources, kinds, and sizes that it is no longer pragmatic to identify each.

Consistency (Please see soil consistency)

Consociations (soil consociations in the soil map) The soil mapping unit is 50 % pure and of the remaining 50 % impurities, half are similar soils and the other half are dissimilar soils

Control section A downward dimension of 1.5 m, which for purpose of scientific investigation is the lower limit in describing the soil profile.

Crest Summit or highest point; top of the hill or mountain; angular crest or rounded crest reflects the geology of the area and its influence on the soil that eventually developed.

Dentritic pattern Used to describe the tree-shaped river and its tributaries and sub-tributaries.

Diagnostic In soil classification, this refers to a set of criteria required for a particular described soils to fit into the taxon.

Digital cartography Also called digital mapping, is the application of computer science and geographic information science to produce visual communication of spatial concepts, data, and models and thereby create and analyze maps using computers.

Dissected landscape The network of dissecting lines brought about by the development of distinct ridges and valleys resulting from sediment transport processes in sloping areas.

Dokuchaev-Jenny-Gerasinov triad Refers to the most common approach to describing soil evolution as arising from the interplay of the factors of soil formation, the visible product of soil-forming processes, and the distinguishable features that eventually developed such that through soil survey and classification, the soil map output represents the spatial quantification of the philosophical framework.

Eluviation The removal of soil materials from the surface soil horizon and their partial deposition in a lower horizon; used to describe the translocation process in the soil horizon where the material was removed.

Estuary Partly enclosed coastal body of brackish water forming a transition between the saline sea water and the river water and sediments.

External soil drainage The ease with which water can run off the surface of the land; the natural removal of excess water from the surface of the land (natural surface drainage); refers to the water movement in relation to the position of the soil with respect to the landscape.

Factors of soil formation Initially espoused in 1941 by Han Jenny (1899–1992), the process of soil formation is influenced by several factors, the most important of which are parent material, climate, living organisms (especially native vegetation), topography, and time.

Feel method (of soil texture determination) The soil is moistened and rubbed between the fingers and the thumb, and an estimate of the amount of the various particle sizes is made. Surveyors can master the feel of various soil textures from laboratory soil samples with pre-determined texture and be equipped with sufficient experiences by the time they go on field work.

Flood plain An area adjacent to a stream or river from the bank of its channel extending to the base of the enclosing valley walls that usually experiences flooding during periods of high discharge; the flood plain is generally a part of the alluvial plain encompassing the low-gradient delta.

Fluvial Processes associated with rivers and streams and the deposits and landforms created by these processes as in *fluvial* erosion.

Food security Defined by World Food Summit of 1996 as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life". It is a complex sustainable development issue, linked to health, sustainable economic development, environment, and trade.

Food self-sufficiency Being able to meet food consumption needs particularly those relating to staple food crops, from own production rather than by buying or importing.

Food sovereignty The right of the people to healthy and culturally appropriate food produced through ecologically sound and sustainable methods; and the right to define their own food and agriculture systems; putting the aspirations and the needs of those who produce, distribute, and consume food at the heart of the food systems and policies rather than the demands of markets and corporations.

Genetic key Also referred to as the soil concept, describes the central or essential characteristics that distinguish one soil taxon from another.

Gley The soil is waterlogged or water saturated for a long period of time and exhibits properties characteristic of a reduced or anaerobic condition.

Gravels (Pebbles) Rock fragments in soils usually 2–75 mm in diameter, *cobbles* are 75, 25 mm diameter, *stones* are 250–600 mm diameter, and >600 mm diameter are considered *boulders*.

Heavy cracking Soils that shrink during dry conditions and swell during the rainy season, usually characterized by dominance of smectites or family of expansible 2:1 phyllosicate minerals.

Highland (hilly and mountain) soils Those found in areas with altitude above 300 m above sea level, slope of 18 % and above, developed from various rocks mostly shale and sandstone, basalt and andesite, and limestone; major land uses are forest, grasses, and shrubs.

Horizon The horizontal layer that constitutes a soil profile; the top soil is usually referred to as the A-horizon, the subsoil is the B-horizon, and the substratum is the C horizon. (See also *master horizon*).

Humic materials, humic substances Major components of organic matter in soils, making up much of the characteristic brown color of decaying organic debris, and contributing to the brown or black color of the surface soil.

Hydropedology Emerging sub-discipline of soil science intertwined with hydrology with focus on the interphase between the hydrosphere and the pedosphere.

Illuviation The translocation of silicate clays from an upper layer and deposition by percolating water of clay or humus to the lower horizon; used to describe the translocation process in the soil horizon where the material was deposited.

Internal soil drainage The downward movement of water through the soil profile, the net permeability of all soil layers in a profile.

Jarosites The sulfate mineral associated with acid sulphate soil environment.

Karst A distinctive landscape formed from the dissolution of calcareous or carbonated rocks such as limestone, dolomite, and gypsum by the dissolving action of water over thousands of years and characterized by sinkholes, caves, disappearing streams and complex of underground drainage systems.

Krotovinas Invertebrate animal passageways in the soil. In pedology, this is a type of terrestrial bioturbation by burrowing animals and contributes to the physical re-arrangement of the soil profile by soil organisms.

Land limitation (also limiting factors) Term traditionally used to refer to constraints in agricultural use such as topographic limitation (high slope) as well as clayey and stony topsoil which limit the use of cultivation implements; land capability classes are based on the presence and severity of limiting factors.

Leaching The downward loss of water-soluble plant nutrients from the soil due to rain and irrigation and a contributing factor to groundwater contamination.

Lacustrine deposits Soil parent materials that originated from deposition and settlement of particles in the lake; soil parent materials of lake origin.

Limnic materials Basically organic and mineral materials deposited in water by precipitation or through action of aquatic organisms like diatoms and algae. Usually classified as coprogenous earth, diatomaceous earth, marl, and gyttja.

Lithologic discontinuity This is a geological term but when applied to soils, refers to the presence of a second parent material in the soil horizon.

Lowland soils These developed from alluvial, collo-alluvial, marine, and lacustrine deposits with slopes ranging from 0 to 8 %, temperature of more than 25 °C and altitude of less than 100 m above sea level.

Map scale The ratio of a distance on the map to the corresponding distance on the ground.

Master horizons The collective term for the five most common soil horizons, which are: O (surface horizon consisting of organic materials at various stage of decomposition), A (the surface horizon), E (the subsurface horizon that has been heavily leached), B (the subsurface horizon where the leached minerals in the E horizon accumulated), and C (the least weathered subsurface horizon).

Massive soil structure A grade of soil aggregation where the entire soil horizon appears cemented in one great mass (coherent) in contrast to *single grain structure* where the individual soil particles show no tendency to cling together (non-coherent); both massive and single-grain are considered as structureless soils or absence of observable aggregation or natural lines of weakness.

Mixed mineralogy At the family level of soil classification refers to the composition of the soil's clay mineralogy, a mixed clay mineralogy denotes non-dominance of a particular clay mineral; under an X-ray diffractometer examination, the mixed layer clays are identified by the presence of non-rational series of reflections.

Mottles, mottlings Spots of different color than that of the soil matrix, usually associated with fluctuating water table.

Munsell Color Chart Developed by Prof. Albert H. Munsell and adopted by the USDA as the official color system for describing soil color in the field, this is a colorimetry that specifies colors based on hue, value (lightness), and chroma (purity). The soil color is compared to the book of color chips and the numerical value is noted as hue value/chroma (e.g., 10 YR 4/2). The soil moisture state is always stated when soil color is described.

Narrow alluvial valleys Usual characteristic of highland valleys dominated by meandering streams.

Neocolonialism The geopolitical practice of using capitalism, business globalization, and cultural imperialism to control a country, in lieu of direct military control or indirect political control. Originally coined by Ghanaian president Kwame Nkrumah to describe the promotion of the culture of the neo-colonist country in order to facilitate the cultural assimilation of the colonized people and thus opens the national economy to the multinational corporations of the neo-colonial country.

Nodules Cemented bodies of various shapes commonly spherical or tubular, that can be removed as discrete units from the soil. In contrast, concretions are similar to nodules except for the presence of visible concentric layers of material around a point, line or plane in the concretions. Nodules and concretions are inter-changeable (e.g. carbonates, gibbsite, silica, titanium oxide).

Organic matter Soil compounds derived from the remains of once-living organisms such as plants and animals and their waste products. Organic matter that has broken down into a stable substance and resists further decomposition is called *humus*.

Ortho-image map An aerial photograph or a high-resolution satellite image that has been geometrically corrected (orthorectified) such that the scale is uniform and can be used to measure true distances.

Paleopedology The discipline that studies the soils of past geological eras, from recent to the earliest period of the earth's geological history.

Parent material The rock material or the alluvial deposit where the soil originated.

Peats, peatlands, peat soils Classified in *Soil Taxonomy* as Histosols, these are organic soils or soils developed from the decay of vegetation under wetland conditions; and the prolonged absence of oxygen slows down decomposition.

Ped The soil particle; the smallest structural unit of soil, usually a block or granule formed by natural processes and detached from the rest of the soil by natural lines of weakness.

Ped coatings Refers to layer of a variety of substances that covers soil particles such as "clay skins" or clay films also called argillans, carbonate coats, ferriargillans (a redoximorphic feature), mangans (also a redoximorphic feature), gibbsite coats, and silica (silans or opals).

Pedology A branch of soil science that deals with the study of soils in their natural environment; the focus is on genesis, morphology, and classification of soils.

Pedon The smallest three dimensional unit or volume of a soil containing all the layers or horizons. This is actually more of an abstraction because in practice, we describe and sample a one-dimensional soil profile and assume this to be a pedon. The pedon is the soil body with profile features whose arrangements and combinations over a geographic area are unique.

Pedo-ecological zone These are natural units developed by the Bureau of Soils and Water Management adopted for national planning and represent broad ecological resource management units derived from an association of soils and their environments, particularly such factors as landscape, elevation, slope, and temperature. Four pedo-ecological zones were identified for the whole Philippines: *Warm Lowlands*, *Warm-Cool Uplands*, *Warm-Cool Hilly lands*, and the *Cool Highlands*.

Pedometrics The application of the methods of mathematics and statistics in the study of the genesis of soils.

Pedoturbation The mixing of the soil, consists of the destruction of the features of illuviation; could be either mechanical or biological in nature.

Penetrometer The instrument used to measure soil hardness.

Peraquic soil moisture regime Soils under fluctuating water table but the ground water is always at or very close to the surface.

Phlinthite Weakly cemented, iron-rich, humus-poor reddish materials that form platy, polygonal, or reticulate patterns, and hardens irreversibly when exposed to atmosphere and to repeated wetting and drying.

Piedmont A low plateau, a landform usually located at the foot of a mountain developed from the debris deposited by shifting streams.

Pipette method of soil texture determination This is also based on Stoke's Law. Samples of the soil suspension are extracted at a given depth after a pre-determined settling time for size fraction (sand, silt, and clay), dried, weighed, and calculated for the proportion. Used when more accurate analysis is required and when the soil sample is rather small for the hydrometer method to be used.

Polypedon A contiguous group of similar pedons and the basic unit of soil classification; it is a taxonomic unit and the basis for delineating soils in the field, homogenous, and theoretically represents a single taxon concept. It is abstract because what is delineated is a complex soilscape pattern. Its concrete equivalent is the soil mapping unit.

Primary or residual soils Soils that developed in-place from the underlying rock material below.

Pumice A light volcanic rock of highly vesicular and rough textured volcanic glass, typically light colored, formed when lava cooled quickly above ground; as against *scoria* (also called volcanic cinders or cinder cones) which has larger vesicles, thicker vesicle walls, dark colored, and denser.

Quaternary Geological time period espoused by Abraham Werner who divided the earth's crust into Primary, Secondary, Tertiary, and Quaternary. The quaternary period covers the start of the Pleistocene epoch some 2.6 million years ago until the Holocene epoch around 12,000 years ago.

Reconnaissance soil survey This is an intermediate intensity level (compared to an *exploratory, semi-detailed, and detailed* soil survey) to provide information and interpretation for national and provincial agricultural planning purposes. Boundaries between the soil types and phases are plotted based on field observations at approximately 10 km intervals; the degree of detail is determined by landscape and its probable use. Soil survey maps published by the BSWM from 1934 to 1965 were completed at reconnaissance soil survey level.

Redoximorphic features Soil morphological characteristic such as gleying and mottlings which are associated with chemically reduced or water submerged conditions; could be an indication also of poorly-drained soils. Soils with redoximorphic features are described to have aquic conditions.

Regolith This refers to the substratum of unconsolidated mantle of weathered rock and soil materials that overlay a solid rock; not all soils have a substratum of weathered rock, especially those whose parent materials were transported by water or gravity.

Residual soils Also called primary soils, soils developed in-place; soils developed from the rock below.

Routine (also referred to as prescribed) soil sample analyses This is set of laboratory analyses required depending on the purpose of the study. The soil survey samples for taxonomic classification has its own set of required laboratory analyses which would differ from farm soil samples for soil fertility assessment. Data interpretation even for the same parameter differ since soil survey sample laboratory results are used as diagnostic criteria for soil classification while those for farm samples are generally interpreted in terms of fertilizer requirements.

Sangguniang Bayan The legislature of municipal governments in the Philippines. It passes ordinances and resolutions for the effective administration of the municipality, the powers are defined by the Local Government Code of 1991.

Saprolite Chemically weathered rock; usually found at the lower zones of the soil profile that developed from the underlying parent material, the deeply weathered bedrock surface.

Semi-detailed soil survey This is higher map scale output compared to reconnaissance type of survey. More detailed soil types and phases are plotted on the base map with additional focus on soil variations of significance to land use such as relief, stoniness, etc. to indicate mappable differences of significance to rural development planners. Usually the observation distance is half a kilometer between sampling sites. Most of the BSWM map outputs in the latter part of 1960s to the present are semi-detailed.

Sinkholes (also solutional depressions) A natural hollow place or depression in a land surface with subterranean passage (cave) that occurs in limestone areas and formed by the action of water or by collapse of the cave roof.

Slickensides subsoil structural features resulting from the moving past each other of two masses at angles of 20–60°, polishing and smoothing the surface due to the swelling of clay minerals and shear failure.

Secondary or transported soils In the Philippines, the most common agent of transportation is water; the soil parent material originated from the upper areas, washed down to the streams and river systems, and accumulated in lower areas.

Sedimentary rocks Type of rock formed by the deposition of materials from a weathering and erosion source and hardens at the point of deposition due to pressure or cementation.

Skeletal soils These are shallow soils and lack horizon development. These are *Orthents* in the USDA *Soil Taxonomy* and *Lithosols* in the FAO Soil Classification.

Soil The thin layer of the earth's surface where plants anchor their roots. It is a living and dynamic system which forms at the interface between the atmosphere and the lithosphere in response to forces exerted by climate and organisms, acting through time, on a parent material in a specific landscape position.

Soil classification Deals with the systematic organization of our knowledge about the soils to remember their properties and to understand their relationships by grouping into hierarchical classes soils based on their common properties. Although the soil is a continuum, in soil classification, the soils are treated as discrete units and treated as a population.

Soil color Is described by quantitatively matching the color of a soil clod with a standard chip in the Munsell Color Chart. Each color is described in terms of hue, value, chroma.

Soil concept Also referred to as the genetic key, describes the central or essential characteristics that distinguish one soil taxon from another.

Soil consistency The strength to which soil materials are held together; the degree of cohesion and resistance of the soil to deformation.

Soil conservation survey A type of soil survey with the objective of assessing soil disturbances and soil hazards in a given area when a development project or activity is undertaken.

Soil ecology The study of the complex interactions between and among the soil organisms and the abiotic composition as they relate to nutrient cycling, soil physical and chemical properties, and the soil biodiversity.

Soil fertility mapping This is a generated activity based on the variability and dynamics of various soil properties, sampling design and intensity, interpolation techniques, and mapping protocol designed for the purpose of assessing the state of soil fertility and provide the specific fertility management recommendations to sustain agricultural productivity. Soil fertility as defined by the Soil Science Society of America, 1973 is the status of the soil with respect to the amount and availability of plants to elements necessary for growth. This is usually assessed in terms of the soil's capacity to hold major cations like calcium, magnesium, potassium, and sodium, and for acid soils, hydrogen, aluminum, and manganese.

Soil genesis The study on the origin and formation (evolution) of soils. It is a branch of pedology which is also concerned with morphology, classification, and mapping.

Soil hardness The compaction of soil particles usually related to ease of root growth and soil properties descriptive of tilth.

Soil mapping unit The spatial manifestation of the soil taxonomic unit; a landscape unit defined by a complex pattern of contrasting soils dissected into its component elements.

Soil matrix The part of the soil with the dominant color, usually more than 50 %.

Soil mineralogy The study of primary (chemically unaltered) and secondary (chemically altered) minerals in soils. Since soils are weathered rocks, the sand, silt, and clay fraction usually have undergone physical, chemical, and biological alterations when examined under x-ray diffraction, thermal, elemental, and optical analyses. It involves classification, characterization, and studies on mineral surface properties and weathering pathways for the purpose of assessing the suitability and behavior of the soil for various land uses.

Soil micromorphology A branch of soil morphology that deals with description, interpretation, and measurement of in-situ (unaltered, undisturbed) soil features within various horizons at microscopic level. Soil micromorphology in the field soil survey begins with routine 10x hand lens but more detailed studies are conducted in the laboratory using petrographic polarizing microscope after preparing thin sections (0.03 mm thickness) with rock-cutting saw of diamond cut-off blade and stabilized with resins.

Soil morphology The description of the soil profile in terms of observable attributes like color (at defined soil moisture content), texture, structure, presence of roots, mottling, consistency and friability, and other features that can be observed in the field. A pit is normally dug as standard (although an available roadcut is considered an acceptable alternative) to within control section.

Soil phase This is a unit of soil outside *Soil Taxonomy*, usually a functional unit designed to fit the purpose of the soil survey. Phases of a taxon at any categorical level, from order to series, can be defined to recognize landscape properties (such as slope and erosion) or soil properties (presence of lithic layer, gravelly or stony layer, soil depth), and other relevant diffentiae that makes a particular soil unit different from the typical character of a soil type.

Soil profile The vertical exposure of the horizons of a pedon.

Soil science Defined by the Soil Science Society of America as the science that deals with soils as a natural resource on the surface of the earth including soil formation, classification and mapping, physical, chemical, biological, and fertility properties per se, and these properties in relation to the use and management of soils.

Soil series The lowest category in soil classification, usually named after the place where it was first described.

Soil skeleton Refers to coarse fragments (>2 mm) found in the soil.

Soil structure The aggregation of soil particles into larger units called peds and delineated by natural lines of weakness.

Soil texture The distribution or proportion of particle sizes: sand, silt, and clay.

Soil type Refers to the specific soil texture classification of a soil series: loam, clay loam, sandy clay loam, sandy loam, loamy sand, sand, silty clay loam, silt loam, silt, silty clay, clay.

Soil survey and classification The branch of soil science that deals with the classification and mapping of soils. Traditional or classical soil survey is focused on quantifying soil evolution spatially based on the Dokuchaev-Jenny-Gerasinov triad: factors → processes → features. There are emerging new concepts in soil survey and classification.

Soil Taxonomy The system of soil classification developed by USDA; different countries usually develop their own system of classification, there are also various international soil classification systems.

Solum This refers to the top soil and the subsoil or the A and B horizons.

Stratified Used to describe the rock parent material of the soil (as in stratified shale), refers to presence of planes of parting or separation between individual rock layers reflecting formation by successive beds of deposited materials.

Subsoil The layer of the soil below the topsoil, generally lacks the organic matter and humus of the topsoil and expectedly lighter in color.

Substratum This is the general term for the C-horizon; the layer excluding the bedrock that is little affected by soil forming processes.

Taxon The class of soils at any level or category within the classification system considered as one classification unit.

Taxonomic unit Usually defined as the soil map legend and theoretically represents a single taxon concept.

Translocation One of the four soil horizon development processes (the other three being addition, transformation, and removal). This involves the movement of the soil-forming materials basically by the action of water or by burrowing animals like worms and ants.

Tertiary In reference to geological time, espoused by Abraham Werner where the earth's rocks are divided into four types, Primary, Secondary, Teritary, and Quaternary. In modern terminology, Tertiary refers to epochs covering from Paleocene at the start of Paleogene period some 66 million years ago until Pliocene at the end of Neogene period some 3.6 million years ago.

Top soil The surface soil, the upper, outmost layer of the soil about 5–20 cm from the surface.

Tuff Volcanic tuff, tuffaceous materials, sedimentary rock composed of compacted and cemented volcanic ash, pumice, and scoria from volcanic eruptions, usually soft and porous.

Typical pedon The soil profile described for the dominant soils in a given soil mapping unit to represent the taxonomic unit. This is a reference soil profile for a particular soil taxon to illustrate the central taxon concept which is generally a range of properties. No pedon observed and collated in the field is likely to be central for all ranges, but the Typical (also called the *Representative*) Pedon is near the center of the ranges for the morphological, physical, and chemical properties and for geographic distribution.

Udic soil moisture regime The soil is not dry in any part for as long as 90 cumulative days (3 months) in normal years; most common to soils in areas with well distributed rainfall and there is enough rain even in summer.

Upland soils These developed from different parent materials and physiographic position, with slopes ranging from 8 to 18 %, temperature regime of 22.5, 25 °C, elevation of more than 100 m but less than 500 m above sea level.

Ustic soil moisture regime The soil is dry in some or all parts for 90 or more cumulative days in normal years, but moist in some part either for more than 180 cumulative days per year or for 90 or more consecutive days.

Valley A type of landform representing the depression between two hills or mountains, usually dissected by a river or stream.

Vertic property A diagnostic horizon for soil classification, characteristics of soils with swelling and shrinking property.

Watershed A basin-like landform, its boundary usually defined by the topographic divide (ridgelines), where all of the water drains into the lower elevations and stream valleys.

Weathering The decomposition or breaking down of rocks and minerals, both physical and chemical, and when combined with organic material becomes soil.

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