UNIT ONE

1. INTRODUCTION TO NATURAL RESOURCES

1.1. Definition of natural resources

The word resource is a general term, which refers to any element or substance useful for the satisfaction of man's requirement. More systematic definitions are as follows.

- Resource is any substance or property that is of actual or potential value to man.
- Resources are the physical and human potentialities and actual values that constitute the basis of material and spiritual satisfaction of human requirement.
- Another systematic definition is given by Prof. E.W. Zimmerman, stating that resource does not refer to a thing or a substance but to which a thing or a substance may perform or to an operation in which it may take part in the function of or operation of attaining a given end, such as satisfying a want..

All the above definitions are not unlike and have common meanings. They meant that a resources could be anything or property which comprise a substance or property, which is of physical or human component, and have an actual or potential value e.g. it could be presently being used or to be in the future by man. It is useful in satisfying human needs (both material and spiritual requirements) either directly or indirectly, and in one-way or another. A resource, therefore, is something material or abstract that can be used to satisfy human wants and deficiencies i.e. the existence of a resource depends on its utility and functionality. The above conceptual definition gives basically two broad categories and components or resources: Natural or physical resources and human resources.

The major and general distinction or difference between the things in our surroundings is that, some are physical elements or substances found in nature, while others are human creations or man made things. The physical elements or substances found in nature constitute the categories known as Natural resources, while the man made things and the labor as well as the skill vested on their creations constitute the category of resources known as Human resources. A more systematic definition of the two is as follows.

- ✓ Natural resources comprise the physical elements or combinations of elements of nature found in any environment, and useful for the satisfaction of man's requirement. They include energy, water, land, soil, plants, air and so, on. These Natural components of the environment constitute the basis of all life support system.

- ✓ Human resources comprise all the potentialities, creation and cultural values of any society. These resources consist of Man's labor, skills, and abilities (knowledge) and the materials and wealth created by these potentialities and capabilities of the society.

1.1.1. The Scope and subject Matter of Natural Resources

As the course title -The Geography of Natural Resources Managementll implies this course material is confined to the study of the major category of resources known as Natural resources. To deal on the other group, known as human resources is beyond the scope of this course.

However, man / people occupy a pivotal position in all the geographical studies, particularly in Human geography. Similarly, humans and their related attributes have a significant place and are significantly treated in the study of Natural resources. Because: First, Natural resources are in the service of man. It meant that they are exploited and used to meet human needs and wants and as a result, are only considered to be resources. Second, people, their number, capabilities attitudes, culture and their creations play a vital role in altering, producing, managing and developing or destroying and degrading natural resources. Therefore, human's including their potentialities, capabilities, socio-cultural creations and values (Constituting human resources) are treated in this course with respect to the above inter-relations and interactions with natural resources.

Geography is an integrative spatial science which is devoted to the study of physical and human elements, their inter-related aspects and attributes on the earth surface. Thus, two broad categories of elements and their related aspects constitute the subject matter of geographical studies:

- ✓ Physical elements or phenomena
- ✓ and human elements and attributes

Geographical study, thus, concerned with the spatial dimensions of physical phenomena and human or cultural phenomena on the earth surface and with spatial interrelationships and interactions, and the resulting characteristics within and in between these two broad elements. It also gives focus with regards to their formations, distribution, relationships, functions and organization over the geographical space. It pays emphasis to the analysis and explanation of the patterns and characteristics these elements and aspects constitute or going to produce within and/or among themselves spatially as well as temporally in any given environment.

Natural resources are composed of elements and combinations of elements of nature in any given environment. They are principal constitute of the physical phenomena's, of which geography is mainly concerned in its spatial dimension, Human's and their socio-cultural and economic values (the human phenomena) have a determining role in altering the spatial patterns and characteristics produced by natural resources in any environment.

The Geography of Natural resources, therefore:

- ✓ Is a specialized sub-field of physical geography;
- ✓ Deals on natural resources studies, which are the chief constitute of physical, biological and atmospheric components of any environment and are the major concern of geography.
- ✓ Is concerned with the analysis and explanations of the organization, patterns and characteristics of natural resources in any given environment. It also pays attention to the investigation and explanation of their importance and the influences they have with-in ecosystem and an environment, as well as on human socio-cultural and economic life. It also adds to this dimension, the analysis of the reciprocal relationships. This means, it also investigates and describes how humans and their resulting attributes affect and change the existing spatial patterns and characteristics of natural resources in the processes of obtaining and producing their material and spiritual necessities.

1.1.2. Approaches to the study of Natural resources

In its study of Natural resources, geography applies the following methodological approaches.

- ✓ **Regional Approach**: - is concerned with assessment, identification and explanation of the natural resources in any given environment, or a given geographical area or region. E.g. the natural resources of Ethiopia, or Africa. Here, specific given environments, areas or regions are a central focus concerning their natural resources study.
- ✓ **Systematic Approach**: - is concerned with analysis or investigations and explanations of theories, concepts principles and models about natural resources as a whole. This approach is concerned with the ecological and environmental organizations, relationships, functions and interactions with in and between natural resources and with that of humans and their activities. E.g. The Geography of Natural Resources, or ecosystem,
- ✓ **Resource Approach**: - It places emphasis to the study of individual resources or a group of resources as they occur in nature or an environment. Example: Atmospheric Air pollution and ozone layer depletion, or soil resources, Biogeography, etc.

Geography, under the application of the above three approaches, uses the following methods or techniques to study about natural resources.

- Observation, through field trips, tours, voyages, etc.,
- Description of actual (spatial and/or temporal) conditions,
- Investigations / Analysis of theories. Concepts, principles and models
- Statistical investigations and Explanations of graphs, Charts and maps,
- Research Studies and reports.

1.2. Classifications and Types of Natural Resources

1.2.1. Basis for Classifications

Natural resources could be classified in to different categories or groups on the basis of certain concepts that would serve as criteria of classifications. Some of these include:

- ✓ The kind of environments forming or constituting various types of ecosystems;
- ✓ The form of life that the resource consist of or possess;
- ✓ The nature of the regeneration capacity of a natural resource
- ✓ On the pattern of occurrence and distribution:
- ✓ Possession or ownership system of resource
- ✓ Nature of management, control and utilization of resources and their environments

These are some general concepts. Each concept can consist of broad basis or criteria for classification of natural resources into several categories or groups of resources.

1.2.2. Major Categories and types of Natural Resources

A. Resources Based on Environmental System

Natural resources are basic constitute of ecosystems that are confined to varied environments.

- ✓ Ecosystems are basic organizational units that are mainly composed of natural resources found in any environment over virtually all of the earth. Ecosystem refers to the functional interactions and relationships between resources and the environment, as basic organizational unit.
- ✓ Environment is the space on the earth. The space or the environment forms the habitat to which resources are confined and derive their functional interrelationships and interactions.

The earth's environmental system is very broad and diversified. From the point of ***major environmental systems***, ecosystems and their components (Natural resources) are basically organized in to three broad categories:

i. **Terrestrial ecosystems**- over land surface further sub-divided in to two groups.

- **Lithospheric ecosystems** – which include the zone of rocks and minerals.
- **Biospheric ecosystem** - living matter (plants and animals).

ii. **Aquatic ecosystem**- comprises the hydrosphere or the zone of water. It usually refers to ecosystems confined to marine (ocean and sea) environments.

iii. **Atmospheric ecosystem**- comprises the zone of air surrounding the earth's surface. This realm refers to the lower portions of the atmosphere consists of various gaseous substances that affect the vast complexes of life support systems in any environment.

- Within each or separate environmental system there could be a number of ecosystems.
- Each ecosystem forms interdependent and inter-locking organizational units (systems) within and between environments. For example: - with in terrestrial environments several varied ecosystems can exist consisting high mountain lands, dry hot lands, tropical hot-humid areas, wind ward slopes, warm temperate low lands, cold polar areas, etc. that are composed of a number of but more often similar resources, distinctively adapted to the specific organizational unit and environmental system.

❖ On the basis of the form of life. All elements and substances of the natural environment consist of two major form of life system. Living and non- living things similarly natural resources on the basis of the form of life they consist of have been classified into:-

1. **Biological or Biotic resources**- this group consist of living resources mainly comprising plant and animal life (resources).
2. **Abiotic resources**- are non-living resources, that could be further divided into

✓ Geophysical/ chemical resources consisting organic or inorganic substances such as land, minerals water, soil etc.

✓ Atmospheric and gaseous resources consisting air, sun light/ heat, tidal power or energy.

B. Classifications on the basis of the regeneration capacity of Natural resource: -

Regeneration refers to the capacity or the nature of a resource to replace or substitute itself naturally, so as to maintain sustainable life or existence with in the environment, even under the impact (or the interference) of the activities of man. Here are some of the natural processes through which Natural resources regenerate or replace their substitutes, to maintain sustainably rich and diversified ecological systems:

- **Recycling** e.g. energy cycle, air gaseous (carbon, Oxygen, Nitrogen etc) cycles, water (or Hydrological) cycle, etc;

- Photosynthesis & food chain or web; Weathering, Decomposition, and Natural erosion;
- Reproduction (birth); Growth/re-growth, Germination or planting and seedling; Crystallization/Re crystallization, etc

Natural resources in any environment have varied capacity and rate of regeneration. On the basis of the regeneration capacity natural resources are classified in to two broad categories.

1. Renewable Resources
2. Non-renewable resources

1. Renewable resources: - of the two most widely accepted categories, the group known as renewable resources comprises the most significant and widely frequent types of natural resources. Renewable resources are resources that are recurrent, meaning they can replenish themselves in the foreseeable future. They are also known as flow resources. The Renewable resources:

- Are replaceable in character, because they regenerate themselves through reproduction or recycling (energy and material cycles, Nutrient cycles, bio/geo-physical and chemical cycles, photosynthesis, Gaseous cycles, and so on)
- Comprise all living or biotic resources and most of the Non-living or abiotic resources for example: Living /biotic- such as living organisms or animals and plants (vegetation), and Non living / a biotic - like solar energy, land and soil, water, Air etc.
- If carefully and properly used, they may last indefinitely, but misuses or overuses are likely to affect the capacity and rate of regeneration of these resources.

The renewable resources can be further classified based on their exhaustion or vulnerability under inappropriate use by human beings) into:

a. Inexhaustible resources- are all those which remain unaffected by human action. Resources comprising this group are found in abundance and continue to pour on the earth in whatever way they are used by man. These resources sometimes are referred as Non-critical resources.

These resources are beyond the ability of man to change or manage. These include the earth's surface area or land surface area, Oceanic surface area, and solar radiation. They could be further grouped into:

I. ***Immutable or perpetual resources*** include those, which are not affected in a known way in terms of quality and quantity. Example, solar energy, wind etc
II. ***Misusable resource***- includes those, whose quality, but not their quantity is affected. Example marine water, and land surface.

b. Exhaustible resources: - are resources that seem endless and unmanageable in time, but are subject and exposed to some damage depending on human mismanagement and abuses. They are often referred as critical resources. They include air, fresh water, soil, vegetation and wild life. They could be further grouped in to: -

A) Maintainable resources- those that can be easily maintained e.g. soil, vegetation and wildlife.

B) Non-maintainable resources- those that can not maintained easily and within short span of time e.g. Air and water. Renewable resources however can be renewed and replenished relatively by natural process if managed wisely. Just a resource is renewable does not mean that it can never be exhausted. Thus, a renewable resource will not be exhausted as long as it is used at a rate of regeneration known as maximum sustained yield.

- *The maximum rate at which a renewable resource is used without impairing or damaging its ability to regenerate (renewal) is called maximum sustained yield. If this yield is exceeded a potentially, renewable resource is turned into non-renewable resource.*

Presently Global environmental warnings indicate that the maximum sustained yields of the exhaustible resources are being exceeded in most parts of the world.

2. **Non-Renewable Resources**: - are resources that would not replace or regenerate by natural processes. This group of resources:

- Are also referred as fixed or fund (capital) resources from the human point of view, because are formed slowly and their supply is limited in nature. Therefore, with use are diminished or last definitely though time, and once they are used up, they are gone forever.
- Are irreplaceable or non-replaceable in character, even under appropriate way of utilization. It consist most mineral resources, such as coal, petroleum, Natural gas, Ferrous and Nonferrous metals, etc.

From the point of sustained utilization, the non-renewable resources further can be divided into:

i. Recyclable resources: - include those materials that can be recycled or reused repeatedly for different purposes using various methods or techniques. So, some of the metallic ores and their products could be recycled using different techniques to reuse them or their products repeatedly for various purposes.

- Recycling is an artificial technique through which a resource or a material is reused or cycled again and again in order to:
  - Maximize its value or duration of service (use)
  - Reduce waste

- And reduce environmental disturbance.

ii. Non-recyclable resources- those include non- renewable resources whose products can not be recycled for reuse. This group comprises particularly the fossil fuels (coa,l natural gas and Natural oil) which will be totally exhausted once they had been worked out for human use.

This group of resources become available (sustained) though natural processes that are related to geological time scaling only, i.e., the decaying of fossil remnants and their natural change in to fossil quells through prolonged geological time.

C. Classification on the basis of location and Distribution- there are four categories of natural resources on the basis of their occurrence and availability (or their location and distribution) spatially on the earth. These include: -

i. **Ubiquitous-** are resources that are spatially available or are occurring everywhere, like soil, Air and rocks or stones.

ii. **Commonalities**- comprise resources found in many places or that spatially occur at frequent locations. Example: Fresh water features: rivers, lakes and springs) plants or vegetation, certain common wild animals and a few constructional minerals.

iii. **Rarities**-refers to resources that occur in few places or which are spatially rare. Example: - Fossil fuels, precious minerals (Gold, Diamond, Uranium), certain metallic ores (Iron, Copper, etc.) a few wild animals (Lions, Tiger, Giraffes, etc.) and so on.

iv. **Uniquitous-** are resources found and peculiar to one specific location or place. Example- kangaroo in Australia, Mt, Nyala, Walia Ibex, Gelada Baboon Red fox and a few species of Birds in Ethiopia, etc.

D. On the basis of development stage

This classification particularly confirms for Non renewable (mineral) resources- The development and utilization of natural resources particularly that of the Non-renewable resources primarily depends up on:

- ✓ The knowledge of availability /discovery,
- ✓ Identifying the quantity and quality,
- ✓ Finding a use-value /economic value
- ✓ Determining feasibility of development using available capital and technology.

These necessary preconditions change and vary for a particular environment and society through time, affecting or determining whether a resource is going to have a potential or actual value.

- On the basis of development stages (i.e., their discovery, production and utilization) that natural resources possess at any particular time, are grouped in to:

1. **Potential or Reserve stock resources**- stocks refer to the material components comprising mass energy, biotic and a biotic matter. The group potential or reserve stock comprises resources which presently are not developed, but which may be developed in the future, as determined by the above four necessary preconditions (knowledge of discovery of the occurrence and location, quantity and quality, identifying use or economic value and feasibility of development)

Potential or reserve stock resources could be dividing further in to sub-groups on the basis of man's knowledge of these resources.

i. ***Possible Reserve-stock*** is a resource with a known quantity, which have not yet developed and produced, but which can be exploited (produced) economically with existing technology at any time in the future. So, often are called proven reserves,

ii. ***Probable reserve stock*** is a conditional resource which its state of availability and economic development is not ascertained with the existing economic and technological conditions. But in future resources regarded in this category may become available and economical for development.

iii. ***Hypothetical*** or ***speculative reserves stock*** comprise a resource which is not fully discovered or known to exist, but expected to be available based on the presence of favorable environmental and geological conditions but are not based on preliminary explorations (surveys) that will be carried to study the resources of a country or a region.

iv. ***Developed stock resources***- this category comprises resources, which are actually identified, developed and being presently extracted or produced to meet a given end. They are also known as operative reserve stocks. Example: gold and platinum in Ethiopia.

E. Classification based on Utility or Use Value: -

Many of the natural resources are directly sold as a source of income, while some others have indirect money value. On the basis either direct or indirect cash value, natural resources are grouped into:

A. ***Utilitarian resource***- These are resources that have direct money value. Example land minerals, fresh waters, fish, and trees, are some of the resources which are usually directly sold for money to obtain income.

B. ***Non-utilitarian resource***- comprise resources which have direct environmental amenities and scenic value, but an indirect money value. Example Landform features, wildlife, Oceans and seas, atmospheric air, and solar radiation.

F. Classifications on the basis of resource or property ownerships: -

Based on who owns and manages a particular property or resource, they could be classified in to the following groups:

A. ***State property resource***: - is a resource controlled and managed under the ownership of the state or the government.

B. ***Private property resources***: - these are resources owned and managed by individuals, a family or an enterprise/firm in private.

C. ***Common property resources***: - Some resources are owned and utilized by groups of people or a community in a village or a particular natural region. Every person, a committee or heads and elders of the community usually manage the resources. Accordingly, there are two kinds of access and utilization in relation to these resources:

- ✓ ***Open access***- in which every body or member uses the resource in his own right, requirement and way (both in terms of personal need, quantity and method)
- ✓ ***Managed access***- In some case, where common property resource ownership prevails, the utilization and management of the resources is controlled and run by committee, elders or leaders of the community or the group.

In general, the type of resource or property ownership system in a particular region or a country is determined by certain prevailing factors like the kind of political system, the nature of socio-economic policy and structure, stage of socio-cultural and technological advancement of the society and the type and critical value of the resource.

G. Classifications based on collectivity of consumption and subtractive status some natural resources are consumed collectively / in association, while others individually/ separately, and still some others in-group or certain association, and so have different status of diminish ability or subtractive characteristics.

Based on collectivity of consumption and subtractive behavior**,** therefore**,** natural resources are often grouped into: -

i. Pure collective resources: - It refers to resources that are collectively consumed and as a consequence the quantity available does not individually diminish (or subtract) with in an ecosystem or an environment.

In this kind of pure collective resources, it is the quality that is going to be affected as a whole. Example sunlight, Air, land surface, and ocean water. These resources are also called non-subtractive resources.

ii. Non-collective resources- these include resources that are consumed or exploited independently (individually) and consequently diminish independent of others (in isolation) Example: certain peculiar animals, springs and ponds, most minerals and so on. These groups of resources are also called subtractive resources. They commonly comprise resources that are not significantly related (or associated) with other resources existence or sustainability.

iii. **Partly collective or party subtractive resources**- This category consist of resources that are consumed in part collectively or in association and as a result partly diminish in collective at varying rate. For example pasture lands or grazing fields, lakes, plankton, parks, forest trees, etc.

H. Based on the use (or Access) and management of Natural resources

Resources could be also grouped on the basis of specified restrictions imposed or attached to their use and management by law or agreements from governments or international organizations. These groups include:

A. **Exclusive resources-**are resources, which possess and intended to meet some, specified conditions (purposes) and whose use and management is restricted. These consist resources usually delineated as Bio-sphere reserves (Games, Parks, Sanctuaries, Zoos); resorts; play grounds, Scientific research centers, secret places, cultural and religious centers (Churches, Mosques, Spiritual holiday and ritual centers), and so on.

B. **Non-exclusive resources**- are determined depending on the nature of specification and restriction on the resource use and management. This group comprises resources that are open to use or visit freely or with lesser restrictions and expenses. Also include resources, which lack any particular specification about their status of use and management. Example; open lakes, river and streams, open ocean bodies and seas (beyond specified distance away from the boundary line of adjacent country), inaccessible open forests, High mountain slopes, certain kinds of wild animals (Hyena, snake, Jackal etc.,) cold polar frigid zones, etc.

UNIT TWO

2. SOIL RESOURCES

2.1. Definition and Importance of Soil

Definition of soil: soil is the loose surface covering of the land in which all plant life grows. It is a complex mixture of weathered minerals and rock particles, partially decomposed organic matter and host of living organisms. Thus, soil is an assemblage of mineral particles organic matter, living organisms, water and air components that form the surface covering of the land. It can be considered an ecosystem by itself. It is a terrestrial abiotic resource although some pedologist considers it as a living (biotic) resource. It constitutes the geo physical and chemical component of land surface.

The Importance of soil: soil is a very critical or essential material of the earth surface.

It constitutes the substances (nutrients, minerals, air, water etc.) through which all plant life draws.

It is a home of certain micro-organism and small creatures and contains organic compounds, nutrients and moisture, and maintains the balance of the ecological system.

Generally speaking, life would have been impossible without this essential component of the biosphere. The organic growth and cycles or the ecological system is sustainably maintained under the availability of stable and well-composed soils.

2.2. Soil Erosion

Soil erosion generally refers to the activity or processes of detachment, transport, and loss of the soil and soil materials by water, wind, ice and gravity. Erosion involves both the loss of the soil itself and loss of organic and mineral nutrients found in the soil. Soil erosion does not apply to the steady or slow process of nature, which involves the trans-location of parent (or soil-forming) materials, and result in the formation and development of soil and large depositional lands (such as deltaic or alluvial plains, etc,). This steady-natural and non-destructive (or building) process of erosion is called Natural or Geological erosion.

Soil erosion applies to the rapid process of erosion known as accelerated erosion. Accelerated erosion is the process involving the large scale removal, transportation and degradation of soil particles and nutrient materials constituting the land. The activities of the mobile agents on natural or geological processes of erosion changes or accelerate to a destructive- degradation level (stage)- under the interference of inappropriate human activities on the natural processes of erosion and the soil ecosystem. Thus, substantial erosion of the soil is possible when the two processes, natural and accelerated erosion are simultaneously

operative on soil and land. Gravity, water, wind and ice are known as mobile agents of erosion. However, running water and wind are the dominant agents of accelerated erosion. Depending on the mechanism and medium through which these agents of erosion work, accelerated erosion can be divided in to Sheet erosion / sheet-wash, Rill and gully erosion, Stream / river erosion, Leaching, Wind erosion.

- ✓ ***Sheet erosion*** –involves the horizontal surface wash of soil and soil materials by run-off.
- ✓ ***Rill*** *and* ***gully*** erosions involve the detachment and carrying or transporting of consolidated soil material and rock particles by running water at the same time digging and forming rills and gullies at varied depths and widths on slopping fields.
- ✓ ***Stream*** *or* ***river erosion***-erosion at stream or river channels and banks, involving the transportation of soil and soil materials in solution, suspension and bed-load transport.
- ✓ ***Leaching***- is the process of downward transport of dissolvable mineral and organic matter by percolating water in solution.
- ✓ ***Wind erosion***- wind is one of the major agents of erosion, particularly in arid areas. It sweeps high wind velocity in non- vegetative dry lands causes an extensive destruction to soil materials and human life.

2.2.1. Factors affecting soil erosion.

In all forms of erosional processes, there are certain factors or variables that play an influential or determining role, in two ways:-

- ➢ By either speeding or accelerating the work of the natural agents, and increasing the extent (or degree) of loss and degradation of the soil and land; i.e., by highly disturbing the natural or geological equilibrium to the state of causing damage or destruction to the soil and land.
- ➢ Or controlling or regulating the activities of the mobile agents to work at a steady natural equilibrium state, with little or no damage to the soil and land.

The major variables affecting soil erosion are climatic factors, soil properties, Vegetation cover, human activities and topographic /Relief features,

A. Climatic factors

The important climatic factors / or elements/ that affect soil erosion comprise:

- ✓ Precipitation mainly amount and duration (frequency) and intensity of rain fall;
- ✓ Type and velocity of wind;
- ✓ Temperature- radiation receipts, amount and intensity of heat, and its changes.

i. **Precipitation conditions-** particularly pertaining to amount and duration or frequency of rainfall and the intensity (rate) of rainfall are the most force-full factors (individually or in aggregate) causing accelerated soil and land erosion, through their activities in splashing or breaking and detaching particles, increasing and speeding run off, and more severe stream flow.

   Generally speaking, the heavier the rainfall, the bigger and more intense the rain drop in an area, and subsequently the greater the impact (or the force) with which it strikes and breaks the particles of the soil and land, and the more rapid the amount of seepage or percolation, run off, and the turbulent the stream flow- actions and thus, the greater the degree and intensity of the loss of the soil, soil materials and degradation of the land.

ii. Wind velocity

More speedy and power full winds, mainly in arid and semi-arid areas cause considerable soil loss through different ways:

- Saltation- increased evaporation and concentration of salt on the soil surface by blowing wind.
- Suspension- transport of soil particles in suspension by turbulent action of blowing wind.
- Surface creep-a steady interrupted movement of dispersed soil particles under the influence of blowing wind.

In general, under high wind velocity soil particles are picked up from one location and are blown, often over longer distance, to another location. This process of wind erosion sometimes causes dust storms (like hurricane); forms sand dunes (like Ergs, ridges, etc); buries localities with deposition; and creates arid conditions.

iii. Temperature

Temperature conditions, mainly pertaining to amount and intensity of heat radiation receipts, and its alternate changes affect soil erosion indirectly through the influence (impact) on the pedogenic factors and processes involved in soil formation. This could be seen in the following role's that temperature plays among various pedogenic factors and processes. Generally speaking, rainfall amount and intensity increases with temperature (thus, the other controls of climate being constant). This is because, the ability of warm air to absorb more water is high, and increases with temperature increase. Therefore, erosion by running water is quite serious and more severe in tropical and sub –tropical areas. The cooler the climate, the more likely for rainfall to be steady and the water erosion to be less severe or disastrous on the soil. Changing conditions of warm and cool temperatures affect the degree of weathering of parent material and the amount of particles available for accelerated erosion, because determines the amount and duration of

time available for the factors of weathering process and erosion. High temperature also facilitates the decaying of organic materials (under humid conditions) and the action of micro-organisms in decomposing this decayed matter, and thus affect the amount of soil material available to be taken off by the mobile agents of erosion.

B. Type and nature of vegetation cover: - in the world, the general coincidence of soil and vegetation zones with climatic belts show clearly the effect of climate on natural vegetation. These consequently clarify that climate affects the erosion conditions of an area directly, as well as through the vegetation, cover. Vegetation composition and distribution forms the natural cover of the soil and land; hold soil particles through its root; reduces the force of rain-splash by their leaves from breaking and detaching the soil particles; breaks the force of wind and running water; shade the soil from fierce or intense heat and reduce amount of moisture loss through evaporation; and add organic humus, which stick soil particles together and improve soil structure. Thus, all these contributions affects control of accelerated erosion, and regulate the mobile agents to work on the soil and land at the natural- equilibrium state.

In the absence of vegetation cover, wind erosion is more several in arid climates than elsewhere. In arid and semi-arid regions, the absence of vegetation cover is accompanied by lack of organic matter (humus) and this makes the soil more susceptible to severe erosion by running water from infrequent and intense rainfall and more frequent-intensive winds.

C. Topography / Relief: - Topographic or relief features (or settings) impose different degree of influences on the extent and rate of erosion of soil and soil materials:

- Directly through the kind and nature of the slope, such as altitude, levelness or steepness, gradient, etc and the aspect of the slope
- Indirectly by affecting the type and nature of climate; the nature of vegetation cover; the pedogenic processes and the amount of parent material available, associated parent material available in association with various topographic settings.

Slope, depending on the type and degree of the gradient (steep, gentle or undulating gradient) can reduce soil erosion; or accelerate soil erosion by increasing the velocity of flowing water and the amount of susceptible surface material available for soil erosion. Sloppy fields are more vulnerable to soil erosion. Because the capacity of running water to carry away the soil is maximum on inclined and steep-barren surfaces; while is minimum on flat undulating (or plain) surfaces. For example, a four times increase in the degree of the slope is estimated to double the velocity of the flowing water and can increase its erosive

power four times and its carrying capacity 32 times. Thus, other than sheet erosion, rill and gully erosion are a severe problem on mountainous sloppy fields.

On nearly leveled land there is limited run off, because much of the water is held as stagnant and depression storage. Thus, on leveled surfaces the capacity of water to percolate and leach down the soluble nutrients is greater as compared to that on steep slopes. Besides sheet erosion is relatively severe on a concave slope than on a convex slope, due to high drying rate, greater steepness, and thin and shallow soil depth.

Non-uniformity of slopes and development of valleys (due to dissection) associated with mountainous topography also enhances run off and stream erosion.

The aspect of the slope is also important in affecting soil erosion. From experience, slopes that face south and west direction in the northern hemisphere suffer more from erosion than those that face north or east, due to greater differences in temperature and moisture. Soils on north facing slopes are better covered with vegetation, relatively moist and have relatively better organic content than south facing slopes.

South facing slopes, which face the sun directly, are exposed to more heat, excessively drying conditions, little vegetation cover and organic humus content. Thus, aspect conditions would increase the detachment and transportability of the soil particles of the south facing slopes than that of the north-facing slopes in northern hemisphere mountainous region.

iv. The properties of the soil

Soil erodibility is largely dependent upon the texture, structure, organic matter content, and the nature of acidity of the soil, among other factors.

Texture or the composition of different particle sizes (clay, silt and sand) determines the porosity and permeability of the soil. Soils dominated by coarse-grained particle sizes (like sandy soils) have greater porosity and permeability, and consequently become loose or less intact; and are more erodible than the others (silt or clay soils).

Organic matter (humus) content in the soil determines the capacity of the particles to stick together and its resistance to runoff and blowing wind. Humus improves soil structure by attaching particles and increases the soil resistance to erosive forces.

Acidity facilitates the chemical decomposition of minerals and organic matter, and consequently enhances the susceptibility of soil particles to the erosive forces. Under humid conditions particularly accelerates the process of leaching (downward transportability) of soluble minerals and organic substances.

Structure is determined by the properties such as texture, porosity, humus content, mineral mater, and acidity or alkalinity of the soil. It includes the aggregation, the cohesion, thickness and porosity of the particles in forming the most common arrangements with fairly distinctive shape and size (peds). These affect the absorptive and retentive capacities (moisture status), the sickness or detachment of the particles and the solubility of the nutrients, and thus, the degree of the transportability as well as leachness of the soil and soil materials.

Soils with greater absorptive and retentive capacities reduce run off and are less erodible. Whereas high porosity and detachment or solubility increases the erodibility of the soil.

v. Human Activities: -

The activities of human beings directly or indirectly are the chief factor that causes accelerated soil erosion. Humans via their activities are considered as the major cause or agents of soil degradation, because all the other factors play roles to the extent of retarding or accelerating soil erosion depending on human interference.

The Human activities that disturb the natural state and cause accelerated erosion, and the degradation of soil and land are:-

i. **Deforestation**: - cutting, Clearing, Burning and over grazing the trees, forest plants or the vegetation cover. These comprises cutting trees and burning the residual mulch to obtain wood for construction, housing or to secure fuel energy consumption; clearing and burning the plant cover or forest cover to secure and prepare farmland, as in that of shifting or fallow cultivation; overgrazing, that involves grazing of fields or pasture areas repeatedly (continuously) or by allowing too numerous animal traffic above supporting capacity of the pasture fields, so as the natural grass and plant cover will become unable to recover again.

   These activities will destroy the natural vegetation and expose the soil surface to direct raindrops, runoff and stream water or wind, thereby greatly enhancing the erodibility of the soil.

ii. **Improper or bad land use and farming practices**: - farming when poorly or improperly managed can make the problem of erosion much worse, although it is believed that all farming activities would likely to disturb the soil stability. Poor farming practices that could worsen the soil erosion mainly includes:

1)Slash and burn practices:- the removal and burning of plant cover and residual mulch from soil surfaces.

2)Over cultivation: - permanent and prolonged cultivation of the same farm plot impoverishes soil nutrients particularly in dry soils and soils with poor or deficit nutrients.

3)Mono cropping: - is related to over cultivation in terms of continuity of cultivation, but differs in that it involves the growing of the same crop on the same farm plot repeatedly. The practice can deplete a particular type of nutrient most used by the crop and deprives the possibility of nourishment of diversified organic matter in the soil.

4)Ploughing perpendicular or vertically to the slope- ploughing in line to the slope will pave an easy way for down slope flow (runoff) of water and deprives contour plough depressions that can hold back the flow and enforce the gradual seepage (in filtration) of the water in to the soil.

5)Absence of mixed farming- in traditional agriculture, sticking to either crop farming or livestock farming alone can deprive the inter-dependence between the two activities, in that can reduce the amount of manure from animal dung or crop residual to be added in to the soil.

2.1.3 Effects of Soil Erosion.

Soil erosion, which may called the "Creeping death of the landll is a worldwide problem. It affects the land from which the soil is washed, damages the area downstream by floods and sediments, destroys farmlands and harms an economy of a region. The major effects and problems of soil erosion may include loss of the soil, loss of nutrients, excess of certain elements in the soil, desertification, floods and siltation, loss of agricultural land and crop failure, ecological degradation, destruction of utility services and economic harms; and health problems.

i. **Loss of the soil**: - Erosion continually removes or wears away the surface soil. Each year 75 million tons of top soil is lost around the world. Soil loss is usually worst in areas of high rainfall and sloppy mountainous regions. In Ethiopia, the loss is estimated at 10.5 million tons annually. The Awash alone account for 2 million metric tons annual loss of soil in the country.

ii. **Loss of nutrients**: - erosion degrades the soil in many ways and qualities, among which the major one is that it causes the deficiency of important minerals and organic elements that are expected in the soil by decreasing the organic content; removing (depleting) the soluble minerals like carbonates, sulfates, phosphate, etc.; and depriving the elements and nutrients needed for plant growth.

The amount of essential nutrients lost by erosion is considerably high from the top valuable soil. The loss is particularly severe during the process of down leaching of dissolvable nutrients, although considerable loss also results during surface transportation by running water and wind. This can be seen easily; in that flood deposited materials contain greater proportion of nutrients than the normal or stabilized soils. The removal of inorganic minerals and organic matter means a loss of all the fertility elements and the productivity condition of the soil.

iii. **Excess of certain elements in the soil:-** erosion, such as by wind or leaching can result in excess of certain elements, like:

- **Salt: -** an excess salt resulting from excessive evaporation or deficiency of rain is not conducive for plant growth.
- **Iron: -** When leaching removes dissolvable minerals, in excess amount of insoluble iron remains on the top soil and can cause toxic hazard.
- **Excess of water from poor seepage (such as in clay soils) can cause** rotten plant roots and peat in the soil; underground water table to rise up; Stalinization problem, and increase salt on the upper soil layer.

iv. **Desertification: -** desertification can occur through gradual development on a good land or though expansion or invasion from adjacent deserts to bordering areas, due to deforestation, and soil and land degradation.

It is estimated that the spread of deserts threats over one-third of the world land surface. The expansion of deserts to border areas has become critical especially in the Sahel, Andes and parts of South Asia.

From land that is very severely at risk to desertification, is estimated that productivity have reduced by over 50%; while from other lands that are certainly at risk, the productivity decline ranges from 25% to 50% annually.

v. **Floods and Siltation: -** sedimentation, which is a quick built up of river and stream beds with coarse materials that cannot readily transported further away, results due to an increase in the rate of erosion beyond the geologic norms. It causes the reduction of the flow bed by fill materials and the capacity of the channel to carry an increased water or runoff. This leads to the flow of water over the banks and its spread over large surface area in sheets known as floods.

Siltation is the fill up of reservoir dams with sediments. Silt, clay and organic materials remaining in suspension are carried to the lower end of reservoir dams and cause the siltation of reservoirs that are built up for generation of H.E.P., or to provide irrigation water, urban domestic (drinking) water supply or fish

farm. The rate at which siltation occurs depends on the erodibility of the soil in water shed area, type of agricultural practice, nature of climate and topography in the total water shed area and the ratio between the size of the water shed area and the volume of the reservoir. A considerable proportion of eroded sediment reaching a reservoir is largely contributed by stream (river) bank erosion.

Siltation can cause reduction water supply carrying capacity of reservoir dams, failure of power (HEP), irrigation potential, domestic water supply and damage to dams and loss of considerable national asset.

vi. **Loss of agricultural land and crop failure**: - all the so far mentioned consequences of accelerated erosion and land degradations can turn a productive land into bare and non-productive area, or can cause crop failure, or in times crop damage from flooding, siltation, or dissection and fragmentation of land; And thus greatly affect food security, and have resulted to a considerable decline in the agricultural output of many countries of the world.

vii. **Ecological degradation and loss of sustainable environment**: - soil is a biotic geophysical resource useful to the recycling and regeneration of critical resources like plants, water, air, climatic factors and others. Its loss and damage can create series imbalances between these critical resources and can create inhospitable ecological systems.

viii. **Destruction of utility services and Economic harms**: - other than the so far listed problems, erosion can cause the following economic harms.

- ✓ gullies and ravines create social and economic isolation;
- ✓ Winds, runoff and landslides can cause tilting and failing offences and poles;
- ✓ Floods and sedimentation fills, blocks or buries ditches and channels;
- ✓ Railways, roads or sewages are sometimes blocked by drifting sand, moving rock fragments and soil materials;
- ✓ The cost of maintenance of these amenities, besides their cost of provision is a considerable loss to national asset.
- ✓ Besides, soil particles from high concentration of harmful gases and acidic nutrient can cause air and water pollution.

ix. **Health problems**: - Erosion of the soil can affect health conditions of people or can cause sickness under certain specific circumstances. Thus, for example dust storms that result to prolonged dust inhalation can cause great inconveniences and sometimes illness like pneumonia, bronchiate, etc and even deaths. It can cause also inflamed eyes or trachoma. Besides, toxic

chemicals and hazardous wastes from polluted soil and water can cause a serious threat to human health problems.

2.3. Conservation methods of soil resource

2.3.1. Principles and Strategies of Soil Resource Conservation.

Erosion working beyond the geologic norm is the primary problem of the soil and land. Accelerated erosion basically occurs when soil particles are detached by action of forceful rain drops, by action of reactive solutions, and activities of man and animals; and when the mobile agents and percolating water picks up, removes and transports this detached particles and nutrients within them.

Therefore, soil conservation principles and strategies should basically be geared towards protecting, minimizing or arresting these actions and problems. The strategies generally include:

- Minimizing and preventing powerful rain drops and the detachment of soil particles there by improving infiltration and soil moisture by using soil granulation techniques and vegetative coverings.
- Reducing or Controlling surface runoff and soil transportation by applying soil stabilization techniques and mechanical structures that allow safe-disposal or flow of water.
- Maintaining the nutrient materials in the soil and improving their structure by employing biological methods.
- Influencing people to conserve the soil and land.

The principle also under lies that these strategies could provide a substantial result when only the various methods are combined together in to practice.

2.3.2. Methods of Conservation

1. Protecting and controlling the Removal of the soil- there are two general methods that involve several practices, which are useful in preventing the detachment of particles by intercepting raindrops and reduce the removal of soil and soil materials. These include:

a) The use of vegetation cover and soil granulation techniques
b) The use of artificial or mechanical structures.

The use of vegetation cover and soil granulation techniques: - These comprise afforestation and Reforestation afforestation refers to the planting of trees of indigenous species over areas that are naturally devoid of plant cover, such as mountain slopes, hill-sides, bare fields around farms and river banks; while reforestation applies to replacing or substituting trees after cutting or planting on deforested areas; grow tree crops, grasses, legumes plants on higher terraces; grow drought resistant crops and plants in drier or

semi-arid areas; plant shelter belts or wind breaks in arid and semi-arid areas to break the force of wind or divert the direction of blowing wind.

These practices are useful in that which help to intercept rain drop and reduce the force of wind; reduce the velocity of runoff, cut-off the action of running water; increase porosity and granulation and hence, improve infiltration capacity of the soil, reduce drying condition of the soil and improve soil moisture.

1. The use of mechanical structures

These are manmade earthy works useful in reducing or controlling soil erosion, particularly around agricultural land. These include:

i) **Diversion drains or channels-are diverts** or intercepts constructed by excavating (or digging) the land across the slope to conduct or lead water to safe outlet and control the removal of the soil. Are constructed to divert runoff from a hillside to a leveled bottom field or divert water out of active gullies into a safe, non-destructive out let. The diversion drains or channels should have to be covered with suitable spreading grasses or low growing bushes to prevent them from destruction and further erosion.

ii) **Terracing** – involves the constructing of broad channels across the slope of rolling land. Terraces are land embankments usually constructed on more or less leveled contour line across the slope of a rolling land. They are useful in that:

- Reduce the length and gradient of the slope;
- Retain or hold back the water running down the slope and the soil;
- Facilitate percolation;
- Improve tillage operation on sloppy fields.

Terraces are constructed in a series of steps or separated and widely spaced ridges depending on the kind (steepness) of the slope and the extent of runoff down the slope.

iii) **Bunding** – involves the practice of placing an embankment or a bund across the slope by using a part of the soil surface itself, to save rain water from runoff and reduce erosion (sheet erosion). There are several types of bunds:

- *Contour bund* – is the most common type of soil embankment constructed across the slope of the land in contours or at right angle to the altitude of the slope in equally spaced lines. It forces the water to walk rather than running down, creating a barrier to flow, increasing down seepage and soil moisture, and reduces soil loss.
- *Peripheral bund* - constructed encircling the boundaries of an area, particularly farmlands.

- *Marginal bund* – constructed at the lowest part of the catchments (stream banks) without any reference to slope or gradient (or contours).
- *Side bund* – constructed along the slope, usually at right angle to the contour bunds.

2. **Biological methods of maintaining soil materials** – These methods comprise suitable measures that enable to prevent and maintain nutrients found in the soil, at the same time providing improved structure to the soil and protecting soil erosion. The biological methods involve practices that enable to protect the depletion of soil nutrients such as organic humus; minerals and water from the soil, or that provide these nutrients and improve the soil structure. These methods comprise two general methods, which comprise a number of several useful practices and techniques. These include:

a) Securing the natural vegetation cover and growing plant coverage on the soil – plants beside their importance in reducing or controlling the detachment, removal or transportation of the soil; are also significant in maintaining nutrients and improving the soil structure. Some of the useful methods of provision of plant coverage to the soil are Afforestation, Reforestation, Growing tree crops and drought resistant food crops and vegetative plants, shelter belts, and applying controlled grazing systems.

b) The application of proper cultivation methods and suitable measures to protect agricultural lands. These include biological measures related to agricultural land and practices; which are useful in protecting the existing nutrients and improve their status in the soil. They comprise:

i. **Contour ploughing** – also known as contour farming and applies to the tillage of farm land found on sloping fields in contours, horizontal curved lines at right angle to the slope. The contour ploughs make small embankments that act as a barrier to the flow water, increase the infiltration of water into the soil and improve soil moisture.

ii. **Strip cropping** – this involves the growing of different crops that have varied soil depleting and run-off resisting behaviors, in alternate strips of rows or bands at right angle to the slope of the land. The practice usually involves the planting of open growing (or erosion permitting – coffee, cotton, maize, etc) crops in a series of rows or strips alternately with close growing (erosion resisting – teff, leguminous, often alfalfa, etc,) crops. However, strip cropping could be classified further into different practices, based on the type of crops employed, the nature of slope and the strips. These consist of:

1. **Contour strip cropping** – this involves the growing of field crops (such as ground nut, horse bean, peat) alternately with cereals on sloppy fields, using regular- long and narrow strips of

variable width. The method is applied when the unevenness of the slope makes difficult to use exactly parallel strips.

2. **Field strip cropping** – is applied on soils of high permeability with fairly uniform (or even) slopes or on undulating land without well-defined slopes. The practice involves the planting of farm crops with different erosion resisting capacities in more or less parallel strips.
3. **Buffer strip cropping** – are strips of permanent cover crops (such as coffee, cotton, orange, etc, with grasses like alfa-alfa), usually practiced on steep and badly eroded areas, that do not fit into a regular cereals or crop rotation. The strips are generally planted with perennial crops, legumes crops, grasses or shrubs on a permanent or temporary basis.
4. **Wind strip cropping** – is a practice of planting tall-growing crops and low-growing crops in alternately arranged straight and long, but relatively narrow-parallels strips laid right across (or at right-angle to) the direction of wind, particularly in semi-arid and dry land.

The strip cropping methods maintain soil nutrients and control erosion in two ways:

- **By slowing down flow of running water through the close-growing strips of crops.**
- **By increasing percolation rate**, which in turn reduces total volume of runoff and improves soil moisture available for plant growth, and at the same time adding organic materials that improve the soil structure.

iii. **Mulching** – this practice involves the covering of the soil surface with crop residues, stubble, straw, or wood-chips, etc. as determined by the amount of rainfall, aridity and type of soil. Is a useful practice to farmlands confined in dry areas of limited rainfall amount and high rate of evaporation. It enables to reduce the loss of moisture through evaporation and the soil through incidental runoff, at the same time facilitating infiltration of rainwater and improving soil structure from the decomposition of organic materials.

iv. **Crop rotation** –is a system of farming by which different crops with varying nutrient depleting characteristics are grown on the same land (farm plot) in a specific order in different growing period (or seasons). The crops in the rotation system may comprise a variety of legumes crops, cereals, grasses, etc. grown in specific orders of rotation on a farm plot. The benefits of rotation of crops are soil protection by reducing runoff, improve soil structure, in that different crops have different depleting behaviors and leaves behind crop residues that add organic matter and nitrogen to the soil, than that of cultivating the same crop permanently (always) on a specific

farm plot (known as mono cropping). Crop rotation, thus help to maintain soil fertility and productivity

v. **Multiple or mixed cropping system** – this farming system involves the growing of different crops which have varied responses to soil erodibility and to building up soil fertility, by mixing up together on the same farm land. The practice is usually carried by mixing organic nutrient maintaining or improving crops with soil depleting crops; small stem with long-stem crops; dense foliage cover or more canopy plants (crops) with sparse foliage or less canopies; etc.

vi. **Mixed farming** – is a practice of keeping animals alongside of crop cultivation, to enhance supporting advantages that could be obtained from the two practices, in improving the organic status of the soil and its structure.

vii. **Fertilization** – applies to the use (or adding-up) of animal manure, crop-residues green manures and/or artificial chemical fertilizers.

3. Research, Education and promotion activities:-

Besides these erosion control mechanisms and practices, intensive research and educational activities, promotional works and technical assistance provisions have to be carried or implemented to influence people's concern and involvement in the conservation of soil and land.

UNIT THREE

3. NATURAL VEGETATION RESOURCES

3.1. Definition of Natural vegetation

Natural vegetation refers to all naturally growing plant varieties that have varied adaptations, densities and patterns of distribution.

Natural vegetation is one of the most useful biotic resources of the earth's land surface, consisting great varieties of plants that are composed of the following and growing in isolations or in association and forming the surface covering of the land.

- Varieties of trees and grasses;
- Many kinds of wild herbs, bushes and shrubs,
- and several dependent and parasitic plants,

The varieties of plants that constitute vegetation form the natural coverage or clothing of the soil and land, and the natural habitat for many kinds of wild animals, of which some are ground dwellers, while others are tree dwellers (Arboreal). Besides the natural vegetation is the main source of food for many herbivores (plant eaters) wild animals. Thus, without plants or vegetation it is impossible think of wild animals, even of the carnivores and omnivores.

3.2. Importance of Natural Vegetation

Plants, which are the natural constitute of vegetation provide great uses or values both directly or indirectly to man and the ecological system. Some of this value include:-

A. Economic value: - Plants provide man with essential food materials, clothing as well as shelter are sources of different varieties of food stuff materials, in that; directly provide certain seeds, fruits and herbs, as that used by some primitive (backward) communities who are gathers and inhabit wild games to be hunted by those who are hunters; and indirectly provide food stuffs via the food chain, because plants form and protect the soil in which crops are cultivated or grown and provide pasture which support animal life. Of Kinds of forest products, that are used to obtain fuel-energy in many traditional societies; used as constructional and building materials for shelter or houses, bridges

and a variety of service facilities; employed as raw material in the lumber, and plywood, pulp and paper industries and many other manufacturing establishments.

B. Ecological value: - The natural vegetation plays a primary basic role in maintaining the ecological system in several ways. These include:

i. Plants form the natural sources of foodstuffs and the habitat of wild life resources.

- The natural vegetation is the natural home of many different kinds of animals, comprising forest, ground dwellers and tree dwellers.
- Plants make up the sources of food and the basis of survival, directly for herbivores (browsers -leaves eater and grazers-grass eaters), indirectly through the food web for carnivores (flesh eaters) and Omnivores (both plant and flesh eaters)
- Wild life, in turn are basic constitute of the resource system, playing their own role in maintaining the ecological system and providing economic value to man.

ii. Natural vegetation, including wild animals provides and maintains a balanced and sustained ecological system, in that:

- Upon death, their body decomposes to form the fertile nutrient material in the soil called humus;
- Plants form the natural coverage of the soil and land protecting soil from direct-extreme heat, excessive rain drops, strong wind, accelerated run-off and stream flow, and severe erosion and degradation;
- Facilitate decomposition, the infiltration of water, the movement and inter-mixing of nutrients and help to maintain or improve soil moisture and ground water reserves;
- Serve to improve soil structure and fertility status;
- Facilitate the recycling and regeneration of water, air and organic matter, & energy through photosynthesis (O_2, C_2 , H_2 cycles); evapo-transpiration , nutrient cycles (food web) decomposition, etc);

C. Aesthetic and Scientific values:- these values of vegetation and its habitat include:-

i. Provide different scenic values and attractive landscapes with clean- fresh air and variety of wild games that form or constitute recreational environments for people's mental and physical refreshments.

ii. Both plants and animals form the focus and basis of scientific research or studies, from which useful information and knowledge is derived in the fields of science, medicine and innovation,

3.3. Factors for the Variation of Natural Vegetation

The natural vegetation of the earth consists of great varieties of plants that have varied adaptations, compositions, densities and patterns of distribution.

The major factors affecting the nature of adaptations, growth, structural properties and distributions of various kinds of plants are:

a. The nature of climate, namely temperature, rainfall, wind velocity and net evaporation are chief climatic factors.

b. Relief or landform condition, pertaining particularly to altitude, slope and aspect conditions are important,

c. Soil conditions, comprising the texture, structure, permeability and its related nutrient and moisture retaining status are chief factors in the nature and pattern of plant growth and their distribution.

These factors affect and cause structural variations of vegetation spatially over land surface. Structural variation and description of vegetation is based on the physical properties and forms of plants. It comprises varieties in the following physical properties or forms:

- **Life form of plants trees**, shrubs, grasses and parasitic or dependent plants are major life forms
- **Size and distribution**- refers to the difference in sizes, that is usually classified as -tallǁ, –mediumǁ and -lowǁ growing plants, as well as their composition and pattern of distribution of the different life forms of plants
- **Coverag**e – refers to the degree to which the forage of individual plants of a given life- form cover the ground beneath them, usually regarded as barren or very sparse; Discontinuous or scattered; tufts or patches (groups of association), or continuous coverage.
- **Periodicity**: - refers to the response of the plant foliage to the annual climatic cycles and regular cold conditions. Based on their periodic responses, are commonly classified into **deciduous** plants and **evergreen** plants.
- **Leaf shape and size**: - the type of leaf of plants usually varies in shape, size and texture. The most common categories of lead-types include Broad leafed; Needle leafed; Spine, represents plants with transforming leafs, and besides, the leaf texture of plants widely ranges from

membranous leaves of average thickness, through thin and delicate (filmy) leaves, hard thick leathery leaves to that of very greatly thickened (succulent) leaves, that vary according to climate, relief and soil condition. These leaf structures affect the degree of control or loss of water through the leaves to the air (evapotranspiration).

3.4. The major Biomes of the World

The **Biome** is a major broad group of biotic resources of an ecosystem that is mainly based on plants as well as animal life.

The major biomes are basically grouped on the basis of structural distribution of their plants that vary according to climate, relief and soil conditions. The major biomes that are recognized primarily on the basis of distribution of vegetation include:-

A. Forests B. Savanna C. Grassland

D. Desert E. Tundra

A. Forests: - are the prominent components of natural vegetation. Forests are assemblages of trees with similar or varied composition and densities, forming layers of foliage that largely shade the ground. Forests may grow continuously covering large area, or in patches (discontinuous association), and often may consist of grass. Forest can grow in both warm-humid and cool-wet climates. But a good forest climate is the one with warm temperature, large annual precipitations and moist sub-soil.

World forest biomes widely range with climate and latitudes. Thus the forest biomes of the world can be further divided in to:

- Equatorial and tropical rainforest,
- Mountain forest,
- Monsoon forest,
- Broad leafed evergreen forest,
- Mid- latitude deciduous forest,
- Needle leaf (coniferous or Taiga) forest

B. The savanna Biome- consists of a combination of trees and grass lands, with varied proportion and spacing, usually producing a pattern known as park landscape. It forms the natural habitat of savanna animals (Antelopes, Giraffes, Elephants, Zebra, Lions, etc).

Savanna is closely associated with warm climates having alternate rainy and dry season. It widely occurs in the wet-dry and semi-arid type of tropical climates. It may comprise several sub-types based on amount of temperature, rainfall, soil moisture and rate of evaporation (aridity).

C. Grass land biome: - consists of largely or entirely herbs which may include grasses, grass like-plants, and often scrubs and few trees, that may range from continuous to discontinuous coverage.

Grassland biome is closely associated with both the semi-arid type of mid-latitude climate, sub-humid type of sub-tropical climate and moist continental climate. They usually form the habitat of grass dwellers (such as rabbits, and smaller mammals).

D. The desert Biome: -

Many areas of extreme aridity (representing at least 6% of the world land area) consist of thinly dispersed plants, comprising xerophytes plants like cactus, few tufts of grasses and few scrub plants.

A large area of the surface of the deserts is bare ground exposed to direct insulation and forces of wind. This Biome consists of few ground animals, dwelling in the soil and under rocks (reptiles like lizards, snakes, and others).

E. Vegetation of the Tundra Biome: - it consists of most commonly dwarf shrubs, mosses and lichens, and also a variety of flowering herbs and grass-like plants that flourish during brief summer rains.

Tundra climate is cold throughout the year, with ground permanently frozen, and even with possible forest during the short and brief summer time. The areas around the arctic circles and Antarctica, and also high elevations around the snow line (in the middle and higher latitudes) constitute this biome. It is mostly is the home of snow dwelling animals like Reindeer, whales, polar bear and others.

3.5. Factors Affecting Natural vegetation

The major factors that cause the destruction of natural vegetation and habitat resources are:

- Human factors
- Climatic changes
- natural disastrous

A. Human factors: - humans by their activities are the principal or greatest cause of destruction and disappearance of vegetation. Human activities that cause deforestation include:-

- Clearing and burning the natural plant cover, to secure space for farming, settlement, and construction purposes.
- Cutting trees to obtain logs for industrial raw materials, or wood for construction, fuel energy consumption and other purposes
- Over grazing the natural plant cover beyond its grazing capacity, so that it could not regenerate and recover.

Deforestation is predominantly a major problem in developing regions of rural based agricultural economies due to population growth, expansion of agricultural land and settlement.

B. Climatic changes, pertaining particularly to long prevailing drought and aridity are altering the existing biomes diversity (due to declining coverage and expanding desertification).

C. Natural disastrous- caused by volcanism, landslides, thunder- fire, etc. can cause in times unexpected and extensive destructions of forest biomes, as it have been seen in many parts of the world.

3.6. The consequences of the Deforestation

Deforestation primarily implicates the loss of plants, which are the surface covering of the land. Deforestation consequently threats:

a. Soil and land: Deforestation

- Exposes the soil unprotected to run off and accelerated erosion.
- Deprives the soil organic humus and aggregated structure.
- Exposes the land to strong (or fierce) sun shine, reduces amount of percolation, and this increases soil aridity by increasing amount of loss of moisture though run off and evaporation
- Increases the extent of flooding and rate of siltation
- Exposes land to desertification

b. **Habitat and wildlife resources**: - deforestation destroys the habitat (or home) and the source of food of many animals. It threats animal life, so that they become extinct or disappear.

c. **Ecological system and human life: -** deforestation causes a severe threat to the ecological system and human life, in that;

- Causes a decline in the amount of crop productivity and food item.
- Leads to the loss of valuable genetic resources and sources of plant medicine.
- Burning and aridity increases the amount of carbon dioxide released into the air, adding to the amount of greenhouse effect and acidity.
- These destructions and losses contribute to the increase in temperature (global warning) and excessive heavy rains in some areas, or drought in others and in general to the existing global climatic change.

The overall effect of deforestation in the growing ecological imbalances and degradations is a severe threat to the very existence or survival of animal life and man himself.

3.7. Methods of Conservation of Vegetation

An effective conservation measure needs an integrated practice that is directed to three general strategies. These include Securing and protecting the existing forests; planting indigenous (genetic species) plants over deforested areas and bare lands; and, the management and development of alternate substitute resources in place of the use of forest products.

In achieving the above strategic goals, the following are some of the useful methods and practices:

a. Forest, woodland and tree resource management and conservation through:

- Controlling and restricting the large scale cutting, removal and burning of forest-plants
- The development and provision of alternative energy resources, such as that of water power (H.E.P), fossil fuels, geothermal and solar energy, in place of the biomass energy resources, particularly in the rural areas and small to medium size towns.

b. The management and developments of rangelands and pastoral areas through:

- Introducing and expending controlled grazing systems that may involve the delimitation of grazing lands, their division into divided (or parcel) pasture plots and the use of rotation grazing system
- Planting fast growing and draught resisting plants and artificial foliage in and around pasture areas, and semi-arid lands
- Along with the above practices developing and providing watering points by drilling underground water holes (wells) and storing rain water in ponds in the pastoral areas is a very essential measure.
- Herd reduction, at the same time securing higher productivity from reduced number of herds increasing the maximum benefit from low animals' population by improving their breads is a useful measure in reducing overgrazing, and to raise the income of the animal herders.

c. Reducing area of arable land and grazing land by improving soil, crop and animal husbandry in order to ensure or increase forest land. The method calls for:

- The development or improvement of agricultural methods, the yields and productivity of both the soil, crops and animals
- The increase in agricultural productivity enables to reduce cultivated and grazing land, and thus enables (or ensures) to protect and improve forest land.

d. Reforestation as well as afforestation

e. habitat and wild life protection:- In addition to the above measures of maintaining and managing the vegetation cover of the land, the following important methods are applied to preserve and protect habitat and wildlife resources:

i. Preserving and establishing biosphere reserves: -these are special kinds of protected to natural areas, consisting major ecosystem (components of vegetation, water features, wild games, etc.) and delineated to preserve and protect habitat and wild animals and so mostly integrated with regional development.

They are usually large enough, self-containing in plant species wild life species, topographic setting and water features, sometimes useful for scientific research and for recreation purposes. They include National parks, Game reserves and Sanctuaries.

UNIT FOUR

4. RANGELAND RESOURCES

4.1 Nature and Characteristics of Rangeland resources

Rangelands are extensive tracts of lands that are essentially unsuited to rain fed crop cultivation, industrial, forestry, protected forests or urbanization but naturally produce forage plants suitable for grazing and browsing (grazing is consumption of standing forages like grasses and forbs while browsing is consumption of edible leaves and woody plants).

Rangelands are not suitable for crop cultivation mainly because of the physical limitations such as low precipitation, very shallow soils and poor drainage. However, they are very important resources since they provide important forage for domestic livestock and wild animals. Some rangelands also support many species of wild life that provide a reservoir of genetic diversity. Rangelands can also produce intangible products such as natural beauty, open space and wilderness that satisfy important societal values and provide recreational opportunities. Rangeland, in general, refers to expansive, mostly unimproved lands on which a significant proportion of the natural vegetation is native grasses, grass-like plants, forbs, and shrubs. Rangelands include natural grasslands, savannas, shrub lands, many deserts, tundra, alpine communities, coastal marshes, and wet meadows. Rangeland is generally arid, semi-arid, sub-humid or

otherwise unsuitable for cultivation. Range lands are characterized by low amount of precipitation (mostly less than 500 mm per year), high rainfall variability and the ecology is particularly fragile.

The rangelands are also ecologically important because of the significant number of endemic species, high species diversity, areas of ecological and geomorphological integrity, unique ecosystems and habitat for rare, threatened and endangered species. With the benefit of hindsight there is now an appreciation that past management practices and some current ones have, in many areas, proved inappropriate to the rangelands. These practices have resulted in accelerated soil erosion, increased numbers and distribution of weeds and feral (untamed) animals, reduced water quality, soil salinity, the decline of and changes to native plant communities, and decreased biodiversity. This has led to significant areas of the rangelands being degraded, calling into question on their long term sustainability under current use.

4.2 Major Rangeland Types and their Distribution

Rangelands are the most diverse category of the world's open land resources. The major rangelands of the world include **temperate grasslands, the tropical savanna, tropical open woodlands and desert shrub lands.**

1. Temperate Grasslands

They are almost treeless grass covered areas found mainly in the temperate and subtropical zones. They dominate areas where distinct summer and winter seasons occur, with fairly dry period, and where precipitation does not fully meet the needs of trees and shrubs. Most of the temperate grasslands of the Northern hemisphere are found within the interior continental climates, where precipitation is just barely equal to potential evapotranspiration.

In the less continental climates of Southern hemisphere, such as those of South America, the grasslands develop mainly in the rain-shadow of the Andes Mountain in Argentina and Uruguay. Temperate grass lands can be divided in to Prairies and the Steppe or short grass Prairies. Tall grass Prairies are mostly found between forests and grass land lands where there is relatively abundant amount of rain fall. Where moisture is lesser, the dominant vegetation is short grass prairie or steppe; the grass becomes bunched and tufted with bare ground often visible between bunches. In tall grass prairie, black organic rich Chernozemic soils are common which are among the richest in nutrients and the most fertile in the world. In drier parts of prairies, soils are influenced by salinization. Wide variety of animals, both carnivores and

herbivores inhabit the temperate grassland biomes. The temperate grassland biome is one of the ecosystems that have been strongly disturbed and modified by human beings due to intensive agricultural exploitation and overgrazing; as a result there are very few areas of natural grassland left in the region.

2. The tropical Savanna

The tropical grasslands with scattered drought resistance tress mostly occupy the areas between the tropical rainforests and the drier region up to latitudes of 30◦ North and South.

Climatically, the biome is found closely associated with the tropical wet-dry climate with distinct dry season. Temperature is hot all year long. Rain fall, which ranges from 250 – 500 mm, is concentrated in a few summer months and thus very intensive. Soil moisture is not sufficient to support a full tree cover and hence this biome consists of widely spaced tress and extensive grassland in-between. Most of the tree and shrub species in the tropical savanna are thorny or xerophilous, and shed their leaves during the dry season. Savanna trees commonly have thick fire resistant barks and small drought resistant leaves. This adaptation reduces water loss from the plants. The soils, mostly Leptosols, Vertisols and Luvisols, are fertile compared to other tropical soils. Savannas support the richest diversity of herbivores (grass and herb eaters) and browsing (twig and leaf-nibbling) big animals as well as carnivorous animals. Animals in this savanna include wildebeest, zebras, giraffes, elephant, buffalo, rhinoceros, gazelle, lions, leopards, cheetahs, hyenas etc. Unfortunately, due to hunting and rapid agricultural encroachment, the great herds of game animals in Africa may disappear and shortly be restricted to a few protected reservations.

3. Tropical Woodland Savanna

They are characteristic of the higher tropical latitudes and the biome covers the markedly wet and dry tropical climates of North Africa, Asia and Latin America. Here, large trees are found scattered over continuous grass covered plains that typically form a belt adjacent to the equatorial and tropical rain forests. Most of the tree species shade their leaves during the dry season and have thick fire resistant bark and drought resistant leaves. The African savannas are famed for their enormous herds of grazing and browsing hoofed animals.

4. Desert Shrub Lands

These shrub lands primarily occupy the semi desert climate belt bordering the tropical savanna environment. The desert shrub lands are characterized by rainfall of about 250 mm and vegetation

dominated by low growing shrubs less than 2 meter in height. The shrubs have of major grazing values as precipitation allows considerable growth of annual grass and other fodder plants.

Figure: Range land Scenery

4.3 Problems of Rangeland Resources

The most common problem related to rangeland resources include:-

- ✓ Desertification (the expansion of deserts) due to human activities like uncontrolled grazing, burning, wood cutting, cultivation etc
- ✓ Drought – shortage of rainfall that result in declining of forage quantity and quality.
- ✓ Poisonous plant problems - which cause poor livestock reproduction and weight gain
- ✓ Problems of insects like grasshopper, range caterpillars, black grass bugs etc
- ✓ Problems of predators – have considerable influence on range livestock industry
- ✓ Communal resources- the tragedy of the commons (in most cases there is no tenure system)
- ✓ Shortage of drinking water for their livestock
- ✓ Salinization problem

4.4 Management and Conservation of rangeland Resources

Rangelands are ecologically fragile that needs particular attention. The following strategies help to minimize at least the degradation of rangeland resources.

- ✓ Clear and unambiguous roles for all people and organizations with rangeland management responsibilities, should be outlined, including mutual respect, recognition and support for traditional practices where they are appropriate.
- ✓ Encourage rangeland businesses to manage change through promoting opportunities for diversification, multiple use and alternative resource use.
- ✓ develop mechanisms for the restoration and future management of degraded lands

- ✓ Promote opportunities for alternative or multiple uses of areas held as a common resource, consistent with the principles of ecologically sustainable management.
- ✓ State and Territory Governments should provide clarification of tenure and access to resources to enable users and managers to make appropriate investment and management decisions for ecologically sustainable rangeland management including business viability.
- ✓ Land capability assessment must be the basis for all land use planning in the rangelands.
- ✓ Government agencies and training providers should develop training programs in business and financial skills, share available knowledge on best practice in ecologically sustainable rangeland management and encourage acquisition by rangeland communities of broader management skills.
- ✓ Extension services should be tailored to the rangeland environment needs in collaboration with regional groups and managers.
- ✓ Governments should examine options for affordable access for remote and isolated rangeland managers and users to telecommunications technology relevant to their business needs.
- ✓ Financial and other institutions that plan and deliver services should be sensitive to the ecological time scale, the climatic variability and the regional differences in the rangelands which affect production levels and take into account the variability of commodity prices.
- ✓ The negative impacts of mining, tourism and other industries on rangeland resources should be minimized and adequate rehabilitation of rangelands affected by these activities should occur.
- ✓ Self-reliant rural towns are required to provide economic and social focal points for rangeland communities and access to improved social services.
- ✓ Surface and groundwater resources of the rangelands should be managed in a sustainable manner to ensure long-term quality and availability.
- ✓ Regional planning should be flexible and responsive to the ongoing and changing needs of rangeland communities, managers and the environment.
- ✓ There needs to be an effective program of strategic and adaptive research, development and extension, with direct involvement by rangeland users, managers and communities.

UNIT FIVE

5. WILDLIFE

Wild life includes the untamed or undomesticated plants and animals. Wild life resources comprise all wild living biological forms of life, that are great or small creatures found on the earth. Although few wild living creatures dwell under rock bodies and in the soil or ground; a great majority are dwellers of the natural vegetation.

Wild animals can be used for;

a. Scientific and educational research (valuable information for medical purposes environmental studies)
b. Physical & mental recreation (aesthetic value)
c. Promotion of tourism (economic value)
d. Potential for domestication

Some reasons for extinction of wildlife

- rapid expansion of farmland, settlements, urbanization and industrialization
- expansion of grazing land
- Wide spread practices of illegal hunting by the local people in search of meat, skin, fur, horn and ivory.
- frequent wild fires
- Frequent droughts that results in famine
- Very poor policies & administration of the national parks

What measures should be taken to protect or save this wildlife?

- Establishment of National Parks, sanctuaries & game reserves.
- Establish and implement strong laws that effectively prohibit illegal hunting.
- Controlling and administering the habitat properly
- Educate and encourage local communities to protect their animals' habitats and resources.
- Educate the public about environment protection.
- Monitor and administer existing conservation areas properly.

As you can see, some of these mitigation measures involve direct protection of the animals – for example by establishing and properly administering protected areas; and by training people in how to protect these areas. Establishing Protected Parks, Reserves, and Sanctuaries.

National parks are conservation areas for wild animals in which legal hunting is allowed, with some restrictions. Example: the Ethiopian National Parks are. Gambella, Omo, Bale Mountains ,Awash , Nech Sar, Semein Mountains, Abiyatta–Shalla , Maggo, etc. ***Game reserves*** are wild-animal conservation areas where tourists are allowed to practice licensed hunting. ***Sanctuaries*** are wild-animal conservation areas where hunting is strictly prohibited. Example: Afar Gewane, Babille, Sinkele, and Yabello.

UNIT SIX

6. WATER RESOURCES

6.1. Availability and Distribution of water resource

The earth has a tremendous amount of water, but the largest amount (or proportion) is found in the oceans and seas. According to its occurrence and distribution, water is divided into: non fresh or salty (often-oceanic) water and Terrestrial or fresh water.

A. Non fresh or salty water

Salty water is the water found in oceans and seas. It accounts about 71% of the earth's surface covering and nearly 97% of the total water supply of the earth. It is largely accommodated by four of the major oceans of the earth.

- The pacific- is the largest, covering about 181 million km^2 or one third of the total earth surface.
- The Atlantic ocean- accounts for half of the pacific (or about 90 million km^2).
- The Indian Ocean – is slightly lesser than the Atlantic Ocean.
- The Arctic ocean- is the smallest of all the oceans. Besides a number of adjacent seas, gulfs and bays constitute a considerable proportion of the non-terrestrial salty water.

The non-fresh or salty water cannot be used directly for domestic, agricultural and industrial purposes, with out-processing it. But is the major source of the precipitation that falls to the earth, and serves as a medium of transportation between world regions that are widely separated by vast ocean.

B. The terrestrial or fresh water

Fresh water is the part of the water found on the remaining 29% of the earth's land surface, contained:

- Largely in lakes, rivers and streams;
- In the polar ice caps as solid ice and glaciers;
- In underground between rock holes (openings);
- And also as soil water and in plant trunks and tissues.

Fresh water accounts only about 3% of the total water supply available on the earth. A considerable proportion of this water supply is not easily available or readily accessible to people. Thus, for example:

- The fresh water locked up as solid ice and glacier in the polar ice caps (the Arctic and Antarctica) accounts about 2% of the water (or 67% of the fresh water) on land.
- Water beneath the land surface (the ground or water) accounts about half of the remaining 1% (or about 16% of the fresh water supply on land.

- Rivers and lakes make up about one-fifth of the remaining 1% (or about 3.3 % of the fresh water) on land.
- The rest (the remaining 1/5th or about 3.3 %) is found as soil moisture and as stored water in plants.

The terrestrial- fresh water as a whole forms the major primary source of life on land surface.

6.2. The Importance of Water

The ultimate source of all natural drinkable water on the earth is rainfall. But rain water is rarely used as a direct source, except under conditions where rain water is collected and led to storages to serve as the only available water supply, particularly in areas of severe water deficient.

When rain falls, water runs off into streams and rivers, soaks into the ground percolating through porous strata until it reaches an impermeable stratum upon which it collects forming ground water. Ground water is the source of wells and the springs that feed streams, rivers and lakes. These together constitute the indirect sources of the fresh and natural drinkable water. The fresh water from these supplies constitutes the major source of all life on land surface. The major significance of water can be summarized as follows.

- Major constitute of living matter
- Is basically required for human domestic uses
- For irrigation purposes
- For industrial purposes
- Useful for power production
- Serves as a medium of transport

A. As a constitute of living matter

Water forms from 50 to 90% of the weight of living organisms. All living things, great or small need a lot of water to carry out their life processes.

Protoplasm, the basic material of living cells consists of a solution in water of fats, proteins, carbohydrates, salts and similar chemicals. Water acts as a solvent, transporting, combining and chemically breaking down the above substances. Blood in animals and liquid in plants consist largely of water that serves to transport food and remove waste material. Thus, every organism consists mostly of water in their tissues and organs, and as a result takes a lot of water in different forms and quantities.

B. Domestic purposes

Water is required by every person or family for cleaning, cooking, bathing and removing (or carrying) away wastes. But the water available per person per year is very small and greatly varies from region to region or country to country. Besides, in urban areas a large amount of water is used for waste disposal purposes.

C. For Agriculture

In addition to rain water which allows the production of crops and the rearing of animals, the use of water for irrigation agriculture has a profound effect in improving productivity and increasing food production (output) in the world, particularly in areas of scarcity of rainfall.

D. For industrial purposes

In manufacturing activities water is used in many ways:

- Most water is used as an ingredient (or raw material) in many beverage and soft drink, food canning and processing industries.
- A considerable amount of water is used for cooling purposes, i.e. to cool the steam engines or power producing plants, to cool hot gases produced by refining crude oil, to cool hot steel made by steel mills, and so on.
- Water is used also as a cleaning and waste removal agent in canning and food processing (such as fruit, vegetable, meat, etc), textile industries, etc.

E. For power production

Water is the primary source of energy produced in the form of Hydroelectric power, (followed by the energy from fossil fuels, nuclear power, and solar radiation), that is used to light houses, run industries and stream powered engines.

Hydroelectric power production from flow- waterfalls is the relatively cheaper source of energy than the fossil fuels and the nuclear energy resources.

F. As a medium of transport

Water serves as a medium of transport, in inland navigation and maritime voyage, World trade largely depends on maritime transport, because of two advantages.

- It enables to carry huge and bulky materials at a time, and
- Is the cheapest means of transportation over long distance, inter-continental travels and frights

In contrary, very little of the available inland water bodies (rivers and lakes) are suitable for long distance navigation.

G. For recreational purposes

The availability of water at a particular place can provide recreational sites. People enjoy water spots for swimming, fishing and sailing and as a result build mostly their recreational centers along or adjacent to lakes, rivers, seas and ponds.

H. As a solvent, and agent of chemical and hydrological processes

Water is one of the best-known ionizing agents. Because most substances are somewhat soluble in water, and thus frequently called as the universal solvent. Water combines with certain salts to form hydrates. It reacts with metal oxides to form acids. It acts as a catalyst in many important chemical reactions.

In its movement on and through the earth's crust, water reacts with minerals in the soil and rocks. The principal dissolved constitutes of surface and ground water is sulphates, chlorides, bicarbonates of sodium and potassium and the oxides of calcium and magnesium. Water from shallow wells may contain large quantities of nitrogen compounds and chlorides derived from human and animal wastes.

6.3. Problems of water resources

Though water makes up the largest percentage of the surface covering of the earth, it is a resource which is in short supply for human needs at global as well as micro scale.

The following are profound problems associated with water resource supplies.

i. 97**% of the water supply on the earth is non –useable** directly for domestic, agricultural (irrigation) and industrial purposes, because contains high salt content and constitutes non-fresh water supply.

ii. **The total amount of water on land surface** although is enough for all human needs, but is not evenly or equally distributed throughout the world. This is because:

- Some parts of the world, particularly the vast arid or desert lands (nearly 6% of the world-land surface) suffer from lack of enough (or scarcity) rainfall, ground water, lakes and rivers.
- In some areas the available water, (nearly 2.1% of the total water supply or 70% of the water supply on land surface) is locked up in the form of snow and glaciers in the high latitude in polar ice caps.
- Moreover, 20% of the fresh water supply on land is found buried deep underground between rocks and requires high capital and deep well drilling technologies to make it accessible for direct human use.

iii. **The seasonality of rainfall** over large parts of the world aggravates the scarcity of rain water which is most needed for agriculture, particularly during the dry season.

iv. **Population increase** to a large extent has aggravated the scarcity and problem of water supply. Because, the amount of consumption of available water increases with the rise in the human population number and their necessities (i.e. improvement in living standard and high consumption levels of water).

In developed regions of low population growth rates, most people have access to clean-piped water and good sanitation. In the developing countries that are experiencing high population increment, however, only less than half of the population have access to clean- safe water. For example, in the year 1980, more than 70% of the rural and over 25% of the urban population of the developing regions have lived without clean and safe supply of water. In these parts of the world, many people spend a great deal of their time and energy in collecting and carrying water, rather than on productive activities.

v. **A large proportion of the available water is polluted**, because of human misuse and lack of proper purification techniques.

6.3.1. Water Pollution

Water pollution is a major problem, not only in getting pure drinking water, but also has adverse local and global effect on soil, atmospheric air and biotic life.

The capacity of water to dissolve in large amount numerous substances makes water to occur rarely in pure state in nature. Surface water generally contains larger quantities of turbidity and bacteria than ground water, but ground water contains higher concentrations of dissolved chemicals. Seawater contains high concentrations of dissolved chemicals and some microscopic organisms as well.

During condensation and precipitation, rain or snow absorbs from the atmosphere varying amounts of carbon dioxide and other gases, as well as traces of organic and inorganic materials. In addition, precipitation carries radio-active fallout to the earth's surface.

Water is said to be polluted when it is changed in its quality or composition as a result of human activity. In polluted water the natural capacity of the water to clean itself (or purify) is lessened or completely destroyed. Water pollution arises from discharges of industrial, agricultural and human wastes in to fresh waters. Water naturally has a capacity to decompose some wastes without some adverse impacts on other activities. However, the volume of residues dumped into rivers and lakes nowadays exceeds the capacity of the water to accommodate the wastes without damage or harm.

The major causes of water pollution are:

A. **Domestic wastes and Sewerage**: - waste water from toilets, sinks and both tubs is carried by sewers to a treatment area in a city. The treated or untreated waste is then dumped into a river, or a lake. Wastes such as paper; cloth and other detergents also are added from homes into a lake or a river.

B. **Industrial wastes**: - these include a wide variety of organic and inorganic waste pollutants released by industries such as steel, chemical, paper product and food processing activities. Each activity requires a large amount of water in the manufacturing process and generates a large amount of wastewater, which is dumped into the fresh waters.

C. **Agricultural pollutants**: - fertilizers and pesticides that are applied on fields to increase agricultural productivity are carried by water from irrigation systems or natural run off into rivers and lakes. Fertilizers used in agriculture contain chemicals such as phosphates and nitrates, which disturb the natural life processes in water bodies like lakes and ponds.

6.3.1. 1. The Consequences of Water Pollution

Water Pollution results in the following problems:

- Polluted water if used may cause various diseases like dysentery, cholera, typhoid and the like.
- Pollution may result in the poisoning of aquatic organisms or the depletion of oxygen to excessive growth of microorganisms. This makes the water bodies less habitable for fish life and may cause the increase in hard skin (shell) animals like crabs and crocodiles.
- Water pollution also contributes to the atmospheric air pollution, in that varying amounts of carbon dioxide, organic and inorganic particles and other gases that are dissolved and found in polluted water enter the atmosphere through vapors. These pollutants during condensation and precipitation returns to the ground and in some circumstances may form acid rains.
- Polluted water may poison the soil and contaminate agricultural crops and plants. This is likely to affect the quality of foodstuffs and the general health conditions of people, depending on the concentration of the organic wastes and chemicals in the food intakes, especially when consumed in raw or crude form.

6.4. Methods of conservation of Water Resources

Life is not possible without clean and sufficient water supply. The provision of enough pure water has become now a days a growing global problem draining scarce capital resources for several countries of the

world. The lack of sufficient fresh water has a considerable impact in worsening agricultural production, affecting industrial production and the natural functioning of the ecosystem.

The conservation of water resources should be directed towards;

- Managing and developing the existing fresh water resources
- Proper and systematic utilization of existing water supply at the same time by controlling pollution of water.

1. Managing and developing water resources: - This comprises several measures or practices that enable the sustainable development and utilization of water resources. Some of the measures include:

1. ***Watershed management***. Watershed is the network of streams and rivers by which the entire areas of a region is watered. Watershed management systems can comprise
   - Protecting the natural vegetation cover and re-establishing plant cover on river and stream banks
   - Reducing or avoiding the cultivation and grazing of the land along the edges of watersheds.
   - The development of small dams and reservoirs on small stream canals for proper harvesting and utilization of water.
2. ***Collecting and storing rainwater*** directly in cisterns, reservoirs, ponds, or through watershed systems.
3. ***Digging deep underground wells*** and developing springs and swamps by clearing, collecting and diverting water for various uses from these natural sources.

2. Controlling water pollution and applying proper or systematic utilization of water. This can be achieved by implementing several different techniques, that comprise;

1. Reducing or avoiding impute of pollutants that will be discharged/ dumped to water resources.
2. Recycling of wastewater by using wastewater treatment plants for reuse or before it was dumped in to pure natural water.
3. Removal of pollutants by purification or filter systems from water, through screening and sedimentation-organic and inorganic materials are removed by such methods known as screening and sedimentation, which eliminate suspended materials; aeration or the saturation water with air to produce maximum diffusion, usually by spraying water into the air in fountains, removes odors and taste caused by decomposing organic matter, and also industrial wastes such as phenols and volatile gases as well as chlorine. It also converts dissolved iron and manganese's compounds in to insoluble hydrated oxides of the metals, which may then be readily settled out; treatment with

such compounds as that of activated carbon to remove taste and odors, and chlorination or irradiation to kill infective micro- organisms.

4. Removing the hardness of natural waters. Hardness of natural waters is caused largely by calcium and magnesium salts and to small extent by iron, aluminum, and other metals.

UNIT SEVEN

7. MINERAL RESOURCES

7.1 Meaning of a Mineral

Minerals are materials derived from the earth's crust. They are the largest constitute of the group of resources known as nonrenewable resources. More specifically are defined as follows:

Minerals are naturally occurring inorganic crystalline solids with a definite chemical composition. More broadly, mineral resources are defined as elements, chemical compounds or rock materials that are concentrated mostly in the form of inorganic solids and sometime in the form of organic solids or liquids that can be extracted to obtain valuable products and benefits.

Thus, a mineral is naturally occurring substance with a definite chemical composition of elements or a combination of element that have specific crystalline structure or orderly arrangements of atoms. Thus:

- ✓ Most minerals are composed of more than one element that form chemical compounds but few minerals are composed of a single element and form at the same time a mineral. Most minerals are combinations of two or more elements joining to form a chemically stable compound, but some are entirely made of one element. E.g. Diamond, Gypsum and Graphite.
- ✓ Most minerals are inorganic solids but very few minerals are organic solids or liquids that are derived from organic materials. These include particularly the fossil fuels, namely coal, petroleum and Natural gas.
- ✓ Certain rock materials are considered as minerals. Rocks are mixtures (compounds) of different minerals, that are known as rock forming minerals (include five major rock forming chemical mineral groups, namely silicate, carbonates, sulphides, oxides and the Halides mineral groups). Some building materials like sand, gravel, limestone, quartz etc. are considered as mineral because of their economic importance, while a few others like gypsum, rock salt, and coal form simultaneously both a mineral and a rock.

7.2. Mineral resource classification

Estimates of mineralization are first classified into one of two main categories, either Mineral Resources or Mineral Reserves, depending on the different degrees of technical and economic evaluation. Those two categories of classification are further subdivided according to different levels of geological knowledge and confidence. Mineral Resources must be classified as Inferred, Indicated, or Measured; and Mineral Reserves as Probable or Proved.

1. Mineral resources

The geological characteristics of a Mineral Resource (such as location, quantity, grade, and continuity) are known, estimated, or interpreted from specific geological evidence and knowledge. Mineral Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.

A. Inferred Mineral Resources

An Inferred Mineral Resource is that part of a Mineral Resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. It is inferred from geological evidence and assumed but not verified geological and/or grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes which may be limited or of uncertain quality and reliability. Due to the uncertainty attached to Inferred Mineral Resources, it cannot be assumed that all or a portion of such resource will be upgraded to an Indicated or Measured Mineral Resource as a result of more exploration.

B. Indicated Mineral Resources

An Indicated Mineral Resource is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be assumed. This category has a confidence level higher than Inferred Mineral Resources but a lower confidence level than Measured Mineral Resources.

C. Measured Mineral Resources

A Measured Mineral Resource is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence. It is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are spaced closely enough to confirm geological and grade continuity.

2. Mineral Reserves

A Mineral Reserve is the economically mineable part of a Measured and/or Indicated Mineral Resource. Mineral Reserves are sub-divided in order of increasing confidence into Probable

Reserves and Proved Reserves. Probable Mineral Reserves and Proved Mineral Reserves have the same definition as discussed with respect to Mineral Reserves except that they are further refined in that:

A. Probable Mineral Reserves: are the economically mineable parts of Indicated Mineral Resource and in some circumstances, Measured Mineral Resources; and

B. Proved Mineral Reserves: are the economically mineable parts of a Measured Mineral Resource. A Probable Mineral Reserve has a lower level of confidence than a Proved Mineral Reserve. The choice of the appropriate category of Mineral Reserve is determined primarily by the relevant level of confidence of the Mineral Resource.

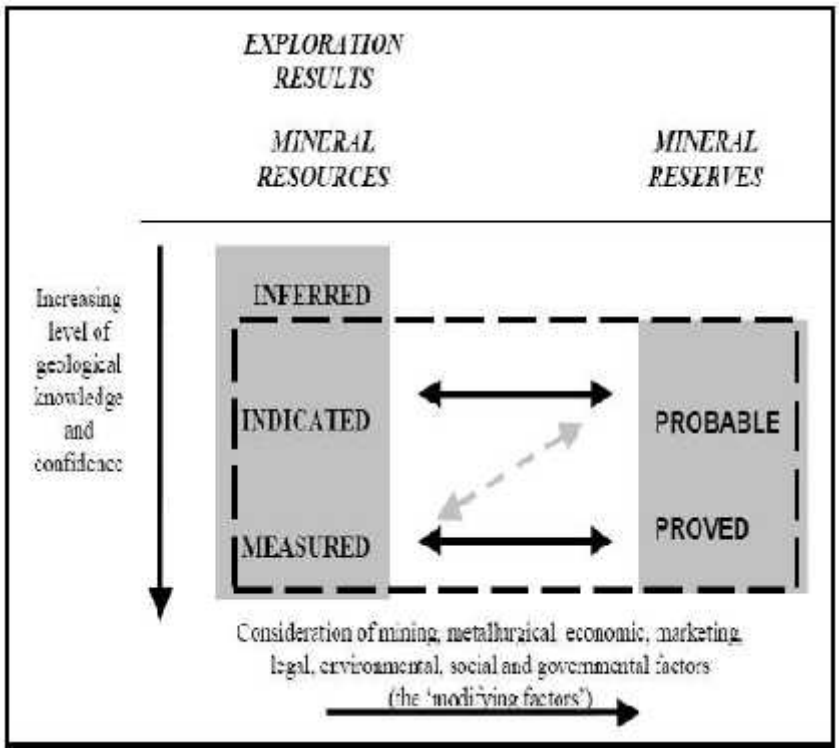

Figure: Relation between Mineral Resources and Mineral Reserves

In Figure, the double-headed arrows indicate that resources can be converted into reserves, and vice versa, between the categories shown. The dashed line between Measured Mineral Resources and Probable Mineral Reserves indicates that this conversion is possible in situations where the collective effect of the modifying factors provide uncertainties which would not permit the Measured Mineral Resources to be converted into Proved Mineral Reserves. It does not indicate a reduction of geological confidence. It follows, also, that an Indicated Mineral Resource could never be converted directly (i.e. without first being upgraded to Measured Mineral Resources) to a Proved Mineral Reserve since there would not be the requisite level of geological confidence.

7.3. Major types of Rock-Forming Minerals

Over 2000 **minerals** have been identified by earth scientists. But a few of them make up most of the rocks of the earth's crust. The most important rock forming minerals can be grouped into the silicates and the non-silicates

A. The Silicates: These are the most common minerals that contain the most abundant elements known as the silicon and oxygen. All the silicate minerals have the same building structure- the silicon oxygen tetrahedron = Si O4. The structure is composed of four oxygen atoms with smaller silicon atom positioned in space between them. The largest silicate structures are then connected to other elements to form silicate minerals.

The primary elements that join silicate structures are:

- **A.** Iron (Fe ++)
- **B.** Magnesium (Mg ++)
- **C.** Potassium (K +)
- **D.** Sodium (Na +)
- **E.** Calcium (Ca ++)

The main groups of Silicate minerals and common examples are:

A. Olivine- consisting of magnesium, iron, silicon and oxygen.

B. Pyroxene- consisting of magnesium, iron, silicon and oxygen.

C. Amphibole- consisting of calcium, magnesium, silicon and oxygen.

D. Augite- consisting of calcium, magnesium, iron, aluminum and silicon and oxygen.

E. Hornblende- consisting of calcium, magnesium, iron, aluminum, silicon and oxygen.

F. Micas including:

- **a.** Muscovite mica- consisting of aluminium, potassium, silicon, oxygen and hydrogen
- **b.** Biotite mica- consisting of potassium, magnesium, iron, silicon, oxygen and hydrogen.

G. Feldspars including

- a. Orthoclase feldspars- consisting of potassium, aluminium, silicon and oxygen.
- b. Plagioclase- consisting of calcium, sodium, aluminium, silicon and oxygen.

H. Quartz- consisting of silicon and oxygen.

I. Garnet- a complex silicate made of different silicate minerals usually found in metamorphic rocks.

Among the above silicate minerals, the feldspars are the most abundant silicate mineral groups that account for 50 percent of the mineral content of the crust. The second abundant silicate mineral is quartz.

Most silicate minerals formed when molten rock cools and crystallizes. The silicate minerals are grouped into:

a. Dark silicates- are silicates that contain ions of iron and magnesium and referred to as ferro-magnesia.

b. Light silicates – these are silicates that do not contain ions of iron and magnesium.

B. The Non- Silicates: These mineral groups are scarce as compared to the silicates. Many of them are important economically. They include the following groups of minerals.

I. Oxides: The Oxides are a group of minerals that are compounds of one or more metallic elements combined with oxygen, water, or hydroxyl (OH). The minerals in this mineral group show the greatest variations of physical properties. Some are hard, others soft. Some have a metallic luster, some are clear and transparent. Some representative oxide minerals include:

- ✓ Hematite (ore of iron)- consisting of Iron and Oxygen
- ✓ Corundum (abrasive and gem stone)- consisting of Aluminum and oxygen

II. Sulfides: The Sulfide Group is an economically important class of minerals. Many of these minerals consist of metallic elements in chemical combination with the element sulfur. Most ores of important metals such as mercury (cinnabar - HgS), iron (pyrite-FeS2), and lead (galena-PbS) are extracted from sulfides. Many of the sulfide minerals are recognized by their metallic luster.

III. Sulfates: The Sulfates are mineral groups that contain one or more metallic element in combination with the sulfate compound SO4. All sulfates are transparent to translucent and soft. Most are heavy and some are soluble in water. Rarer sulfates exist containing substitutions for the sulfate compound. Two common sulfates are:

- ✓ Gypsum – used for plaster making
- ✓ Anhydrite – use for plaster making

IV. Native elements: The Elements Group includes over one hundred known minerals. Many of the minerals in this class are composed of only one element. Geologists sometimes subdivide this group into metal and nonmetal categories. Gold, silver, and copper are examples of metals. The elements sulfur and carbon produce the minerals sulfur, and graphite which are nonmetallic. Examples are;

- ✓ Gold – trade, electronics and medicals
- ✓ Copper – electrical conductor
- ✓ Diamonds – gemstone, abrasive
- ✓ Sulfur – chemicals

- ✓ Graphite – pencil lead and dry lubricants

V. **Halides:** The Halides are a group of minerals whose principle chemical constituents are fluorine, chlorine, iodine, and bromine. Many of them are very soluble in water. Halides also tend to have a highly ordered molecular structure and a high degree of symmetry. The most well-known mineral of this group are:

- ✓ Halite – common salt
- ✓ Fluorite – used in steel making, chemicals and ceramics

VI. **Carbonates**: Carbonates Group consists of minerals which contain one or more metallic elements chemically associated with the compound CO_3. Most carbonates are lightly colored and transparent when relatively pure. All carbonates are soft and brittle. Carbonates also effervesce when exposed to warm hydrochloric acid. Some common carbonate minerals include calcite, dolomite, and malachite.

- ✓ Calcite – used to produce cement and agricultural lime
- ✓ Dolomite – used to produce cement
- ✓ Malachite – is an ore of copper

Among the non – silicates, an important rock forming group is the carbonates group which include the mineral calcite that frequently found in rocks. The two other non – silicate minerals frequently found in rocks next to the calcite are halite and gypsum. In general, the major rock forming minerals are feldspars, quartz, micas, calcite, hornblende, Augite, garnet, magnetite, olivine, pyrite, kaolin and talc.

7.4. Properties of Minerals

The chemical compositions of a mineral are difficult to determine without the aid of sophisticated tests and apparatus. The most easily recognized properties of a mineral are those of its physical properties. The physical properties those are helpful in identification of minerals are:

i. **Crystal form** – some minerals have very distinct crystals as in the mineral quartz. (Large crystals)
ii. **Color** – even though it is least reliable, color is an excellent diagnostic property for minerals such as sulfur.
iii. **Streak** – it is a color of a mineral in its powdered form. It is obtained by rubbing a mineral across unglazed porcelain.
iv. **Luster** – it is the appearance of light reflected from the surface of a mineral. E.g. Shiny for metallic luster and dull for non-metallic luster
v. **Hardness** – this refers to the resistance of a mineral to abrasion or scratching.

vi. **Cleavage** – it is the tendency of some minerals to break along weak bonding. Minerals with excellent cleavage produce smooth surface when broken. E. g. Mica (sheet cleavage), Halite (right angled cleavages) and calcite(triangular cleavages)

vii. **Fracture** – some minerals do not exhibit cleavage and are said to fracture when broken.

7.5. Uses of Minerals

How many of the materials around you are made from some kind of metal? Was brick or stone used to build your home? Of what material is your street, driveway, or sidewalk paved? Do members of your family have jewelry made of gold, silver, or some other precious metal or gemstone? How is your home heated? Does the electricity in your area come from a plant powered by some fossil fuel or perhaps nuclear energy? How would your life and those of family members and friends be different were it not for petroleum products to power vehicles? Do you use chemicals—fertilizers, pesticides, or herbicides—on your own (or fields if you live on a farm area)? All of these and countless other examples point to the importance of minerals and fossil fuels in our daily lives. Most minerals are used to make things. Fossil fuels, on the other hand-coal and petroleum provide much of the energy that makes many things work. We are highly dependent upon both.

Minerals have been used as resources from the moment the earliest human picked up a rock and used it as a tool or weapon. A very strong link exists between rocks (or stones; they are the same) and minerals and human development. In fact, our use of minerals is one of the most common systems of classifying stages of cultural evolution:

Stone Age: This period includes most of human history, during which humans used stones for making tools and weapons (often divided into Old, Middle, and New Stone Age, based primarily upon different stone-working techniques

Copper Age: In its native form, copper is malleable and can be fashioned into different usable items. Its use first appeared in Southwest Asia during the fifth millennium B.C.

Bronze Age: This is a period during which bronze, a blend of copper and tin, began to be used to make tools, weapons, armor, and ornaments.

Iron Age: Around 1200 B.C., iron began to replace bronze as the metal of choice. It, too, was first used in Southwest Asia.

The availability of mineral resources is one of the measures of the wealth of society. Countries that have been successful in the discovery of location, extraction and use or exportation of minerals have grown or

prospered economically than those who have not. Thus, the standard of living of people increases with the availability and production of useful mineral resources, including metals, non-metals and energy fuels.

Mineral resources in general are useful to almost all activities of people. Some of the uses of minerals include;

- ✓ As sources of energy and fuel used to run machineries. They include the fossil fuel minerals- Natural gas, petroleum and coal.
- ✓ For building and construction materials, these include sand, gravel, clay/ stone for brick cement and asphalt; and steel, aluminum and ceramic minerals for various constructions.
- ✓ As raw materials in a variety of manufacturing industries. For example Iron, copper, tin etc., are used for the production of a wide variety of manufactured goods, such as Iron for making steel; Aluminum is useful in air craft manufacture and making beverage cans; Copper is used as electric conductor, Lead is used in electrical batteries, soda-ash in chemical products, and Kaolin (clay) is an important ingredient in ceramics.
- ✓ Some minerals such as phosphates, nitrates, potash, and the like, are used for the production of fertilizers.
- ✓ Copper-brass lead, Zinc, Titanium (pigments) with some cement and ceramic materials are used for making asbestos, glass-tile plastic and fibers.
- ✓ Petroleum products (by-products) are used for making plastic floor tiles or other plastics.
- ✓ For furniture synthetic fibers that are made from minerals steel springs and mineral varnish.
- ✓ For the production of food and clothing. Food is grown using minerals fertilizers and is processed and packed by machines, steel and glass containers made up of metals and ceramic minerals.
- ✓ While Natural fibers grown by mineral fertilizer and synthetic fibers made from minerals are used for making cloths.
- ✓ Some minerals are used for ornamental purposes; precious minerals like gold, platinum, and silver are used mainly for ornamentation.
- ✓ In addition to the above, drugs and cosmetics, chemical items, window screens, light bulbs porcelain fixture nuclear reactors (from uranium and others) utensils and jewelries (from diamond, tantalum, gold and others) are also made from mineral and mineral products.

7.6. Environmental Impacts of Mining activities

The following are some of the impacts and problems of mining processes.

A. Removal and disturbance of the land cover and materials in the mining area large scale mining operations disturb the land by directly removing materials in the area, like vegetation, soil and rock cover. The removals cause changes in topography, result in dumping of wastes in other sites, dust at mines are likely to affect the air resource, even though care is often taken to reduce dust production by sprinkling roads

B. Water resources are particularly vulnerable to degradation; even if drainage is controlled and measures are taken to reduce sediment generation and resulting pollution. At mining sites, water resource problems include;

- ✓ Surface drainage is often altered by dumped rock materials at mining sites.
- ✓ Run off from precipitation (rain or snow) may infiltrate into waste material, leaching out trace elements and minerals.
- ✓ Ground water may also be polluted by mining operations when waste comes into contact with slow- moving subsurface water. Sub-surface infiltrates on ground water causes leaching of sulphide minerals from mine wastes, often producing acid water that may pollute ground water. Polluted ground water eventually may seep or flow into streams and pollute surface water. The reclamation of pollute ground water is very difficult and costly.

C. Physical changes and pollution of land, soil, water and air associated with mining operations, directly or indirectly affects the biological environment and produce severe aesthetic degradations. For example mining activity causes removal and destruction of forest resources; contact with toxic soil or water directly kills living organisms; mining operations causes indirect impacts such as change is soil nutrient cycling, change in total biomass and species diversity, instability of ecosystem due to alteration (damage) of vegetation, ground and/or subsurface water availability and quality.

D. Social impacts associated with large-scale mining activities; result from a rapid influx of workers into mining sites. The social impacts include:

- ✓ Stress on local services, such as water supply problems, disposal of solid wastes, problems (shortages) of schools and rental houses, if the areas are un prepared for such growths and related problems.
- ✓ Land use shifts from open range, forest and agricultural land to urban land and mining centers.
- ✓ The construction activities and urbanization processes coupled with the mining operations affect local streams through sediments, increased pollution, and reduced water quality.
- ✓ Air quality is reduced due to more vehicles, dust from construction and generation of power.

- ✓ The utilization of uranium inside nuclear reactor for atomic power plant and nuclear weapons creates radioactive materials, and could hurt people if released; and facilitate the global warming problem.

7.7. Methods of conservation of Mineral Resources and overcoming Environmental Impacts

Following are some of the strategies that can be followed for the conservation of high quality mineral resources:

- ✓ Use of alternate sources of energy like solar energy, hydroelectric energy etc. Some of the energy resources are renewable (solar energy, wind power, geothermal power & Hydro-electric power) substituting the fossil fuels (coal, oil and gas) by these renewable energy sources has manifold advantages. Thus, enables to reduce the amount of carbon emission to the atmosphere and control air pollution, global warming and other related problems. It overcome the problem of scarcity of mineral resources and saves huge national per capita that could be invested on these minerals
- ✓ Social or public use of mineral products, particularly the use of public transportations such as bus and trains in urban areas instead of private or individual cars (transport). This would minimize the amount of mineral material used for the production of the service and the amount of smoke and carbon emission to the air.
- ✓ Re-use and recycle the minerals and their products. In recycling, used and discarded items are collected, re-melted and reprocessed into new products, e.g. gold, lead, nickel, steel, copper, aluminum, silver, zinc, etc. However, minerals in other products are lost through normal use, such as paints containing lead, zinc or chromium. During reuse used products are collected and used over and over again, e.g. reuse of glass bottles.
- ✓ Using the mineral resources with a greater efficiency.
- ✓ Avoid over-exploitation of the mineral resources.
- ✓ Use of biogas as a fuel for cooking instead of the non-renewable sources of energy.