Mohamed Behnassi
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Sustainable Food Security in the Era of Local and Global Environmental Change

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Editors
Mohamed Behnassi
Faculty of Law, Economics
and Social Sciences
Ibn Zohr University of Agadir
Agadir, Morocco

Olaf Pollmann
SCENSO GbR - Scientific
Environmental Solutions
Sankt Augustin, Nordrhein-Westfalen
Germany

Gabrielle Kissinger
Lexeme Consulting
Vancouver, BC, Canada

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About the North–South Center for Social Sciences

The North–South Center for Social Sciences (NRCS) is a research institution founded by a group of researchers and experts from both Global South and North as an independent and apolitical institution. Based in Morocco, the NRCS aims to develop research and expertise in many social sciences areas with global and local relevance from a North–South perspective and an interdisciplinary approach. As a think tank, the NRCS aspires to serve as a reference locally and globally through rigorous research and active engagement with the policy community and decision-making processes. The NRCS is currently chaired by Mr. Mohamed Behnassi, Doctor Professor of Global Sustainability and Health Politics (www.nrcs-center.org).

Preface

Human activity is increasingly changing the global environment at an unprecedented rate while humanity is facing a range of complex and interrelated challenges: global warming, ecosystem disruption, biodiversity loss and, for many, increasing difficulty in meeting basic human needs for energy, food, water and shelter. As a result, environmental issues are inextricably linked to many aspects of local, regional and global development, and human security and politics.

A series of recent events have generated interest in food security and food systems, particularly the recent news coverage of high food prices which were variously blamed on biofuels, growing demand for meat and dairy products, commodity speculation and climate. Other arguments have arisen about the potential impacts of climate change on food availability and water – as the projections of climate change become even more serious – and about the role of integrated policy and governance in shaping food security. The price increases highlighted the connections between food systems in different places – e.g. drought in Australia and demand for meat in Asia, biofuel policy in the US and Latin America and between the local food movement in Europe and export farmers in Africa. The challenges facing food systems will accelerate in the coming decades, as the demand for food will double within the next 25–50 years, primarily in developing countries, and with the WTO agriculture talks in disarray, making options for reforming trade policy is highly contentious.

Food security and agricultural growth remain high on the science, policy and development agendas. Most research linking global change and food systems focuses solely on the impact of climate change on agricultural production or the impact of agriculture on land use, pollution and biodiversity. However, interactions with other aspects of the food system – such as food processing, packaging, transporting and consumption, and employment derived from these activities – are often overlooked. There are also important new questions about the interactions between the governance of climate and food such as those associated with carbon trading and labeling, and the role of the private sector in carbon mitigation and in the management of food systems.

Technical prescriptions alone will not manage the food security challenge efficiently. Adapting to the additional threats to food security, arising from major environmental changes, requires an integrated food system approach, not just a focus on agricultural practices. Many key issues for the research agenda can be highlighted here: adapting food systems to global environmental change requires more than just technological solutions to increase agricultural yields; tradeoffs across multiple scales among food system outcomes are a prevalent feature of globalized food systems; within food systems, there are some key underexplored areas that are both sensitive to environmental change but also crucial to understanding its implications for food security and adaptation strategies; scenarios specifically designed to investigate the wider issues that underpin food security and the environmental consequences of different adaptation options are lacking; price variability and volatility often threaten food security and more attention needs to be paid to the governance of food systems and to the changing of eating patterns.

Addressing food systems holistically, rather than as separate components such as agriculture, markets or nutrition, demands the engagement of multiple disciplines and researchers to understand the causes and drivers of vulnerability. This volume is a contribution to the construction of this new paradigm.

The Editors

Agadir, Morocco — Mohamed Behnassi
Sankt, Augustin — Olaf Pollmann
Vancouver, BC, Canada — Gabrielle Kissinger

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I have been honored to share the editorship of this volume with my colleagues Dr. Olaf Pollmann (Senior Scientist, CEO SCENSO – Scientific Environmental Solutions, Germany) and Gabrielle Kissinger (Principal, Lexeme Consulting, Canada) whose commitment and intellectual potential made the editing process a smooth and exciting experience.

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While the real value of this volume should be credited to authors of chapters, whose papers have been accepted for publication after a rigorous peer-review, any shortcomings or omissions remain the editors' responsibility. However, the editors and the Publisher are not accountable for any statement made or opinion expressed by the chapters' authors.

Mohamed Behnassi

Contents

Notes on Contributors

Aboussaleh, *Youssef*
Aboussaleh: HDR (2009), PhD (2004) in Nutrition and Development, Ibn Tofail University; MSc (1999) in Nutrition and Health and State Agronomic Engineer (1988) in Nutrition and Food Economics at Agronomic Institute Rabat in collaboration with Iowa State University, Ames, IA, USA (1985–1986). He has been teaching and researching mainly Food and Nutrition and Cell Biology at Faculty of Sciences, Ibn Tofail University, since 1993. From 1988 to 1992, He is the Supervisor of Nutrition and Food quality of Campus Restaurants at the Ministry of High Education, Rabat. Recent publications: Sbaibi, R., Aboussaleh, Y., 2011, *Exploratory study of the staturo-ponderal status of the middle school children in the rural commune Sidi El Kamel in North Western Morocco*. Antropo, 24, 61–66. www.didac.ehu.es/antropo. Youssef Aboussaleh, Mohamed Rguibi, Ahmed Ahami Household food security in Morocco, Biosantè N° 5, 2010.

Afechtal, *Mohamed*
Afechtal is a PhD student (2010–2012) at the University of Catania (Italy) in cooperation with the Mediterranean Institute of Agronomy in Bari (Italy); master of Science in Integrated Pest Management of Mediterranean Fruit Crops (2007) from the Mediterranean Institute of Agronomy in Bari (IAM-Bari), Italy; Agronomic Engineer (2007) – option: Plant Protection – from the Institute of Agronomy and Veterinary Hassan II in Rabat (Morocco). Certificate of Training of Trainers (2007), Crop Life Africa Middle East, from the Mediterranean Institute of Agronomy in Bari (IAM-Bari), Italy. Recent publications: Di Serio, F., Afechtal, M., Attard, D., Choueiri, E, Gumus, M., Lolic, B., Matic, S., Navarro, B., Myrta, A. (2010). Detection by Tissue Printing Hybridization of Pome Fruit Viroids in the Mediterranean Basin: Incidence and Biodiversity. 21st ICVGTFC. pp:76.

Afolabi, *Kolawole Daniel*
Dr. Afolabi hails from Ogbomoso in Oyo State of Nigeria, bagged a bachelor of Agriculture in Animal Science from Obafemi Awolowo University Ile-Ife, Osun State, Nigeria, in 1994; master of Science in Animal Science (Agricultural Biochemistry and nutrition) in 2000 from the University of Ibadan, Ibadan, Nigeria;

Postgraduate Diploma in Education from the University of Ado-Ekiti, Ado-Ekiti, Nigeria in 2008; and Doctor of Philosophy in Animal Nutrition from the University of Ibadan, Ibadan, Nigeria, in 2009. He was a Teaching and Research Assistant at the Department of Animal Science, Faculty of Agriculture and Forestry, University of Ibadan, Ibadan, in Nigeria and presently a Senior Research Officer at Livestock unit of Rubber Research Institute of Nigeria, Iyanomo, Benin City, Nigeria. He has many scholarly publications in local and international journals and has attended many conferences. He is happily married with children.

Ahami, *Ahmed*
Ahami is a Doctor in Human Biology and Psychology (1985 and 1990), Grenoble University, France; and Director of Research Unit on Human biology and Health. He has been teaching and researching since 1991 in Ibn Tofail University. Research areas: Cognition and Food Beavior. Recent Publications: F.-Z. Azzaoui, H. Hami and A.O.T. Ahami Memory impairments and its interaction with environmental factors in children aged 6–8 years living in Gharb plain (N-w of Morocco) European Psychiatry Volume 26, Supplement 1, 2011, Page 264/Youssef Aboussaleh, Mohamed Rguibi, Ahmed Ahami Household food security in Morocco, Biosantè N° 5, 2010.

Akintayo, *Oluremi*
Oluremi Akintayo is an Agricultural Economist and a Research Fellow with the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria.

Ayantoye, *Kayode*
Dr. Ayantoye graduated from the University of Ibadan in 1994. Later, he obtained master of Science and PhD from the Department of Agricultural Economics, University of Ibadan, Nigeria. He has publications in reputable journals.

Balogun, *Olubunmi Lawrence*
Dr. Balogun started his training in 1988 at the University of Ife (now known as Obafemi Awolowo University), Nigeria, where he obtained the bachelor of Agriculture degree (Agricultural Economics). He thereafter proceeded for his master degree in Agricultural Economics at the University of Ibadan and completed the program in 1997. He recently completed his PhD in Agricultural Economics from the University of Ibadan, Nigeria. He has publications in reputable journals (local and international).

Bani, *Salma*
Ms. Bani is currently pursuing her PhD degree in Sustainable Food Production System. She earned her MSc in International Agricultural Marketing, New Castle University, UK, 1990–1991; Diploma in Agricultural Marketing, New Castle University, UK, 1990–1991; and BSc (Hons.) Agriculture, Somali National University Somali, 1982–1985. Ms. Bani has published and presented papers in International Conferences in the Middle East and Europe. She worked in diverse positions including agricultural economist, food policy specialist, head of commodity analysis unit with FAO and head of monitoring and evaluation section with GIZ project.

Currently, Ms. Bani is employed as a senior executive, strategic planning in the Ministry of Municipality and Urban Planning Kingdom of Bahrain.

Behnassi, *Mohamed*
Mohamed Behnassi, PhD, is an Associate Professor at the Faculty of Law, Economics and Social Sciences (Ibn Zohr University of Agadir, Morocco). He is the Founder and Director of the North–South Center for Social Sciences (NRCS), Member of the Engineering and Agriculture Task Group (World Federation of Engineering Organizations) and Member of the Executive Board of the World Forum on Climate Change, Agriculture and Food Security. His core teaching and research areas are Global Health and Sustainability Politics and Governance. He has published many books with international publishers such as *Global Food Insecurity* (Springer, 2011), *Sustainable Agricultural Development* (Springer, 2011), *Health, Environment and Development* (European University Editions, 2011) and *Climate Change, Energy Crisis and Food Security* (Ottawa University Press, 2011). Currently, other book projects are being published. He has also published numerous papers in accredited journals and communicated several oral presentations in relevant international conferences. In addition, he has organized many outstanding scientific events such as (1) "Health, Environment and Sustainable Human Development", May 2007, Agadir; (2) "The Integration of Sustainable Agriculture, Rural Development and Ecosystems in the Context of Food Insecurity, Climate Change and the Energy Crisis", November 2009 in Agadir; (3) "Climate Change, Agri-Food, Fisheries and Ecosystems: Reinventing Research, Innovation and Policy Agendas for Environmentally- and Socially-Balanced Growth", May 2011, in Agadir; and (4) GECS-2012: "Global Environmental Change and Human Security: The Need for a New vision for Science, Policy and Leadership", November 2012, in Marrakech. Dr. Behnassi is also practicing consultancy by monitoring human rights at work and the sustainability of the global supply chain in MENA Region. Recently, he completed a US State Department-sponsored Civic Education and Leadership Fellowship at Syracuse University and the Maxwell School of Citizenship and Public Affairs (Syracuse, New York). Currently, he is the manager of two key research projects: "Food and Health Security Face to Climate Change in Morocco: An Adaptation Strategy within the Perspective of an Integrated Governance", sponsored by the Royal Institute of Strategic Studies (IRES), Morocco; and (2) "Civic Education and Engagement as Pre-Requisites to Boost the Democratization Process in Morocco", sponsored by the State Alumni Engagement Innovation Fund (US Department of State).

Bishokarma, *Nirmal Kumar*
Mr. Bishokarma is a PhD scholar at Kathmandu University, Nepal, and Swiss National Centre of Competence in Research (NCCR) North–South. His thesis research focuses on food security, climate change and exclusion issues. Before joining the university he worked for Nepal Livelihoods and Forestry Programme of Department of International Development of UK for 10 years as capacities of Regional Programme Coordinator, Climate Change focal person and District Manager. Before that, he had worked for United Mission to Nepal and on German

Development Cooperation (GIZ)-supported project for 5 years. Mr. Bishokarma has published half a dozen English articles in peer-reviewed journals published in Nepal on the subject of social and institutional aspect of food security, climate change and natural resource management.

Burgers, *Paul*
He is a senior researcher with the International Development Studies, Utrecht University. From 1995 to 2002 he has worked with the World Agroforestry Center in Zimbabwe and Indonesia. (Agro) forestry and sustainable rural development for livelihood improvement are his main fields of interest. He combines his scientific work with his own business CO_2 Operate BV, where for one he sets up and manages pro-poor emission reduction projects in Indonesia.

Chouichom, *Seksak*
Seksak Chouichom earned his baccalaureate degree in Agricultural Extension and Communications in 1998 from Kasetsart University, Bangkok, Thailand. He specialized in rural development and economics and was awarded a master of Science in Agricultural Extension degree by the same university in 2001. He has since worked at the Thailand Institute of Scientific and Technological Research as an agricultural extension specialist. In 2007, he was granted a postgraduate scholarship by The Royal Thai Government to pursue higher studies at the Hiroshima University which granted him a PhD in Agricultural Economics in 2011.

D'Silva, *Joyce*
Joyce D'Silva is the Ambassador and former Chief Executive of Compassion in World Farming, the leading charity advancing farm animal welfare worldwide through research, education and advocacy. Joyce has led Compassion's international work, establishing links with Chinese academics, the FAO and with the Islamic world. Joyce is a compelling communicator on the impacts of industrial livestock production on animal welfare, the climate and the environment. She has presented at the European Parliament, the European Group on Ethics in Science and New Technologies and the World Bank and at the Egyptian conference on "Islamic Principles in Humane Transport and Slaughter of Animals" in 2008. She has authored chapters for several books, including *The Future of Animal Farming* (Blackwell 2008). She compiled and co-edited *The Meat Crisis: Developing More Sustainable Production and Consumption* (Earthscan 2010), details of which are at ciwf.org/meatcrisis.

Halliru, *Salisu Lawal*
Salisu Lawal Halliru is a lecturer at the Geography Department Federal College of Education Kano, Nigeria. He obtained a bachelor degree of Science in Geography and Postgraduate Diploma in Environmental Management from Bayero University Kano and is a specialist in Environmental Management. His area of teaching and research interest include climate change, population, poverty and environmental education. He has to his credit published articles in scholarly journals and papers presented at many learned conferences. Through this, he co-ordinates a research project on poverty indices. The grant came through an external source from UK that

his proposal yielded. Moreover, he participated in another field work on child's geographical perspective in Nigeria. This yielded the publication of an academic paper in an International Journal of Geographical Information Science.

Kalungu, *Jokastah W.*
Jokastah Kalungu is an experienced Irrigation and Water Resource Engineer with MSc in Irrigation and Drainage Engineering (USP, Brazil) and a BSc in Agricultural Engineering (JKUAT, Kenya). She has over 10 years of experience in the field of agriculture and water-related projects. She has worked in Kenya, Malawi and Mauritius. Before joining the South Eastern University College as a Lecturer, she had worked with the Ministry of Irrigation and food security in Malawi, ICRAF, under a RELMA project, Kenya Rainwater Association, GIBB Africa Ltd, among others. Due to her interests in climate change and food security issues, she secured a PhD scholarship under CALESA (Adapting Agriculture to Climate Change) Project. Jokastah is registered at the Hamburg University of Applied Science, Germany, and based in ICRISAT, Kenya.

Kissinger, *Gabrielle*
Gabrielle Kissinger is the principal of Lexeme Consulting, in Vancouver, Canada. Consulting services focus primarily on international forest carbon, REDD+, government affairs and corporate social responsibility. She has almost 20 years of experience working at the interface between government policy and land use pressures. She has produced results working in partnership with various levels of government companies ranging from start-ups to large timber companies, investors, major donors and a full range of environmental NGOs. Her research applies an interdisciplinary approach to find tenable solutions, drawing from ecological economics, ecology and conservation science, and public policy. Her work has served multiple geographic regions, from the Great Bear Rainforest in coastal British Columbia, Canada, to northern New England in the US and Lesotho, Southern Africa. She holds a MA in Natural Resources Management and Environmental Policy from the Tufts University and BAs in Philosophy and Political Science from the University of California, Santa Barbara.

Kokaye, *Haroll Senakpon*
Kokaye graduated as an Agricultural Economist Engineer from the University of Parakou (Benin); he holds a master degree in Transition Studies with major economic development and world agricultural market from the University of Giessen (Germany). As a research assistant he has been involved in many socio-economic studies related to food security, adoption and impact of new agricultural technologies, soil fertility management, crop rotation modeling and optimization techniques with University of Parakou, Agricultural Policy Analysis Program, in Benin and the University of Giessen.

Leal, *Walter*
Prof. Walter Leal Filho has a first class degree in Biology and a doctorate in Environmental Science (PhD), having also completed a post-doctorate program on environmental communication. He also has a higher doctorate Dr. rer.nat. habil.)

in environmental information (DSc), a DPhil in sustainable development and holds the titles of Doctor of Letters (DL), Doctor of Literature (DLitt) and Doctor of Education (DEd) commensurate with his scientific performance and outputs translated by over 250 publications among books, book chapters and scientific papers. He is the Director of the Research and Transfer Centre “Applications of Life Sciences” at the Hamburg University of Applied Sciences and a Senior Professor at the London Metropolitan University Business School, being a member of the team at the Centre for International Business and Sustainability. He is also a member of the Projects Complaints Mechanism of the European Bank for Reconstruction and Development. In 2009, he created the International Climate Change Information Programme (ICCIP) which is the world’s leading program on environmental education information and communication, running the on-line climate conference series.

Liao, *Laurence M.*
Lawrence M. Liao is an aquatic biologist and Associate Professor at the Graduate School of Biosphere Science, Hiroshima University. He holds a BSc from the University of San Carlos (Philippines), an MSc granted by the University of the Philippines in Diliman and a PhD in Biology conferred by the University of North Carolina at Chapel Hill. He taught and conducted research in aquatic biology at various universities and laboratories in the Philippines, Singapore, Taiwan, Thailand and Canada. His current research interests include taxonomy and systematics of algae, Southeast Asian ethnobiology and environmental and wildlife management.

Mwangi, *Moses*
Dr. Mwangi is an engineer with interest in Integrated Water Resources Management. For about two and a half decades, he has performed in a multiplicity of developments endeavors and organizations, with emphasis placed in support to people’s social, political and economic wants, with a focus on the arid and semi-arid lands. He has served in various locations and capacities in both the Kenyan and international settings on researches, resources mobilization and development, and management for livelihoods shore up. Currently, he is a Lecturer at the South Eastern University College (a Constituent Constituency of the University of Nairobi) in the School of Water Resources Sciences and Technology where he also heads the Department of Hydrology and Water Resources Management.

Noorka, *Ijaz Rasool*
Dr. Noorka is an emerging scientist working on crop water stress in the Department of Plant Breeding and Genetics, University College of Agriculture, University of Sargodha, Pakistan. His teaching and research interests are diversified and focusing on environmental stress and management, sustainable development, decision support systems and modern agriculture ethics. He is supervising a number of students for their research leading to MSc (Hons) and PhD degrees. He is the current Incharge Students Affairs, Librarian and Chairman Sports Board of the University College of Agriculture, University of Sargodha, Pakistan. He is honored to be the

founder and Secretary General of Pakistan Agricultural Scientist Society (PASS), and President of World Forum on Climate Change, Agriculture and Food Security (WFCCAFS), a joint venture of Pakistani Scientists with International counterpart. He has presented his research work in many international forums in countries like UAE, Egypt, Saudi Arabia, China, Morocco, Kuwait, Sri Lanka, Iran, South Africa, Sudan, France, Japan, Italy and India.

Oyewole, *Babatunde*
Babatunde Oyewole is a specialist in Agricultural Communication and Extension. He is a consultant with Land Sustainers, an agricultural firm in Ibadan, Nigeria.

Parthasarathi, *Sangeetha*
Parthasarathi is a doctoral researcher at the Global and European Studies Institute, University of Leipzig in Germany. She holds an MA in Global Studies from the Universities of Vienna and Leipzig. Her current research project focuses on Food Security in India: Political Influences of Farmer Organizations and Development Oriented NGO's in the States Food Policy Making.

Ramachandran, *Nira*
Nira Ramachandran is currently the ICSSR Senior Fellow at the Institute of Economic Growth, New Delhi. Her interest areas include food security, nutrition, gender, child labor and related issues. She has provided consultancy to a number of International organizations including the FAO, UNWFP, UNICEF and the World Bank. She devotes part of her time to a research NGO, the Bhoovigyan Vikas (Earth Care) Foundation. She holds a PhD from the Jawaharlal Nehru University, Delhi, and has also been trained abroad. She has lectured extensively and conducted training programs in the areas of food security, environmental sustainability, primary education and project management techniques. She has to her credit published several articles in peer-reviewed journals as well as a number of books including *Towards a Food Secure India: Issues and Policies*, C*oming to Grips with Rural Child Work: A Food Security Approach, Carrying Capacity of Mussoorie* and *Monitoring Sustainability: Indices and Techniques of Analysis*. She has held a range of teaching and research positions at well-known academic institutions including the Indian Institute of Management, Bangalore, Bangalore University, Delhi University and the LBS Academy of Administration, Mussoorie, the premier training institution for the Indian Administrative Service.

Schmidt, *Michael*
Schmidt is the head of the Department of Environmental Planning at the Brandenburg University of Technology (BTU) Cottbus, Germany. His scientific research and lecturing fields include environmental planning, environmental assessment, strategies for sustainable development, techniques for combating desertification as well as monitoring and evaluation. He promotes long-term cooperation in research and education with environmental experts in Syria, Yemen, Jordan and Vietnam.

Shabbir, *Shahid A.*
Dr. Shabbir is a Salinity Management Scientist at the Dubai-based International Center for Biosaline Agriculture (ICBA). He earned a PhD degree from the University of Wales, Bangor, UK, in 1989; BSc Hons and MSc Hons (Soil Science) from the University of Agriculture, Faisalabad (UAF), Pakistan, in 1977 and 1980, respectively. He joined ICBA in 2004 and has over 30 years of experience (Pakistan, UK, Australia, Kuwait and UAE) in soil-related RD and E activities. He has held many positions: Associate Professor Soils (UAF), Pakistan; Associate Research Scientist in Kuwait Institute for Scientific Research, Kuwait; and Manager of Soil Resources Department, Environment Agency, Abu Dhabi, UAE. He is a prolific author of over 150 publications in peer-reviewed refereed journals, proceedings, books and manuals. He is a life member and the current Vice President of the World Association of Soil and Water Conservation (Middle East). He is a recipient of Sir William Roberts and David A. Jenkins Awards.

Sharma, *Sagar Raj*
Dr. Sagar Raj Sharma has a PhD in Development Economics from Fukuoka University, Japan. He is an Associate Professor and the Head of the Department of Development Studies at Kathmandu University, Nepal. He is also a senior researcher of the National Centre of Competence in Research (NCCR) North–South. His research areas include land and conflict, food security and livelihood vulnerabilities, migration and its impacts, and foreign aid and development.

Susanti, *Ari*
She is a PhD researcher at the Utrecht University, International Development Studies. She got her bachelor degree in forestry from the Faculty of Forestry, Gadjah Mada University, Indonesia, in 1999. She continued her study at the International Institute of Geo-information Science and Earth Observation (ITC), The Netherlands, and got her master degree in Geo-information Science. She has been working for the Faculty of Forestry, Gadjah Mada University, since 1999. She is interested in multi-disciplinary research related to forestry and natural resources management.

Tabasum, *Saba*
Tabasum is a PhD scholar working on wheat water stress under the supervision of Dr. Ijaz Rasool Noorka.

Tavignan, *Silvére*
Dr. Tavigan has a PhD in Agricultural Economics from the University of Giessen (Germany). He is currently an Assistant Professor at the Department of Agricultural Economics and Rural Sociology, Faculty of Agronomy, University of Parakou. He teaches optimization techniques in the field of agriculture. His research areas focus on organic cotton and Bt, renewable energies and climate change.

Techoro, *Prosper Somah*
Techoro is a PhD candidate/Teaching Assistant at the Department of Environmental Planning, Brandenburg University of Technology (BTU) Cottbus, Germany. He was awarded a master of Science degree in 2005 by BTU Cottbus, Germany. His current

research interests are focused on the human dimensions of climate change, on understanding the impacts of climate change and how they relate to vulnerability of the subsistence farmers particularly in sub-Saharan Africa. His current research interests are focused on the human dimensions of climate change and on the understanding of the impacts of climate change and how they relate to the vulnerability of the subsistence farmers particularly in Sub-Saharan Africa. His PhD research topic is about "Climate Change Impacts on Subsistence Agriculture-Options of Adaptation".

Yamao, *Masalino*
Dr. Yamoto holds a master and PhD degrees in Agriculture from the Hokkaido University, Faculty of Agriculture, Agricultural Economics. He is currently a Professor at the Department of Bioresource Science, Graduate School of Biosphere Science, Hiroshima University. His research areas focus on agronomy and general fishery studies.

Yegbemey, *Rosaine Nérice*
Yegbemey is an agricultural economist engineer and a research assistant at the Department of Agricultural Economics and Rural Sociology, Faculty of Agronomy, University of Parakou. He is currently a PhD student in Agricultural Economics at the University of Giessen (Germany). His researches focus on adaptation to climate change and sustainable agriculture in developing countries.

Yusuf, *Sulaiman Adesina*
Dr. Yusuf is a Senior Lecturer in the Department of Agricultural Economics, University of Ibadan, Nigeria. He has published many papers in some reputable journals, both locally and internationally.

Zokufa, *Tozie*
Zokufa holds a BTech degree in Environmental Health and has spent 10 years as a veterinary public health practitioner (meat inspector) working for both the private and public sectors, focusing on primary and secondary meat inspections, abattoir auditing and meat safety awareness campaigns at local community levels. He is currently the representative of Compassion in World Farming South Africa.

Contributors

Youssef Aboussaleh Nutrition and Health Laboratory, Faculty of Sciences, Ibn Tofail University, Ames, IA, USA

Mohamed Afechtal Mediterranean Agronomic Institute of Bari, Valenzano (Bari), Italy

Kolawole Daniel Afolabi Livestock Unit, Rubber Research Institute of Nigeria Iyanomo, Benin City, Nigeria

Ahmed Ahami Nutrition and Health Laboratory, Faculty of Sciences, Ibn Tofail University, Ames, IA, USA

Oluremi Akintayo Farming Systems Research and Extension Programme, Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Oyo State, Nigeria

Kayode Ayantoye Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria

Olubunmi Lawrence Balogun Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria

Salma Saeed Ahmed Bani Senior Executive Strategic Planning, Planning Department, Ministry of Municipality and Urban Planning, Manama, Bahrain

Mohamed Behnassi Faculty of Law, Economics and Social Sciences, Ibn Zohr University of Agadir (Morocco), Agadir, Morocco

North–South Center for Social Sciences (NRCS), Agadir, Morocco

Nirmal Kumar Bishokarma Department of Development Studies, Human and Natural Resources Studies Centre (HNRSC), Kathmandu University, Jawalakhel, Lalitpur, Nepal

Swiss National Centre of Competence in Research (NCCR) North–South, Jawalakhel, Lalitpur, Nepal

Paul Burgers Faculty of Geoscience, International Development Studies, Utrecht University, Utrecht, The Netherlands

Seksak Chouichom Department of Bioresource Science, Graduate School of Biosphere Science, Hiroshima University, Higashi Hiroshima, Hiroshima, Japan

Marketing Division, Technology and Innovation, Management Department, Thailand Institute of Scientific and Technological Research (TISTR), Pathum Thani, Thailand

Joyce D'Silva Compassion in World Farming, Godalming, UK

Salisu Lawal Halliru Department of Geography, Federal College of Education Kano, Kano, Kano State, Nigeria

Jokastah Kalungu School of Water Resources, Science and Technology, South Eastern University College, Kitui, Kenya

Research and Transfer Centre Applications of Life Sciences, Hamburg University of Applied Science, Hamburg, Germany

Gabrielle Kissinger Lexeme Consulting, Vancouver, BC, Canada

Sénakpon E. Haroll Kokoye Department of Agricultural Economics and Rural Sociology, Faculty of Agronomy, University of Parakou, Parakou, Republic of Benin

Walter Leal Research and Transfer Centre Applications of Life Sciences, Hamburg University of Applied Science, Hamburg, Germany

Lawrence M. Liao Graduate School of Biosphere Science, Hiroshima University, Higashi Hiroshima, Hiroshima, Japan

Moses Mwangi School of Water Resources, Science and Technology, South Eastern University College, Kitui, Kenya

Ijaz Rasool Noorka Department of Plant Breeding and Genetics, University College of Agriculture, University of Sargodha, Sargodha, Pakistan

Babatunde Oyewole Land Sustainers, University of Ibadan, Ibadan, Oyo State, Nigeria

Sangeetha Parthasarathi Global and European Studies Institute, University of Leipzig, Leipzig, Germany

Nira Ramachandran Institute of Economic Growth, New Delhi, India

Michael Schmidt Department of Environmental Planning, Brandenburg University of Technology (BTU) Cottbus, Cottbus, Germany

Shahid A. Shabbir International Center for Biosaline Agriculture, Dubai, United Arab Emirates

Sagar Raj Sharma Department of Development Studies, Human and Natural Resources Studies Centre (HNRSC), Kathmandu University, Jawalakhel, Lalitpur, Nepal

Swiss National Centre of Competence in Research (NCCR) North–South, Jawalakhel, Lalitpur, Nepal

Ari Susanti Faculty of Geoscience, International Development Studies, Utrecht University, Utrecht, The Netherlands

Faculty of Forestry, Gadjah Mada University, Yogyakarta, Indonesia

Saba Tabasum Department of Plant Breeding and Genetics, University College of Agriculture, University of Sargodha, Sargodha, Pakistan

Prosper Somah Techoro Department of Environmental Planning, Brandenburg University of Technology (BTU) Cottbus, Cottbus, Germany

Silvère D. Tovignan Department of Agricultural Economics and Rural Sociology, Faculty of Agronomy, University of Parakou, Parakou, Republic of Benin

Masahiro Yamao Graduate School of Biosphere Science, Hiroshima University, Higashi Hiroshima, Hiroshima, Japan

Rosaine Nérice Yegbemey Department of Agricultural Economics and Rural Sociology, Faculty of Agronomy, University of Parakou, Parakou, Republic of Benin

Institute of Project and Regional Planning, Faculty of Agriculture, Nutrition, and Environmental Management, Justus-Liebig University of Giessen, Giessen, Germany

Sulaiman Adesina Yusuf Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria

Tozie Zokufa Compassion in World Farming, Somerset West, Cape Town, Republic of South Africa

List of Abbreviations and Acronyms

AARI	Ayyub Agricultural Research Institute
AIDS	Acuired Immuno Deviency Syndrom
ANOVA	Analysis of Variance
BAPPENAS	Ministry of Agriculture, Agriculture and National Development Planning Agency
BAU	Business as Usual
BMI	Body Mass Index
CAFO	Concentrated Animal Feeding Operations
CH_4	Methane
CO_2	Carbon Dioxide
CRED	Centre for Research on Epidemiology of Disasters
DADO	District Agricultural Development Office
DAS	Days After Sowing
D&D	Deforestation & Degradation
DDS	Dietary Diversity Score
DO	Delivery Orders
DNPI	Dewan Nasional Perubahan Iklim
EAD	Environment Agency Abu Dhabi
EF	Ecological Footprint
EFSA	European Food Safety Authority
Embrapa	Brazilian Agricultural Research Corporations
FAO	Food and Agriculture Organization of the United Nations
FCFA	Franc Central African (West African CFA fanc)
FCPF	Forest Carbon Partnership Facility
FFQ	Food Frequency Questionnaire
FGD	Focused Group Discussion
gha	Global Hectares
GCC	Gulf Cooperation Council Countries
GDP	Gross Domestic Product
GHI	Global Hunger Index

GHGs	Greenhouse Gas Emissions
GMO	Genetic Modified Organisms
GS	Gulf States
HDSA	Human Development in South Asia
HLPE	High Level Panel of Experts on Food Security and Nutrition
HIV	Humanes Immundefizienz Virus
ICBA	International Center for Biosaline Agriculture
ICCAFFE	International Conference on Climate Change, Agri-Food, Fisheries and Ecosystems
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IDB	Islamic Development Bank
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IFRC	International Federation of Red Cross and Red Crescent Societies
INPE	Brazil's National Institute for Space Research
IPCC	Intergovernmental Panel on Climate Change
IRAD	Institut de Recherche Agricole pour le Développement
ISPO	Indonesian Sustainable Palm Oil Production
IWMI	International Water Management Institute
KISR	Kuwait Institute for Scientific Research
LEAD	Livestock, Environment and Development
LGA	Local Government Area
LULUCF	Land Use, Land Use Change and Forestry
MANOVA	Multivariate Analysis of Variance
MacroZEE	Ecological-Economic Macrozoning initiative
MDGs	Millennium Development Goals
MoARD	Ministry of Agriculture and Rural Development
MRSA	methicillin-resistant Staphylococcus aureus
MRV	Measurable, Reportable and Verifiable
MQVRT	Measurement, Quantification and Verification, with Registration and Transparency
NARCS	National Agricultural Research Systems
NCCR	National Centre of Competence in Research
NCDC	National Climate Data Center
NCHS	National Center for Health Statistics
NEEDS	National Economic Empowerments and Development Strategy
NFC	Nepal Food Corporation
NOAA	National Oceanic and Atmospheric Administration
NGO	Non-Gouvernmental Organization
N_2O	Nitrous Oxide
NPC	National Planning Commission
NRCS	North–South Center for Social Sciences
NTFP	Non Tiber Forest Product
OAE	Office of Agricultural Economics

OBEPAB	Organic Agriculture in Benin
P	Precipitation
PDDS	Partial Dietary Diversity Score
PET	Potential Evapotranspiration
PEACE	Pelangi Energi Abadi Citra Enviro
PRA	Participatory Rural Appraisal
REDD+	Reduce Emissions from Deforestation and Forest Degradation
R-PPs	Readiness Proposals
RSPO	Round Table on Sustainable Palm Oil
RTS	Return to Scale
RUAF	Resource Centres on Urban Agriculture and Food Security
SEEDS	State Economic Empowerments and Development Strategy
SEUCO	South Eastern University College

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Part I
Combating Food Insecurity: A Global Responsibility

Chapter 1
Managing Food Systems, Climate Change and Related Challenges to Ensure Sustainable Food Security: The Urgent Need of a Paradigm and Policy Shift

Mohamed Behnassi

Abstract Addressing the challenge of global food security in our era is strongly linked with other global issues, most notably climate change, population growth and the need to sustainably manage the world's rapidly growing demand for energy, land, and water. Our progress in ensuring a sustainable and equitable food supply chain will be determined by how coherently these long-term challenges are tackled. This will also determine our progress in reducing global poverty and achieving the Millennium Development Goals. The challenge is to deliver nutritious, safe and affordable food to a global population of over nine billion in the coming decades, using less land, fewer inputs, with less waste and a lower environmental impact. All this has to be done in ways that are socially and economically sustainable. In this paper, we try to analyze the different challenges affecting the global capacity to build a food system with the potential to enhance a sustainable food security. Actions needed to make such a paradigm and policy shift, in both developed and developing countries, have been demonstrated.

Keywords Food security • Climate change • Eating patterns • Adaptation • Natural resources • Food losses and waste

1.1 Introduction

Food is the most basic of all human needs and collective food security governance has been with us since the dawn of human society. Failure to perform it effectively has inevitably engendered social unrest. The riots in capital cities around the world

M. Behnassi (✉)
Faculty of Law, Economics and Social Sciences, Ibn Zohr University of Agadir (Morocco), Hy Salam, Agadir 80000, PO. Box 14997, Morocco

North–South Center for Social Sciences (NRCS), Agadir, Morocco
e-mail: behnassi@gmail.com

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in late 2007 are reminiscent of the hungry crowds that threatened the life of Roman Emperor Claudius in AD 51 and the bread riots that helped to spark off the French Revolution in 1789. History and common sense tell us that a functioning food system is an indispensable pillar of a stable economy and a society capable of reproducing itself. However, achieving a permanent food security has become increasingly complex. For most of the twentieth century, it was mainly focused on issues of agricultural production. Today access and ecological concerns are understood to be equally relevant. Food system needs to consider not only how food is produced but also how it is processed, distributed, and consumed. Food system and governance have become a complex web of processes and often overlapping or contradictory formal policies and regulations, complicated by unwritten rules and practices that are not subject to political oversight (McKeon 2011).

Thus, addressing the challenge of global food security in our era is strongly linked with other global issues, most notably climate change, population growth and the need to sustainably manage the world's rapidly growing demand for energy, land, and water. Our progress in ensuring a sustainable and equitable food supply chain will be determined by how coherently these long-term challenges are tackled. This will also determine our progress in reducing global poverty and achieving the Millennium Development Goals. The challenge is to deliver nutritious, safe and affordable food to a global population of over nine billion in the coming decades, using less land, fewer inputs, with less waste and a lower environmental impact. All this has to be done in ways that are socially and economically sustainable.

Within this perspective, the present chapter aims at analyzing the different challenges affecting the global capacity to build a food system with the potential to enhance a sustainable food security. Actions need to be taken to ensure food security, in both developed and developing countries, have been highlighted.

1.2 Food Systems, Climate Change and Other Challenges: The Unachieved Food Security

The European Commission President has stated on 2010, "*a world where one billion people are hungry is not just a deep stain on our collective conscience. It is a growing threat to global security. If the financial crisis has taught us anything, it is that, if we ignore risks building up in the system, it is much harder to manage them.... Like the fight against climate change, the fight against hunger cannot wait* . . .".

According to the 1996 World Food Summit "*food security at the individual, household, national, regional and global levels is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*" (FAO 1996). For Guyomard et al. (2011), this definition broadens the initial focus of the 1974 World Food Summit on the volume and stability of food supplies, by including secured access for all people, especially the most vulnerable, to available supplies, and by incorporating food safety and nutritional balance. The 1996 definition also reflects concerns about food composition and nutrients requirements for an active and healthy life.

Food may be the staff of life, but affordable access to food and good nutrition is still a huge challenge in many parts of the world. Guyomard et al. (2011) indicates that global food is clearly – and increasingly – insecure. According to FAO figures (2010), 925 million people were undernourished and many people were affected by vitamin and mineral deficiencies – one out of three in developing countries according to Beddington et al. (2011). At the same time, 1.5 billion adults were overweight in 2008, including over 200 million obese men and nearly 300 million obese women (Beddington et al. 2011). In addition, a growing number of low and middle-income countries are facing a double burden of malnutrition, i.e., the persistence of under-nutrition, notably among children, along with a rapid rise in overweight and obesity, and diet-related chronic diseases.

On a planet with sufficient food for all, a billion people go hungry (FAO 2010) while another billion over-consume, increasing risks from chronic diseases (Foresight 2007). A number of causes contributed to the jump in the cost of food: low levels of world cereal stocks; crop failures in some major exporting countries and export restrictions in others; increased demand for meat in East Asia; rapidly growing demand for agricultural commodities for biofuels; and rising energy and agro-chemical prices. Although such dramatic price hikes have now relatively eased, prices still remain high in many developing countries despite record production. Worse, global food prices appear to be on the rise once again according to the latest FAO Food Price Indexes.

Global Food Security Challenges and Drivers

Some of the main drivers underlying the challenge of ensuring food security are summarized in brief in the following points.

- Global population growth, coupled with demographic change, increasing affluence and urbanization, will lead to growth in demand for food and changing patterns of demand – rising affluence is associated with increases in food consumption, especially of meat and dairy products. Much, but not all, of the expansion in population will occur in developing countries: improving food security (especially affordability, access and availability) is closely linked with the need to reduce poverty.
- Global climate and other environmental changes that will have direct or indirect impacts on food production and supplies include rising carbon dioxide and other GHGs, leading to rising temperatures, changing rainfall patterns and increasing incidence of extreme weather events (such as storms, floods, heat waves and droughts), rising sea level and ocean acidification. Changing climate may also lead to changes in the

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distribution and/or severity of pests and diseases (in crops and animals, including zoonotic infections where disease organisms transfer from vertebrate animals to humans) and has the potential for severe impacts on food production and animal welfare. As well as threats, changes in climate may offer new opportunities for food production in some parts of the world.

- Environmental impacts of farming and food: negative impacts can include increasing water and land use, soil erosion and degradation, loss of biodiversity, as well as GHG emissions and water pollution.
- Key resources for agriculture are limited, notably land, fresh water and energy, but also sources of other inputs such as mineral phosphate (an essential plant nutrient). Shortages of resources may be exacerbated by increasing competition, for example from urban and industrial development.
- Social drivers include urbanization, demographic change, issues of land tenure, governance and international security, changing patterns of consumer needs, preferences, choices, tastes, habits and practices affecting the demand for and consumption of different foods and patterns of waste.
- Economic drivers include issues of trade, land tenure, food markets and their volatility, supply and distribution, regulation, affordability and accessibility (particularly in the developing world) with associated globalization.
- There is a need to ensure adequate nutrition, including not only calories but all necessary macro- and micro-nutrients for healthy and balanced diets for populations throughout the world. At the same time as increasing numbers of people globally are inadequately fed, the over-consumption of high-calorie diets adds to the rising demand for food, with all the associated economic, social and environmental impacts.

Business as usual in our globally interconnected food system will not bring us food security and environmental sustainability. Several converging threats – from climate change, regional conflicts, population growth and unsustainable use of resources – are steadily intensifying pressure on humanity and world governments to transform the way food is produced, distributed and consumed (Beddington et al. 2011).

The food system faces additional pressure as the global population grows, to around nine billion by 2050 (United Nations Population Division 2010), and as diets shift towards higher consumption of calories, fats and animal products. Food insecurity afflicts communities throughout the world wherever poverty prevents assured access to food supplies. As well as causing widespread human suffering, food insecurity contributes to degradation and depletion of natural resources,

Table 1.1 Status of selected global parameters

People in the world (updated on Dec. 2012)	7.06 billion
Undernourished people (2010)	0.9 billion
Overweight people over age 20 (2008)	1.5 billion
People living on less than USD 1.25 per day (2005)	1.4 billion
People living in dryland areas (2007)	2 billion
People dependent on degrading land	1.5 billion
Losses due to climatological events (extreme temperature, drought, forest fire) (2010)	USD 7.5 billion
Area of agricultural land (2009)	4.9 billion hectares
Area of croplands, pasture and grazing lands devoted to raising animals	3.7 billion hectares
Annual growth in world agricultural production (1997–2007)	2.2 %
Food produced for human consumption lost or wasted annually	1.3 billion tonnes

Source: Beddington et al. (2011)

migration to urban areas and across borders, and political and economic instability (Table 1.1).

Our climate is also changing and, given the levels of greenhouse gases (GHGs) already in our atmosphere, will continue to do so. In the coming decades, global climate change will have an adverse overall effect on agricultural production and will bring us toward, and perhaps over, critical thresholds in many regions. Areas currently suffering from food insecurity are expected to experience disproportionately negative effects. To reduce the effect of climate change on food supplies, livelihoods and economies, it's believed that nations must greatly increase their adaptive capacity in agriculture – both to long-term climatic trends and to increasing variability – as an urgent political priority.

Within this global context, many scientists have endeavoured to identify pathways to achieving food security in the context of climate change. Many believe that food systems must shift to better meet human needs and, in the long term, balance with planetary resources. This will demand major interventions, from local to global scales, to transform current patterns of food production, distribution and consumption. Investment, innovation, and deliberate effort to empower the world's most vulnerable populations will be required to construct a global food system that adapts to climate change and ensures food security while minimizing greenhouse gas emissions and sustaining our natural resource base. Greatly expanded investments in sustainable agriculture, including improving supporting infrastructure and restoring degraded ecosystems, are an essential component of long-term economic development. The sooner they are made, the greater the benefits will be (Beddington et al. 2011).

Over the course of the twenty first century, the world will need to produce significantly more food in order to deliver a basic, but adequate, diet to everyone. The amount of food required will be even greater if current trends in diets and the management of food systems continue. However, food security is not just about supply matching demand. The development of agricultural and food systems must be viewed in the context of sustainability. It must take into account the progressive

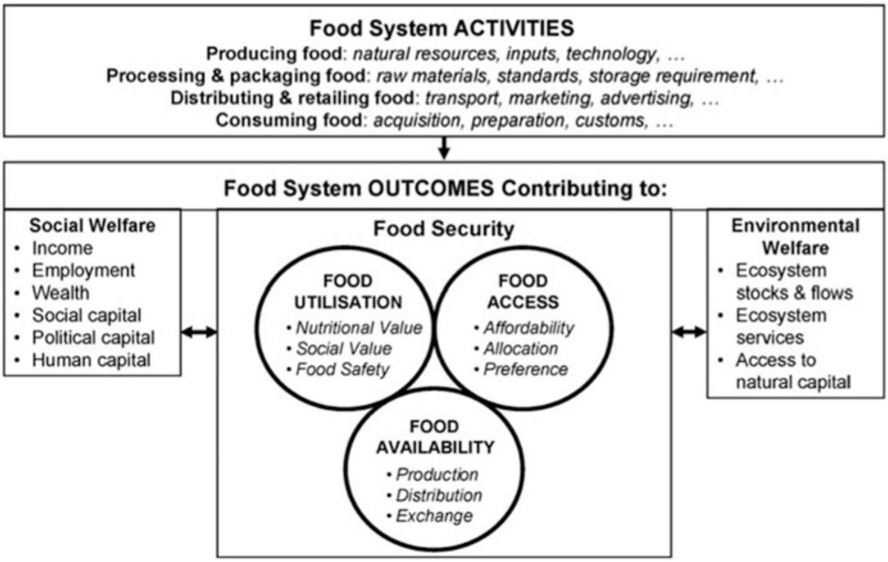

Fig. 1.1 Food system concept (Source: Editorial 2009)

depletion of fossil energy, the protection of soil and water resources, the preservation of biodiversity and the issue of climate change. If they are to feed more than nine billion by 2050, farmers around the world will have to produce crops using less fossil fuel in an environmentally friendly way. They will also have to provide energy and industrial commodities in place of petrochemical products, as well as environmental and rural services like water management, biodiversity protection, carbon sequestration, or diversified and open landscapes. In addition, food consumption habits will need to adapt. The Foresight Study Agrimonde (Paillard et al. 2010) clearly shows that by 2050 eating patterns will be a major issue of world food security. It shows in particular that Western dietary pattern cannot be generalized throughout the world (Fig. 1.1).

In this broad perspective, we need to make concurrent efforts to establish climate-resilient agricultural production systems, make efficient use of resources, develop low-waste supply chains, ensure adequate nutrition and encourage healthy eating choices. Together, these processes will found a sustainable food system. Intensification of food production must be accompanied by concerted action to reduce GHGs from agriculture to avoid further acceleration of climate change and avert threats to the long-term viability of global agriculture. Making these changes, although technically feasible, requires urgent, collective and substantially increased action internationally, nationally and locally (Beddington et al. 2011).

As climate change amplifies the environmental and socioeconomic drivers of food insecurity, it is imperative that we prioritize where, how and when to act. The threats posed by climate change to food supplies and livelihoods are likely to be spatially variable. We will need to identify global hotspots where the threats are greatest and to develop specific, practical interventions to boost resilience in these areas while benefitting from the positive opportunities.

In Europe, North America and elsewhere, a combination of intensive agriculture, food storage practices, retail systems and eating habits generates high per capita GHG emissions and food waste. The environmental and human diversity of the planet prevents the imposition of one-size-fits- all solutions.

Humanitarian, environmental and global security concerns demand a global commitment to improve the situation of a large proportion of the human population that is currently food insecure or vulnerable to food insecurity. This requires the reinforcement of resilience to climate shocks and food price volatility, halt land degradation, and boost productive assets and infrastructure. There are countless entry points for action. Many policies and programs provide ample evidence of multiple benefits for livelihoods and the environment, with meaningful participation at local and regional scales (Beddington et al. 2011).

The multiple emergent challenges – food insecurity and undernutrition, climate change, increasing competition for energy and water, degradation of land and biodiversity – are connected in complex ways and demand an integrated management approach. Adaptive management and governance to improve nutritional security, economic prosperity and environmental outcomes will require a much better global system for integrating spatially explicit information about agriculture, ecosystem services, markets and human populations in real time. Existing and future investments in information and knowledge must be structured to identify limits, inform trade-offs and deliver practical guidance for a sustainable future, not simply to maximize single components of the food system. Such an information system will give us a richer understanding of the dynamic systems we depend on and enable us to renew and broaden our efforts to secure a more sustainable and healthy food system for our own and future generations.

As a global community, we need to navigate toward a "safe operating space" that provides adequate food and nutrition for everyone without crossing critical environmental thresholds. Plotting a course towards this space will require innovative technologies, institutions and policies, and will severely test our social, technological, and agricultural ingenuity. In all circumstances, we will need a governance system at multiple levels that accommodates participation, learning and the ability to adjust existing processes for more efficiency. To be successful, we will need a robust, widely shared appreciation of agriculture as a multifunctional enterprise that delivers nutritious food, rural development, environmental services and cultural heritage, through and beyond the twenty-first century.

1.3 Ensuring Global Food Security: Some Recommended Actions

Without a global commitment to reducing GHGs from all sectors, including agriculture, no amount of agricultural adaptation will be sufficient under a destabilized climate in the future. While change will have significant costs, the costs of keeping unchanged the current path are already enormous and growing. Given the already intolerable conditions for many livelihoods and ecosystems, and the time lag between research and development and widespread application, we need to take urgent actions. Some selected actions are presented in the below analysis.

1.3.1 Changing Eating Pattern

Acting on eating patterns is a key condition for ensuring global food security in the future. The reason behind this assumption is that there is a strong correlation between food production and consumption. According to the Foresight Study Agrimonde (Paillard et al. 2010), if daily food consumption per person keeps steadily increasing, it will reach 3,600 kcal in 2050 and the world will have to produce no less than 62 G kilocalories for feeding nine billion people at that date (Scenario "Agrimonde GO"); but if daily food consumption per person remains limited to 3,000 kcal in 2050, only 42 G kilocalories will need to be produced to achieve this goal – that is 32 % less (Scenario "Agrimonde 1").

Ensuring global food security does not mean setting up a common eating pattern for every part of mankind: although undoubtedly have tended to coverage over the past decades, eating patterns remain diverse throughout the world, determined by a complex set of physiological, economic, historical, cultural and sociological factors. From that perspective, the Westernization of eating patterns is not suitable for every part of the world because of its numerous shortcomings and drawbacks, especially in terms of health and environmental implications.

A holistic approach is needed to make eating patterns more suitable and healthy. This involves first reducing losses and waste along the whole chain (production, distribution, and consumption). Such a reduction strategy should result in significant savings of fossil energy and other natural resources, and those savings are a key condition to increasing the sustainability of both eating patterns and food systems. In fact, eating patterns and food systems can be sustainable if they rely on a thrifty use of fossil energy and other resources, such as land and water. Setting up such systems must be a priority on the worldwide research agenda. Lastly, food security can be ensured thanks to healthier and more sustainable food diets. This objective requires assessing the impacts of food diets, both nutritionally and environmentally. Far from being imposed, more sustainable diets must be based on changes recognized by everyone. This means a better understanding of food consumption values and behaviours and of their various determinants, so as to favour desirable

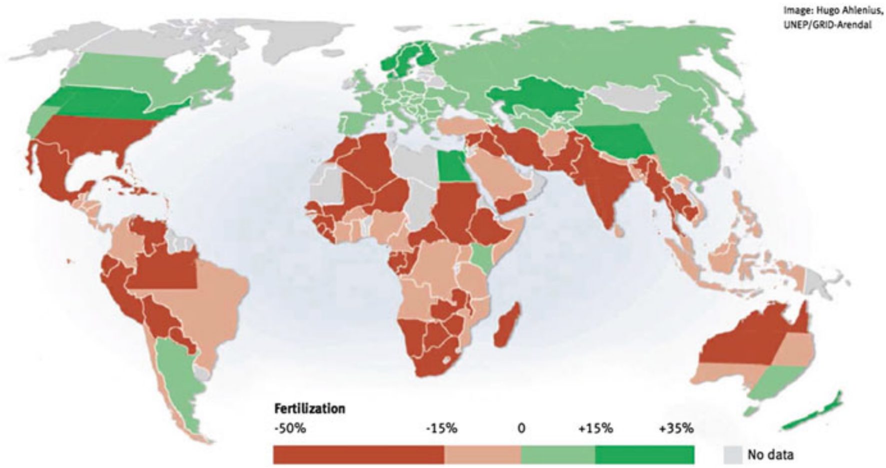

Fig. 1.2 Projected changes in agricultural production in 2080, due to climate change (Source: Cline 2007)

changes through actions on demand and supply factors, and also on the relative prices of foodstuffs. These actions, of course, will have to take the specificities of individuals, social groups and countries into consideration.

Many actions need to be taken to ensure food security throughout the world. And many of these actions have something to do with eating patterns. In other words, when it comes to food security, nothing can be carried out if eating patterns are not taken into consideration.

1.3.2 Reducing Significant Food Losses and Waste at Distribution and Consumption Levels

At global level, less than half of the calories produced by farmers ever make it onto the dinner table, as illustrated by Fig. 1.2. In the early 2000s, farmers globally produced an average of 4,600 kcal per capita per day, including nearly 600 kcal lost at the time of harvesting or just after. At that stage, the percentages in losses were strikingly higher in developing countries compared to developed nations. The remaining 4,000 kcal used were divided between animal feed (43 %) and human food (57 %). The 1,700 kcal used for animal feed produced in return 500 kcal in the form of eggs, dairy product or meat. Over the 2,800 kcal available for human consumption, another 800 kcal were lost through distribution and final consumption. At this stage, the percentages of losses were much higher in countries where the diet transition was achieved or occurring, than in the developing world. Finally, on average, the 4,600 kcal produced from plant products for each inhabitant of the world, only 2,000 ended up for actual human consumption (Smil 2000).

These figures show that reducing losses and waste, from field to plate, is a potentially powerful lever that can be used to increase world food availability and define more sustainable food systems and diets. These losses and waste correspond to both market (pecuniary) and non-market (environmental) costs. It is relatively easy to reduce post-harvesting losses, through efficient disease control and the development of infrastructure for storage, transport, and marketing. At this level, it is essentially a matter of investment and thus of budget resources. It is much more difficult to reduce losses and waste at distribution and final consumption levels since this requires profound changes in food consumption patterns and possibly an easing of regulations (as long as food safety requirements are met). There is notably a data shortage on the amount, quality and causes of food waste and losses at the household level.

1.3.3 Balancing Food Security and Climate Change: The Strategic Role of Climate-Smart Agriculture

According to FAO estimates, food production must increase by at least 70 % to meet the growing demands of a world population expected to surpass nine billion by 2050. Meeting that demand is further complicated by the world's changing climate, which poses severe risks to food security and the agriculture sector. Changing weather patterns can be expected to lead to increased temperatures and rainfall, severe droughts and flooding, shorter growing seasons, changes in ocean temperatures and fish stocks, heat stress on crops and animals, changes in disease patterns, and reduced crop yields. In addition, some poor developing countries could suffer disproportionately from climate change impacts because temperatures and precipitations are often already close to the tipping points beyond which crops fail or animals die, despite having contributed the least to GHG emissions. For example, Africa is responsible for a mere 4 % of global GHG emissions, but the potential impact of climate change on the African continent could be devastating. Here, an equitable share of long-term funding to help poorer nations deal with global warming (especially in terms of adaptation) is imperative.

Within this perspective, many studies and successful experiences have recently catalyzed thinking about the ways in which agriculture – which has a vital role in global food security, development and natural resources use – can and must be fully integrated into national strategies and a consensus-based multilateral framework to address the challenges of climate change (Elbehri et al. 2011). Consequently, it's increasingly believed that agriculture must become central to future climate-change and food security debate and governance. This is on account of at least three important interrelated reasons:

- *Firstly*, agriculture is the sector most vulnerable to climate change and many threats, including the reduction of agricultural productivity, production stability and incomes in many areas of the world already characterized by high levels of food insecurity and limited means of coping with adverse climate impacts.

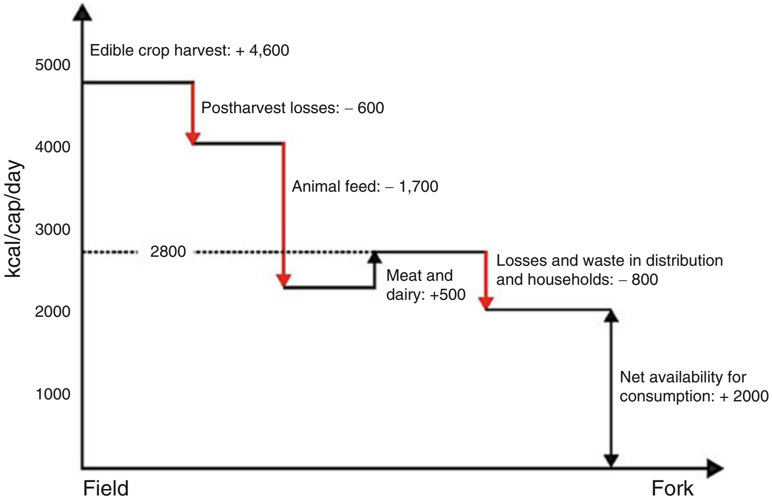

Fig. 1.3 From field to fork: estimation of food losses, conversion and wastage in global food chain (Source: Lundqvist et al. 2008) from Smil (2000)

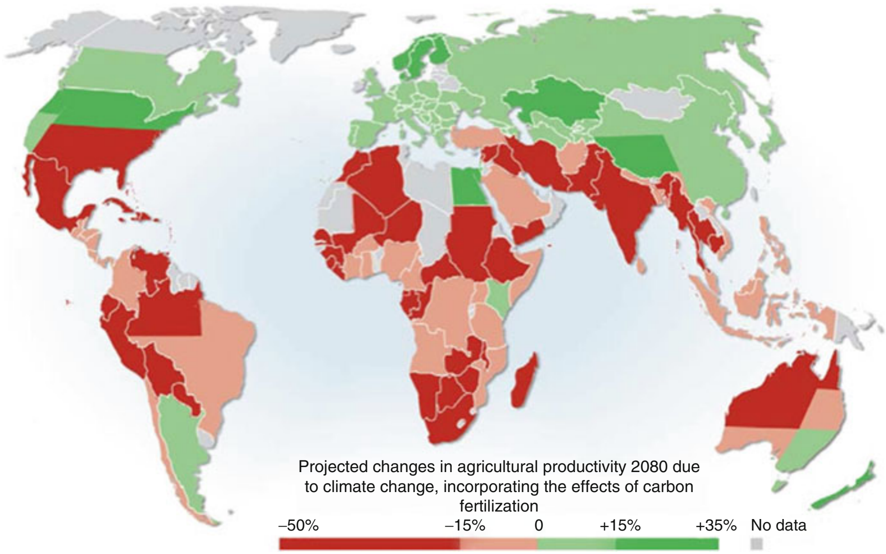

Fig. 1.4 Long-term projected changes in agricultural productivity, from 2007 to 2080 (Cline 2007)

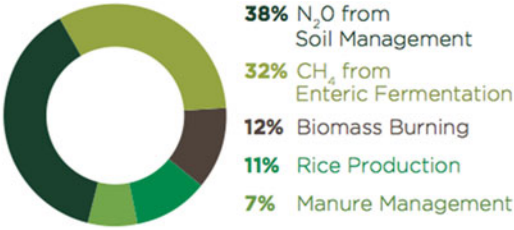

Fig. 1.5 Emissions in the agriculture sector (Source: IPCC 2007; Smith et al. 2008)

Moreover, climate change will affect agriculture through higher temperatures, greater crop water demand, more variable rainfall and extreme climate events such as heat waves, floods and droughts. Many impact assessment studies point to severe crop yield reductions in the next decades without strong adaptation measures, especially in areas where rural households are highly dependent on agriculture and farming systems are highly sensitive to inclement climate. The impacts of climate change on our ability to feed a growing world population are being robustly documented. Climate models indicate that rising temperatures may have a beneficial effect on crops in the temperate areas. Tropical and subtropical areas, however, may experience significant reductions in crop productivity in a long-term perspective, i.e., towards 2080 (Figs. 1.3 and 1.4).

- *Secondly*, agriculture is not only affected by climate change, but also contributes about 20 % of the GHGs which cause climate change (including land clearing). The two most harmful GHGs from agriculture are nitrous oxide from soils and methane from cattle, but carbon dioxide emission due to conversion of forests to cropland, is also important.
- *Thirdly*, agriculture can be a major part of the solution: enhancing food security while mitigating impacts of climate change (agriculture has the potential to capture a significant part of the excess atmospheric carbon in the soil in the form of organic matter). This mitigation potential can be largely achieved in developing countries. In addition, many potential adaptation measures are drawn from existing good practices that promote sustainable agricultural development: shifting crop rotation to optimize the use of available water; adjusting sowing dates according to temperature and rainfall patterns; planting crop varieties better suited to new weather conditions; and creating wind-breaks on arable land to reduce water and soil run-off (Fig. 1.5).

Based on the above reasons, it's needless to demonstrate the urgency of implementing measures which favour actions and policies that simultaneously address climate change mitigation and adaptation in agriculture while supporting development objectives and ensuring food security. In terms of mitigation, it is fundamental to rethink the ways agriculture is practiced in industrial economies. In developing countries, mitigation practices include conservation agriculture, organic agriculture and greater reliance on renewable energy for domestic use in rural households . Finding ways to reduce reliance on chemicals and synthetic fertilizers and creating incentives to promote the use of renewable energy throughout the modern agricultural systems is of the utmost urgency and requires concerted policy action.

In terms of adaptation to climate change, potential strategies should be multi-dimensional, ecological and socio-economic. Much agricultural adaptation occurs autonomously at the local level as farmers adjust their planting systems to climatic change. Planned adaptation occurs at the sectoral and national levels and includes policies such as addressing changes in food insecurity, identifying vulnerabilities, re- assessing agricultural research priorities, and strengthening agriculture extension and communication systems. Planned action on climate change adaptation should build on, coordinate with, and remove impediments to autonomous local adaptation, while pursuing sector-level and long-term adjustment (Elbehri et al. 2011).

In addition, adaptation of the food system will require complex social, economic and biophysical adjustments to food production, processing and consumption. Such changes will be most difficult for the poorest and most vulnerable regions and populations. Moreover, climate change models suggest that severe effects are likely to be felt in tropical regions, especially the expected further drying of the arid tropics. Many of the poorest countries are found in these regions and hence the nations least able to adapt may be the most affected. Any hope of making substantial progress on the poverty and hunger Millennium Development Goals thus requires successful adaptation in least-developed countries. But all countries will eventually be challenged by climate change (HLPE 2012).

1.3.4 Collect Information Locally, Share Knowledge Globally, and Refocus Research to Address a More Complex Set of Objectives

The information base available to facilitate policy and program developments to reduce the food security effects of climate change is awfully inadequate. National governments need to improve their efforts. But there is also a need for international data gathering on climate change and its effects to improve information on vulnerable communities, populations and regions.

Local lessons learned can be made much more valuable when shared. The knowledge already gained by farmers about practices that work in their conditions today could prove invaluable to farmers elsewhere in the future. But some consequences of climate change are outside the realm of recent human experience and focused, systematic data generation efforts are needed to develop effective response efforts. Because the benefits cross national borders, knowledge gathering and sharing requires global coordination as well as national programs.

A major increase in the quality and quantity of the biophysical, economic and social data available to policy makers is required. Particular challenges include:

- linking existing and future data sources using global metadata standards;
- making use of modern technology (ICT, remote sensing) to harvest real time data;
- enabling disaggregated data collection, including at the intra-household level, to identify drivers of social vulnerability to food security and challenges to mitigation and adaptation; and
- improving the pipeline from data gathering, analysis and feeding into policy making (HLPE 2012).

1.4 Conclusions

Plausible climate and socio-ecological change scenarios can be invaluable tools in developing appropriate response options for ensuring food security and human wellbeing in the future. Climate change effects on the vulnerable are significant but are by no means the only threats to sustainable food security. Sustainable development efforts that lead to broad-based economic growth are essential to addressing the needs of vulnerable people and regions. Given the uncertainties in local and regional outcomes of climate change, policies and programs that are based on specific climate scenarios could potentially be counterproductive. Rather, efforts should be based on activities that provide both sustainable economic growth and increase resilience to a wide range of potential climate change threats.

Humans have had to adapt the way they produce, process and consume food to changing circumstances since agriculture came into existence after the last ice age. The challenges – and opportunities – posed by climate change thus need to be seen in the context of the ever changing biophysical and socioeconomic environment within which the now globalized food system exists. However, the need for the food system to adapt to climate change has several unique features. First, climate change will affect the whole globe so all food production systems will need to make changes. Second, adaptation will need to occur at a time when the food system is suffering many other pressures: for example increased demand from a larger and wealthier global population, increasing competition for water, land and other inputs, and almost certainly higher – and more volatile – energy prices.

Adaptation of the food system will require complex social, economic and biophysical adjustments to food production, processing and consumption. Such changes will be most difficult for the poorest and most vulnerable regions and populations. Moreover, climate change models suggest that particularly severe effects are likely to be felt in tropical regions, especially the expected further drying of the arid tropics. Many of the poorest countries are found in these regions and hence the nations least able to adapt may be the most affected. Any hope of making substantial progress on the poverty and hunger Millennium Development Goals thus requires successful adaptation in least-developed countries. But all countries will eventually be challenged by climate change (HLPE 2012).

Climate-change adaptation starts from an assessment of risks and vulnerabilities of a specific system, of how climate change will modify them and what impact it will have on food security. There is seldom a single best way to adapt. And adaptation does not necessarily require new technologies, but is often mobilizing existing practices and resources in a different orientation. Adaptation can require substantial changes in the food system and therefore will need to build on comprehensive approaches.

Climate-change adaptation will certainly require new practices and changes in the livelihood strategies of most if not all food producers as well as other actors throughout the food chain. But the changes required are more systemic and must involve farmers, retailers and intermediaries in the food chain, agri-business, the financial sector and civil society. It will require action and oversight by governments, international organizations, and civil society organizations concerned with food security and sovereignty,[1] hunger and sustainable development (HLPE 2012).

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[1] Food sovereignty is defined as “the right of peoples and sovereign states to democratically determine their own agricultural and food policies” (IAASTD 2008).

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Chapter 2
The Meat Crisis: The Ethical Dimensions of Animal Welfare, Climate Change, and Future Sustainability

Joyce D'Silva

Abstract The Meat Crisis is not the lack of meat to feed an increasingly carnivorous human population, but the absolute impossibility of sustaining the earth if we do not begin to limit our consumption of animal products. This paper explains why there is a crisis and it also offers equitable policy options to deal with this crisis. Most human activities have an ethical dimension. In farming, there are ethical issues regarding care of the soil and natural resources. Livestock farming carries an extra ethical dimension as it deals with the lives and well-being of other sentient beings. In view of the threat from livestock-related greenhouse gas emissions (GHG), it is important that agriculture adapts and mitigates its negative impacts. Some promote the view that industrialisation of livestock farming is the best way forward. However this proposed partial solution is myopic and totally fails to take account of the growing body of scientific research on the health and welfare of farm animals. The ethical question may be: Is it right to push farm animals to ever greater levels of productivity if this undermines their well-being? Seeking ever greater levels of productivity of meat and dairy products may also lead to adverse health effects on humans from over-consumption. Increasing the levels of obesity and allied diseases such as Type 2 diabetes, colon cancer and heart disease may place a great strain on the health systems of developing countries. In fact greater productivity and increased consumption are at the root of the unsustainable Meat Crisis. To overcome this crisis we need to seek ethical answers that promote agricultural systems in order to benefit the environment, protect the welfare of animals and produce health-giving products for our populations.

Keywords Climate change • Environment • Ethics • Farm animal welfare • Greenhouse gas emissions (GHGs) • Human health • Industrialisation • Livestock farming • Sentient beings • Sustainable agriculture • Water

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J. D'Silva (✉)
Compassion in World Farming, River Court, Mill Lane, Godalming, UK GU7 1EZ
e-mail: joyce@ciwf.org

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2.1 Introduction

The Meat Crisis is not the lack of meat to feed an increasingly carnivorous human population, but the absolute impossibility of sustaining the earth if we do not begin to limit our consumption of animal products. This paper explains why there is a crisis and it also offers equitable policy options to deal with this crisis.

Like any other human activity, farming can be measured in many different ways. We can measure its economic effects on both individual farmers, on agribusiness companies and on national agricultural exports and Gross Domestic Product (GDP). We can of course measure the amount of crops grown and compare yields with previous years or nearby farms.

We can measure a farm's purchase and use of global resources, such as crops for animal feed, nitrogenous fertilizers and chemicals used as pesticides or herbicides. More especially we might want to measure the water footprint and water use of the farm.

We can measure farming's environmental impact: the amount of pollution it causes locally or further afield. For example, we could measure its impact on the soil – does it enrich the soil with organic matter or denature the soil with artificial fertilizers? We can measure any leakage of slurry effluent or fertilizer run-off into local streams, lakes and rivers. We may be able to calculate how much greenhouse gas is released, influencing climate change, or how much ammonia, which can lead to acid rain.

There is another way we can assess farming activity: we can give it an ethical assessment. If farm workers are not paid a living and fair wage, we could say this particular farm was operating an unethical business. If the farmer was purposely allowing polluting effluents to run into the local river, we could say this was unethical behaviour as it would harm others.

When we rear animals on our farms we have a whole new ethical dimension to add. Animals are sentient beings, that is, they are capable of enjoying their lives and are also capable of suffering. So if a farmer mistreats their animals, then we would say that this was unethical behaviour.

Traditional small-scale farmers have always been aware that their animals can suffer. Generally they have done their best to treat the animals well. They may have done this as it was in their economic interest to do so, but also probably because they could recognise emotions like fear and reaction to pain in their own animals and they tried to avoid causing suffering to them. It is vital that we investigate food production methods which support the livelihoods of small scale farmers, reduce pollution, protect and if possible enhance the environment, protect the wellbeing of animals and produce food which is positive for human health.

2.2 Climate Change

With around 18 % of anthropogenic greenhouse gas emissions (GHGs) attributed to livestock production (Steinfeld et al. 2006), livestock farmers urgently need to limit the emissions from their production systems.

To achieve this goal, farmers need to know where these emissions come from. We know that some come from the natural digestive processes of animals, in particular from ruminants such as sheep, goats and cattle. These animals release methane, one of the most potent GHGs, into the air. In addition further GHGs are emitted from the animals' manure. However, many of the total livestock farming GHG emissions come from processes that may be external to the farm in question. They may come from the cutting down of rainforest to grow soya for animal feed, which is then imported and used on the farm.

Further emissions, largely of highly toxic nitrous oxide, come from the nitrogenous fertilizers used to grow crops for animal feed, whether on the farm where the animals are reared or on a distant farm in another continent (Steinfeld et al. 2006),

How we respond to climate change is an ethical issue. If we cannot curb climate change, then the future of life on earth, as we know it, could become impossible. Farmers, along with all global citizens, need to curb both their lifestyle emissions and the emissions associated with their job/profession.

There are many as yet unanswered questions about how best to reduce emissions from livestock farming. Keeping ruminant animals on pasture is beneficial as pasture land acts as a carbon sink, with carbon being sequestered in the soil (as long as it is not ploughed up).

Others have proposed more high-tech solutions, such as keeping dairy cows in completely enclosed, air-conditioned sheds, where the methane is extracted and used as biogas. Other solutions involve changing the animals' feed. Grass-based animal diets tend to produce more methane than grain-based diets, so adding more grain and less forage to the feed may reduce methane output.

Apart from being expensive to introduce, both these suggested "solutions" have major drawbacks for the animals themselves. Cattle are ruminants and their natural environment is outdoors, preferably with grass to graze. Obviously in very cold or very hot weather they will need shelter or shade. But keeping a four-legged animal in a confined indoor environment where they never get to exercise their limbs is surely going to cause the animals a prolonged degree of frustration and possible ill-health (EFSA 2009a). As such it should be regarded as unethical.

In 2009 the European Food Safety Authority (EFSA) produced a series of expert Opinions and Reports on the welfare of dairy cows. One of these makes clear that permanent indoor housing is bad for cows, saying: "If dairy cows are not kept on pasture for parts of the year, i.e. they are permanently on a zero-grazing system, there is an increased risk of lameness, hoof problems, teat tramp, mastitis, metritis, dystocia, ketosis, retained placenta and some bacterial infections" (EFSA 2009b).

Changing from a forage-based diet to a grain-based diet may reduce methane emissions from cattle, but cereals and soya are not the natural food of cattle or sheep. Such foods can be used as part of the animals' ration, but using too much is likely to promote acidosis in the digestive tract. This in turn can weaken the animals' feet, making them more prone to painful lameness conditions. Unethical again!

2.3 Resource Use

Traditional small-scale farmers often keep just a few animals, many of whom may roam freely, such as chickens scavenging for most of their food. Pigs too are good scavengers. Goats can be very destructive of the local environment, stretching or jumping up to eat the leaves of trees. As a result they are often tethered and their food is brought to them. Tethering can cause welfare problems. Cattle may roam, but if there is insufficient grass, they will need further forage cut and brought to them or extra cereal feeding.

In the large factory farms of global agribusiness there is little opportunity for scavenging or indeed grazing. The animals are kept indoors or in huge outdoor mud yards. In the USA the indoor farms are called CAFOs – Concentrated Animal Feeding Operations – and the outdoor mud yards are called feedlots. Note that the definition of each system is based on feeding the animals, not nurturing them in the traditional sense of caring for them. The feed is a mix of cereals, soy and processed forage, with the non-forage component kept at a high level to encourage swift, meaty growth or high yield of milk.

Not only are such diets harmful to the animals' health and well-being in the long run, but they are using cereals and soya grown on land which could have been used for growing crops for direct human consumption. Already nearly 40 % of global cereals and over 90 % soya are grown for animal feed (Lundqvist et al. 2008; Steinfeld et al. 2006).

In a world where around one billion people go to bed hungry at night, it seems very unethical to be using so much of the earth's productivity to feed animals raised for meat and dairy. It could only be justified, if the animals produced more in output than was fed to them. Sadly this is not so. With industrial intensive farming, research shows that to get 1 kg edible beef you need to give the animal 20 kg feed. For pigs the figure is around 7.3 kg feed and for chickens around 4.5 kg (Smil 2000). This means that much of what we feed to animals is in fact wasted from the point of view of feeding the world.

Right now many people are rightly concerned with post-harvest losses in the developing world. It is vital that farmers are helped to have safe storage for their harvested grains. In developed countries, there is great concern at the amount of food wasted by consumers who buy too much food, allow it to rot and then throw it away. But little attention has been given to the even greater losses associated with the wastage of feed-stocks fed to livestock in order to produce meat. The UN Environment Programme has calculated that the cereals that are expected to be fed to livestock by 2050 could, if they were instead used to feed people directly, provide the necessary food energy for 3.6 billion people (Nellemann et al. 2009).

It seems unethical to feed so much precious cereal and soy to animals when people are going hungry.

The other priceless global resource is water. Animal products have a much larger water footprint per kilogram or per calorific value than crop products. The world's leading water footprint expert, Professor Arjen Hoekstra calculates the water footprint of 1 kg of beef as around 15,500 l, although grass-fed beef carries a lower footprint. Sheep meat comes in at 6,100 l per kg, pork at 4,800 l, with chicken and goat meat at around 4,000 l per kg. This compares with 1,300 l per kg of wheat, and 900 l per kg of maize (Hoekstra 2010).

Professor Hoekstra urges governments and food companies to take measures to reduce the water footprint of our diets and to inform consumers so that they are able to cut their individual dietary water footprint (Hoekstra 2010).

If we look at the water requirements of individuals for hygiene, cooking etc., we can see that an individual's water needs for a year, 18,500 l, are only a little greater than the water footprint of 1 kg of industrially produced beef! (Liu and Saveniji 2008).

Once again, ethical issues regarding the long term sustainability of the earth we live on means we need to address our growing consumption of meat and dairy products, especially those produced in industrial, factory farms.

The UK Government's Office for Science published a major Foresight Report in 2011 on "The Future of Food and Farming". Authored by experts from around the world, the Report advises that policy makers need to consider "regulatory and fiscal interventions to introduce disincentives for the types of livestock production most responsible for the identified negative outcomes; and secondly, consider the full spectrum of options for demand modification to reduce consumption of the most damaging types of meat in high- and middle-income countries where consumption is highest" (Foresight 2011).

The Foresight report concluded "Demand for the most resource-intensive types of food must be contained", adding that "major increases in the consumption of meat, particularly grain-fed meat, would have serious implications for competition for land, water and other inputs" (Foresight 2011).

In addition, if we look at the well-being of the industrially farmed animals themselves, we can see that viewing them solely as production units has had profound and adverse impacts on their health and welfare.

2.4 Animal Health and Welfare

One of the hidden scandals of industrial farming is the breeding of farm animals for ever higher levels of productivity. We have pushed many breeds to the brink, with serious adverse effects on the animals' metabolism and making them so stressed that their own immune systems are weakened and they become more vulnerable to disease. FAO points out the loss of biodiversity with breeds in danger of disappearance.

A prime example is the modern broiler (meat) chicken. Most of the breeds of chicken used throughout the world are controlled by just three major international breeding companies. They have bred these chickens to reach their slaughter weight ever more quickly, in order to increase annual productivity and profit. The chickens now reach slaughter weight in 35–41 days, around half the time they took just 40 years ago.

In a 2010 Scientific Opinion, the European Food Safety Authority (EFSA) stated that this marked increase in growth rate is largely the result of genetic selection. It stresses that "it is generally accepted that most of the welfare problems [of broilers] are caused by genetic factors" (EFSA 2010). The Opinion points out that there is an increased mortality associated with faster growth rates whereas slower growth rates have a lower mortality.

One way to measure chicken lameness is to "gait score" the way the chickens walk. This is measured on a scale from 0 – normal walking – to 5 being severe lameness. A study into broiler chicken lameness, commissioned by the British government, found that on average 27.6 % chickens had a gait score of 3 or higher, i.e. lameness that is likely to be painful, and that a major risk factor was the breed of the birds. Some of these chickens had difficulty reaching the food and water points in the broiler sheds; in the worst cases they could barely move at all. Only 2.2 % had no walking problems (a 'gait score' of 0) (Knowles et al. 2008).

These fast-growing broiler chickens also develop other metabolic-related diseases such as ascites, where their chest cavity fills with liquid, and Sudden Death Syndrome, where they literally drop dead.

Backyard chickens, often of strong native breed, can walk, run and even fly up into trees to perch, but the fast-growing commercial chickens are no longer able to fly or run and spend most of their time sitting on the floor, where the litter material can become wet or sticky unless it is managed well. This lack of exercise can lead to leg weakness and skin sores, which is a widespread problem in broiler chicken farms. In severe cases the sores develop into painful ulcers. It is a sad reflection on industrial farming that sitting down is now the main behaviour for fast-growing broiler chickens. Such industrial conditions are ideal breeding grounds for bacteria. Most industrially produced chickens are not only routinely immunised against a host of infectious diseases, but are also given antibiotics on a routine basis in order to prevent infection. This over-use of antibiotics in livestock farming is contributing to the global problem of antibiotic resistance (in both humans and animals) (Compassion in World Farming 2011).

It does seem ethically unacceptable to intentionally breed chickens who grow so fast that they are highly likely to suffer painful conditions like lameness and appear predisposed to a range of sometimes fatal health conditions.

The other big problem in the poultry industry is the dependence of many countries on imported inputs: feed (mainly soya and maize), genes (as only three companies effectively manage the selection of birds) and other materials (feed additives, veterinary treatments, etc.). This may create a situation of vulnerability, as the cost of poultry meat production may become more and more volatile because of the volatility of the price of inputs.

We can see the impact of breed on the modern dairy cow too. In the developed world, many dairy farmers use the high-yielding Holstein breed of cow, either pure-bred or an animal with significant amounts of Holstein in her genetic make-up. Holstein cows have long, lean bodies and can produce astonishing amounts of milk. Over a 30 year period, these cows have been bred to double their milk yields and they can now produce over 50 l a day, which equates to 10,000 l a year, probably about 10 times more than calves would drink from their mothers.

What does this doubling of milk yield mean for the cows themselves? To sustain this level of production, they have to spend most of the day eating. Any time for rest or socialising with other cows is severely limited. They have, in effect, become milk production machines. Worse still, they require large amounts of cereals and soy to sustain their milk yield. Often these feed-crops cannot be grown on the farm and are imported, frequently from another part of the world, such as soy from Brazil, which is exported to Europe, China and other countries. In Brazil, for example, this has resulted in a huge expansion of soy production, resulting in cattle grazing being pushed ever further into the forest and the environmentally-sensitive Cerrado area (Greenpeace 2006; Conservational International 2008).

But cows are ruminants and their digestive system is designed to function well on a grass-based diet, high in forage. Eating lots of cereals causes too much acidity in their gut and this in turn can cause lameness in their feet.

Professor John Webster, a leading global expert on dairy cows, declares lameness is a 'severe problem' for cows. A survey of thirty-two dairy farms showed a mean annual incidence of lameness of 54.6 new cases of lameness per 100 cows (Clarkson et al. 1996). Webster adds that the number of cows with lameness problems in a dairy herd is likely to exceed 20 % (Webster 2005).

The actual shape of these cows has also been altered to give an ever-larger udder so that she can produce more milk. This is also one of the contributory factors to increasingly high levels of mastitis, painful udder inflammation. A wide-ranging investigation into the incidence of mastitis in dairy herds estimated 47 – 65 cases of mastitis per 100 cows per year as the likely average (Bradley et al. 2007).

A major review of the scientific literature by EFSA concluded that "Long term genetic selection for high milk yield is the major factor causing poor welfare, in particular health problems, in dairy cows" (EFSA 2009b).

So when higher levels of productivity are called for as an answer to the greenhouse gas problem, we need to be careful. Very high levels of productivity can have severe adverse effects on the health and welfare of farm animals. Whilst better feeding of an undernourished dairy cow is obviously a good thing, we should look carefully at the actual breed of the animals and the content of their feed. We should favour hardy, local breeds, which are adapted to the environment and have better levels of resistance to local diseases.

Ethical farming also means we need to examine closely the environments in which we keep animals. All animals need plenty of space in which to walk around as well as species-specific extras. For example, hens and chickens like to roost on perches, raised well off the floor. This is a behaviour inherited from their jungle fowl ancestors, who needed to keep away from predators, especially at night. Hens also like to lay their eggs in a comfortable and quiet nest. Keeping hens in cages frustrates these behaviours.

Pigs have highly sensitive snouts (the prominent nose/mouth area) and need to be able to root in the soil. If kept indoors, they need to have rooting material like straw or rice husks provided. Big factory farms for pigs often keep them on concrete or slatted floors, where their behaviour is frustrated and they are in a constant state of discomfort too.

Many breeding sows are kept in narrow individual sow stalls (gestation crates) throughout their 4- month pregnancies, unable to turn round. Fortunately this unethical system is being phased out by legal ban in the European Union, by government action in New Zealand, by popular vote in some US states and by industry action in South Africa and Australia.

In natural conditions, such as light woodland, the pigs would spend up to 50 % of their time using their snouts to root in the soil, seeking tubers and grubs to eat and another 23 % in foraging behaviour (Stolba and Wood-Gush 1989). Such behaviour is totally impossible in the confines of a concrete and metal-barred crate.

Some will say that if pigs are kept indoors, then it is easier to capture their effluent and convert it to biogas etc. But it is surely unethical to sacrifice the wellbeing of these sentient beings in order to remedy problems which we humans have caused.

There is another strong argument urging us to avoid the use of industrial-scale mega-farms, and that is the risk to human and animal health.

2.5 Healthy Food and Farming

The keeping of large numbers of animals in confined spaces facilitates the development and transmission of disease. A report by the FAO, *Industrial Livestock Production and Global Health Risks*, points out that industrial livestock production plays an important part in the emergence of highly pathogenic avian influenza and other diseases. Similarly, the US Council for Agriculture, Science and Technology has warned that a major consequence of modern industrial livestock production systems is that they potentially allow the rapid selection and amplification of pathogens (Otte et al. 2007).

Over the last decade, serious outbreaks of both avian flu and swine flu have demonstrated the potential threat to humanity from these viruses. Many believe that it is only a matter of time before one of these viruses mutates (probably in a factory farm environment) into a type which is highly contagious and probably fatal to humans.

The evolution and rapid spread of avian flu (H5N1) was a result of the activities of the poultry industry. It happened at a time of very rapid growth in poultry production worldwide, especially in Asia. Intensive large-scale poultry production accounted for much of this increase. The number of meat chickens slaughtered in China in 2005 (7.2 billion) was over 3 times as many as in 1990 and in Indonesia, the number of chickens slaughtered in 2005 had more than doubled since 1990. The percentage increase was 90 % in Asia as a whole and 50 % in Africa (FAOSTAT 2012).

The infection spread fastest in areas of highest poultry density, in both commercial and backyard farms and villages holding chickens and domestic waterfowl such as ducks and geese. A United States Department of Agriculture (USDA) report on the outbreak in Laos in 2005, reported that of the 45 outbreaks, 42 occurred on commercial poultry farms. Smallholders affected by the outbreak were all situated near large commercial holdings (USDA FAS 2005). Crowded conditions in intensive poultry farms allow the virus to circulate among large numbers of birds at close quarters and are believed to have a role in the mutation of 'low pathogenic' viruses to become highly pathogenic. Rapid spread may also be encouraged by the lack of genetic diversity of modern commercial poultry.

It's not only these dangerous viral diseases which emanate from livestock farms. Some of the most devastating infections affecting human health are also a result of foodborne illnesses. A 2011 US study ranked poultry products (nearly all of which in the US come from factory farms) as the worst offender in terms of effects on individual quality of life and costs. In the United States, poultry-related illnesses cause over $2.4 billion in estimated costs of human illness annually and the loss of 15,000 Quality Adjusted Life Years a year (Batz et al. 2011).

Large factory farms tend to address the problem of disease challenge by the regular preventive use of antibiotics, which is contributing to the emergence of antibiotic resistance. Some also administer antibiotics in the animals' feed or water in order to speed up growth still further. The more we over-use antibiotics in a routine fashion in either humans or animals, the more likely we are to increase the current dangerous levels of antibiotic-resistant bacteria, which can infect both us and the animals, sometimes with fatal results.

Bacterial infections are encouraged by the crowded and stressful conditions in which animals live in factory farms. When animals are administered an antibiotic that is closely related to an antibiotic used in human medicine, cross-resistance occurs and disease-causing bacteria become resistant to the drug used in human medicine. The consensus of the world's veterinary and medical experts is that it is dangerous and unjustifiable to use antibiotics that are related to drugs of critical importance in human medicine for 'preventive' administration to groups of apparently healthy animals. The world's public health experts, including from the World Health Organization, are agreed that drug-resistant bacteria are created in farm animals by antibiotic use and that these resistant bacteria are transmitted to people in food and then spread by person-to-person transmission (Compassion in World Farming 2011).

Antibiotic resistance leads to foodborne infections in humans that would not otherwise occur, that are more severe, last longer, are more likely to lead to infections of the bloodstream and to hospitalization, and more likely to lead to death. Severe infections by foodborne bacteria include life-threatening urinary infections and blood poisoning. Children are particularly likely to be infected by drug-resistant foodborne bacteria that have developed in food animals as a result of over-use of antibiotics.

The use in food animals of antibiotics that are critically important in human medicine is implicated in the emergence of new forms of multi-resistant bacteria that infect people: these include new strains of multi-resistant foodborne bacteria such as Salmonella, Campylobacter and E. coli.

The use of the important fluoroquinolone group of antibiotics in poultry production is implicated in the growth of worldwide resistance to fluoroquinolones such as ciprofloxacin that are important in human medicine (Compassion in World Farming 2011).

The over-use of antibiotics in intensive pig farming, including the important cephalosporin group, is implicated in the emergence of a new 'pig' strain of the superbug methicillin-resistant Staphylococcus aureus (MRSA), first identified in 2004–2005 in the Netherlands. This has spread rapidly among pigs in many European countries, to people who are in contact with the animals, and from these people to the community and to hospitals (Nunan 2007).

Of course individual animals or groups of animals who are ill should receive antibiotics if they are the appropriate treatment option, but these vitally important drugs should never be used in a routine way (in animals or humans). Governments should apply strict controls on their use and they should only be prescribed by a veterinary practitioner and should not be available for over-the-counter sale.

In developing countries, the use of antibiotics in smallholder farms, mainly in dairy herds, is bringing many problems to the supply chain. It is difficult to identify the farms that do so, as batches of milk from numerous smallholders are mixed in cooperative collection centres. Therefore, one single batch of some litres of milk may contaminate the whole quantity of milk delivered by various farmers. The milk industry's response to date has been to penalise the whole community of farmers by refusing to pay their daily deliveries. This demonstrates the need for better training of farmers, no matter where they are, in quality care of their animals so that antibiotic use can be minimised. The milk industry also needs to help farmers in a more positive manner and assist them via training and auditing, rather than penalising people who may already be struggling financially. The other health issue related to the whole question of livestock production is the question of consumption. How much meat and dairy is good for us?

In poorer developing countries, where protein intakes are too low, eating some meat and dairy products is likely to be a sensible addition to the diet. However in the developed world, and in urban areas of transition economies like China, meat consumption has reached levels which can be highly detrimental to good health. The World Cancer Research Fund and the World Health organisation have all begun to address this issue.

> Whilst consumption of meat, eggs and milk can be a useful source of protein in the diet, particularly for those with low nutritional status, high levels of consumption can have adverse effects on human health. The twentieth century change from more plant-based diets to energy-dense diets, high in fat and animal foods, has played a key role in the upsurge in diet-related, preventable health problems and diseases, from obesity to type 2 diabetes, many types of heart disease and some cancers. Rates of these diseases are now growing rapidly in the developing world as western-style diets become more common (Robertson 2001).

A group of leading public health specialists published a paper on this in 2007, saying: "Recent estimates from public health experts suggest that a reduction of around 60 % in daily intake of meat in developed countries would help reduce excess weight and obesity and offer other health benefits to individuals and society" (McMichael et al. 2007).

Although it is impossible to be specific about the contribution of animal products to levels of obesity, it is clear that a high percentage of the saturated fat content of the average Western diet is obtained from animal sources. One study has identified meat, dairy foods, eggs and table fats and oils as contributing 63 % of the total fat, 77 % of the saturated fat and 100 % of the cholesterol consumed by Americans (Nestle 1999).

Margaret Chan, Director General of the WHO has written "reduced consumption of animal products in developed countries would bring public health benefits" (Chan 2009).

The 2007 Report from the World Cancer Research Fund (WCRF) recommends that we should "eat mostly foods of plant origin" and "limit intake of red meat (beef, lamb, pork) and processed meat" (bacon, ham, etc.), as these two types of meat "are convincing or probable causes of some cancers". The link to colorectal cancer is "convincing". The Report recommends that those who eat red meat should eat no more than 500 g a week – around 71g per day (WCRF/AIRCR 2007).

A further study from the US National Institutes of Health shows that those who eat a lot of red and processed meat have a 20 % greater risk of developing colorectal cancer and a 16 % increased risk for lung cancer plus increased risks for oesophageal and liver cancers (Cross et al. 2007).

Sadly, as the western high meat and dairy diet continues to permeate the diets of the middle classes in developing and transition countries, it is likely that illnesses associated with hunger and under-nutrition will be replaced by a growth in illnesses associated with over-consumption, including over-consumption of meat and dairy products.

2.6 Conclusion

The Meat Crisis is not then, the lack of meat to feed an increasingly carnivorous human population, but the absolute impossibility of sustaining the earth if we do not begin to limit our consumption of animal products.

Food accounts for 23 % of humanity's ecological footprint (WWF 2011). It has been estimated that if the entire human population lived as the typical North American, including a meat-heavy diet, we would need five planets the size of earth – one could add that we would need the water from those planets too (WWF 2011).

Suddenly, how we farm animals and the numbers we farm becomes a vital global issue. Equally the amount of animal products we all consume becomes not just an issue of taste preference or income/economics but a global ethical issue of huge importance.

We need to seek ethical answers which promote agricultural systems which benefit the environment, protect the welfare of animals and produce health-giving products for our populations.

There are ethical imperatives here: we must protect the fragile earth on which we live; we must use its resources wisely, probably frugally, and well. We must respect the animals whom we raise to produce meat, milk and eggs for us, as they are sentient beings, deserving of good treatment and a decent quality of life. Finally we owe it to ourselves and future generations (not to forget the health burden placed on our countries which could be avoided by healthier eating) to moderate our consumption of animal products if we fall into the category of high consumption.

All these areas of ethical concern can be addressed – and should be addressed – at both individual level and also at policy level. For too long, governments have based their livestock policies on the presumption that "more is better". With so much clear and mounting evidence that this is not so, new policies for truly sustainable and humane livestock farming need to be developed, with animals being seen not only as sentient beings, but also as consumers of the earth's resources (just as we are!) and as playing an impactful role in the local and global environment. Governments and international policy organisations and investment banks must also have the courage to address the issue of consumption. Healthier diets, lower in animal products, need to be advocated strongly and supported by educational campaigns, better labelling and possible tax measures to reduce consumption.

If we all get it wrong about the Meat Crisis, then it will develop into an even more threatening environmental and health crisis; if we get it right, then we can look forward to a greener world, where fewer animals are farmed, but in better conditions, and where consumption of their products is valued at its true cost. Then we can anticipate truly sustainable levels of production and consumption and a planet worth handing on to future generations.

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Chapter 3
Dietary Options for Climate Change Mitigation

Tozie Zokufa

Abstract With global warming on everyone's agenda and livestock production responsible for 18 % of global greenhouse gas emissions, we are beginning to understand our symbiotic relationship with the environment. Conventional farming makes unsustainable demands on natural resources of land and water, is a pollutant, and a danger to human health in terms of antibiotic resistance and over-consumption. Better diet choices have to be made to positively affect an individual's carbon footprint. This paper investigates why the City of Cape Town has endorsed Compassion in World Farming's campaign for One-Meat-Free-Day-A-Week.

Keywords Diet • Consumption • Greenhouse gas emissions • Climate change • Factory farming

3.1 Introduction

The City of Cape Town acknowledges that climate change is real and needs urgent attention from all and should not be procrastinated for future generations to attend to it. This paper looks at the production of ruminant products and its impact on climate change and animal welfare. It is in humanity's interest to conserve and protect our environment and its inhabitants. Governments and corporates currently are developing policies addressing the mitigation of greenhouse gases (GHG), however there is an aspect of mitigation that is not adequately and thoroughly entertained, i.e. our excessive consumption of animal products. The challenge facing developing countries is to find equilibrium between population growth, increasingly affluence and food security. This study was based on an extensive

T. Zokufa (✉)
Compassion in World Farming, P.O. Box 825, Somerset West, Cape Town, Republic of South Africa 7130
e-mail: tozie.zokufa@ciwf.co.za

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review of the literature on livestock GHGs and its impact on climate change and animal welfare. Recommendations and a call to fight climate change through changes in our plates are addressed.

3.2 Livestock Production Impact on the Environment

While the production and consumption of all foods contributes to GHG emissions, it is increasingly recognised that livestock's (ruminants) contribution to the food total is particularly significant. Projected changes in climate during the twenty-first century will occur faster than in at least the past 10,000 years with predominantly adverse consequences for developing countries and poor people within them. Animals have traditionally played an important role in agriculture, not only as a source of food but also as a way to recycle nutrients and build soil organic matter. Their manure deposited on croplands or rangelands helps build the fertility of the soil. In recent decades, however, industrial agriculture has increasingly separated animals from the land. More and more meat production is occurring in concentrated operations commonly called factory farms, where animals are confined to inadequate space and cannot exercise their natural behaviour.

There is a noticeable rise in urban densities of developing countries, where in most societies there is increasing affluence, coupled with global population growth which intensifies consumer demand for livestock-derived protein. For example in 1970 the Chinese population consumed 4 kg of meat per capita per year compared to the 54 kg per capita per year in 2009. An average American consumed 194 lb of red meat and poultry in 1970 compared to the 221 lb in 2005. Currently, livestock is one of the fastest growing agricultural subsectors in developing countries and its share of agricultural GDP is already 33 % and is rapidly increasing. This growth is driven by the rapidly increasing demand for livestock products; this demand is being driven by population growth, urbanization and increasing incomes in developing countries.

The developed countries have adopted methods of farming to meet the increased demand in meat and other animal derived proteins. However the intensification systems adopted have had negative impacts on the environment and the welfare of animals. The standard Western diet, which is heavy on meat and light on vegetable intake, is taking a significant toll on the environment. Socioeconomic development over this century will greatly alter production, trade, distribution and consumption of food products worldwide, as a consequence of population growth, economic growth, and diet changes in developing countries. Demand for meat and meat products in developing countries has increased with the increase in middle/working class communities. Affluent citizens in middle- and low-income countries are adopting similar high-meat diets although possibly these trends can still be influenced towards meat preferences which are beneficial to both health and climate, before they turn into hard-to-change traditions. One study that examined this growth in consumption found that the gap between developed and developing

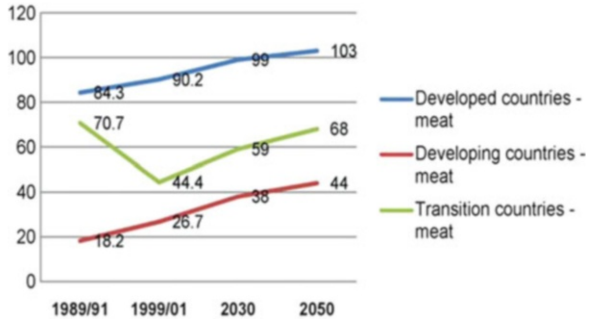

Fig. 3.1 Projected trends in per capita consumption of meat products to 2,050 kg/ person/year (Source: World agriculture: Towards 2030/ 2050)

countries will remain even in 2050 (see Fig. 3.1 above). Developing countries have a major role to play in this sector, where they can lead the way in sustainable and humane agriculture.

The share of animal products in the diet has increased consistently in developing countries, whilst growing more slowly in developed countries. Economic growth and changing lifestyles in some developing countries, most notably in China, are causing a growing demand for meat and dairy products. Meat demand in developing countries rose from 11 to 24 kg per capita per year during the period 1967–1997, achieving an annual growth rate of more than 5 % by the end of that period. A consensus has emerged that developing countries are more vulnerable to climate change than developed countries, because of the predominance of agriculture in their economies, the scarcity of capital for adaptation measures, their warmer baseline climates and their heightened exposure to extreme events.

3.3 The Plate-Climate Debate by Developing Countries

Through burning of fossil fuels and eradication of forests, human activity has caused the carbon dioxide (CO_2) concentration of the atmosphere to increase by some 25 % since the industrial revolution, and that increase continues. Aspects of globalisation are jeopardising health by eroding social and environmental conditions, exacerbating the rich-poor gap, and disseminating consumerism. In the developing world the rate of intensive animal production is increasing at a rate of 4 % per annum. Worldwide, greenhouse-gas emissions from agriculture are estimated to exceed those from power generation and transport. Methane (CH_4) and nitrous oxide (N_2O), combined, are more important emissions from this sector than is carbon dioxide.

Methane is a potent greenhouse gas whose full contribution to climate change has recently been re-assessed as being more than half that of carbon dioxide. Greenhouse gases, primarily methane, carbon dioxide, and nitrous oxide, are given off by the animals during the digestion process. Worldwide, agricultural activity, especially livestock production, accounts for about a fifth of total greenhouse-gas emissions, responsible for 60 % of the emission of these gases, thus contributing to climate change and its adverse health consequences, including the threat to food yields in many regions. Policy attention should be paid to the health risks posed by the rapid worldwide growth in meat consumption, both by exacerbating climate change and by directly contributing to certain diseases. To prevent increased greenhouse-gas emissions from this production sector, both the average worldwide consumption level of animal products and the intensity of emissions from livestock production must be reduced. The Livestock, Environment and Development (LEAD) Initiative has identified the livestock sector as a major player in climate change, responsible for 18 % of GHG emissions measured in CO_2 equivalent. Livestock production is responsible for 37 % of global methane emissions, 65 % of global nitrous oxide emissions and 9 % of carbon dioxide emissions. In 2005, agriculture accounted for 60 % of nitrous oxide and 50 % of methane. There is an estimated increase of between 30 and 65 % of nitrous oxide by 2030 due to increase in manure production by animals of global anthropogenic emissions. The Middle East and North Africa and Sub-Saharan Africa will experience the highest growth, with a combined 72 % increase in emissions during the period 1990–2020 particularly in South-central Africa (including Angola, Zambia, DRC, Mozambique and Tanzania), with a consequent increase in GHG emissions. On the other hand overproduction will only exacerbate the damage to food production and the environment due to global warming. Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. In some countries, yields from rain-fed agriculture could be reduced by up to 50 % by 2020. Climate change is projected to impinge on sustainable development of most developing countries of Asia as it compounds the pressures on natural resources and the environment associated with rapid urbanization, industrialization, and economic development

3.4 Impact on the Duty to Care

In this sub-section the researcher highlights the negative impact industrial agriculture has on the animals. Firstly, ruminants would be fed grain instead of grass and pigs and chicken would be crammed in inadequate spaces where they cannot perform their natural behaviours, e.g. stalls for sows and battery cages for hens respectively. Hundreds of thousands are packed tight together in factory farms far from the public's view. In these conditions they are subject to a number of chronic and production-related diseases due to high level of stress. Antibiotics are routinely administered. The crowded conditions in factory farms, as well as many of their production practices, raise ethical concerns about the inhumane treatment of animals and consumers are starting to ask questions about the source of their meat. Mentz states that feedlots tend to rape all of the ethical norms relating to the housing and treatment of cattle. Secondly transport, where animals are transported for long hours between cities or countries and in some instances days on a ship, e.g. from Australia to the Middle East. Thirdly would be slaughter, where there is inadequate legislation on humane methods of slaughter and/or policing thereof. As production intensifies in developing countries, concerns over animal welfare will surely surface. Evidence for this is suggested by cultural attitudes toward cows in India, by the strong religious views on ritual slaughter held in many parts of the world, and by the esteem that traditional stock raisers everywhere hold for their cattle. In South Africa consumers have complained to National Consumer Commission about the processes involved in animal production.

3.5 Mitigation

A reduction in the consumption and production of meat and other animal products would create a space for farmers to farm extensively and therefore create a better environment for farm animals. The soil would act as a carbon sink, hence the endorsement of a One-Meat-Free-Day-A-Week by the mayor of Cape Town. Globally total GHG emissions must be reduced by at least 80 % by 2050, so it is vital that policy and research focus on reducing emissions. Improved management practices and emerging technologies may permit a reduction in emissions per unit of food (or of protein) produced. One study investigated organic agriculture which is often ignored in discussions of climate change mitigation, but is worth considering. Barron states that in France, for instance, it has been estimated that a national conversion to organic agriculture could possibly decrease greenhouse gas emissions by 10 % including: carbon sequestration (−4 % from increasing carbon in soils of 7–10 million tonnes per year); nitrous oxide (−3 % from organic soil management); methane (−1 % from enhanced manure management); carbon dioxide (−2 % from no use of chemical fertilizers and decreased transport and greenhouse cultivations) and organic agriculture is also known to be more animal welfare friendly.

However others argue that intensification mitigates GHG (study of different scenarios of gas emissions from 1961 to 2005) stating that careful and efficient management of nutrients and water by precision farming, incorporation of crop residues, and less intensive tillage are critical practices in pursuit of sustainable and increased agricultural output, however these studies do not take into account the increase in dietary preference of meat. Agricultural GHG offsets can be encouraged by market based trading schemes and these could include tax exemption or incentives from the government and also biogas. In addition to reductions in CH_4 and N_2O, the shift to low-meat diets induces a reduction in agricultural area, and subsequently leads to land availability for other purposes such as energy crops, forestry or nature reserves. The re-growth of vegetation on these abandoned areas leads to a substantial, though transient, uptake of CO_2.

Mitigating the animal agriculture sector's contributions to climate change necessitates comprehensive and immediate action by policy makers, producers, and consumers. Enhanced regulation is required in order to hold facilities accountable for their GHG emissions. New agricultural policies are needed that consider a reduction of environmental effects as well as a shift towards improved public health and, in particular, a reduction of non-communicable chronic diseases. Changes towards a more plant-based diet could help substantially in mitigating emissions of GHGs in short, our 'need' for livestock products very much depends on who we are, on our ability to access a variety of substitute foods and on what policies are put in place to ensure food security.

3.6 Recommendations

Emissions can be reduced through improved diets to reduce fermentation in ruminants' digestive systems and improved manure and biogas management. Any changes in the animals' diets must be monitored to see if they produce any harmful health or welfare impacts. Water pollution and land degradation can be tackled through better irrigation systems, better management of waste and improved diets that increase nutrient absorption. Free-range cattle can have a positive influence on natural ecosystems when they graze in a sustainable fashion. The U.S. Department of Agriculture (USDA) Agricultural Research Service found that moderately grazed land (one cow per 1.6 acres) had more biodiversity than did un-grazed or heavily grazed land. Animal derived products should be part of climate policy decision Regulations should be introduced to foster climate friendly production practices and consumption.

3.7 Conclusion

The City of Cape Town in South Africa endorsed a call by Compassion in World Farming for people to eat less meat for the betterment of the environment, human health and animal welfare.

Concerns about the long- term productivity of natural resources, including land, water, air, and biodiversity, will not be reflected in market prices unless governments and international organizations define and establish mechanisms to reflect the present and future value of natural resources. Institutions that provide regulatory frameworks need to be developed and a legal authority that implements environmental policies needs to be established or reinforced. There is a need for emerging farmers to adopt climate friendly farming methods, however governments and policy makers should be guiding their respective countries in drafting policies that protect the nutritional needs of their people, the livelihoods of their farmers, the welfare of farm animals and the climate.

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Chapter 4
Linking Forests and Food Production in the REDD+ Context

Gabrielle Kissinger

Abstract In order for REDD+ carbon emission mitigation targets to be reached, the primary driver of forest clearing globally—agriculture—must be fundamentally addressed by governments implementing REDD+ Programmes. This chapter evaluates the extent to which countries participating in the World Bank Forest Carbon Partnership Facility (FCPF) readiness activities are actively linking REDD+ and agriculture policies, programmes, institutional and governance arrangements. Based on 20 current country readiness proposals (R-PPs) submitted to the FCPF, the analysis reveals that overall, REDD+ strategies and actions generally fail to address agricultural drivers. The paper poses a general roadmap for how countries can more adequately address agricultural drivers in their REDD+ strategies, including: identifying clear strategies to address demand-side and market pressures, and how government action can influence those; sorting out tenure and land access rights; strengthening cross-sectoral policies; linking mitigation to adaption; boosting efficiency and production of agricultural systems; and incorporating agricultural carbon measurement in national MRV systems. Brazil and Acre State, Brazil, are highlighted as a case study, as both jurisdictions have overcome, at the national and sub-regional scale, many of the hurdles faced by other governments analyzed in this chapter.

Keywords REDD+ • Agriculture • Drivers • Deforestation • Governance • Forest policy

G. Kissinger (✉)
Lexeme Consulting, 3552 West 8th Avenue, Vancouver, BC, Canada
e-mail: gabrielle@lexemeconsulting.com

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4.1 Introduction

REDD+ is a set of policy approaches and positive incentives to reduce emissions from deforestation and forest degradation, and promote conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. Adopted in Cancun, Mexico at the 16th meeting of the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties, the REDD+ agreement enables the first global mechanism under the UNFCCC to address the large contribution of forest carbon emissions—currently 12–15 % annually (van der Werf 2009)—to global greenhouse gas (GHG) emissions.

Recent remote sensing, combined with population and economic trends, illustrates that agricultural production for domestic urban growth and agricultural exports to other countries are the primary drivers of tropical deforestation, with the impact of smallholders decreasing (DeFries 2010). The Food and Agriculture Organization predicts that the world's population will increase 34 % by 2050, to about 9.1 billion people, and consumption patterns will increase, resulting in a 70 % increase in the demand for food by 2050, with an increase of 49 % in the volume of cereals produced and an 85 % increase in the volume of meat produced (UN Food and Agriculture Organization (FAO) 2009). While yield increases can satisfy some of this demand, the expansion of agriculture into forest areas is inevitable. Rainforests were the primary source for new agricultural land throughout the 1980s and 1990s, with over 80 % of new agricultural land coming from intact and disturbed forests, rather than previously cleared land, and this trend is expected to continue (Gibbs 2010). Simply closing off areas to agricultural production will not deliver long-term food supply needs.

Agricultural productivity is expected to decrease in non-temperate regions of the world, while increasing in temperate zones of North America, Europe and Asia. The anticipated result for developing, non-temperate countries is that they will need to import more food—a projected 45–50 % increase in total net cereal import volume by 2050 relative to the year 2000, with some also predicting price increases of 20 % in the short to medium term (Hoffman 2011). Agriculture has become the most important and controversial issue in the Doha Round, with pressure from the European Union and the developing countries, led by Brazil and India, applied to the US to reduce its domestic support for agriculture, thus increasing developing country export opportunities (European Parliament Fact Sheet 2010). While a settlement of the Doha Round may boost developing country exports to the temperate north in the short term, the resulting increase in demand for agricultural products will challenge tropical countries facing increasing climate change impacts on agricultural systems. Thus, tropical countries face considerable challenges ahead, and will need to balance climate change impacts on agricultural systems with growing demand for food, and rising prices.

Within the UNFCCC, there is debate as to how to include the agricultural sector in emissions reduction strategies currently being negotiated. Land use emissions account for 30 % of global greenhouse gas (GHG) emissions (IPCC 2007). This chapter focuses on how REDD+ readiness strategies must respond to and incorporate agricultural drivers of forest clearing, and argues that countries must not wait for the UNFCCC to agree whether and how to include agriculture in international climate change agreements. Rather, countries pursuing the REDD+ pathway will increase their success in meeting their REDD+ mitigation targets and goals by directly addressing agricultural drivers of forest clearing and developing the policy, governance, MRV mechanisms, and benefit-sharing necessary to impact agriculture's role in unsustainable forest conversion and emissions.

This chapter evaluates the extent to which countries participating in the World Bank Forest Carbon Partnership Facility (FCPF 2010) readiness activities are actively linking REDD+ and agriculture policies, programmes and institutional arrangements based on 20 current country readiness proposals (R-PPs) submitted to the FCPF. Brazil and Acre State, Brazil are highlighted as a case study, as considerable hurdles identified in the country investigation of FCPF R-PP's have been overcome:

- While a recent the drop in soybean commodity prices may have affected agricultural expansion in the Amazon, there is clear evidence of a national deforestation target and national agricultural policy being linked. Recent deforestation rates have decreased, while agricultural production increased (see Sect. 3.5). It should be noted that this activity commenced in advance of more formalized REDD+ arrangements, which are still under development.
- The goal is to link all scales (national, state, local) in Brazil's emergent REDD+ strategy, with state targets and strategies being nested in national economy-wide targets.
- Acre State's REDD+ programme encompasses all lands and land use types, including the full-range of agricultural uses that impact Acre's forests; it offers a mix of incentives and payments, bundled under an umbrella REDD+ programme tied directly into the Acre Sustainable Development Plan; its emissions reduction targets are nested within federal targets; it is based on multi-sectoral land use plans; and governance of the programme appears strong, with enforcement ability.

4.2 Methodology

The most current country REDD+ Readiness Proposals (R-PP) submitted to the World Bank Forest Carbon Partnership Facility, available on the FCPF website, were reviewed. Countries participating in the FCPF were chosen rather than countries participating in UN-REDD Programme, as there are more of them receiving assistance (24 as compared to 13), and five countries currently participate in both—DRC, Indonesia, Panama, Tanzania, and Viet Nam. Although 37 countries are participating in the FCPF, only those at the REDD+ programme readiness proposal or readiness plan stage were reviewed. Furthermore, only those with enough documentation in English were reviewed (thus Central African Republic

(R-PP in French), Nicaragua and Peru (R-PP's in Spanish) were omitted). Indonesia's UN-REDD National Joint Programme Document submission (dated October 2009) contained more detail than its May 2009 FCPF submission, so the UN-REDD submission was relied upon. The following countries were included in the REDD+ readiness plan review:

– **Africa**: DR of Congo, Ethiopia, Ghana, Kenya, Liberia, Madagascar, Republic of Congo, Tanzania, Uganda
– **Asia**: Cambodia, Indonesia, Lao PDR, Nepal, Vietnam
– **Latin America**: Argentina, Costa Rica, Guyana, Mexico, Panama, Suriname

Country submissions were evaluated against the following criteria:

– Are the scope and scale of current and future agricultural sector or related land use deforestation and degradation drivers accounted for in the R-PP?
– Are the proposed REDD+ policy and programmatic interventions adequate to affect the scope and scale of agricultural drivers?
– Are the government ministries or agencies that can directly affect agricultural or related drivers either planning to or actively engaged in altering their plans and/or mandates to accommodate REDD+ strategies and objectives? Does the government (via the lead REDD+ agency, multi-sectoral committees, etc.) have the means to reconcile conflicting policies with the REDD+ country objectives?

Analysis of the R-PP's was entirely based on the content of the country submissions. The FCPF R-PP template encourages countries to assess direct and indirect drivers of D&D and factors both within and outside the forest sector, major land use trends and forest policy and governance issues. Further, the FCPF requests countries to assemble multi-sectoral approaches to the countries' REDD+ readiness government response.[1]

The purpose of the FCPF Readiness Phase is to support countries transitioning into REDD+ program and institutional development, and implementation. Thus, R-PP documents identify potential REDD+ strategies, based on stakeholder engagement and inter-ministerial consultations, which will lead countries toward adoption of a final REDD+ plan. The FCPF template requests country submissions to identify structure of REDD-decision-making and institutions established or

[1] Component 1 on organizing and consultation in the FCPF template states, "The purpose of setting up the National Readiness Management Arrangements is to manage and co-ordinate the REDD readiness activities whilst mainstreaming REDD into broader strategies such as the national low carbon strategies and national development plans. A country may approach the management arrangements for REDD via existing coordinating bodies or may establish a cross-sectoral and functional working group that is inclusive of key stakeholders with well defined roles and responsibilities essential for this purpose but which feeds into an overarching national climate change mitigation management arrangements. Such arrangements are likely to require the involvement of a number of government agencies (e.g., forests, environment, agriculture, transportation, planning, finance, Prime Minister's or President's office, etc.), civil society, and other affected stakeholders in a meaningful way."

planned, existing policy and governance affecting REDD+, feedback and input from stakeholder consultations, and candidate REDD+ strategy options, based on that input (among other information requests). As such, this assessment is meant to be preliminary and coarse in nature, based on information available, not final country REDD+ strategies and plans.

While not participating in the FCPF process, Brazil is participating in the Forest Investment Programme as a pilot country, and has signed a bilateral partnership agreement with the Government of Norway. What makes Brazil stand out as a case study is not only its carbon-rich and extensive tropical forests, but its remarkable track-record so far of overcoming many hurdles identified in the country investigation of FCPF R-PP's, such as multi-sectoral engagement and agreement, decreased national deforestation rates, coupled with increased agricultural production. Recent updates to the California Governor's Climate and Forests Task Force on Brazil and Acre were reviewed, along with federal and state legislation.

4.3 Results and Discussion

4.3.1 Are the Scope and Scale of Current and Future Agricultural Sector or Related Land Use D&D Drivers Accounted for in the R-PP?

Countries with a checkmark in the second column of Table 4.1 indicates agricultural production and expansion is reported as *the* primary driver of deforestation and degradation. Of 20 countries reviewed, 16 report agriculture as the primary driver of D&D. Agricultural drivers of D&D include a full range of clearing activities related to plant and animal-based food products, ranging from smallholder impacts to large-scale commercial and industrial agriculture production, primarily soybean, oil palm and cattle for meat production. Ethiopia reports population expansion into forest areas and the related resource needs, such as agriculture and livestock management combined with use of fire as the primary driver. Shifting cultivation is cited by many countries as the primary driver, however the extent of the impact in Liberia is particularly acute: it affects 5.1 million hectares, or half of the country's land area.

Of the 4 countries that did not cite agricultural production as the primary driver, either forestry or mining are cited as primary drivers, while agricultural impacts are still measurable. For instance, Suriname cites mining as the primary driver (though offers no specific estimates) followed by population growth, agricultural plantations and biofuel production as key drivers, and the numbers support agriculture's importance: 100,000 hectares was recently cleared in the northern interior region for oil palm plantations and the Agricultural Sector Plan (2004) seeks to promote cultivation in the 1.5 million hectares along the coastal area (comprising valuable mangrove forests).

Table 4.1 Agriculture as a key driver in deforestation and degradation based on analysis of Forest Carbon Partnership Facility REDD+ Readiness Plan submissions

Country	Agriculture is primary D&D driver	Agricultural D&D drivers commercial/industrial or smallholder
Argentina	✓	Industrial
Costa Rica	✓	Both
Cambodia	✓	Smallholder
DR of Congo	✓	Smallholder
Ethiopia	✓	Unknown
Ghana	✓	Smallholder
Guyana	Mining	
Indonesia[a]	Unknown	Unclear. Non-government sources indicate industrial agric.
Kenya	✓	Smallholder
Lao PDR	✓	Both
Liberia	✓	Smallholder
Nepal	Unsustainable logging	
Madagascar	✓	Unknown
Mexico	✓	Both
Panama	✓	Both
Republic of Congo	✓	Smallholder
Suriname	Unknown	Unknown
Tanzania	✓	Both
Uganda	✓	Unknown
Vietnam	✓	Industrial

[a]Based on information in Indonesia's UN-REDD National Joint Programme Document (2009, October)

Insufficient information was provided in some country submissions to attribute 'primary D&D driver' status to any one particular land use. Agricultural drivers vary between regions, especially in large and geographically diverse countries. Indonesia reports that smallholder agriculture is the key driver in Sulawesi, whereas in Kalimantan and Sumatra, it is primarily due to the mechanized logging of lowland forest with a second stage of clearance for oil palm and pulpwood plantations. Indonesia unfortunately does not provide enough detail in its FCPF and UN-REDD submissions to ascertain the amount of deforestation attributed to each D&D driver, thus Table 4.1 reflects this uncertainty. However, Indonesia's overall deforestation rate between 2003 and 2006 was about 1.17 million hectares per year, and it is well documented that conversion for oil palm plantations occurs at a large scale (Koh 2011), and with dramatic impacts on carbon emissions due to the immense carbon storage in the forest and, especially, in the peat soils that are widespread in Indonesia.

Adding to the complexity of the role of agriculture as a driver of D&D in countries participating in REDD+ is the myriad of underlying drivers that enable land conversion and unsustainable use of resources. Governance and institutional failures (including inadequate enforcement) are directly cited by Costa Rica, DR Congo, Ethiopia, Ghana, Kenya, Lao PDR, Liberia, Nepal, Madagascar and

Tanzania as critical underlying drivers that REDD+ strategies must address. The low financial returns of forest use in comparison with alternate uses, the 'tragedy of the commons' where lack of local user rights, inadequate land tenure and common access act as a disincentive for sustainable forest resource use.

The third column in Table 4.1 indicates whether agricultural drivers of D&D are primarily commercial and/or industrial or predominantly caused by smallholders. Argentina and Vietnam offer the boldest examples. Industrial soybean cultivation accounts for 70 % of Argentine deforestation. Vietnam's export commodities (coffee, cashew, pepper, shrimp (affecting coastal mangroves), rice and rubber) drive forest conversion, and future agricultural policies will increase production for rubber and cashew, while stabilizing coffee production. Ghana reports varietal changes in cocoa (from shade-grown to full-sun varieties) as having a dramatic effect on deforestation in the high forest zones. Other countries with significant commercial/industrial impacts on forests are: Lao PDR (plantations fuelled by foreign direct investment), Costa Rica (meat exports to the US, promoted by government lending policies), Mexico (82 % of deforestation due to agriculture or grazing, with NAFTA significantly influencing amount of exports into the US), and Tanzania (increasing biofuel production). Most countries (15 out of 20) indicate increasing commercial/industrial agricultural uses, particularly serving export and urban markets, and biofuel production.

Based on the information provided in the R-PP's, it is very difficult to identify the impacts of food-production versus non-food related agriculture (largely rubber, palm oil for non-food uses; and corn, sugarcane vegetable oils and animal fats for biofuels; and sugar cane, corn, sorghum for bioethanol) on forestland clearing, in terms of hectares cleared per year and projections into the future. Countries experiencing commercial/industrial scale agriculture-related forest clearing largely cite food production as the primary driver (meat exports, rice, coffee, sugarcane). While Indonesia's R-PP includes very little information about this well-documented driver of Indonesian forest-and peat-land clearing, Liberia's current palm oil investment proposals amount to $2.95 billion, covering 494,500 hectares. Argentina and Cambodia cite biofuels as a future factor, but do not offer specific figures on existing and projected areas to be used in plantations. Vietnam and Cambodia cite rubber production as a primary cause of land conversion.

The impacts of smallholder agricultural clearing are largely tied to poverty, lack of tenure and access rights (or communal rights, with inadequate incentives for stewardship), and poor agricultural practices resulting in soil degradation (particularly cited by Uganda and Madagascar). In Cambodia, 60 % of the population is dependent on agriculture, with 41 % rural households deriving between 20 and 50 % of their total livelihood value from forest use. Poverty is particularly a driver of smallholder incursions into forests in DR Congo, Ghana, Kenya, Nepal, and Madagascar. The lack of tenure or need to clarify tenure rights affects smallholders in Ethiopia, Ghana, Nepal, Madagascar, Mexico, Suriname, Uganda, Tanzania and Vietnam. In the Democratic Republic of the Congo, the communal property/customary use tradition, with no license/permitting requirements for smallholders, results in an absence of formal institutions and processes to guide land use decisions.

4.3.2 *Are the Proposed REDD+ Policy and Programmatic Interventions Adequate to Affect the Scope and Scale of Agricultural Drivers?*

Full evaluation results of whether proposed REDD+ strategies and policy frameworks are adequate to affect agricultural drivers are presented in column 2 of Table 4.2, found below. While readiness proposals are not inferred to be final REDD strategies, they are detailed and thoughtful assessments. Overall, countries demonstrate acknowledgement of the importance of addressing agricultural drivers of D&D, but REDD+ strategies and actions generally fail to address agricultural drivers. A summary of that evaluation was based on prioritizing country responses and identifying commonalities, which fell into the following categories: sorting out tenure and land rights; inefficiencies of agricultural systems; lack of operational clarity in draft readiness concepts; countries identified clear conflicts between REDD+ and national agriculture (or related) policies and linkage of REDD+ to low carbon development plans and other higher-level policy platforms.

Sorting out tenure and land rights: This cross-cutting issue was cited by many countries as being a prerequisite to addressing smallholder agricultural impacts, and holds the potential to address poverty and forest-dependent people's disenfranchisement. Addressing this issue will lay the critical groundwork for designing benefit-sharing mechanisms that provide financial incentives to leave forests standing. Twelve countries cite this as critical: Argentina, DRCongo, Ethiopia, Ghana, Liberia, Nepal, Madagascar, Republic of Congo, Suriname, Tanzania, Uganda, and Vietnam. However, Nepal identifies absentee landlords with land being cultivated by tenants as problematic, but it is unclear whether the proposed activity of community forestry can address this issue. In Madagascar the issue of free access to resources is a problem, which tenure and rights can remedy. The parliament of the Republic of Congo considered a bill in 2010 on customary and cultural rights. Payments for Environmental Services systems in Costa Rica, viewed by many as a model for REDD+, have been restricted to owners and holders of natural forests under forest management regimes.

Inefficiencies of agricultural production systems: Many countries report this as problematic, particularly Vietnam, Madagascar, and Uganda. However, all countries that specify this as directly affecting D&D offer unclear causal pathways in their REDD+ readiness strategies. Furthermore, none of the R-PP budgets reviewed allocate funds for this purpose, beyond commissioning studies and gathering more information.

Lack of operational clarity in draft readiness concepts: Many countries emphasize the need for incentives for small producers and the agricultural sector, aligning sectoral goals and objectives, or redirecting agricultural development to degraded areas with low carbon and co-benefit values. Yet very few countries offered specific examples on how these strategies would be implemented, and whether key Ministries are committing and devoting resources to those strategies. Other

Table 4.2 Evaluation of FCPF R-PP country submissions: influencing agricultural drivers of deforestation and degradation

Country	Is proposed REDD+ strategy adequate to affect agricultural drivers of D&D?	Clear enough multi-sectoral links to affect agricultural drivers of D&D?
Argentina	Strong track-record of government intervention: 35 % export tax on soybean exports, National Forest law of 2007 already curbed deforest. by 60 % in one hotspot (programme funded via 2 % of tax imposed on export agriculture commodities (budget is $100 million in 2010)).	Finding a way to align REDD strategy with the 2006 law promoting biofuel production will be key.
	Focus of building on National Forest Law, to improve data, MRV system, land tenure systems and benefit-sharing, and expanding income-generating activities for forest-dwelling communities makes sense.	Moratorium on deforestation until each province implements land use planning for national forests (OTBN). Only 4 of 25 provinces have aligned provincial plans/ regulations with OTBN, thus need much greater capacity and enforcement at provincial and municipal levels. Should consider linking OTBN to larger-scale land use plans (incl. agric).
	Not clear how incentives for small producers and the agricultural sector will be operationalised.	Deforestation risk index will help drive action.
Costa Rica	Government lending policies seem largest hurdle, but strategy does not address how to rectify this. Expansion of Payment for Environmental Services Program critical, especially with smallholders.	Need to align REDD+ strategy with new government "Creation of a National Agricultural and Rural Development Strategy for the 2010–2020 period", which supports producers in expanding production to export markets.
Cambodia	The following are good candidate strategies: Promote agricultural intensification in existing large farming landscapes; Redirect agricultural development to degraded areas with low carbon and co-benefit values Review regulations for land concessions and increase land use planning	Unknown at this time, as it is unclear how candidate strategies would be endorsed and supported by other Ministries, unclear how to align recent economic land concessions with REDD+, (concessions amount to 6 % of land area, and do not include provincial concessions) and illegal logging still rampant despite 2002 moratorium.
DR of Congo	Unclear at this time-main emphasis on data collection	REDD policies not yet aligned with poverty reduction and sectoral programme strategies. No clear plan or timeline on how to achieve this.

(continued)

Table 4.2 (continued)

Country	Is proposed REDD+ strategy adequate to affect agricultural drivers of D&D?	Clear enough multi-sectoral links to affect agricultural drivers of D&D?
Ethiopia	Clearly the policy focus on smallholders, providing methods for reforestation, PFM, agro-forestry and agricultural intensification are very important. However, need a parallel strategy to counter strong federal–level policies promoting conversion.	While MoARD has one seat on Enviro Council and REDD Steering Committee, not clear this is enough to counterbalance strong GoE policy objectives supporting industrial agriculture and biofuel expansion.
	Also need an adequate forestry ministry to be built (regional and business-oriented Regional Forest Enterprises are not enough)! Should be a larger part of R-PP and REDD + readiness.	Need a stronger governance and enabling environment.
Ghana	Unknown at this time, presume this will be clearer after policy studies are completed.	The Cabinet level political body (ENRAC) and National Climate Change Committee are well positioned to promote multi-sectoral mitigation and adaptation policies.
	Critical to mainstream REDD+ with new low carbon growth plan (national and sectoral developments) Reform tree tenure regime and benefit-sharing to agric. small-holders. REDD+ (shade) friendly cocoa work group critical – how to promote shade-varieties at scale	Need more information on how the comprehensive low carbon growth plan will achieve this (spatial plans, legal tools, etc.) and overcome current lack of institutional means to address multi-sectoral conflicts.
Guyana	Unclear whether training and capacity-building in the mining sector will alter mining activity. Also noted projects currently in permitting pipeline will continue.	Low Carbon Development Strategy may be best route to reconcile sectoral differences.
	Need more info on how agro-forestry and community agro-forestry as solutions in REDD+ can be operationalised, as well as system of benefit-sharing.	GL&SC in process of creating regional zoning maps for appropriate uses, but EXCLUDES mining and forestry concessions. Mining activities on State Land managed by GGMC and forestry activities in State Forests by the GFC, and while needed coordination is referenced, R-PP contains no clear policy route to reconcile these.

(continued)

Table 4.2 (continued)

Country	Is proposed REDD+ strategy adequate to affect agricultural drivers of D&D?	Clear enough multi-sectoral links to affect agricultural drivers of D&D?
Indonesia	Policies are not yet developed, will be explored. District-level spatial planning key, but R-Plan should identify how those outputs will be codified (does not mention that Multi-stakeholder-endorsed District plans for REDD must have endorsement from MOA or Agric and National Development Planning Agency (BAPPENAS)).	Does not indicate MOA, BAPPENAS or provincial and more importantly District governments are ready to take action, amend existing mandates, and make significant changes to existing decision-making on permitted uses. It is noted BAPPENAS sits on Nat'l REDD Programme Exec. Board.
Kenya	Unclear whether REDD policy will affect Local Authority decisions.	Integration of REDD+ into broader climate change and sustainable development planning and National Climate Change Response Strategy is key. Need to feed spatially-explicit future trajectories of emissions/removals under different economic and development scenarios into multi-sectoral policy and strategy development.
	Strong higher-level directives (Agric. Act and recent Constitution) are promising, though R-PP not clear on exactly how this will affect D&D drivers. More work needed on driver assessment. Recent reversal of previous government decision to convert a large area of the Mau forest catchment to agriculture viewed as proof of new forest governance/policy serving REDD+ needs.	Proposed new constitution = tree cover of at least 10 % of the land area of Kenya (Article 69 (1)(b)) will help align multi-sectoral and regional interests.
Lao PDR	It is noted a major aim of forest policy has been the stabilization of shifting cultivation, but with limited success.	Half the emissions from LULUCF are on lands which forest authorities control, the rest is dependent on decisions and actions by other sectors that require land for other purposes.
	Addressing shifting cultivation via extension to ethnic group communities on agroforestry – need to see how the model introduced on the sloped northern lands designed by farmers, based on their experiences with NTFPs can be reinforced and expanded.	Not clear how gov't will influence the massive influx of Foreign Direct Investment for cash crops and plantations, especially when this is supported by the agriculture policy priorities.
Liberia	Proposed actions seem adequate, however R-PP admits Conservation Agriculture could be a 10-year	The Food and Agricultural Policy and Strategy (FAPS) lists forestry, natural resources management and

(continued)

Table 4.2 (continued)

Country	Is proposed REDD+ strategy adequate to affect agricultural drivers of D&D?	Clear enough multi-sectoral links to affect agricultural drivers of D&D?
	process, still needs to be streamlined into MoA, MoA currently under capacity to take on. Other options: irrigated lowland rice cultivation or subsidizing fertilizer inputs.	climate change as key action areas which serves to commit MOA to REDD
	Good precedence: New Forestry Reform Law (2006); est. Community Forestry Development Committee's, resulting in annulled forest concession contracts, national and community level forest management processes and benefit sharing. Also VPA. Must do more to sort out customary land rights.	Good consideration of enabling laws necessary for REDD, particularly legislative enactment. Must resolve contention between the sector ministries.
Nepal	Still unknown as REDD strategy not yet finalized Land reform and consolidation of smallholdings critical: Esp. in Terai, land owned by absentee landlords and cultivated by tenants. Community forestry already demonstrated as successful in reducing poverty, increasing forest cover, and creating rural employment (except in Terai).	Very solid acknowledgement of the necessity of combining food security, adaptation and mitigation together, as well as rural poverty, tenure and governance. Will take much more fleshing out to identify specific actions where gov't can influence outcome.
Madagascar	The current system of free access to resources and inefficiency of traditional agricultural systems is huge—local tenure systems, integrated planning at all scales, effective forest governance, and benefit-sharing systems addressing rural poverty and food security will be essential for REDD+ to succeed beyond pilots.	Unclear at this time. First objective is to address tenure and forest governance institutions.
Mexico	Deforestation risk index, track record of ROCYMAF, and PES program hold potential. Unclear whether ProArbol (to promote reforestation and SFM), PROCAMPO (promotes cultivation of corn and beans) and PROGAN (promoting animal husbandry) are effective as models for REDD. Consideration of economic incentives quite robust; i.e. valuation index on ecosystem services at the community level, spatially-explicit study on opportunity costs of non-forest land use options.	Once REDD Work Group is in place, role of SAGARPA may increase. Much will depend on role of the Climate Change Intergovernmental Commission in driving policy agenda, ability for risk index and land use tools to drill down to detail needed to drive land use decisions, as well as macro-economic aspects of trade relations with the US.

(continued)

Table 4.2 (continued)

Country	Is proposed REDD+ strategy adequate to affect agricultural drivers of D&D?	Clear enough multi-sectoral links to affect agricultural drivers of D&D?
Panama	Good existing programmes and success to build upon: community environmental business and investment programmes	National environment objective establishes a solid link between cross-sectoral adaptation and mitigation (REDD) and there exists a strong enabling framework via Constitution.
	New REDD+ PES system would cover 58 % of national territory.	REDD programme to link to national strategy to combat extreme poverty to build social capital
	>30 % of REDD Fund will go toward management structure for natural resources and environmental management of indigenous comarcas, based on the Program of Decentralization and Deconcentration of Environmental Management proposed by ANAM. (Note: Indigenous comarcas of Ngöbe-Buglé has highest deforest. rate of 2.7 %/year.)	PES programme will policy of infrastructure development incorporating plans for conservation of forest cover
	Will need to address: agricultural credit favours the extensive livestock system, which will undermine REDD+ efforts.	Limited effectiveness of title deeds for territorial stabilization of the farming population.
Republic of Congo	Focus on addressing tenure rights (did Parliament pass the bill on customary and cultural rights in 2010?), sustainable management of forest resources, and improving agricultural productivity are directly tied to the key drivers.	Must have the national land use plan (PNAT) in place to align multiple sectors.
	Strategy Options Assessment Framework a useful way to evaluate their strategy options.	Must still define how a REDD+ Credit (and benefit-sharing) will be operationalised under Congolese Law
Suriname	Based on opportunity cost approach, will REDD+ compete with gold mining? Probably not, however REDD+ could greatly affect shifting agriculture.	Key is motivating decisions via Multi Annual Development Plan and revision of Agricultural Sector Plan, *with* capacity and resources to make the shift.
	Need to see more emphasis on appropriate siting of agricultural expansion, such as on degraded lands with low carbon sequestration/storage potential	

(continued)

Table 4.2 (continued)

Country	Is proposed REDD+ strategy adequate to affect agricultural drivers of D&D?	Clear enough multi-sectoral links to affect agricultural drivers of D&D?
Tanzania	Still in developmental phase. Most D&D on 17 million ha of 'general forest' with no mgmt. regime. Participatory Forest Management- integrate communities into forest mgmt., serve as basis for rapid REDD readiness. However, it is noted that poor governance (corruption) at local, district, regional and national levels has so far restricted success of centralized forest mgmt., PFM and SFM.	Unclear at this time. Need to align REDD+ with Kilimo Kwanza, national policy seeking increased agricultural production. Also need national land use study.
Uganda	Clarification of tenure and property rights, increasing intensification of agriculture (note interest in maintaining soils), and addressing adverse impacts of livestock grazing are key. However, very unclear causal pathway to achieving success on these.	No direct mention of role Ministry of Agriculture, Animal Industry and Fisheries would play in implementing strategies listed in previous cell, or what they have agreed to.
Vietnam	Annex 7 of R-PP: The Underlying Causes and Strategic Options to Address Forest Conversion from Agriculture – good basis for preparing strategy	Any ability to amend the Five Year Plan of 2011–2015 – Agriculture and Rural Development to align with REDD+?
	Promoting alternatives to forest clearing: more intensive agricultural cultivation, encouraging production of higher-value crops and vocational training for off-farm income opportunities.	Also need to evaluate recent gov't decisions allowing 100,000 ha of rubber plantations in central highlands.
	Independent international auditor review and assessment provincial and district Socio-economic Development Plans relevant to REDD+: good, ensure results feed back into strategy development	Future agricultural policies will stabilize area for coffee, but rubber and cashew will increase. How to align with REDD+?
		Massive reallocation of tenure to local communities and legal entities (away from state agencies and local authorities), though hampered by lack of funding and overlapping mandate with MONRE, which oversees land allocation and MARD, in charge of forestland.

countries identify the need to scale up pilots or regional- and site-level models, but offer little detail on how success can be achieved in doing so. The Lao PDR cites an existing forest policy seeking to stabilize shifting cultivation, but this policy has had limited success. Thus, a challenge for the LAO PDR will be how to scale up the success of the model introduced on the sloped northern lands that combines agro-forestry, farming and non-timber forest products. More detail is needed on how this can be achieved.

Countries identified clear conflicts between REDD+ and national agriculture (or related) policies: Argentina will be challenged to align its REDD+ strategy with a 2006 law promoting biofuel production, which promotes vegetable oils and animal fats for biofuels, and sugar cane, corn, sorghum for bioethanol. The R-PP does not indicate how Argentina will reconcile this policy conflict. Furthermore, Argentina stands out for taking decisive action by mandating a moratorium on deforestation until each province implements land use planning for national forests. However, only 4 of 25 provinces have aligned their provincial plans with the national land use plan for forests, and greater capacity and enforcement at provincial and municipal levels is cited as a major need to move this forward. Guyana's Lands & Surveys Commission is in the process of creating regional zoning maps for appropriate uses, however mining (the largest D&D driver) and forestry concessions are notably excluded, so any ability to link cross-sectoral strategies spatially is severely diminished. Tanzania's REDD+ objectives will have to be reconciled with Kilimo Kwanza, a national policy seeking to increase agricultural production.

Linkage of REDD+ to low carbon development plans and other higher-level policy platforms: It is noteworthy that some countries have high-level government commitments to low-carbon development paths. Ghana is one example, however more information will be required to assess how that commitment will affect national and sectoral development related to REDD+ strategy development. Kenya's Agriculture Act and recent constitution offer a strong basis for their REDD + strategy, and a recent reversal of a previous government decision to convert a large area of the Mau forest catchment to agriculture is offered as proof that the new forest governance and policy will serve REDD+ goals. Panama exhibits strong enabling policy and governance frameworks for REDD+ via its national environmental objective (addressing both mitigation and adaptation) and constitution, which established collective ownership rights for indigenous communities and seeks to balance sustainable development and biodiversity conservation.

Lastly, it is worthwhile noting that some countries have placed moratoriums on land clearing, in the hopes of stopping D&D or arresting it until adequate planning and implementation of REDD+ (and related) strategies are carried out. As mentioned above, Argentina established a moratorium on deforestation until each province implements land use planning for national forests. The land concession moratorium announced by the Lao PDR Prime Minister in 2007 and subsequent legislation has slowed large-scale concessions, however a loophole has enabled inappropriate selection and allocation of land. And despite Cambodia's moratorium (in 2002) and cancellation of logging concessions, illegal logging for domestic use among smallholders is still a problem.

4.3.3 Are the Government Ministries or Agencies That Can Directly Affect Agricultural or Related Drivers Either Planning to or Actively Engaged in Altering Their Plans and/or Mandates to Accommodate REDD+ Strategies and Objectives? Do Governments Have the Means Through Which They Can Reconcile Conflicting Policies with the REDD+ Country Objectives?

Full evaluation results of whether there are adequate cross-sectoral linkages between key government ministries (and mandates) to affect agricultural drivers are presented in column 3 of Table 4.2, found above. Overall, the analysis revealed that there are serious obstacles, but there also exist opportunities, to create meaningful cross-sectoral linkages that can alter strong economic forces and existing government targets and mandates. Obstacles include:

Some countries simply need an adequate forestry ministry, while others clearly recognize the limits of their forest authority to address agricultural pressures: Management of Ethiopia's forests is currently under the jurisdiction of the agriculture ministry (MoARD), however forests been neglected in this context and the regional and business-oriented Regional Forest Enterprises are inadequate to serve REDD+ needs, resulting in a new emphasis on creating a dedicated federal body to manage forests. The Lao PDR acknowledges the limited jurisdiction of the forest authority, as half of national LULUCF emissions are on lands outside of their control. Tanzania notes that most D&D occurs on 17 million hectares of 'general forest' that currently has no management regime. It should be a priority for the Tanzanian government to address this.

Consultation does not infer a change in mandates: Countries have responded to FCPF's encouragement to create cross-sectoral working groups, involve stakeholders including industry representatives from non-forestry sectors in committees, and consult with non-forestry Ministries (often via National REDD+ Steering Committees). R-PP's are generally unclear how agreement and accommodation will be made on conflicting programmatic strategies and how and when tough decisions will be handled. Very few R-PP's mention the role of legislative decisions, which are often critical for changing national priorities and ministry targets and mandates.

Cross-level government commitment: How REDD+ policies will affect sub-regional and district government decisions: Kenya notes the importance of local authorities in determining land use decisions. Tanzania notes that poor governance and corruption at local, district, regional and national levels has so far restricted the success of centralized forest management, participatory forest management and sustainable forest management, which are key aspects of their REDD+ strategy. While Indonesia has demonstrated strong leadership on REDD+ at the highest levels (most notably the President of Indonesia), the R-PP and UN-REDD Programme submission does not indicate that Ministry of Agriculture, Agriculture and National Development Planning Agency (BAPPENAS), provincial and more importantly district governments are ready to take action, amend existing mandates, and make significant changes to existing decision-making on permitted uses, which are key aspects of their jurisdictional power.

The opportunities for reconciling conflicting mandates or goals include:

The importance of tools and mechanisms to reconcile conflicts: If there do not exist higher-level policies such as national low-carbon development commitments to harmonize sectoral strategies, emphasis should be placed on tools and mechanisms that inform trade-offs and reconcile conflicts. Argentina's deforestation risk index could be a powerful tool to inform future evaluation of siting of new agricultural or biofuel concessions. Kenya shows great promise in their spatially-explicit future trajectories of emissions/removals under different economic and development scenarios, which will hopefully feed into multi-sectoral policy and strategy development. Aligning sectoral plans by recalibrating targets, accounting for adaptation strategies, creating spatially-explicit and multi-sectoral land use plans that are transparent, and link to newly created MRV systems will be critical.

Linking mitigation to adaptation: Argentina, Ghana, Liberia, Nepal and Panama already have or will create Adaptation Working Groups under National Climate Change Committees and hope to link their REDD+ strategies to those. Countries that can identify REDD+ priority strategies and institutions, with direct and iterative links to agriculture adaptation—such as precipitation altering agricultural production and differentiated responses of specific crops (for instance wheat being more susceptible to climate change impacts in Africa than other crops, such as millet (Müllera 2011))—will increase the ability to calibrate their policies over time.

Countries that stand out as models, demonstrating strong recent interventions affecting agricultural land use patterns: Argentina placed a 35 % export tax on soybean exportation, and its National Forest law (2007) deforestation programme is funded via a 2 % tax imposed on export of agriculture commodities. The budget for Argentina's deforestation programme was $100 million in 2010. The result is that Argentina has curbed deforestation by 60 % in one hotspot. Panama's community environmental business and investment programmes (as an alternative to slash-and-burn agricultural practices), and Costa Rica and Mexico's experiences with payments for environmental services, stand out as success stories to build upon.

4.3.4 *Case Study: Success in Brazil and the State of Acre*

4.3.4.1 Brazil

Brazil offers a unique example of increased agricultural production, while simultaneously decreasing national rates of deforestation, and has achieved results even prior to finalization of a national and state REDD+ strategies. While not participating in the FCPF process, Brazil has signed a bilateral partnership agreement with the Government of Norway and participates in the Forest Investment Programme as a pilot country.

Its agricultural gains over the past decade are astonishing: Brazil's grain production increased 99 % between 1996 and 2010 (Government of Brazil, IPEADATA). Brazil ranks number one in world production and exports of coffee, sugar, and frozen concentrate orange juice; number two in soybeans, tobacco, beef, and poultry (USDA 2011). Between 1990 and 2008, soybean production increased 196 % (Zanon 2010). The revolutionary increase in national agricultural production is largely attributed to the Brazilian Agricultural Research Corporations' (Embrapa) "system approach"—improving soil in the cerrado grasslands (by adding lime and techniques for fixing nitrogen that decreased use of fertilizers); adapting the African *brachiaria* grass to Brazil's cerrado, opening up formerly unsuitable areas to livestock production; and finally, with cross-breeding, adapted soybeans (typically a temperate crop)to a tropical climate with acidic soil.

Brazil's National Institute for Space Research (INPE) announced deforestation in the Amazon over 2009–2010 decreased 13.6 % from the previous year, and is the lowest rate measured by INPE since 1988, when INPE's annual surveys began (National Institute for Space Research 2010). Brazil has launched the second phase of the National Plan for the Prevention and Control of Deforestation in the Legal Amazonia. However, recent scrutiny over Cargill's soya production practices in Santarém, Pará state, raises questions about accuracy of satellite-monitoring systems that until 2 years ago were incapable of detecting deforestation on individual farms (Nature 2011). Furthermore, there are dramatic regional differences in deforestation rates, and not all forest biomes are consistently included in deforestation estimates, such that clearing of the cerrado in Mato Grosso was omitted from deforestation estimates provided to the California Governor's Climate and Forests Task Force (Filho 2010), while it is considered an important forest class in that state. Brazil is preparing the National Plan for Prevention and Control of Deforestation for the second most relevant biome in Brazil, the cerrado (Brazil Ministry of Finance, unspecified date).

In 2009, Brazil established an economy-wide target to reduce carbon emissions between 36.1 and 38.9 % by 2020 compared to a reference scenario of business as usual. The target was incorporated in the National Policy on Climate Change, ratified by Congress. Plans to reduce emissions in different economic sectors are being developed in consultation with civil society in the sectors of energy, agriculture and in the steel industry. In total, 12 sectoral plans will be implemented by the end of 2011 (Teixeira 2010). In July 2010, Brazil's ban on the commercialization of soy grown in the Amazon was extended for the fourth consecutive year (reinforced by the Bank of Brazil's December 2010 announcement that it will veto agricultural credit for soy farmers who want to plant in newly cleared forest), a critical output of cross-sectoral pacts.

One of Brazil's largest export products is ethanol. The Brazilian National Agro-energy Plan seems to reinforce the objectives of its 2004 Action Plan for Deforestation Control and Prevention in the Amazon, as the Agro-energy Plan guides future siting to "Optimizing the use of areas affected by human action on natural vegetation (anthropic impact), maximizing the sustainability of the production systems, discouraging unjustifiable expansions of the agricultural frontier and encroachment upon sensitive or protected systems, such as the Amazon Forest and the Pantanal region, inter alia, should be discouraged. Bioenergy projects could also contribute to the reclamation of degraded areas (Brazilian National Agro-energy Plan 2006, p. 11)." It will be important to monitor whether future biofuel expansion and siting upholds the intent of this section.

4.3.4.2 Acre State

Seven of the nine Amazon states have already developed and approved their own action plans to fight deforestation at the local level. Acre State is an impressive example of how a sub-regional REDD+ programme seeks to fulfil emissions reductions from D&D while bringing small-, medium- and large-scale producers into its programmatic objectives.

The programme encompasses all lands and use types, including the full-range of agricultural uses that impact Acre's forests: It is not limited to state lands or only forest resources, but rather encompasses private and public lands, protected areas agricultural land and indigenous lands. Implementation across the landscape is to occur through a phased approach.

Offers a mix of incentives and payments, bundled under an umbrella REDD+ programme tied directly into the Acre Sustainable Development Plan, including: (1) a Programme for Valuing Environmental Assets—including best practices and property certification (including payments) for family farming in already cleared or altered areas, and support for forest management in intact forests, and (2) the Recuperation of Altered Areas Programme—including reforestation, agro-forestry and ranching on cleared and degraded areas, and (3) the Carbon ISA Program—established to create and implement economic and financial instruments to achieve emission reduction targets, infrastructure and instruments for measurement, quantification and verification, with registration and transparency (MQVRT), strengthening the cooperation and alignment at the international, national, subnational and local levels, benefit-sharing, and promoting a new model of sustainable local and regional low carbon development (State of Acre 2010, p. 14).

Nested within federal targets: Acre's emissions reduction target mandates compliance and alignment "with the goal of reducing emissions, contained in Federal

Law number 12.187 of 2009 (ibid, p. 2).” It mirrors the 80 % Amazon deforestation reduction target.

Based on multi-sectoral land use plans: “Compliance, by programs linked to SISA, with the provisions set forth in the Law number 1.904 of June 5, 2007, which established ZEE/AC(Ecological-Economic Zoning of the State of Acre) (ibid. p. 2).” Acre’s zoning initiative reflects the strategy and approach of the Amazon Ecological-Economic Macrozoning initiative (MacroZEE), announced in March 2010, which guides, at a regional scale, the design and spatial distribution of public policies for development, territorial planning and the environment, based upon sustainability criteria. Deforestation will be avoided by halting the expansion of agriculture and cattle ranching into areas of native vegetation, and promotes the use and recovery of degraded lands for agribusiness (Government of Brazil 2010).

Governance of the programme is strong, with enforcement ability: A State Commission for Validation and Monitoring, the Regulation, Control and Registration Institute, Scientific Committee, Group of Councils, and theAgency for Development of Environmental Services of Acre State, a private and public joint stock corporation, overseen by the Forestry Department, charged with: developing strategies aimed at raising funds and attracting investments in programs, prepares action plans and projects, helps align financing for environmental services, and manages and disperses assets and credits arising from ecosystem services and products deriving from the programs, subprograms, plans and projects (State of Acre 2010, p. 11).

4.3.5 Roadmap for How to Address Agricultural Drivers in REDD+ Strategies

What follows is a skeletal roadmap for how countries can more adequately address agricultural drivers of D&D in their REDD+ strategies. Individual countries should consider these, but must ultimately tailor strategies to suit the specific agricultural drivers and national/regional contexts.

– **Identify clear strategies to address demand-side and market pressures, and how government action can influence those**—For countries facing commercial/industrial-scale agriculture pressures, this is of great urgency. Countries should start by addressing the appropriate siting of small- and large-scale agricultural expansion vis a vis their REDD+ strategies. However, countries will need to more directly engage mechanisms that can influence marketplace demand, such as certification and influencing lending policies.

  • Countries can encourage agricultural product certification systems that will steer investment and demand to agricultural producers and products that meet certification standards—such as endorsement and promotion of the

Roundtable for Sustainable Palm Oil, principles and certification standards of the Roundtable on Sustainable Biofuels, and the Sustainable Agriculture Network (operating in Central and South America). As mentioned above, Acre State, Brazil also offers a model for how to promote best practices and property certification (including payments) for small and large agricultural producers via their Programme for Valuing Environmental Assets, an integral part of their state-wide REDD+ strategy.
  - There is a growing trend towards application of procurement policies and supply chain transparency, particularly for controversial products. In recent years, scrutiny of illegally-harvested timber has increased, with France, Germany and the UK adopting green public procurement policies affecting illegally-harvested wood, and they are increasingly considering similar commitments related to agricultural products. The World Bank Group recently adopted a framework and International Finance Corporation strategy to guide future engagement in the global palm oil sector. Countries will increasingly need to consider those external commitments, but can also shape domestic lending guidelines applied to loans and investment decisions by banks, such as the Bank of Brazil December 2010 announcement that it will veto agricultural credit for soy farmers who want to plant in newly cleared areas of the Amazon forest.

– **Strengthen cross-sectoral policy and implementation alignment**—Countries with clear conflicts between REDD+ and national/regional agriculture (or related) policies must put this first on the agenda for multi-Ministerial decisions and identify clearly the pathways to bring resolution (legislative decisions, further stakeholder input, etc.).

  - Further, place emphasis on development of tools and mechanisms, linked to policy formulation, that help reconcile sectoral conflicts, such as Argentina's deforestation risk index and Kenya's spatially-explicit future trajectories of emissions/removals under different economic and development scenarios. Effective land use planning is also a critical basis for aligning sectoral interests, and demarcating how to overcome differences in jurisdictional power between national, regional and district levels of government.
  - Link REDD+ to low carbon development plans and other higher-level policy platforms in order to create strong enabling legal institutional frameworks.

– **Sort out tenure and land access rights**—reconciling tenure and access rights is cross-cutting and fundamental in many R-PP's citing smallholder agriculture impacts, and those governments should focus energies immediately on increasing forest-dependent and indigenous people's access to forests and bring certainty to their ability to gain tenure and access benefit-sharing.

– **Link mitigation to adaptation**—Countries must link forest and agriculture strategies addressing both mitigation and adaption approaches to identify how to meet domestic food supply needs in the future (given population growth, increasing urbanization, regional changes in precipitation and other climate change impacts), while safeguarding carbon stocks.

- **Boost efficiency and production of agricultural systems**—REDD+ strategies can promote more efficient use of land by steering agricultural expansion to already degraded lands (that hold low potential for recruiting carbon-rich regeneration of forests) and can help to steer agricultural extension services to priority landscapes and/or those with greatest potential conflicts with the REDD+ strategy. In countries where shifting agriculture (smallholder impacts) is problematic, a mixture of settling access and tenure rights plus extension programmes (such as Liberia's conservation agriculture), depending on the circumstances, will be critical. Emphasis should also be placed on promoting agricultural intensification activities that also increase carbon storage (such as agro-forestry), combine animal husbandry and food production (Mexico's PROGAN ecológico) and are geared towards increasing soil fertility (Brazil's success with techniques for fixing nitrogen that decreased use of fertilizers is a model). Countries should apply REDD+ readiness funding to furthering this goal.
- **National MRV systems incorporate agricultural carbon measurement**—Increasingly, countries are recognizing the benefits of greenhouse gas inventories that include all land-uses, to track changes in all terrestrial carbon pools. While the financing and capacity may not yet exist in many countries to achieve this, building data inventories and tracking agricultural uses/carbon emissions in the design of MRV systems for REDD+ will help address an informational shortcoming many countries identified related to the role of agriculture in forest clearing. Such information is critical in fine-tuning national and regional REDD+ and agriculture policy development.

4.4 Conclusions

REDD+ offers an unprecedented opportunity to establish policies, institutions and capacity to address agricultural drivers of land conversion. The review of FCPF R-PP's illustrates that many countries have a long way to go before fundamentally addressing agricultural drivers of D&D.

While there is a need to focus REDD+ investment in bolstering national-level forest governance, particularly in countries facing illegal logging and inadequate forest-sector institutions, focusing only on the forest sector is not enough to confront and reconcile agricultural drivers of forest clearing. This chapter argues that in order for REDD+ carbon emission mitigation goals to be reached,

- the primary driver of forest clearing globally —agriculture— must be fundamentally addressed by aligning REDD+ targets with transformational change in agricultural systems that intensify arable farming and production without causing further agricultural expansion, satisfy domestic needs before serving export markets, are geared towards stabilizing food-security in the face of increasing climate change impacts, and solidify forest-dependent community and smallholder tenure and access rights, and

– national governments engaging in REDD+ must focus their REDD+ readiness activities and development of national strategies on establishing adequate enabling legal institutional frameworks (such as low-carbon development commitments); governance; and measurement, monitoring and reporting (MRV) systems that account for and are responsive to the role of agriculture in forest clearing, stretch beyond the forest sector, and align long-term objectives of safeguarding terrestrial carbon stocks while providing food for a growing population.

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Part II
Managing Linkages Between Climate Change and Food Security

Chapter 5
Gender, Climate Change and Household Food Security: A South Asian Perspective

Dr. Nira Ramachandran

Abstract Research on the impacts of climate change indicates greater severity on certain groups and social classes. There is a general consensus that women in the developing countries will be harder hit than men by slow changes in temperature and precipitation which would increase the burden of daily provisioning of food, water and fuel, and also in the advent of weather related disasters, where the onus of providing and caring for the family rests on the woman. While forecasts of climate change in different geographical regions retain an element of uncertainty and women's response to such potential changes can at best be estimated, in the case of weather induced natural disasters like cyclones, hurricanes or floods, the differential impacts on men and women, their distinct coping mechanisms and the success/failure of relief/rehabilitation and preventive measures has been well documented. In fact, disasters serve to highlight the disproportionate costs that women will have to bear as a result of climate change. As it is undisputed that the frequency of natural disasters will increase with global warming, lessons drawn from gender differentiated impacts and gendered response to such disasters may provide useful inputs for food security policy.

Keywords Climate change • Disasters • Gender • Household food security • Women

> Climate change is not gender neutral. Women are generally more vulnerable, representing the majority of the world's poor. They are also more dependent for their livelihood on natural resources that are threatened by climate change.[1]

[1] Gro Harlem Bruntland, Keynote Address: Levers of Global Security: Examining How a Changing Climate Impacts Women, 21 September, 2007.

Dr. Nira Ramachandran (✉)
Institute of Economic Growth, New Delhi, India
e-mail: nira_ramachandran@hotmail.com

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5.1 Introduction

Climate change is no longer a perceived threat; the forerunners of this change are here, and have begun to impact the livelihoods, quality of life and the very life span of men, women, and children. As in all other life altering situations, gender relations play a significant role, especially in the countries of South Asia, where the gender divide remains a rigid one. Women in South Asia, who are primarily responsible for household food security, caring for the young, the old and the infirm, making provision for drinking water and fuel, and working alongside men in the fields, often have to take on the additional responsibility of independently managing the family farm, when men migrate in search of jobs. This often has adverse impacts on household food security and nutrition status.

Rain-fed agriculture in South Asia has always been vulnerable to the vagaries of the South West monsoon, which see year to year fluctuations from flood to drought, often rendering thousands homeless and asset-less and brought to the point of re-starting life from the scratch. To further exacerbate the situation, rising global temperatures and the increasing probability of climatic hazards and unusual cycles of flood and drought, are likely to push below the poverty line even the small proportion of the population just beginning to reap the benefits of the economic boom in the subcontinent. This could result in a long-term setback for the fight against poverty in these countries.

Yet another concern is the increasing frequency of weather related disasters in the recent past. Over the past decade, weather related disasters accounted for 90 % of all reported natural disasters, 86 % of all deaths from natural disasters, 99 % of all those affected by natural disasters and 63 % of damage caused by natural disasters (World Disasters Report 2002, 2003). The period has witnessed as many as 2.5 billion people affected and over US$400 billion in damages (Table 5.1). These figures reflect an alarming increase in vulnerability to extreme weather events.

What is even more alarming is the disproportionate costs that women pay for any disaster. Global evidence suggests that women bear the brunt of any disaster with disproportionate costs in terms of loss of life, livelihoods, health and a longer and more tedious path to rehabilitation. As Bruntland (2007) writes, “These detrimental effects [of climate change] can already be felt in the short term through emergencies such as landslides, floods and hurricanes. More women than men died during the 2003 European heat wave and as a result of Hurricane Katrina in the US”. The situation is far worse in Asia, where women still lag behind their male counterparts in terms of education, earning capacity and independence. Asian Tsunami survivors in many places were males in the ratio of 3:1 (Sharma Fox 2008).

Disasters serve to highlight the disproportionate costs that women will have to bear as a result of climate change. While these costs may not be readily apparent as women slowly adapt to the changing environment with changes in climate and bear the additional burden of time, labour and money which they can ill afford, to meet their basic needs, they are clearly visible in the case of natural disasters. The tenuous hold on food security of innumerable households in the region, as in many other parts

Table 5.1 Escalation of disasters

	1970s	1980s	1990s	1993–2002
No. of reported disasters	1,110	1,987	2,742	2,935
No. reported killed	1.96 m	800,000	790,000	531,000
No. reported affected	740 m	1.45 bn	1.96 bn	2.5 bn
Amount of disaster damage	131 bn	204 bn	629 bn	655 bn

Source: World Disasters Report (2002, 2003)
m million, *bn* billion

of the world, is already beginning to slip. The Food and Agricultural Organization of the United Nations (FAO) projects the number of undernourished people in the developing world to have increased from 848 million to 1,020 million from 2003–2005 to 2009, mainly because of the food crisis and the world economic recession (FAO 2009). The Global Hunger Index (GHI) 2009 shows that South Asia and Sub Saharan Africa continue to suffer from the highest levels of hunger. The GHI, in fact, goes further to state that high rates of hunger are also linked to health and survival inequalities between men and women and suggests that reducing gender disparities in key areas, particularly in education and health, is essential to reduce levels of hunger.

The paper will review and document the gender-differentiated impacts of climate related disasters in South Asia with a view to pinpointing the threats, particularly those impacting food security, which women in the region will face with climate change. The objective is to provide pointers for preventive policy measures aimed at making adaptation to climate change gender neutral in the long run and thereby countering the expected deterioration of household food security.

5.2 Disaster Risk in South Asia

The high cost borne by the South Asian countries in terms of loss of lives and assets can be seen in Table 5.2.

The major climate related disasters in South Asia involve floods, droughts and cyclones. With rising temperatures,[2] glacial melts in the Himalayan Mountain system which controls the hydrology of the region not only threaten the sustainability of the entire Indo-Gangetic river basin, but are giving rise to a new threat through the formation of unstable mountain lakes, which can breach their banks and sweep away all the settlements downstream. Bhutan, for example, is in imminent danger of such a disaster with an average glacial retreat of 100–130 ft per year (HDSA 2005).

[2] Average temperatures in the Himalayas have risen by 1 °C since the mid-1970s (HDSA 2005).

Table 5.2 Estimated deaths and damage cost from natural disasters in South Asia (1980–2005)

Countries	Deaths	Damages (million US$)
Afghanistan	19,000	1,983,000
Bangladesh	179,603	16,272.2
Bhutan	280	3.5
India	133,144	32,018.1
Maldives	102	476.1
Nepal	9,948	1,304.6
Pakistan	83,062	6,839.2
Sri Lanka	36,349	1,670.4
South Asia	442,488	58,584.2

Source: CRED (2005, Natural Disaster Mitigation Policy in Afghanistan accessed at: http://iisee.kenken.go.jp/net/seismic_design_code/afghanistan/afghanistan.pdf)
Note: Data for Afghanistan is from a different source and has not been included in the regional totals

Table 5.3 Average annual physical exposure to disaster risk for floods in South Asia (1980–2000)

Countries	Physical exposure (people per year in millions)	Physical exposure as % of total population (2000)
India	157.5	15.6
Pakistan	48.8	34.6
Bangladesh	51.9	37.9
Nepal	17.2	74.8
Sri Lanka	4.1	21.6

Source: HDSA (2005)

Apart from this newly emerging threat, seasonal flooding is a serious hazard in most of South Asia. Table 5.3 provides estimates of the population exposed to flood risk each year.

While the numbers affected by floods seem insignificant in Nepal as compared to India or even to Pakistan and Bangladesh, they represent almost the full population of the country. In the case of Bangladesh and Pakistan, almost half the population is exposed to flood risk. Conversely, in the case of India, the proportion of population at risk is low, but the actual numbers involved are very large. With 158 million people and over 40 million hectares of land exposed to the dangers of flooding every year, the costs in both economic and human terms are extremely high.

Flash floods occur regularly in Nepal causing shifts in river channels and creating new flood zones which displace people. In Bhutan, river bank erosion and inundation of agriculturally important valleys are a constant threat during the monsoons (HDSA 2005).

The Maldives with its low elevation of merely 1.5 m above sea level regularly faces coastal flooding, as does Bangladesh.

The Indian Ocean being one of the six major cyclone prone regions of the world is annually exposed to a number of cyclones averaging about 6 per year, of which nearly 50 % are quite severe. This is particularly so in the case of Bangladesh, where the densely populated agricultural belt is located at the Head of the vulnerable Bay of Bengal (HDSA 2005).

According to a recent report (Araujo et al., undated), women and children are 14 times more likely to die than men during disasters, Gender and age differentials in mortality rates were strikingly apparent in the aftermath of the Asian Tsunami[3] where the largest number of fatalities were women and those under the age of 15 (Mitchell et al. 2008).

The adverse consequences of both floods and droughts on food security need no elaboration. However, the fact that the negative impacts of such weather induced recurrent hazards is magnified several times over in the case of vulnerable populations does need elucidation. For those living on the brink of poverty and hunger, even a small shock can prove calamitous. The majority of the rural population in the South Asian countries is totally dependent on rain fed mono-cropping, with no reserves of cash or other inputs in case a ripening crop is destroyed by floods/ unseasonable rains or sowing is delayed because of tardy monsoons. With the steadily reducing farm size, both landowners and agricultural labour regularly face several months of food insecurity even when the weather is dependable.

The sharp increase in the frequency of weather related disasters has also brought about a change in the social structure of rural communities. The “feminisation of agriculture” and the resultant “feminisation of poverty”, terms which are now common in development literature, originate in the exodus of the young male working population to urban areas in search of employment. That this is very largely a weather related process has, perhaps, not been sufficiently stressed or explored. The result is another gender differentiated economic process, which leaves the woman as a de facto head of the household shouldering the burden of the farm and the family, yet denied access to property rights, bank loans or technology transfer from government officials. These limitations are further compounded by the fact that women in rural areas are poorly educated, unused to business dealings and prevented by tradition from leaving their homes or interacting with unknown males.

5.3 Household Food Security in the Face of Climate Change

Bohle et al. (1994) write “The implications of climate change for world food poverty may be assessed in two ways:

– To link models that integrate the dynamics of resources, population, economy and political systems; and

[3] While Tsunamis are not climate induced, but result from undersea earth movements, the impacts are not unlike those of floods but with immensely magnified impacts.

– To assess present vulnerability to hunger and famine and infer lessons for coping with future climate change."

By focusing on the existing vulnerabilities created by gender disparities in South Asia, and the likelihood of these vulnerabilities being further accentuated in the context of climate change, this paper seeks to enquire into the implications of climate change for gender and food security, not in a global or regional context, but in the context of the household. The tenuous hold of large numbers of South Asian families on even basic food security makes them immensely vulnerable to the ill effects of climate change. The UN Millennium Project has adopted two indicators to measure progress toward the MDG target of cutting the proportion of people living in hunger to half of the 1990 level by 2015. These are:

– The proportion of the population without access to 2,400 cal per day.
– The proportion of children below 5 years of age, who are undernourished.

Current statistics reveal that over one-fifth of the population in India, Pakistan, Sri Lanka and Bangladesh does not have access to the minimum requirement norm of 2,400 cal per day (See Table 5.4). In Bangladesh, over one-quarter of the population is food insecure. However, Afghanistan records the highest rates of undernourished population with 61 % of the total population consuming less than the minimum calorie norms, and nearly half the children under the age of five being underweight. In general, child under nourishment levels far exceed those of adults. In India and Bangladesh, over 40 % of children below the age of 5 years are undernourished (weight for age), while Nepal follows close behind at 39 %.

In so precarious a situation, the projected reduction in crop yields with climate change could well push countless families into food deprivation and ultimately chronic hunger and malnutrition. A crop model for South Asia indicates that the average yields in 2050 for crops will decline from 2000 levels by about 50 % for wheat, 17 % for rice, and 6 % for maize because of climate change (IFPRI 2009). Average calorie availability in Asia in 2050 is expected to be about 15 % lower with cereal consumption projected to decline by as much as 24 %. The number of malnourished children in South Asia which was projected to fall from 76 to 52 million between 2000 and 2050 is likely to remain at 59 million as a result of climate change, resulting in an additional seven million undernourished children in the region (IFPRI 2009).

Table 5.4 Food insecurity in South Asia

Country	% Undernourished population	% Undernourished children <5 years
Afghanistan	61	48.0
Bangladesh	26	41.3
India	22	43.5
Nepal	16	38.8
Pakistan	23	31.3
Sri Lanka	21	21.1

Source: Ramachandran (2011b)

5.4 Gender Differentiated Impacts of Disasters

Disasters by their very nature are tumultuous events wiping out lives, hard earned assets and security, and rendering the affected populations homeless and destitute. Natural forces are blind to social or economic disparities among their victims, but social constructs tend to override this equalizing effect and create far more severe fallout on the most vulnerable, particularly women. Constrained by lack of education, restricted mobility and limited access to resources, women feel the impacts of disasters far more severely than men. This disparity in impact is not limited to women at the individual level, but has repercussions for the entire family, as more often than not it is women who bear the entire responsibility for household food security, sourcing of essential supplies like water, fuel and fodder, caring for children, the old and sick, as well as the livestock. It may safely be stated that denying a woman equity in relief measures-material or financial, amounts to denying relief to all dependent on her for survival. Saddled with the responsibility of other lives, particularly those of children, women are often unable to save themselves during a disaster, and if they do survive, are unable to access relief supplies or migrate to safer areas without male support. As Lin Chew and Ramdas (2005) write, "At times, essentials like blankets, mattresses, and even food and water, have been distributed based on the needs of single adults, forcing mothers to share meagre rations in order to feed their children. In other cases, women have been too intimidated to collect aid when the distribution of supplies is controlled by men. Government compensation for loss often completely excludes women in societies where only males are recognized as heads of household. The Sri Lankan government offered 5,000 rupees (about $49) to families affected by the tsunami, but in Batticaloa, the regional capital of the eastern coastal area, authorities recognized only male-headed households, so women whose husbands had died couldn't claim the money. In Thailand, the government paid twice as much to families for the funeral expenses of men than for those of women" (Lin Chew and Ramdas 2005). It has been quite rightly stated that "Women and children constitute the majority of victims seen in the media's representation of natural disasters. Beyond the camera lens in the follow-up policies, however, there is a trend for women to be rendered almost invisible" (Jones 2000). Documentation of gender differentiated impacts in disaster situations have been undertaken by several International agencies and researchers. Neumayer and Plűmper (2007) find that natural disasters affect women more adversely than men in terms of the effect of disasters on the life expectancy at birth. What this means is that natural disasters on average kill more women than men or kill women at a younger age than men, and the more so the stronger the disaster. Yet the extent to which women are more likely to die than men or to die at a younger age from the immediate disaster impact or from post disaster events depends not only on disaster strength itself but also on the socioeconomic status of women in the affected country. The higher women's status, the smaller is the differential negative effect of natural disasters on female relative to male life expectancy.

What clearly emerges is the fact that women are much more severely impacted than men, whether in terms of loss of life, injuries, lack of access to relief measures or pace of rehabilitation. According to the New York-based Women's Environment and Development Organisation (WEDO), during the 1991 cyclone that killed 140,000 in Bangladesh, 90 % of victims were women and in the case of the 2004 Asian tsunami, 70–80 % of those who died were women (Deen 2010).

The fact that such disparities are more apparent in developing countries underlines the fact that these inequities result because of differences in education, mobility, awareness, communication and independence rather than physical strength. Jones (2000) writes "It has been argued that vulnerability to natural disasters and their consequences is gendered and socially constructed, meaning that women and men face different challenges during natural disasters because their roles in society have been constructed differently". According to the Pan American Health Organisation (2002), looking at natural disasters from a gender perspective is an urgent requirement to understand what disaster means to everyday reality: "The majority of relief efforts are intended for the entire population of a disaster-affected area, however, when they rely on existing structures of resource distribution that reflect the patriarchal structure of society, women are marginalised in their access to relief resources".

Government efforts to enhance food security in South Asia often focus on the provision of subsidised food to poor families, nutrition supplements to mothers and pre-schoolers, and school meals for older children. Disaster disrupts the flow of regular assistance threatening women's ability to care for themselves and their children. In Gujarat, India for example, many women depended on the provision of shakti packets to help meet their basic daily nutritional needs. Distribution stopped temporarily after the earthquake cutting women off from one of their sources of subsistence (Women Thrive Worldwide, undated).

Additionally, the extended family system may result in an expansion of women's household responsibilities after a disaster. Displaced family members seek refuge with those who have already resettled, and women face the challenge of providing for their growing families, while access to resources dwindles. In particular, women struggle to provide water. Disasters tend to damage water systems, and women, who are chiefly responsible for transporting water, tend to spend more time fetching water cutting into their already limited time for other necessary activities like income generating ventures.

Disasters destroy lives and for those who survive, they destroy livelihoods. This is particularly so in the case of women. Tied down with the responsibilities of caring for children, parents and sick or disabled family members, women are not free to migrate in search of livelihoods as men do. This limited mobility further accentuates the vulnerability created by the resource dependency of women's livelihoods. When disaster destroys natural resources, women lose their only source of income. In Gujarat, India, many women employed in the agricultural sector were deprived of their livelihoods after the earthquake hit in 2001. Shifting underground hydrological systems made agriculture less profitable, driving down the demand for workers with the types of skills that women had developed and women were deprived of even their minimal incomes (Women Thrive Worldwide, undated).

Ownership of land or a house is often the deciding factor in recovery after disaster strikes. The right to property is still denied to women in South Asia. While most South Asian countries have made efforts to ensure women the legal right to property, in practice women are usually denied these rights or voluntarily surrender their claims in favour of sons or brothers, through social compulsions. This can be self destructive when disaster strikes. If women do not have the right to own property, they can lose their homes and fields and the means of rebuilding their lives. In Pakistan, for example, a researcher documents a case in which a male family member invoked Sharia Law so that he could inherit his deceased relative's land. The widow and her two daughters found themselves homeless (Women Thrive Worldwide, undated).

Social constructs of gender appropriate behavioural patterns are a major cause of differential disaster impacts. Oxfam (2005) reports when the tsunami hit the coast of Indonesia many women in the rural coastal areas were at home, whereas the men were out at sea fishing or otherwise away from home. In India many women were waiting at the seashore for the fishermen to arrive. In both cases, many more men were spared because the waves only gather height and strength as they approach the shore and have their most fatal impact directly at the coast. Similarly, during earthquakes the men are more likely to be out in the open or in more robustly built factories and public buildings while the women are at home in dwellings more easily struck down by earthquakes. Clearly this type of natural disaster is likely to affect women more adversely, given that inadequate building structures are by far the main cause of earthquake fatalities (Noji 1997). Even when men are at home, they are not necessarily equally affected as women. In earthquakes in India men reportedly survive better even those events that hit at night because during warm nights men sleep outside and on rooftops, a type of behaviour impossible for most women, who became trapped in their domestic homes (Krishnaraj 1997). In Bangladesh, following the cyclone and flood of 1991, women waited at home for their husbands to come and move them to safety, and lost their lives in the process. Men who were in the marketplace heard the warnings and managed to escape to safety, while women lacking similar communication channels perished.

5.5 Lessons from Gender-Specific Disaster Impacts to Meet the Challenge of Climate Change

Gendered constructs clearly lead women to experience disasters much more harshly than men in the same socio-economic class. It is logical to anticipate that women will be similarly disadvantaged by the impacts of climate change. The repercussions of gender disparate impacts on household food security in the context of dwindling natural resources and the expected reductions in food crop yields can easily be visualized. In the context of climate change, traditional food sources become more unpredictable and scarce. Women face loss of income as well as harvests—often their sole sources of food and income. A participatory study of rural areas in South Africa (Babugur 2010) shows sharply diminishing returns from farmland (worked by men), as well as home gardens (cultivated by women) on which rests family food security. In the face of unprecedented weather changes and shifting seasonal patterns, the diversity of food crops in the home gardens has reduced leaving the families short of both cash income and food. Related increases in food prices make food more inaccessible to poor people, in particular to women and girls whose health has been found to decline more than male health in times of food shortages. In the rural areas of South Asia as in other parts of the developing world, biomass such as wood, agricultural crops, wastes and forest resources are indispensible to livelihoods as well as food security. Climate change has resulted in declining biodiversity, which severely restricts the coping capacity of the rural poor. A study of tribal villages in four states of India (Ramachandran 2004) found that the population in villages with access to forests suffered from food shortages but rarely faced starvation, unlike those denied such access because of location or other constraints. Rapidly depleting forest resources also make the daily foraging for fuel and fodder for domestic animals more difficult. This is yet another task which falls to women and girls and can take from 2 to 20 or more hours per week. Fisheries in many societies will be worsened by climate change impacts. This leads to loss of income for poorer women, increases in prices of fish, and lowering of protein levels in diets (Damptey and Mensah 2005). Women are often restricted from leaving their communities, even though migration is a coping mechanism often used by men. This is due to the fact that gender roles dictate that they remain at home and carry out reproductive tasks and to the fact that, having less education, they are less likely than men to find employment. Remaining at home can leave them vulnerable in two ways: first, they stay where climate change has hit hard, and second, they miss out on the economic opportunities and enrichment of personal experience that migration affords (UNDP 2010).

Given the gender differentiated impacts and vulnerabilities, men and women will also have different priorities and responses to climate change in terms of coping and adaptation so as to build resilience (Babugur 2010). Can lessons be drawn from the above documented disaster experiences? It is clear that women are disadvantaged because of the:

- Gendered division of labour and responsibilities
- Unequal access to education, information, assets
- Restrictions on mobility
- Dependence on men for decision making
- Unquestioned acceptance of their secondary status

The same factors are likely to hinder their adaptation to climate change, and in its wake, household food security. While the first factor, i.e., the gendered division of labour and responsibilities inside and outside the home are deeply entrenched in tradition and unlikely to change in the foreseeable future, the other four factors may be responsive to change if suitable efforts are made. Across South Asia, governments, NGOs and International Agencies are focusing efforts on increasing the enrolment of girls in school and providing incentives to encourage attendance and retention in an effort to reduce gender disparities in education. It is accepted that despite some progress, many parents remain reluctant to send girls to school, and girls are the first to be withdrawn if finances become constrained. The right to inherit property, particularly agricultural land, which can provide a lifeline in case of disasters or even minor setbacks like failed harvests lies in personal law, which varies by religious denomination, and is rarely in favour of women, except in the matrilineal society of Bhutan and parts of North Eastern India. Restrictions on the mobility of both girls and adult women, though less than earlier, still remain more or less strictly enforced. Traditional cultural norms can affect women's ability to adapt to climate change. In Niger, rural women are generally not allowed to move outside their villages. Since they always remain in the same environment, they are neither exposed to, nor learn to adapt to, various situations, which can put them at greater risk when changes occur. Since men often leave their villages to find work, they explore and experience different environments, gaining new skills and accumulating knowledge and other resources (money, social networks, etc.) that are valuable for adaptation (UNDP 2010).

The last two controlling factors are more internal than externally imposed, and are likely to respond only to concerted efforts for women's empowerment. While empowering a woman as an individual is far from easy, much success has been achieved through the formation of women's groups, whether for economic or social objectives. Women typically form strong social networks within their communities, thereby meeting a prerequisite for collective management of the risks posed by climate change (UNDP 2010). Women's groups have successfully taken on co-operative agriculture, horticulture, small scale food processing, dairying, and other manufacturing as well as dealing with reconstruction and rehabilitation in the aftermath of disasters. After Hurricane Mitch, in 1998, Guatemalan and Honduran women readily took on traditionally masculine tasks like building homes and shelters, hauling water and digging wells. Six months after Banda Aceh, Indonesia was devastated by the tsunami, more than 70 % of the local civil organizations working in the area were women's groups or groups mostly staffed by women (Jones 2000). As Enarson (2000) writes "Women's local community knowledge, strong social networks, key roles in families, and active work roles make them resourceful social actors in crisis, yet they are rarely recognized as 'front-line' responders". Ariyabandhu (2000) also underlines that "Women's extremely high degrees of resilience in difficult situations, and the will to survive and ensure their family survival is noted not only in disasters, but in daily struggle for life. During calamities, taking care of the meagre belongings of the family, ensuring food and water for the family members, looking into the concerns of rebuilding the livelihoods, securing the seed and other productive material, taking care of the sick and old are almost entirely done by women". Yet, their efforts remain largely unappreciated.

Not only do empowered women deal effectively with disasters, but they also devise efficient strategies to cope with climate change. In southern Bangladesh, women have devised a new system of cultivation in response to the increased frequency of flooding and water logging. Floating gardens, or Bairas, have been devised using water hyacinth (Baira), a local invasive weed that floats in water. Floating mats have been developed on which soil, manure and rotting Baira can be spread and a number of crops can be cultivated. These mats simply ride out water-logging and flooding. They are easy to build using local resources and know-how, are recyclable and sustainable, and are ideally suited to the particular problem faced (UNDP 2010).

In Banaskantha, a drought prone district of Gujarat, India, women recycle water at least 3–5 times over (Bhatt 1995), while in Rapar Taluk, Kutch, in the same state, during the dry season, women collect water by digging shallow wells or veerdas in the dry riverbed and scooping out water which has percolated beneath the surface (Acharya, undated). With increasing climate variability, salinization of drinking water sources is becoming a major problem for the people of southwest Bangladesh. During the dry season, when lack of potable water becomes an acute crisis for households, it becomes the responsibility of women, irrespective of their physical condition, to provide drinking water for their families. Since water sources in the neighbourhood are all affected by high salinity, women need to travel long distances, sometimes up to ten kilometres on foot every day over rough terrain, in search of water. This consumes an enormous amount of their time (ELIAMEP 2008).

5.6 Conclusions

This paper has attempted to review the gendered impacts of disasters to gain an understanding of the expected gendered impacts of climate change. The lessons drawn, it is hoped, would indicate where the strengths and weaknesses of women lie, and how these can be channelled to enhance mitigation and adaptation strategies; the ultimate focus, of course, being the enhancement or at least the maintenance of household food security. While there clearly is a gendered element to vulnerability, there similarly are gendered differences in adaptation. However, it must be reiterated here that women are not just helpless victims of climate change – women are powerful agents of change and their leadership is critical. Women can help or hinder in dealing with issues such as energy consumption, deforestation, burning of vegetation, population growth and economic growth, development of scientific research and technologies, and policy making, among many others (Aguilar et al., undated). Their local knowledge and particular experience of natural resource management and coping strategies during crisis are vitally important for the formulation of any adaptation strategies that hope to be successful. But in order to capitalize on this knowledge, there must be a gendered approach to adaptation that gives women a voice and the ability to participate within the development process (UNDP 2010).

It is also important to note that the threats to household food security posed by climate change are not restricted to food crops and livestock alone, but necessarily involve other supporting resources like water, fuel and fodder as well as access to cash incomes. As women's livelihoods in the rural areas of South Asia as in other parts of the developing world, are heavily dependent on bio-mass, the resource constraints posed by the changing climate further curtail the meagre income accruing to them.

Not only do the unpredictable weather patterns resulting from changing climate negatively impact the availability of essential resources, but they also impose additional burdens on women's time and labour in accessing them, with negative repercussions on the caring functions of women. This assumes major significance in the countries of South Asia where the persistence of high levels of malnutrition, especially among young children, is often directly attributable to lack of time for caring. Even simple remedial measures like feeding young children small amounts of nutritious food several times a day to improve nutrition levels or keeping drinking water in covered pots, and handling food only with washed hands to reduce the risk of diarrhoeal diseases are difficult to put into practice when a woman is overburdened with innumerable responsibilities.

While it has been rightly stated that "Empowering and investing in women are key to combating the effects of desertification and paving the way for poverty alleviation in the world's least developed countries" (UN WomenWatch 2009), ensuring household food security in the rapidly changing climate scenario involves more than the empowerment of women. It calls out for immediate policy measures to put in place the basic infrastructure for assured drinking water, sanitation, healthcare and education, particularly in high risk areas. To face the challenges which lie ahead necessitates building resilience in populations, particularly in the case of those who are already rendered vulnerable because of malnutrition, ill health and poverty, and face the additional risk of being located in geographically susceptible areas. The capacity to bounce back after a shock or adapt to a gradually deteriorating environment lies in an individual's health, knowledge, and access to a strong support structure. While this applies equally to men and women, it is evident that women need additional support to cope with the unequal burden they bear.

As awareness of climate change and its probable impacts remains limited in both rural and urban areas, communication strategies gain in importance. The urgency of introducing appropriate adaptation/mitigation measures must be effectively communicated. The synergistic relationship between the impacts of climate change and the factors controlling nutrition and health need to be understood and conveyed to high risk populations. For example, introducing water/energy conservation strategies, and providing improved access to water, fuel and fodder to reduce women's work-load helps both in promoting sustainable resource use and increasing caring time- a determining factor in child malnutrition. Encouraging the adoption of hygienic practices/ improved sanitation could significantly reduce malnutrition and the disease burden at present and in the future. Setting up of community initiatives, perhaps in coordination with women's groups for emergency relief could prove a viable support system to tide over the expected time lag in receiving relief from outside sources, whether government or international agencies (Ramachandran 2011a).

Agricultural and rural development strategies must recognize the important roles that women play in food security and nutrition, as farmers, marketing agents, stewards of natural resources, providers of childcare and chief preparers of meals within the household (Hawkes and Ruel 2006). The consultation and participation of women in climate change initiatives must be ensured, and the role of women's groups and networks strengthened. Concerted efforts are required at policy, programme and project level to speed up the process of empowering women to face and successfully cope with the additional challenges coming their way in the task of ensuring household food security.

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Chapter 6
The Threats of Climate Change: Implication for Food Crisis in Sub-Sahara Africa

Olubunmi Lawrence Balogun, Sulaiman Adesina Yusuf, and Kayode Ayantoye

Abstract Food insecurity remains endemic in most of the Africa countries, with climate factors such as rainfall variability as a major cause. The significance of this variability is clear when we consider that in sub-Saharan Africa, agricultural production accounts for up to 90 % of food needs. Socio-economic conditions and the adverse impact of unpredictable weather on the agricultural production of communities in sub-Sahara Africa have long been recognized as an important cause of malnutrition in the region. The paper reviews the current state of knowledge related to the threats of climate to food crisis in sub Sahara Africa. Long-term climate change is linked to global warming. This increase is partly due to the influence of human activities on nature such as exhaust gas emissions from vehicles, coal burning for energy, and deforestation. Tackling these challenges of climate change will require the use of sophisticated surveillance and response systems. Therefore, mitigation policy that assures food security at all time is recommended to achieve the Millennium Development Goal 1 to reducing by half people suffering from hunger by 2015.

Keywords Climate change • Rainfed agriculture • Food crisis • Global warming • Sub-Sahara Africa

6.1 Introduction

Sustainable food security in a world of growing population and changing diets is a major challenge under climate change. Although estimates of food insecurity vary (Barrett 2010), the number of undernourished people already exceeds one billion and feeding this many people will require more than incremental changes (Federoff et al. 2010). Food production may need to increase by as much as 70 % by 2050

O.L. Balogun (✉) • S.A. Yusuf • K. Ayantoye
Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria
e-mail: blarrybunmi@yahoo.com

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when the global population will number nine billion (World Bank 2007; Royal Society of London 2009). Food security depends not only on gross production of staples, but also on agriculture's ability to provide a diverse and balanced food basket, socio-economic factors that determine whether poor people particularly women are able to purchase, store, prepare and consume sufficient food.

Sub-Saharan Africa is uniquely vulnerable to climate change because it already suffers from high temperatures, less predictable precipitation and substantially greater environmental stresses than other continents (IPCC 2001, 2008). According to the Food and Agricultural Organisation (FAO) of the United Nations, one in three people living in sub-Saharan Africa were chronically hungry in 2008. The region accounts for 25 % of the global figure of chronically undernourished. Despite a decades-long of governments' effort in the region to reduce hunger, trends show an overall increase in the number of undernourished people. In 1990–1992, 169 million people were considered undernourished, and that number jumped to 212 million in the 2003–2005 periods. Not only does this represent an increase in the absolute number of hungry people, but also an increase in the percentage of hungry people living in the region. Sub-Saharan Africa moved from having one fifth of the world's hungry in 1990–1992 to having one quarter of the world's hungry in 2003–2005 (FAO 2008). The food crisis of the past 2 years, brought on by rising fuel prices, severe weather conditions, an increase in the use of food crops for biofuels, and changes in diets had a devastating effect on less economically developed nations, including many in sub-Saharan Africa (Food and Water Watch 2008). In 2007 and 2008 price increases from between 30 and 150 % for staple foods have influenced the number of people going hungry (Oxfam International 2008). In 2007 alone, more than 24 million people became undernourished in Africa. The number of people that suffered from chronic hunger continued rising in 2008 and the projections that food prices will stay high through 2015 paint a bleak picture of the future (FAO 2008).

Agriculture is of great importance to most Sub-Saharan African economies, supporting between 70 and 80 % of employment and contributing an average of 30 % of gross domestic product (GDP) and at least 40 % of exports (Commission for Africa 2005). Majority of the poor resides in rural areas and depends on agriculture for their livelihoods. The failure of agriculture to take off in Sub-Saharan Africa has been attributed to the dependence on rainfed agriculture; low population densities; the lack of infrastructure, markets, and supporting institutions; the agro-ecological complexities and heterogeneity of the region; low use of fertilizers; and degraded soils (World Bank 2007). Running out of food is a very common phenomenon in sub Sahara Africa because crops often fail as a result of the effect of climate change (such as the unpredictable pattern of rainfall). This is an indication that climate change is already having a significant impact on Africa's food security.

A number of factors have led to sub-Sahara Africa being a region plagued with poverty and malnourishment. While there are many resource rich countries in sub-Saharan Africa, climate and geography in most of the equatorial countries does not lend itself to productive agriculture. Droughts, floods, and other severe weather conditions have contributed in no small measure to food SSA food insecurity (Wermuth 2003). Climate change poses great risks to poor people whose livelihoods depend directly on the use of natural resources. In fact, many African countries have been coping for the past several decades with a "silent" crisis of climate variability whose impacts on food security have been devastating without always being highly visible. Global climate change poses great risks to poor people whose livelihoods depend directly on the use of natural resources. This situation has severe impact on cereal production, which relies mainly on rain-fed agriculture. Since the end of the 1980s, inter-annual gross cereal production in the Sahel has varied by 20 % on average. The significance of this variability is clear when we consider that in sub-Saharan Africa, agricultural production which accounts for up to 90 % of food needs of the region (Dembélé 2001). Socio-economic conditions and the adverse impact of unpredictable weather on the agricultural production of communities in sub-Sahara Africa have long been recognized as an important cause of malnutrition in the region. Understanding the potential implications of climate change for food systems requires evaluation of a complex set of climate, environmental, and socioeconomic factors. Sub-Sahara countries are particularly vulnerable to climate change because of their dependence on rainfed agriculture, high levels of poverty and other endowment. The United Nations Development Programme (UNDP) had observed that the progress in human development achieved over the last decade may be slowed down or even reversed by climate change, as new threats emerge to water and food security, agricultural production and access, and nutrition and public health (Ludi 2009).

Africa is the most vulnerable region to climate change because widespread poverty limits adaptive capacity. The impacts of climate change on agriculture could seriously worsen livelihood conditions for the rural poor and increase food insecurity in the region. The World Development Report 2008 (World Bank 2007) identifies five main factors through which climate change will affect agricultural productivity: changes in temperature, changes in precipitation, changes in carbon dioxide (CO_2) fertilization, increased climate variability, and changes in surface water runoff. Climate change will alter development strategy in ways that are not yet well-understood, with profound threats to agricultural production. Due to the sensitivity of agriculture to climate variability, climate change presents a significant potential threat to food security and economic growth and is likely to exacerbate the run up in global food and energy prices. The paper reviews the current state of knowledge related to the threats of climate to food production in sub Sahara Africa.

6.2 Impacts of Climate Change and Land Degradation on Sub-Sahara Africa

Sub Sahara African economies and communities are affected by climate change through increased extreme weather events, reduced crop yields and livestock productivity, drinking water shortages, reduced potential for hydroelectricity, spread of diseases such as malaria, potential migration and social strife, increased cost of infrastructure maintenance and development, and increased pressure on service delivery and fiscal resources. Table 6.1 shows the number of people affected by disasters in sub Sahara Africa for example, Ethiopia 1995–2008 but data crosschecking shows some disparity in number of victims that may be attributed to underreporting by government officials. The difference in populations affected in between the study areas, mid and lowlands (Arsi-Negele, Shashamane Siraro and Shala) and predominantly highland areas (Kofale and Dodola) is shown in the Table. According to the country level study by Comenetz and Caviedes (2002) the successive drought in 1991–1992 and 1993–1994 has caused comparable affliction to that of 1980s. The 1994 heavy and unseasonal rain has also damaged crops. The damage incurred by 1997–1998 drought was estimated to 28 million dollars (a huge loss to poor countries like Ethiopia) that was again followed by catastrophic flooding in 1998 that compounded food shortages (ibid.). The drought in 2001–2002 has caused food and water deficit to 12.5 million Ethiopians (WFP Emergency Report 2003). Though 2005 and 2006 were relatively a good harvest season in West-Arsi zone, heavy rain mixed with hailstorm in 2006 has damaged ready to harvest crops in Dodola district, and latter followed by the notorious drought of 2007/2008 (total *Belg* rain failure). Similarly, the drought of 2007/2008 was followed by heavy *Meher* rain during the vegetative stage of the crops and latter followed by unseasonal rain during *Meher* harvest season.

The productivity of the natural resource base is likely to decline as a result of watershed erosion, loss of soil productivity, loss of woodlands and forests, desertification, coastal erosion, and loss of aquatic and terrestrial biodiversity with consequent effects on agriculture, forestry, and water resource-based economic activities, fisheries, urban and coastal infrastructure, and tourism. Land degradation processes may be exacerbated by climate change. More intense rainfall promotes soil erosion. Increasing temperatures increase evapo-transpiration rates that reduce soil moisture. Rainfall patterns affect vegetation patterns and the growing period for crops. Prolonged dry spells and erratic climatic conditions may lead to short-term coping strategies such as deforestation to increase livelihoods. They may also help to mitigate the immediate impact of a climatic event, but will prove to be maladaptive in the long term by having adverse consequences for watersheds, biodiversity, and provision of important ecosystem services.

The Fourth African Assessment Report on climate change released by IPCC highlights major issues related to potential impacts as a result of climate change (IPCC 2007). It indicates that Africa is one of the most vulnerable continents to climate change and climate variability. This is a result of the interaction of 'multiple stresses' including land degradation and desertification, declining run-off from water catchments, high dependence on subsistence agriculture, HIV/AIDS prevalence, inadequate government mechanisms and rapid population growth occurring at various levels, and low adaptive capacity due to factors such as extreme poverty, frequent natural disasters such as droughts and floods, and rainfall-dependent agriculture (Boko et al. 2007). The likely impacts of climate change will add to these existing stresses and exacerbate the effects of land degradation. Increased

Table 6.1 Populations affected by both manmade and natural disasters in Ethiopia 1995–2008

District	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Siraro and Shala	1,000	1,050		17,000		2,700		40,515	40,500				5,000	14,500
Shashamane				2,500		16,000		72,413	41,080				9,324	15,000
Arsi-Negele				10,030		18,000		17,230	53,100	5,808			7,000	18,260
Dodola													2,908	5,000
Kofale														5,500
Others													2,727	41,200
Total	1,000	1,050		35,530		61,000		130,218	130,600	5,808			26,959	99,400

Source: Oromiya Region New Zone Study Group. (2006).

temperatures levels are expected to cause additional loss of moisture from the soil, reduced and more intense rainfall and higher frequency and severity of extreme climatic events, such as floods and droughts. These factors are already leading to a loss of biological and economic productivity and putting drylands population at risk of short- and long-term food insecurity. There is considerable variability and uncertainty in climate change projections. Drought-prone areas inter alia are particularly deemed to suffer complex, localized impacts of climate variability/change. In the Sahel, for instance, changes in temperature and rainfall patterns have reduced the length of the vegetative period and make it difficult to continue the cultivation of traditional varieties of long and short cycle millets (Rosenzweig et al. 2007). Given the social, legislative, market and weather-based sources of vulnerability already prevailing in the region, reduction in agricultural productivity and land area suitable for agriculture, even if slight, would cause disproportionately large detrimental effects (IPCC 2007; Dietz et al. 2003).

6.3 Impacts of Climate Change and Challenges of Agricultural Productivity in Sub-Sahara Africa

Agriculture is often considered the most vulnerable sector to climate change. It is affected by the vagaries of climate, and contributes to increasing climate variability and change, directly and indirectly, through the emission of greenhouse gases. Potential impacts of climate change on agricultural production depend on the internal dynamics of agricultural systems, including their ability to adapt to the changes (IPCC 2007). The impacts of climate change on agriculture include: biophysical impacts and socio-economic impacts (Nyong 2008).

6.3.1 Biophysical Impacts

In Mid- to high altitude regions, moderate warming benefits cereal crop and pasture yields, but even slight warming decreases yields in seasonally dry and tropical regions. In mid- to high-latitude regions, temperature increases of between 1 and 3 °C across a range of CO_2 concentrations and rainfall changes, will likely have small but beneficial impacts on the main cereal crops for instance rice, wheat and maize. In the low-latitude regions, where most of the SSA countries (Sudan, Nigeria, Somalia, Ethiopia, Zimbabwe and Chad) are found, even moderate temperature increases are likely to result in declining yields for the major cereals. This could increase the risk of hunger in many parts of the world. Simulations for sub-Saharan Africa estimate that some countries in the region could lose cereal-production potential by 2080 across all emission scenarios (Fischer et al. 2005). These are countries where a large portion of the population depend on agriculture, and where capacities (e.g. technologies, finances, investments, etc.), both at national and farm level to adapt to climate change, are lowest. In addition, most of these countries are currently experiencing conflicts that would further hamper agricultural production. However, global warming will also present opportunities for some countries to expand their agricultural potentials.

- Increases in frequency of climate change extremes may lower agricultural productivity beyond the impacts of mean climate change. Extreme events such as floods and droughts may also lower long-term yields by directly damaging crops at specific developmental stages. Heavy rainfall could precipitate soil erosion resulting in substantial agricultural loss.
- Elevated levels of CO_2 and climate change will have varied impacts on livestock production. Increased CO_2 and global warming will likely produce a dominance of unpalatable and invasive plant species, and could likely have detrimental effects on the nutritional value of extensive grasslands to grazing animals.
- Local extinctions of particular fish species are expected at edges of ranges. Fisheries could be affected by different biophysical impacts of climate change. It is likely that regional changes in the distribution and productivity of particular fish species will continue and local extinctions will occur at edges of range, particularly in freshwater species. In some cases, ranges are likely to increase, and decrease in some. A 1.5–2.0 °C rise in temperature could result in the loss in productivity on the fisheries in northwest Africa and the East African lakes. A simulation under a doubling of CO_2 indicates that extreme wind and turbulence could decrease global fish productivity by 50–60 % in the region.

6.3.2 Socioeconomic Impacts

Most models generally agree that global cereal production would increase by as much as 200 % by 2080 with global warming because of CO_2 fertilization (Fischer et al. 2005). More disaggregated regional models however have shown the disparity in cereal production at more localized levels. These detailed studies show an increasing gap in cereal production between developed and developing regions especially after 2020. There are disparities in cereal production at more localized level in sub-Sahara Africa and in some areas in South Asia where suitable arable land resources are limited. Several models project that climate change could cause a modest increase of between 2 and 20 % in the price of agricultural products in the short to medium term at the global level while temperature increase of up to 5 °C could result in higher output, a small decline in real world cereals prices and global mean temperature beyond that point could lead to a substantial increase in food prices (Easterling et al. 2007; Fischer et al. 2005). Studies have shown that some parts of sub Saharan Africa will experience a reduction in magnitude greater than what is predicted with global models (Boko et al. 2007).

6.4 Climate Change and Challenges of Food Production in Sub Sahara Africa

Climate change is a global warming, in part attributable to the 'greenhouse gases' generated by human activity. Global agricultural output per capita has grown at an average rate of 0.4 % per year since 1961. The negative effects of climate change on crop production are especially pronounced in Sub-Sahara Africa, as the agriculture sector accounts for a large share of GDP, export earnings, and employment in most African countries. The current global food crisis will worsen an already precarious food security situation most especially in developing countries including sub-Sahara Africa. In sub-Sahara Africa countries, especially in seasonally dry areas, crop and animal productivity may decrease significantly due to temperature increases of 2–3 °C, by 2020, climate change could cause, significant decreases in crop yields, declines of 40–90 % of grassland productivity, high levels of desertification and soil salinization in some areas and also lead to increasing water stress, particularly irrigated production systems (IPCC 2007).

Climate-related crop failures, fishery collapses and livestock deaths already cause economic losses and undermine food security, and these are likely to become more severe as global warming continues. A recent study estimates the annual costs of adapting to climate change in the agricultural sector to be over US$ seven billion (Nelson et al. 2009). Sub-Sahara Africa's agriculture and rural economy face challenges which could broadly be categorized into four such as production and productivity-related; infrastructure and market related; environment related; an institutional and policy related. The accumulation of greenhouse gases in the atmosphere has warmed the planet and caused changes in the global climate. Sub-Sahara Africa is the only region in which agricultural output per capita has not seen a sustained increase, with considerable variation over time and across countries. For example, sub-Saharan Africa produces less food per person today than it did three decades ago. The crop model indicates that in 2050 in Sub-Sahara Africa, average rice, wheat and maize yields will decline by up to 14, 22, and 5 %, respectively, as a result of climate change.

In 2001 the UN-sponsored Intergovernmental Panel on Climate Change (IPCC) reported that worldwide temperatures have increased by more than 0.6 °C in the past century and it also estimated that by 2100, average temperatures will increase by between 1.4 and 5.8 °C. IPCC also reported that sea levels have risen by between 10 and 20 cm and snow and ice covers have fallen almost worldwide, while the precipitation patterns characterizing land areas of the Northern Hemisphere have progressively changed. In the same report, IPCC estimated that sea levels would rise by an average 0.09–0.88 m between 1990 and 2100. Responses to climate change can either seek to reduce the level or rate of change (mitigation) or manage its consequences (adaptation). Mitigation of the adverse effects of climate change is a high priority on the international agenda. Carbon trading, under the Kyoto Protocol as well as outside the protocol, is growing rapidly from a small base and is expected to increase dramatically under present trends. Long-term climate change is linked to an increase in global carbon dioxide, CO_2 concentration in the atmosphere, together with a few other greenhouse gases (GHG). This increase is partly the result of the influences of human activities on nature such as exhaust gas emissions from vehicles, coal burning for energy, and deforestation.

Recognizing the urgency of the situation, world leaders adopted the Rome Declaration on world food security and the challenges of climate change and bio-energy on 5 June 2008 and pledged to recognize food security as a priority national development policy. World Health Organisation informed the conference that adequate food intake is a fundamental determinant of health throughout the life course and highlighted the health implications of the current situation. The 2008 Group of Eight (G8) multi-industrialized countries summit also considered the recent rise in food prices which could jeopardize all nutrition programmes and adopted interventions to address the risks and consequences of malnutrition among vulnerable groups.

The food insecurity in sub Saharan Africa is high on the world development agenda. For example in 2005 the G8 summit with great fanfare announced a new aid and development deal for Africa. And yet a year latter instead of increasing aid by a promised 10 %, the reality turned out to be one where aid declined by more than 10 %.

Accompanying changes are likely to be both global, as with rising sea levels attributable to ice-melt, and local, such as changes in rainfall patterns. The impacts of climate change include sea level rise, droughts, heat waves, floods and rainfall variation which could, by 2080, push another 600 million people into malnutrition and increase the number of people facing water scarcity by 1.8 billion (UNDP 2008). It is estimated that 25 % of the population (approximately 200 million people) in Africa at present currently experience water stress, with more countries expected to face high risks as a result of climate change. This may, in turn, lead to increased food and water insecurity for at-risk populations, undermining growth. It is estimated that the net balance of changes in the cereal production potential of sub Sahara Africa (SSA) resulting from climate change will be negative, with net losses of up to 12 %. Overall, approximately 40 % of SSA countries will be at risk of significant declines in crop and pasture production due to climate change (Fischer et al. 2005; Shah et al. 2008). Climate change is expected to increase the number of undernourished people by between 35 and 170 million people in 2080, depending on projected development paths (Shah et al. 2008).

The food security depends on the ability of the world population to supply and distribute enough and quality food to poor households. Rice supply depends on global production, while its distribution depends on the distance from production sites to consumers' residences as well as on transportation systems and facilities.

6.5 Climate Change and Mitigations Policy

Sub-Saharan Africa with about 10 % of the world's population currently contributes some 2.4 % of CO_2 emissions and its share over the last 50 years of the world's cumulative CO_2 emissions is less than 2 %. The potential for mitigation through agriculture in the African region is estimated at 17 % of the global total, and the economic potential (i.e. considering carbon prices) is estimated at 10 % of the total global mitigation potential. Similarly, Africa's forestry potential per year is 14 % of the global total, and the avoided-deforestation potential accounts for 29 % of the global total.

Mitigation refers to elimination or reduction of frequency, magnitude, or severity of exposure to environmental, economic, legal, or social risks, or minimization of the potential impact of a threat or warning. Mitigating climate change requires identifying effective ways to reduce greenhouse gases produced and released to the atmosphere. Adaptation options for sub Sahara Africa are adaptation strategies that concentrate on the reduction of vulnerability to current climatic events and planning for long-term sustainable development.

Various mitigation options have been considered in the agricultural sector. These include: cropland management, grazing land management and pasture improvement, management of organic/peaty soils, restoration of degraded lands, livestock management, manure management, and bioenergy. Some of the recommended practices for better cropland management include:

- Agronomy: implementation of agronomic practices that give higher yields and residues, which can increase soil carbon.
- Nutrient management: This involves improving the efficiency of Nitrogen use by avoiding fertilizer over-applications.
- Tillage/residue management: Practices include low zero-tillage crop management practices, and the retention of residues on farms.
- Water management: This involves the improvement of yields through good and efficient irrigation practices, and better water management.

Increased climate variability and droughts will affect livestock production as well. Smallholders and pastoralists in Sub-Saharan Africa will need to gradually adapt and adopt technologies that increase the productivity, stability, and resilience of production systems (Faurès and Santini 2008). However, with the threats of changes in climate, exacerbating current trends of encroachment on grazing lands by agriculturists and other factors they may be forced to consider other livelihood options, including permanent migration, in order to cope with cumulative changes. Achieving sustainable food security in a world of growing population and changing diets is a major challenge under climate change. Successful mitigation and adaptation will entail changes in behaviour, technology, institutions and food production systems. These changes cannot be achieved without improving interactions among scientists, policy makers and civil society.

Agriculture and related activities also contribute to global warming, by generating greenhouse gas (GHG) emissions and altering the land surface. Agriculture is estimated to account for about 15 % of global GHG emissions and for around 26 % if the emissions from deforestation in developing countries where agriculture is the leading cause of forest conversion are included (World Bank 2007). Around 80 % of agricultural emissions, including deforestation, occur in developing countries (World Bank 2007). There remains much untapped technical potential to reduce agricultural emissions and increase agricultural mitigation of emissions from other sectors, notably through reduced deforestation via changes in land use and agricultural practices.

Climate change mitigation measures recognize that the amount of greenhouse gases in the atmosphere will influence the rate and magnitude of climate change. Therefore it is within the capacity of humans to influence their exposure to change. Potential agricultural management changes that have been proposed by FAO to increase agricultural production, as well as to decrease output variability due to climate variability and extreme climate events (many of which overlap with those proposed for adaptation to climate change): cropland management (e.g. improved varieties, reduced/zero tillage, agroforestry); water management (e.g. (supplementary) irrigation, water harvesting, watershed management); pasture and grazing management (e.g. forage quality, stocking rate management) and restoring degraded lands (e.g. re-vegetation, en-exclosures). However, it must be noted that there can be tradeoffs between short and long term benefits of interventions. Agricultural management practices, including those employed in organic and conservation agriculture capture carbon from the atmosphere and store it in agricultural soils. These practices involve increasing the organic matter in soils of which carbon is a main component. This, in turn, increases fertility, water retention and the structure of soils, leading to better yields and greater resilience.

Climate change mitigation measures include energy conservation measures, implementing land use plans, strengthening institutional and legislative mechanisms, energy efficiency measures, waste management, substituting fossil fuels with renewable energy sources and measures in the transport and agricultural sectors, as well as sequestering carbon biologically through reforestation or geo-physically (inside the earth's core). Certain incentives exist and more should be created to encourage developing countries to mitigate climate change in the agricultural sector. Such incentives for mitigation include:

– Carbon Trading: The emerging market for trading carbon emissions offers new possibilities for agriculture to benefit from land uses that sequester carbon, thereby enhancing carbon storage in soils and avoiding deforestation.
– Expansion of CDM to include aforestation and reforestation projects.
– Incentives for investment in science and technology for low-emission technologies.

6.6 Conclusion and Recommendations

6.6.1 Conclusions

There is a substantial body of work that shows that agricultural production is sensitive to climate change and variations in climate. There are also indications that, the potential effects of climate changes in future productivity are likely to be negative in regions that are already water-limited or positive in regions that are temperature limited. Climate change will have far-reaching consequences for agriculture and the poor and marginalized groups who depend on agriculture for their livelihoods and have a lower capacity to adapt.

The sustainable increase of agricultural production for food security will require efforts to enhance the capacity of crop production systems to adapt to global climate change as well as to mitigate the effects of food production on global warming. While adaptation strategies exist, considerable institutional and policy support will be needed to implement them successfully on the scale required. Technical options for adaptation and mitigation are available and could be further improved. Policy support to agricultural research and development to develop and transfer appropriate and efficient technologies, however, will be vital for the realization of such measures for sustainable food production.

6.6.2 Policy Recommendations

Agricultural development in sub-Saharan Africa faces daunting challenges, which climate change and increasing climate variability will compound in vulnerable areas. The livelihoods of many croppers and livestock keepers in Africa are associated with diversity of options which are likely to diminish because of these changes. Tackling these challenges will require the use of sophisticated surveillance and response systems as well as technologies and policy. In order to promote this transformational change in the agricultural sector, comprehensive action is not feasible without global cooperation, which requires an approach that is equitable, efficient and effective. Innovative ways of financing are needed from all sources, combined with capacity building and access to technology, knowledge and information on best practices. Therefore, policy that assures food security at all time is recommended to achieve the Millennium Development Goal 1 to reducing by half people suffering from hunger by 2015.

Appropriate climate-change policies are needed to unleash this huge potential for pro-poor mitigation investment in Sub-Saharan Africa. Such policies should focus on increasing the profitability of environmentally sustainable practices that generate income for small producers and create investment flows for rural communities. Pro-poor investments, community development, new research, and capacity building can all help to integrate agriculture and land-use systems of developing countries into the carbon trading system, both generating income gains and advancing environmental security.

Agriculture appears to be the most vulnerable sector to the adverse impacts of climate change. To achieve sustainable development, efforts need to be stepped up to mitigate and adapt. Both strategies are very important and should be pursued concurrently. While climate change will likely affect development at various levels, the development approach chosen will also influence future emission of greenhouse gases as well as the adaptive capacity of individuals, communities and countries. It is therefore important that climate change be mainstreamed into developmental policies and plans.

In the agricultural sector, strategies should range from the development and deployment of early warning systems, better agricultural management systems, improved crop cultivars, better and more efficient irrigation systems and good grain storage systems.

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Chapter 7
Climate Change and Food Security in Kano Nigeria: A Model for Sustainable Food Production

Salisu Lawal Halliru

Abstract Climate change and increasing climate variability threaten the attainment of the Millennium Development Goals (MDG), and some of the worst effects on human health and agriculture will be in Africa, particularly in vulnerable regions. Kano state is the most populous state in the country with majority of rural dwellers who are predominantly agrarians but still food security is uncertain. This is largely attributed to climate, which is increasingly becoming harsh. Rainfall is invariably not stable for so many years with recurring drought. Desertification and deforestation of vegetative cover compounded the problem of agriculture in the state. Despites government efforts to provide all the agricultural inputs, agriculture still stagnate and even decline. The issue of climate change was addressed by the agenda that comes out from the climate summits and convention which clearly discussed global climate change issue. It also reviews human activities and their implication to the environment. The world's climate continuing change at rates that are projected to be unprecedented in recent human history. The impacts of climate change on food production were highlighted and discussed in the paper. Data used in this paper were both secondary and primary data. Primary data collected were through Participatory Rural Appraisal (PRA). In this case, focused Group Discussion (FGD) was adopted and farmers were interviewed all to enable us to get in-depth and comprehensive information from farmers who have had experience in the changing trends of climate for up to a period of 20 years and secondary data was derived from many years observations under taken at Malan Aminu Kano international Airport Meteorological station. The collected data was analyzed using simple graphs and mathematics to ascertain the stated postulation that "climate changes grossly affect food security in Kano". The paper recommends that, the climate change management issues raised most be translated into decision and/or

S.L. Halliru (✉)
Department of Geography, Federal College of Education Kano, P.M.B. 3045 Kano, Kano State, Nigeria
e-mail: lhsalisu09@gmail.com

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policy by the stakeholders, in order to ensure food security in the region. This paper also proposes a model for a sustainable agriculture to arrest the problems of declining agriculture, which is environmentally friendly.

Keywords Climate change • Food security • Model • Kano • Sustainable food production

7.1 Introduction

All nations are directly or indirectly affected by changes in the global environment. The changes in the temporal and spatial distribution of rainfall in Africa has adversely affected agriculture and food production of farming communities both directly through changes in agro- ecological conditions; and indirectly by affecting growth and distribution of incomes; and this demand for agricultural products.

We all depend on Agriculture as our source for food, but the system is under threat from climate change. Therefore people in developing countries face a real and direct threat to their food security and livelihood due to their low adaptive capacity.

7.1.1 Sustainable Agriculture

A sustainable agriculture is therefore a farming system that simultaneously meets the need and aspiration of future generation without compromising the ability of generation to meet their own need (Drincha and Rufa'I 2005). Insurance of basic nutritional requirement of present and generation in terms of quantity and quality, Provision of durable employment sufficient income, and decent living and working condition. Maintenance and where possible enhancement in the productive capacity of natural resources as a whole and regenerative capacity of renewable resources without disrupting the basic ecological cycles and balances. We can say that sustainable agriculture will be an effective tool for the attainment of food security.

The world's climate is continuing to change at rates that are projected to be unprecedented in recent human history. The third assessment report of the intergovernmental panel on climate change (IPCC 2001) indicates that the global average surface temperature increased by about 0.6 °C during the twentieth century. The latest fourth Assessment report (IPCC 2007) states that 'most of the observed increase in globally averaged temperature since the mid- twentieth century is likely due to the observed increase in anthropogenic greenhouse gas concentration'. The IPCC climate model projections from 2001 suggest on increase in global average surface temperature of between 1.4 and 5.8 °C from the present to 2,100, the range depending largely on the scale of fossil- fuel burning between now and then on the different models used. A study indicates that the temperature increases by 2,100 may be larger than those estimated in 2001 (Stainforth et al. 2005; Thornton et al. 2008).

The impacts of climate change are likely to be highly spatially variable. At high latitudes, crop production may increase slightly for local mean temperature increase of up to 1–3 °C, depending on the crop, while at lower latitudes crops productivity is projected to decrease for even relatively small local temperature increase (1–2 °C) (IPCC 2007). In the tropics and sub tropics in general, crop yields may fall by 10–20 % by 2050 because of warming and drying but there are places where yield losses may be much more severe (Jone and Thornton 2003). Developing countries are generally considered more vulnerable to the effects of climate change than more developed countries this is largely attributed to a low capacity to adapt in the developing world (Thomas and Twyman 2005).

7.1.2 Relationship Between MDGs Climate Change and Food Security

Climate change and increasing climate variability threaten the attainment of the millennium development Goals (MGDs), and some worst effects on human health and agriculture. Climate change was addressed by the agenda that come out from the climate summits and convention which clearly discussed global climate change issue. One of the eight major goals of millennium Development Goals strategy (MDGs) discussed the issue of declining food security. The agenda stated the fact that there are societal implications of weather, climate and water related process in the earth environment. Some basic points where outlined in the summit, effect of climate in the world food insecurity and low yield production particularly in cereal production among others.

In Nigeria the MDGs has been translated National Economic Empowerments and Development Strategy (NEEDs) and State Economic Empowerments and Development Strategy (SEEDs) by the National Planning Commission (NPC) in 2005. This assisted the nation to understand food security is one of the aspect of development as such is neglected (NPC 2005). Kano states Government comes up with programmed in order to achieve the stated objectives of MDGs, so as to participate in poverty assessment and released the problems the rural are facing areas.

7.1.3 Climate Change Impact on Crop Production in Nigeria

Rain fed system is predominantly as far as Nigerian agriculture is concern and therefore vulnerability to changing climate. Vulnerability of crops to be damage by high temperature varies with developmental stage. High temperatures during productive development are particularly injurious. For example maize (Masara) at selling, to soya beans at flowering and wheat (alkama) at grain falling (Gwary 2008).

Rainfall, being the most important source of soil moisture is possibly the most important factor determining the production of crops. Changing climate can cause changes in annual rainfall received in an area which may cause fluctuation within and between seasons. Variation in the distribution of rainfall within a season may be more serious than a change in the annual total. Drought conditions may be caused by lower amounts of rainfall and sometimes poor distribution due to dry spell within a season. Crop productivity in terms of yield quality and quantity are likely to suffer set backs if such dry periods occur during critical development phase.

Drought lead to total destruction of crops when it extends for a period that is more than necessary. Famine becomes evident and migration of people becomes necessary. High temperature lead to stress occurring during anthesis such as anther dehiscence and pollen shed. Temperature increase beyond plant tolerant. Can have significant consequences on plant and therefore yield. Too much rainfall on the other hand, can cause decline in crop yield due to water logging nutrient leaching, erosion problems and increase incidence of pest and diseases. Intense burst of rainfall may damage younger plants and promote water logging of standing crops. The extent of damage depends on the duration of precipitation and flooding crop developmental stage as well as air and soil temperatures (Gwary 2008).

7.1.4 Food Security

In May 2007, at the 33rd session of the committee on world food security, FAO issued a statement to re affirm its vision of a food secure world'.

> FAO's vision of a world without hunger is one in which most people are able, by themselves to obtain the food they need for an active and healthy life, and where social safety nets ensure that those who lack resources still get enough to each (FAO 2007).

Food security exists when all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1996).

In view of the above definition to be food secure, the amount of food produces commensurate to the population demands in both quantity and quality and common man has access to safe and nutritious food at all times and to attain a food security status the following condition must be met:

– Adequate food production
– Availability of a healthy food with high nutrition quality
– Common man has access to it

FAO stressed that "food security depends more on socio-economic conditions than an agro- climatic ones, and an access to food rather than the production or physical availability of food". It stated that, to evaluate the potential impacts of climate change on food security. It is not enough to assess the impacts on domestic production in food – insecure countries. One also needs to

- Assess climate change impacts on foreign exchange earning
- Determine the ability of food – surplus countries to increase their commercial exports or food aid.
- Analyze how the incomes of poor will be affected by climate change (FAO 2003, 365–366).

7.1.5 Statement of the Research Problem

Kano state is rated as the most populous state in Nigeria but yet; food sufficiently is declining for the poor; Nigerian environment is characterized by fair to good soils but poor and unreliable rainfall and low quantity as the case in arid and semi- arid regions. The rural areas of Nigeria are inhabited by the bulk of the nation's population; they serve as the base for production of food and fibre (Salisu and Umar 2010).

Food remain the most vital because of it centrality to human existence. The ruthless expedition for food has shaped human history, provoking wars, driving migration and underpinning the growth of nations. The recent escalation of food prices call for sober reflection, owing to the fact that globe is facing a worsening food crisis period unseen in the last 30 years. In Kano state majority of the rural dwellers are predominantly agrarians but still food security is not grantee. Climate change has already begun to affect agricultural activities and consequently livelihoods of the population and their ability to support their family's nutritional needs.

7.2 Material and Methods

The study was conducted in Kano state. The state is located between latitude 10°37′ and 10°34 N and 7°34 and 9°29′E. It is bounded on the west by Katsina state, on the south by Bauchi state, on the east by Jigawa state and Katsina state. Kano has land area of about 20,760 km^2 and a population of over nine million (9,383,682). NPC 2006. Most of the land area lies within the Sudan vegetation zone, with the exception of the southern borders where guinea savanna predominates.

Kano state has an arduous (tropical continental type) climate with relatively wide and rapid changes of temperature and humidity. During the months of December and January, the harmattan (dry northeast wind) is at its peak blowing thin dust over the state from the Sahara desert. This dry harmattan winds carrying

Fig. 7.1 Map of Nigeria showing the study area Kano State

dust from the north increase the desiccation effect of high temperature during the long dry season.

The annual mean temperature is 26 °C, the hottest months (April/May) has 31 °C. Olofin (1987), Illoeje (1980) and others discussed the climate of the region in more details. Rainfall variability is of greatest concern in Kano which natural and Agricultural ecosystems are highly sensitive to small variations. The inter annual variability in rainfall in northern Nigeria is large: typically over 20 % of the average annual values. This large variability from year to year often result in drought which bring in their wake much hardship and disasters, with devastating effect on food production and the region's economy. In 1987, about five million metric tones of grain, mainly millet and sorghum, valued at over four billion naira (about 400 million USD) were reported in the local media, (New Nigerian, 12 January, 1988) to have been lost to drought (Tambuwal 2010, Fig. 7.1).

Data for the purpose of this study was sought from both primary and secondary sources. The primary data collected were through Participatory Rural Appraisal (PRA). In this case, focused Group Discussion (FGD) was adopted and farmers were interviewed all to enable us to get in-depth and comprehensive information from farmers who have had experience in the changing trends of climate for up to a period of 20 years. Eighteen local government where purposely selected from 44 local government. The local governments were Doguwa, Sumaila, Rogo, Kura, Tofa, Bichi, Danbatta, Karaye, Tsanyawa and Garko others are Gabasawa, Takai, Shanono, Kabo, Dawakin Tofa, Kiru, Garun Mallan and Kunchi purposive random sampling was employed to select the above local government where data was collected for this study to represent Kano State. The measures for selecting the local governments include the followings:

– Community with a sizable number of farmers in production(Farming)
– Community with farmers that participate in farming not on managerial level.
– Community with Agriculture –economy based community.

The data gathered was analyzed using tables, percentages and other statistics techniques relevant for the data collected.

7.3 Result and Findings

7.3.1 Trends of Rainfall

In the year 1991–2010, the total precipitation in Kano is 855 mm dropped to 407 mm. The mean annual rainfall dissection the region is about 850 mm. The highest rainfall ever recorded is 1,200 mm at Tiga in the extreme south the lowest at Danbatta in the north was 400 mm in 2007 and 2010 respectively. Number of rain days vary from 65 days in the south to as low as 41 in the north east Table 7.1.

In summary of the decadal variability of rainfall at Kano shows that the rainfall was actually decreasing over time. This also correspond with one of the worst sudano-sahelian droughts of 1968–1975 reaching it peak in 1973 leading to a wide spread crop failure as reported by Moretimore (1989) (Fig. 7.2).

7.3.2 Drought

Trends in temperature anomalies indicated that there is a slight increase in temperature above normal in the region with +0.48 °C and satellites indicated that recent warmest year were 1995, 1998, 2001, 2002 and 2003 in decreased order (WMO 2004). Although the increase seems little, but it could be responsible for the drought conditions experienced in April, May and June and in September and October. It could also be the cause of the delay in the on –set of rainfall, as well as its early cessation. The implication of these changes, that is increase and decrease in rainfall and temperature means that there are changes in the climatic pattern of the state.

Major climate related hazards associated with climate change are droughts and extreme flooding. Heat waves due to climate change also pose serious threats to local livelihood. August 20, 2004 flood disaster in Gombe, Goronyo flooding in Sokoto 2010, Ringim flooding in Jigawa state2010, many houses and farmlands were washed away especially those near the river bank, it should be noted that severe unpleasant experiences due to flooding have been noted in many parts of Northern Nigeria with similar climatic conditions (Tambuwal 2010) (Table 7.2, Figs. 7.3 and 7.4).

The observed delay of the on-set of rainfall and the early cessation has serious impact on agriculture. Climate variability and change in Kano state increase food insecurity in the state for instance the production of millet, early maturing varieties of sorghum and maize, rice wheat which farmers adopted in mitigating the severe climate conditions have substantially decline. Beside the delay in the on –set and

Table 7.1 Showing annual rainfall total for Kano (MAKIA) (1991–2010)

Calendar years	Rainfall total (MM)
1991	1087.4
1992	927
1993	920.2
1994	661
1995	699.7
1996	1134.2
1997	1292.7
1998	1,872
1999	1539.7
2000	1,139
2001	1789.4
2002	1033.7
2003	1429.5
2004	978.6
2005	1376.3
2006	1,309
2007	1114.7
2008	1035.9
2009	992.2
2010	911
Total = 20 years	

Source: NIMET MAKIA (2010)

Average for the years understudy = 1162.1 mm

$$\frac{\sum(\text{Rainfall Total for each year})}{\sum(\text{calendar year})}$$

$$\frac{\sum(23,242)}{\sum(20)} = \frac{23,242}{20} = 1162.1 \text{ mm}$$

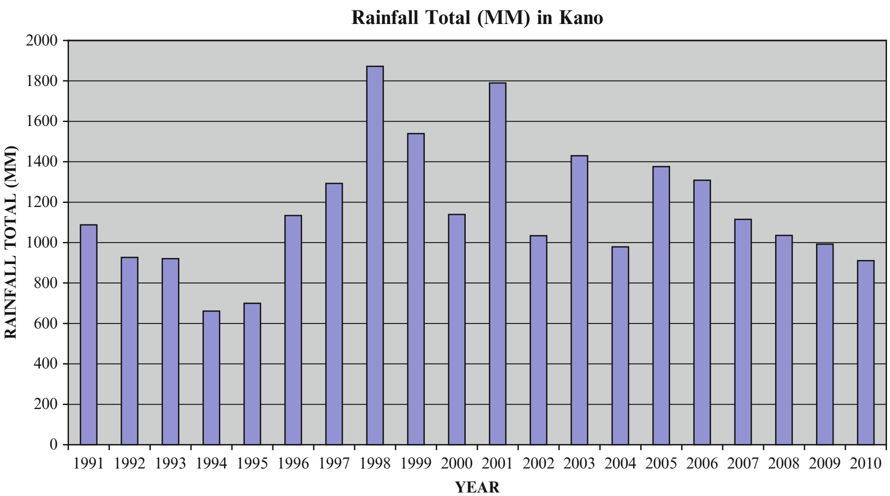


Fig. 7.2 Rainfall total (mm) in Kano State

Table 7.2 Frequency distribution of dates of on-set and cessation of the rain at Kano

On-set	Frequency	Cessation	Frequency
Before 31st March	–	Before 31st July	–
1st April–5th April	00	1st August–5th August	04
5th April–10th April	00	6th August–10th August	00
11Apirl–15th April	01	11th August–15th August	00
16th April–20th April	02	16th August–20th August	00
21st April–25th April	00	21st August–25th August	00
26th April–30th April	00	26th August–31st August	00
1st May–5th May	01	1st Sept–5th Sept	04
6th May–10 May	02	6th Sept–10th Sept	06
11th May–15th May	01	11th Sept–15th Sept	03
16th May–20th May	03	[b]16th Sept–20th Sept	08
21st May–25th May	00	21st Sept–25th Sept	02
26th May–31st	04	26th Sept–30th Sept	00
[a]1st June–5th June	06	1st Oct–5th Oct	00
6th June–10th June	05	6th Oct–10th Oct	00
11th June–15th June	03	11th Oct–15th Oct	00
16th June–20th June	00	16th Oct–20th Oct	00
21st June–25th June	00	21st Oct–25th Oct	01
26th June–30th June	00	26th Oct–31st Oct	01
1st July–5th July	02	1st Nov–5th Nov	00

Source: Author's Field Work (2010)
[a]Mean class of onset
[b]Mean class of cessation

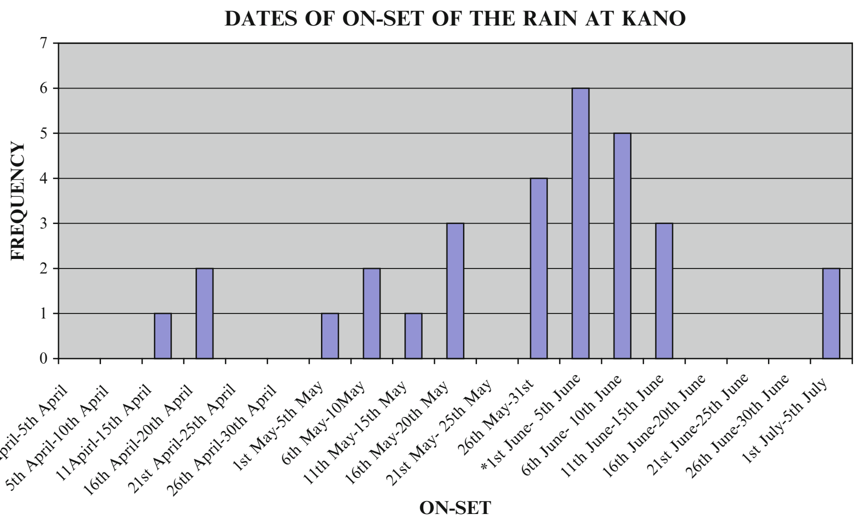


Fig. 7.3 Dates of on-set of the rain in Kano State

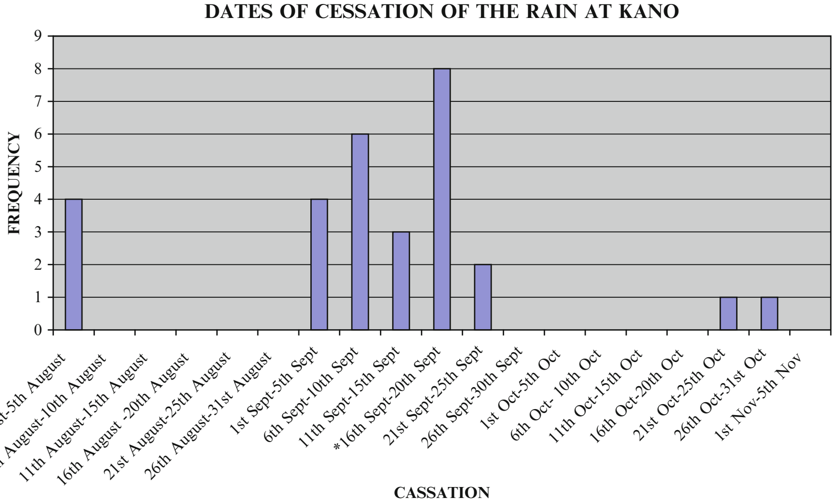


Fig. 7.4 Dates of cessation at Kano State

early cessation of rainfall, increasing variability in its distribution is also affecting agriculture, and food production (Table 7.3).

Equation of Climatic Impact on food production in Kano 1991–2010

$$100 = X + y$$

Where X representing the yield and y is the loss.

Between 1991–2010 X = 100 % therefore 100 = 100 + y

Therefore y = 100 − 100 = 0

Therefore y = 0 which implies there is no lost in the yield during the period 1991–2010

Under the period of 2000–2010

X = 48 and y = ?

Therefore 100 = X + Y

Therefore 100 = 48 + y

$$Y = 100 - 48 = 52$$

Hence the lost in yield is equal to 52 %

Effects of Temperature, water, changing pattern and rising level of are taken into account. Most of the farmers cannot produce what they can feeds their families for the year or even 6 months, therefore no surplus to sell in order to increase one's income.

– High temperature result to heat stress for plants, which decrease productivity in the state generally.

Table 7.3 Climatic impacts on food production in Kano 1991–2010

Grain	Unit	Yield in 1991–2000	Yield in 2000–2010
Rice	100 kg sack	30	20
Maize	100 kg sack	20	10
Millet	Bundles or basket	25	08
Sorghum/Guinea corn	Bundles or basket	20	10
Wheat	100 kg sack	05	00

Source: Author's Field Work (2010)

- Changing pattern. In many places, growing seasons are changing; rainfall is becoming unpredictable and unreliable both in time and volume. That is why the both farmers don't have knowledge as when to plant, farmers in Kano plant differently that is through traditional agricultural knowledge.
- Rising Dam levels causing serious problem (Tiga and challawa dams) which is affecting agricultural productivity not only in the state it also affected neighbouring states e.g. Jigawa flooding 2010. Goronyo flooding in Sokoto state 2010 is another example in northern Nigeria as a result of rising level of Dams which destroyed farmland and crops.
- Water interactions between changing climate, water scarcity lead to decline in agricultural productive and lead to food in security.

Extreme weather events in Kano occur from time to time. Such as unusual heavy rainfall which could result in to flooding. Wind storms are also unpleasant climate conditions suffer by the farmers, because windstorm do burry germinated crops such as guinea corn and millet at the beginning of rainy season as reported by farmers in Doguwa, Sumaila, Rogo, Kura, Rano, Bichi, Danbatta, Karaye, Tsanyawa, Garko, Gabasawa, Takai, Shanono Kabo, Dawakin Tofa, Kiru Garun Malan and Kunchi just before the rains stabilized. Windstorm affect crop yield such as guinea corn, millet, maize and rice (low crop yield) (Table 7.4).

7.3.3 Model for a Sustainable Food Production

This model look at the four dimensional process that will lead to sustainable food production in Kano State and Nigeria as a whole if follow to logical conclusion.

New crops varieties that are drought resistant are to be released to the farmers for their high yielding ability over local varieties as droughts tolerant withstand stressful condition. A struggle for food security will increase unless new crop varieties are deployed and to help farmers to adapt to climate change and also provide them with the climate data.

The second dimension is of the view that good system control, the market fluctuation and stabilization, is the combination of these variable that influence food production, its sustainability and food security. Most farmers are in adequately informed and they have low level of formal education. The low level of literacy and lack of adequate knowledge of modern techniques in food production, which can propel production and yield.

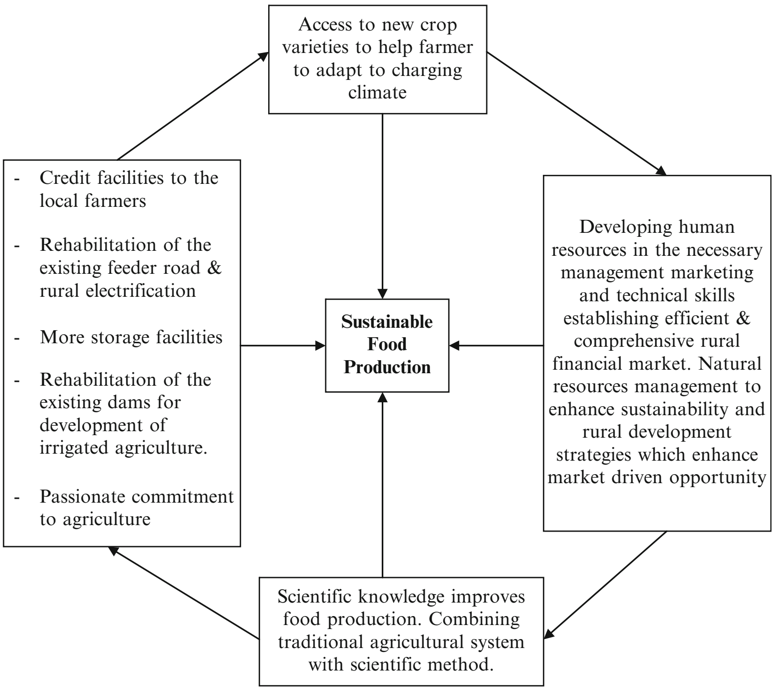
Table 7.4 Respondents view on extreme weather and climate events in Kano

Type	Frequency	Vulnerable area	Sector	Impact
Flood	Several times in times in rainy season	Houses, farmland, road, crops and domesticated animals	Social and agricultural	Severe
Drought	Beginning and towards the end of rainy season	Crops	Agricultural	Severe
Wind storm	Beginning and towards the end of rainy season	Houses, crops	Social and agricultural	Severe
Severe temperature	Beginning and towards the end of rainy season	Crop, domesticated animals, humans	Agricultural	Severe
Rainfall	Unreliable at Beginning and towards the end of rainy season	Water resources and crops	Water resources	Severe

Source: Author's Field Work (2010)

Knowledge is the key factor in the survival of agriculture combining ideas scientific and traditional. The farmers will develop a sound set of producers in food production therefore both traditional and scientific information and knowledge can enhance food production in Kano.

Access to credit facilities by farmers is one of the major constrains facing agriculture in Kano. It will assist access to credit facilities will increase food production, create employment and economic empowerment. Rehabilitation of existing dam for the development will assist farmers – managed and also the continuous monitoring of surface and under water resources to ensure sustainable operation.



7.3.4 Naduke Model (Model for Sustainable Food Production)

Naduke model can be broken through several possible interventions in the field of food production, human- development, education, intervention from policy makers and financial institutions, improved seed varieties.

The model illustrates the need (N), for agricultural (A), urgency (U), in Kano (K), and environment (E). NADUKE model is an advocacy tool to illustrate the likely impact of alternative policy options on the food security status of the population. The objective and advantage of a model like NADUKE is to help users and policy makers to think in terms of the outcomes of alternative policy as a result of increased population everyday in Kano, most importantly, to consider combining traditional agricultural system with scientific methods issues within a holistic framework.

Central or characteristics to NADUKE model is its human development based approach. Population, environment and agricultural development are importantly linked, and affect both the level of food security and poverty in Nigeria. Programmes to alleviate agriculture and enhance food security must, therefore take a multi- disciplinary and integrated approach that harmonized overall population growth with food production growth while ensuring good management of the environment.

7.4 Conclusion and Recommendation

Developing countries contributed relatively little to the causes of global warming but they are the worst affected that they suffer most from its negative consequences because of there low adaptive capacity. There is no gain saying that climate change constitutes a major threat to food production in Nigeria at large and Kano in particular. This research reveals that temperature increases and shifts in rainfall pattern decreases growing periods in Kano and the study area is characterized by hot and dryer weather which treat to food security and challenging the livelihoods of millions of people.

Hence the situation brings about uncertainties on crop production and render farmer production less profitable consequently may shift their interest in crop production which may bring about food insecurity. Adoption of the proposed model will no doubt assist in sustainable food production in Kano and Nigeria at large.

The paper also recommends that seed centre should be provided at all wards and local government to the state so that genetically modified crops species that can survive drought condition should be developed and be planted during drought conditions. Such centres will enable small farmers at local level, farmer automatically can feed himself, sell the surplus, increase his income, improved his own welfare and his family as well.

Loan should be made available and accessible to farmers with more emphasis to small scale farmers so that they can grow and produce enough in society, government and other stakeholders are to provide the loans to the affected areas with minimum interest rate. This will enable them to purchase farm inputs that will boast food production.

More weather stations should be established in the country as a whole and northern Nigeria in particular, so that more climatic data would be generated, analyzed, interpreted and communicated to the teeming farmers for agro climatologically purposes. This could help in achieving food security, enhanced social infrastructure and poverty eradication.

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Chapter 8
Climate Change and Food Insecurity: Institutional Barriers to Adaptation of Marginal Groups in the Far-Western Region of Nepal

Nirmal Kumar Bishokarma and Sagar Raj Sharma

Abstract Evidences show that climate change incidences affect adversely food security of marginal groups whose livelihoods are based on natural resources. The incidences are more harmful to their livelihood assets and strategies to achieve food resources because of both its higher sensitivity to the episodes and their lower adaptive capacity to the negative affects of the events. The preliminary finding from lead writer's ongoing PhD research in the far western region of Nepal and authoresses long experiences in the field of climate change and food security of the country shows that the prevailing institutional barriers cause them highly vulnerable from the risks to secure their food need. This paper claims that both formal and informal economic, social and political institutional hurdles are the major reasons of reducing their capability which increase their vulnerability and limit the adaptive capacity to secure food in climate change variability and extreme events contexts. These institutional impediments in the contexts of Nepal, mostly, include the institutions of land tenure, market, caste and gender based occupation, wage labour, patron-client relations, schools and educations, settlement, untouchability and caste based discrimination, social networking, bargaining power, adaptation policies, and political engagement prevailing in rural area of the country. Therefore, the paper suggests that reformations of institutional barriers are essential for increasing the ability of such groups to resist impacts and adapt the negative impacts of the changes on production, access and consumption of food of marginal groups in sustainable away.

N.K. Bishokarma (✉) • S.R. Sharma
Department of Development Studies, Human and Natural Resources Studies Centre (HNRSC), Kathmandu University, Jawalakhel, Lalitpur, Nepal

Swiss National Centre of Competence in Research (NCCR) North-South, South Asia Office, GPO Box 910, Jawalakhel, Lalitpur, Nepal
e-mail: nirmalkumarbk@yahoo.com

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8.1 Introduction

The subsistence farmers and smallholders living in marginal regions of developing countries are more vulnerable to livelihood and food insecurity due to climate change incidences (Stern 2006; Heltberg et al. 2009) than those from other regions even within the same countries. The evidences show that their livelihood assets and strategies to secure food are climatically sensitive and their capacities to adapt are constrained through different socio-economic factors (Parry et al. 2007; WFP 2009). The discussions to date focus more on geographical constraints regarding the exposure, resiliency and adaptive capacity to adverse affects of the occurrences. On the other hand, there are growing arguments which focus on the institutional processes such as discursive environments (Deressa et al. 2009), bargaining power (Nightingale 2009), and social institutions (Wolf et al. 2010) that are responsible for differentiations of the vulnerability from and adaptation to the events to secure livelihoods and food outcomes of the people.

Simultaneously, the arguments in South Asian countries including Nepal, are increasingly focused on aspects of institutional barriers, which to a large extent determine who have access to what amount and kind of food they have (Gill et al. 2003). The evidences show that these barriers make the individuals, households, and groups living in marginal position more vulnerable to food security (Dahal and Khanal 2010). Also, in a report by IISD (2009), it is claimed that these factors will greatly hinder the ability of such groups towards adaptation to negative impacts of future incidences of climate change, which will be major reason for starvation, and migration of such people. In addition, there are evidences that such barriers are the major reasons because of which these people bear the negative impacts of climate change variability and extreme events (Regmi 2009; WFP 2009). Moreover, some researchers argue that the impacts of climate change will be further exacerbated by exclusion and discrimination prevails in society in future (Elliott and Pais 2006; Dahal et al. 2009; Jones 2010). Therefore, this paper attempts to explore how these barriers affect the capability of marginal groups to adapt to the risks of climate change and other extreme events so that they can remain food secure.

8.2 Conceptual Framework

Food security is a complex issue with multiple and interconnected environmental, social, political, and economic determinants (Drèze and Sen 1989; Ericksen 2008). It depends highly upon the capability of the people to produce, have access and consume the food sustainably (FAO 2008). The capability is the range of choices that people have for securing their livelihoods (Chambers and Conway 1992). The incidence of climate change has impacts on all of these aspects of food security (IPCC 2007; Hahn et al. 2009). In this regard, how people will adapt to secure their food amidst change will determine the future level of hunger and starvation (Du Toit and Ziervogel 2004). This adaptation process includes both vulnerability and adaptive capacity of the people (Robledo and Forner 2005). It is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (Parry et al. 2007). If people are more exposed to climatic changes and extreme events and if they have less resiliency capacity, they are considered to be more vulnerable as their food system will be affected by such events.

The institutions are responsible for inequity in vulnerability and adaptive capacity to the impacts of climate change on different categories of people (Nightingale 2009). The institutions, rule of game (North 1990) and regularized pattern of behaviours (Leach et al. 1999) may be formal and informal (Savoia et al. 2010) that determine the capability of people towards having access to secure food. The capability of people is the ability to avoid exposure to climate change and loss of livelihoods assets (Osman-Elasha 2009). So, the paper adopts the outline on how institutions determine the effects of climate change variability and extreme events on the food security of marginal groups of Nepal.

8.3 Study Area

This is a part of a broader research conducted in the far-western region (FWR) of Nepal. The region is a highly food insecure region of the country, with around 90 % of the households in this region having insufficient access to food (WFP 2008). Moreover, another study shows that 76 % of highly food insecure people of the country are living in the region (WFP 2010). Within this region, poor and marginal groups are the most affected by livelihood vulnerability and food insecurity.

The far-western region of Nepal is more vulnerable from climate change incidences than other region of the country. Changes in terms of rainfall trends, drought, increasing temperature, forest fire, endemic disease and natural hazards are highly felt (Dahal et al. 2009). Also, the increase in temperature is greater in this region than other parts of the country (Shrestha et al. 2000). The region is one of the driest of the country and localized droughts are common (NPC 2010). In recent years, great loss of livelihoods have been recorded in the region from natural hazards such as the huge floods in 2008, forest fire across the mountain region in 2009, cholera epidemic in 2009, and the winter drought of 2008/2009 (MOAC 2010).

Three districts of this region, namely Kailali, Achham and Bajura, are selected for the study purpose. Kailali district is a Terai district of the region and boarders with India in the south. According to the poverty line of Nepalese Rupees 7696 (in 2003 current price, equivalent to approximately 78 US dollars) set by the National Planning Commission (NPC) for Nepal, Kailali has the highest number of poor people in the country (NPC 2007). Achham district is located in the mid-hills of the region. One report of the World Food Programme (WFP 2008) shows that Achham is moderately food insecure district in the region, where about 25 % of the total population are highly food insecure. Bajura is the second lowest developed district in Nepal in terms of its human development index (UNDP 2009). It is a district where around 45 % of the total population is highly food insecure and experiences chronic hunger (WFP 2010).

8.4 Study Methodology

The study has applied multistage and systematic stratified sampling methods to locate primary sampling unit (settlements) and ultimate sampling unit (households) respectively. For this purpose, one Village Development Committee (VDC) from each district, namely, Phulbari, Janalipath and Brahabise from Kailali, Achham and Bajura districts have been selected respectively. Then, two settlements from each VDC are selected. In each stage the selection criteria are the state of climate change incidences and food insecurity in the settlements. The study covers 300 households as the total sample of the research.

The study is descriptive in nature and qualitative methods of social science research have been applied to collect and analyse the data regarding incidences of climate change, impacts on food security and institutional process that determine the impacts. Both secondary and primary information from different and pertinent sources are gathered. The study has employed household survey to collect information about food security situation, vulnerability context, coping and adaptation strategies, etc. Key informant interview has been used to collect information about kinds and system of different institutions, climate change trends and adaptation strategies, food security programmes, etc., while focus group discussions have been used to gather data on major impacts of different development incentives, exclusion and inclusion issues, support structure, inequity in climate change impacts, etc. The study has been conducted using structured questionnaire, ranking, timeline, Venn diagram, relationship, and resource mapping tools to collect data. The collected data are prepared for analysis by coding with appropriate rule and are analysed using SPSS and other participatory analysis tools and techniques. Attempts have also been made to capture the gender perspective regarding institutional aspect of food security and climate change incidences.

8.5 Results and Discussions

Though Nepal is responsible for only about 0.025 % of the total annual Green House Gas GHG emissions of the world (Karki 2007), the country is one of the ten most vulnerable developing countries in terms of impacts of climate change (NCVST 2009). The evidences reveal that marginal groups (*dalits*,[1] women including single

[1] *Dalits* are untouchable caste groups and one of the most marginalised population section of Nepal.

women, indigenous people, landless households, and elderly people) in the country are more vulnerable to food insecurity (Adhikari 2008). As they are the first households and family members to bear the crisis- and shocks, the climatic variability and extreme events have added extra livelihoods burden on them (NSET 2009; WFP 2010). The evidences show that both formal and informal economic, social and political institutional barriers existing in Nepali societies are primary sources of additional vulnerability to the groups. As the institutional barriers are the major blocks for food security to them, they are also major causes of intensifying effects of climate change. Given below are some of the institutional barriers that make these groups more vulnerable to food security (Dahal and Khanal 2010) from climate change incidences.

8.5.1 Economic Institutions

Economic institutions determine the production and income capability essential for food security of the people (Teubal 1992). Findings show that institutions of land tenure, market, gender and caste-based occupations, wage labour and patron client relationships reduce the ability of marginal groups to resist climate change risks and to adapt to its adverse impacts on their livelihoods strategies.

8.5.1.1 Land Tenure

Land is only a resource endowment to produce food. The institution of land tenure determines level of food security in natural resource based livelihoods. In Nepal it is determined by institutions and set of rules which allow the high caste groups to own land in the forms of *Birta*,[2] *Jagir*,[3] and *Rakam*.[4] Almost all of the socially marginalised groups do not fall under these sorts of privileged benefits (Nepali 2010). These institutions exist formally and informally at macro level to micro level in the form of law, legislation, and social practices in Nepal (DFID/WB 2006). In the district of Bajura, there are 7.5 % of total households that are landless of which 86.88 % are from the *dalit* community. The average landholding size of the *dalits* is 1.06 *kattha* (0.03 ha) against 3.4 *kattha* (0.12 ha) of non-*dalits*. There are 11 % women who own land in the study sites. Also, the inheritance law has resulted in the fragmentation of land and elderly people own less areas of land.

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[2] *Birta* means an assignment of income from the land in favor of individuals in order to provide him with a livelihood. It was granted in favour of priests, teachers, religious heads, soldiers, and members of nobility and royal family (Regmi 1999).

[3] Before 1952, it was a common practice in Nepal to assign the income of *Raikar* lands as emoluments to government employees and functionaries. Such assignment was known as *Jagir* (Ibid).

[4] *Rakam* refers to a particular category of land grants and assignments similar to *Raikar*, *Jagir*, and *Guthi* lands on which cultivators are required to provide unpaid labor on a compulsory basis to meet government requirements.

The system of land tenure has made the marginal groups fall into the state of landlessness or near-landlessness. This has shoved their food production ability to risk from climate change thus limiting their choice of adaptations methods. As they have very small holding of agricultural land, they are unable to diversify their agricultural production. Also, they have very poor access to irrigation channels. The irrigation channel systems in the study area are found made based on traditional caste system. In Bharahabise VDC of Bajura district, 270 of the total 1,814 ha of agricultural land is irrigated, however, no area of *dalit's* agricultural land is found irrigated. Rice and wheat are the major summer and winter crops of high caste people which are grown in irrigated land. On the other hand, maize and potato are major crops of low caste groups which are grown in un-irrigated dry land. Findings reveal that almost all the rice grown by low caste groups were damaged due to drought of 2008 and 2009 as it was grown in lands totally dependant on monsoon rain. During the drought the rich upper caste groups used water from their irrigation channels thus facing little exposure towards the incidences. The hailstorm added loss of about 60 % potato and maize grown by lower caste groups, whereas the upper caste groups experienced only a nominal loss. It has reduced food self sufficiency period of the marginal groups from 3 to 1 month.

Also, the climate change has increased the duration of chronic food insecurity[5] to *dalits*. *Dalits'* community in the study sites face more than 9 months of food insecurity. The months of February to March and July to August are agricultural lean season that can also be called hunger season for them. Due to crop loss and late growing season, the period of hunger has been extending for them.

The land tenure system has also been affecting the copping and adaptation strategies of socially marginal groups. To cope with crop loss, the *dalits* have no choice but to sell off their assets such as livestock, ornaments, and land; or borrow money/grain, or opt for migration. They posses very little land and livestock. Since they have less land they are unable to receive loan from the district banks, they are obliged to take money from local money lenders in very high interest rates. This practice is a major cause for loss of land in this area. More importantly, migration to India is the only option for them to cope with climatic risk of food production. In all the study sites, it is found that migration to India has increased in the last 3 years. Also, the children of such groups often drop the school to go to India with their parents.

8.5.1.2 Market

The institutions of market determine the price and purchasing power of people. In the last 3 years there have been extreme events of climate change and the price of food has increased by more than 20 %. Access to food available in the market is

[5] *Chronic food insecurity* describes the inability to meet minimum nutrition on and consumption on needs over a sustained period of time (WFP 2010).

determined by the purchasing power of people (FAO 2008). The level of farm and non farm income, access to credit and involvement in livestock farming plays positive role in adapting to the climate change (Deressa et al. 2009). Hence due to non-functioning formal market and domination of informal market, it diminishes the income and exchange capability of marginal groups. The low caste groups, indigenous people and women in the study region expend almost 80 % of their total income to purchase staple food while high caste people and males expend more money for luxury food (tea, milk, meat) that has very less price change effects. Due to increased price of food, their affordability has decreased. On the other hand, there has been no increase in their earning strategies (wage, product of caste based occupation, etc.). Simultaneously, the institutions of market exclusion has been increasingly making their livelihood strategies more exposed to climatic risks and is reducing the adaptive capacity of them. The livestock based economy is the major earning activity in the study sites. Buffalo milk is the main source of diary products and cash income there. However, milk produced by untouchable caste is not accepted in the local markets in Brahabise and Janalimandali. So, they don't farm such livestock. They rear pig and hen which are not used and purchased by high caste people.

As there are very less formal banking facilities in the study area, it increases the reliance of marginal groups on informal money lenders which is very costly for them to afford the increasing price of food. Also, there are evidences that the food market is dominated by the people belonging to certain castes. People from marginal groups mostly work as porters. The caste based structure of the market has monopolised the food price. Also, there is very little share of information with marginal groups about the market situation. The local marginal groups experience that they pay more price for the same amount of food because they have little information about the price. Additionally, they can't purchase in bulk and they are obliged to borrow the food from the market.

8.5.1.3 The Caste and Gender Based Occupation

The occupation in Nepal is structurally based on caste- and gender-position of households and its members (Regmi et al. 2009). The occupations of high caste groups like Brahmins and Chhetris are as priests, teachers, and service providers, while the occupation of middle caste groups, particularly the Newars, is by and large concentrated in trade and business. The indigenous people work as porters, medicinal plant collectors, and join the Indian Army while the untouchables are found working as blacksmiths, tailors, shoemakers, wage labourers, porters, etc. The women are usually engaged in cultivating crops, collecting fodder and firewood, fetching water, etc. As such, there are very rare incidence of occupation mobility among these marginal castes and gender groups. These occupation positions in study sites are rigidly followed. It is found that the institutionalised occupations of marginal groups are more intense and have longer exposure and less resiliency with increasing temperature, hailstorm, drought, etc. because these occupations are directly attached to nature. The blacksmiths, who are low caste groups and occupy a large section of the population, make their livelihoods by making iron tools. People from this group experienced that increasing temperature has reduced their working hours. More incidences of health problems such as asthma, diarrhoea, and malnutrition have been found amongst this category of people. This decreases their capacity to produce more iron tools and as a result there is a reduction in their buying capacity of food. Local women experience that increasing temperature has dried up drinking water sources and they are forced to walk longer distances to fetch water. Some women in Janalimandali VDC used to collect local asparagu*s* and sell it in the local market, but due to the increasing drought, its production has decreased greatly. As a result they face greater income vulnerability. Also, women mentioned that the grazing resources for farm animals had become more difficult to find due to decline in some local grass species and reduction in the size of some fodder trees. Also, similar to findings of another study (Regmi et al. 2009), the number of livestock had reduced, thus negatively affecting people's food intake.

8.5.1.4 The Institution of Wage Labour

Drèze and Sen (2006) have argued that the victims of food insecurity come from the class of agricultural labours who are often primarily engaged in growing food. Similarly, the marginal groups in the study sites are also found to be engaged in wage labour. 85 % of the total households of *dalits* in the hilly region and 70 % of women members of *Tharu* community (indigenous people of flat-land area) in Fulbari VDC are agricultural labourers. As the labour work is climatically sensitive, they experience more exposure to the extreme events. They are low paid workers and their wage rate has remained unchanged since the last 5 years. Also, there is a disparity between men and women in payment. Men earn up to twice as much as women for unskilled labour. By this earning they are unable to buy necessities such as umbrellas, clothes and other materials which are simple tools to save them from intense climatic events like rise in temperature, change in rainfall patterns, and so on. The change in climate has also reduced the time of working days. Their health is also climatically sensitive. They experience high burden of climate sensitive diseases including malaria, diarrhoea, malnutrition, and respiratory infections. Also, it is found that the wage labours lost their jobs during the drought and were forced to migrate to India in search of alternative jobs.

8.5.1.5 Patron-Client Relation

The rural economy of Nepal is based on patron client relationships between socially disadvantaged (*dalits* and indigenous groups) and advantaged caste (higher caste) people. The caste based patron client institutions like *bista*[6] and *haliya*[7] of Bajura and Achham districts *and Kamaiya*[8] of Kailali district are major institutions in the study sites. In this institution, the lower caste and indigenous people worked for higher caste people; in turn of which they are paid grains during harvest time or are sometimes paid in nominal cash.

The association of *halia* in Brahabise and Janalimandali VDCs has been reducing the production capacity of marginal groups in the context of late rainfall. There exists a local culture that Brahamin caste people should not plough the land. Instead, the low caste group must plough the land for these caste groups. Also, there were evidences of heavy rainfall received in the last week of August and during the second and third week of September – too late to support a productive harvest in the area. This has created shrinkage in the period of rainfall. The lower caste groups should give priority to perform agricultural work for the high caste people. Therefore, they have very little time to look after their fields. As a result they leave their land uncultivated. The *bista* system has been reducing the total receive of the grain due to low agricultural production. As they are paid in grains, it is also reducing their income earning opportunities.

8.5.2 Social Institutions

8.5.2.1 Social Infrastructure

The causes of vulnerability due to climate change include the low education level, poor health and other public services available (Regmi et al. 2009). It is found that education plays a positive role to fight against climate change risks (Deressa et al. 2009). In the study sites there are no infrastructure to measure the climate records. In the area, the some villages have more primary schools and are also better equipped where some sorts of discussion about climate change and its impacts on food security are ongoing. These discussions are carried out through District Agricultural Development Office (DADO) and some NGOs. As the marginal groups are less educated, the women, *dalits* and other marginal groups seldom participate in these discussions. So, they are not being able to calculate the uncertainty of climate change variability and expected losses. They face haphazard climatic incidences and losses from it. Also, the *dalits* and other marginal groups lack access to clean water and sanitation as well as proper health services. They

[6] In this institutions the low caste people make tools, sew clothes, make shoe as the high caste required, in turn they paid grain at harvest time (Coplan 1972).

[7] It is ploughman and master relationships between low and high caste households. It is one kind of slavery (Coplan 1972).

[8] System of bonded labour where one group of indigenous people called tharu worked for their master to pay the debt.

don't have latrines in their homes and thus use public land for defection. Such poor personal hygiene leads to climatically induced diseases that are found to spread amongst these people.

8.5.2.2 Institutions of Settlement

People who live and cultivate marginal land and adopt unsustainable cultivation practices are vulnerable to climate change and food insecurity (Parry et al. 2007). In Nepal, the location of settlement and distribution of agricultural land is socially determined. The location of settlement is based on the institutions of caste in the community. As a result the marginal groups are pushed into unsafe conditions (Adhikari 2008) such as the tributary areas, steep areas prone to landslide and floods, and near to the forest. It is found that they live in small and low-quality, unfertile and un-irrigated patch of land. There is an orthodox belief in the study area that the low caste groups are not allowed to live with the high castes. Witnesses reveal that almost all the houses burned by the forest fire and destroyed through landslide and floods belonged to the *dalits* and other socially marginalized communities. In the study area, five households belonging to the *dalits* were damaged by the forest fire of 2009. Landslide of August 2010 due to heavy rainfall in Brahabise VDC of Bajura district destroyed seven households of the *dalit* community because their settlement was located in landslide prone slope. The land these groups owned for cultivation has very low level of productivity and is more liable to damage through the drought. The study shows that productivity of land of socially disadvantaged caste is three times lower than the land of other caste groups because the former has no facility of irrigation and agricultural inputs, and the land located in flat areas. Also, there exists higher risk of pest and pathogen outbreaks and forest fire on the land of *dalits* and other indigenous communities.

8.5.2.3 Untouchability and Caste-Based Discriminations

The institutions of the untouchability that exist in the rural area of Nepal limit the access of the *dalit* community to social infrastructures for securing their needs for food. The drought has been a major cause of drying the water sources in the rural area. Climate change induced drought has been increasing water scarcity needs for drinking and irrigation. The institution of untouchability has increased the water scarcity for the *dalits*. The evidences find that there are two kinds of water sources that are based on caste system. One is the joint source of different caste groups like in Fulbari VDC of Kailali district, and the other is a separate system for different caste groups. The low caste groups in Fulbari reveal that they can derive water only after the upper castes have taken their share of water. In times of drought they are unable to have access to water because the total amount of water is consumed by higher caste groups.

In Brahabise and Janalimandali villages of Bajura and Achham districts, it is found that there are separate water sources for high and low caste groups. The water sources of the *dalit* community in the sites are located in dirty areas where the livestock of higher caste groups use the water. There is an increasing contamination of water sources of these communities due to increasing temperature and prevalence of insects and pests, and it has also increased health problems.

8.5.2.4 Social Networking

Social capital and relationships affect the capability of communities to adapt to risks related to climate change (Wolf et al. 2010). In the study area it is found that social groups and networking are formed based on caste, gender, ethnicity, age system and similar other factors. The social networks and number of relatives increase awareness and options of adaptation (Deressa et al. 2009). The high caste people tend to have wider networks and wealthy relatives while the case is opposite with other categories of people. Marriage in the rural area of Nepal is considered as a major social networking which is conducted based on caste system and recognised within the caste groups. In the study region it is found that none of the marriage has been conducted beyond caste groups which have limited the social capabilities of marginal groups. Also there are limited informal relationships of friendships, working partners and school partners with the marginal groups. There are less bonded relationships between them. These sorts of exclusions and limitations in the social relations has been limiting information sharing about climate change which can reduce the exposure of these groups and limits their resistance power in relation to climate change. The sharing of capital and food during the crisis period and starvation favours the high caste people in comparison to low caste people.

8.5.3 Political Institutions

The vulnerability is also determined by political power (Louman et al. 2009). Both climate change and food security are increasingly becoming conspicuous in the political debates in Nepal. Political issues particularly affect the ability of people to embrace the planned adaptation process such as the environmental interventions, development activities and food availability through non-market allocation, i.e. food distribution through Nepal Food Corporation (NFC), WFP, etc. Following are some of the institutions that hamper on the capability of these categories of people to adapt to the climate change impacts on food security.

8.5.3.1 Institutions of Bargaining Power

How and who makes the decisions on adaptive responses are made in rural setting which are very important factors of adaptation (Thomas and Twyman 2005). The capacity of the bargaining power of the individual and groups helps to influence the planned adaptation process. The bargaining power is determined by social and legal recognition of legitimacy of the claim (Agrawal 2001). However, the institutions of social relations have negative effects on the bargaining power of the women, *dalits* and indigenous and elderly people in the country (Springate-Baginski and Blaikie, 2007). Caste and gender determine the social and legal legitimacy of the claim of people. *Dalits* cannot articulate their needs and demands before upper castes and females do not speak before male counterparts because these practices are not socially recognized. In the rural areas, socially advantaged groups have discursive hegemony on information about climate change and intervention of the planned adaptation. Thus, these people are unable to frame issues such as well-being and deprivation, which is crucial to understanding in mitigating vulnerabilities.

8.5.3.2 Adaptation Policies

The District Agricultural Development Office (DADO), NFC, WFP and some non-governmental organisations (NGOs) have been formulating and implementing food security programmes that are able to cope and adapt with climate change. However, marginal groups perceive that these policies and activities are not effective and are not linked with their livelihood assets and strategies. Also, these programmes that focus on dominant food culture (i.e. rice) have destroyed local culture that are more climate change resistant (Adhikari 2008). DADO mostly focuses their activities for small irrigation projects, improved seeds and pesticides, etc. These activities aren't suitable for the people who have nominal lands. The NFC distributes food in minimum price. In this distribution of food there is no access of poor and marginalised community because it is based on the income earning opportunities of the people. The extension programmes are oriented towards land-based activities where the *dalits* and women have very poor access. Most of the adaptation activities include landslide control, road stabilization, greenery development that mostly favours the high castes and males. Therefore, most of the *dalit* communities and women employ reactive or autonomous adaptation while other social groups use proactive and planned adaptation.

8.5.3.3 Political Engagements

Nepalese people are considered as highly empowered in terms of politics. How people engage in voting process, pressure groups and different wings of political parties also determine the information of climate change and its impacts on food security. It is found that climate change induced drought, in the study region, has increased hunger and starvation. The marginal groups in the study area were the most affected from such crisis. To reduce such situation, NFC and WFP have initiated the provision of food distribution through their set plans. Evidences show that affected household who are more influential in local politics get more support from these provisions. It is also reported that a lot of food is wasted in preparation of alcohol mostly by people who are politically influential. There is very less participation of the *dalits* and women in the design and implementation of these interventions. As a result, their vulnerability and adaptation options are not included which makes them more vulnerable.

8.6 Conclusions and Recommendations

The evidences from this study have shown that natural resource based livelihoods strategies and food security are sensitive not only due to their location but also due to different institutions through which the resources are managed and food resources are secured. The evidences also show that both the formal and informal social, economic and political institutions increase negative impacts of climate change on the food security needs of the marginal groups (women, *dalits*, indigenous people, landless, and elderly people). Though there are common risks to all the people through climate change variability and extreme events, the institutions reduce the capability of such groups which increase their exposure to climate change events and reduce resiliency and adaptive capacity to further reduce damages through the changes.

The evidences show that drought, late rainfall, and less snowfall have been reducing agricultural production. However, the institutions of land tenure, market, caste-based occupation, wage labour, patron-client relationships have been reducing the production and purchasing ability of marginal groups. The institutions create more exposure for them to the events. Also, these institutions make their income and health more vulnerable towards climate change incidences. Simultaneously, the institutions of schools and social networking make marginal groups less informed about climate change risks. The institutions of untouchability and caste-based discrimination have been limiting the access of untouchable communities to social infrastructures like water resources which are very important for consumption of food. More importantly, both climate change and food security issues in Nepal are becoming more and more visible in the political agenda. Political parties have been using the food as political instrument and it has further increased vulnerability of the marginal communities. Though some adaptation policies have been implemented in the study sites, it doesn't favour marginal community.

Caste and gender relations play a deep-seated role in determining behaviours and access in terms of how individuals react to climate stress, variability and changes (Jones 2010). The evidences show that caste and gender based institutional barriers have significant adverse implications for the lower caste and women's capacity to adapt with climatically induced livelihoods strategies.

Therefore, it is necessary to analyze and include the institutional dimensions of livelihoods and food security, while conducting research activities, mainstreaming climate change adaptation policies and developing planned adaptation interventions. For successful adaptation practices the intervention should focus on the restructuring institutional aspects and removing the barriers of caste and gender based wage labour and caste-based patron client relationships. This aspect also is linked to more effective and inclusive market structure as well, which needs be further researched. For sustainable adaptation in food security, redistribution of land becomes a precondition for the marginal communities. Social policy and social protection can provide better opportunities to the poor to reduce vulnerability and increase adaptation (Heltberg et al. 2009). In these regards, the institutions of microfinance, community fund, safety nets focusing on the marginal community may support sustainable food security and climate change adaptation. To deal with the climate change incidences, it is necessary to deliver indirect interventions applicable to the socially disadvantaged groups. The institution of social fund and insurances that could support the marginalized community seems very much effective intervention in these regards. Also, access to institution of health, information sharing, employment opportunities are vital for building the resilience of the poor.

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Chapter 9
The Impacts of Climatic Change and Options for Adaptation on Some Subsistence Crops in the Sudano-Sahelian Zone of Cameroon

Prosper Somah Techoro and Michael Schmidt

Abstract Sub-Saharan Africa is the only region in the world that has become poorer in the last generation. The climate change is expected to add significantly to the development challenges of ensuring food security and poverty reduction. The majority of these countries are dependent on rain-fed agriculture (96 %) for their subsistence, thereby making them highly vulnerable to recent climatic change. Adaptation to climate change in the crop production sector is therefore very imperative in providing food security and protecting the livelihood of rural poor smallholder farmers and communities. This study used both the top-down and the bottom-up approach in analysing the sensitivity and vulnerability of subsistence farmers in the Sudano-Sahel of Cameroon on climatic change. Analyses of agricultural droughts using the Standard Precipitation Index (SPI) and statistical models were used in investigating the impacts of recent climatic changes on two staple crops, millet Pennisetum glaucum L. and sorghum Sorghum bicolor L. (Moench). Household questionnaires and interviews were also conducted and subsistence farmers' perceptions on climatic change were then analyzed. The findings showed that local subsistence farming communities perceived changes in rainfall and its frequency and rise in temperature. The results indicated that climatic trends appear to be responsible for between 12 and 24 % of the yield variation for both millet and sorghum, with maximum temperature at the growing season being the dominant influence. The droughts were observed in up to about 9 % of the years analyzed. Pertaining to climatic variability and change adaptation, subsistence farmers have changed their planting dates, crop varieties as well as switched from crops

P.S. Techoro (✉) • M. Schmidt
Department of Environmental Planning, Brandenburg University of Technology (BTU) Cottbus, P.O. Box 101344, 03013 Cottbus, Germany
e-mail: techosom@tu-cottbus.de; schmidtm@tu-cottbus.dea

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to livestock and off-farming activities among many others. The result further highlighted the lack of money, poor access to climate information, the encroachment of the desert and the shortage of man power as some of the factors hindering subsistence farmers' ability to climate change adaptation.

Keywords Climatic change • Subsistence crop • Perception • Adaptation • Cameroon

9.1 Introduction

Climate change (CC) is a natural phenomenon and its impacts would add significantly to the development challenges of ensuring food security and poverty reduction in most Sub-Saharan African (SSA) countries (Watson 2001), which is the only region in the world that has become poorer in the last generations (Ravallion and Chen 2004). While human population is growing by 3 % per annum and recently reached to seven billion, yields of major food crops increase is inconsistence with population growth (Inter-Academy Council 2004). Several factors have contributed to the deepening poverty and underdevelopment in SSA. These include the difficulty of coping with climate variability in a continent subjected to frequent droughts, floods, extreme high temperatures and land degradation. In addition, various socioeconomic, demographic, political, institutional, and policy trends have limited the abilities to adapt to climatic variations (Rosenzweig and Hillel 1998; Adger et al. 2007).

The availability of food depends on agricultural production. Seasonal and geographical crop yield availability depends on space, time and rainfall distribution patterns. Since climate is a primary determinant of agricultural production, any adverse changes in climate would likely have a devastating effect on this sector thus, threatening crop failures. Such changes would concomitantly affect the livelihood of the majority of the population that depends on rain-fed agriculture for their mainstay (Sivakumar et al. 2005; Odada et al. 2008). For example, 89 % of cereals in SSA are rain-fed (Cooper et al. 2008) and climate is already a driver of food insecurity (Gregory et al. 2005; Verdin et al. 2005).

Generally, the evaluations of how climate change affects crop yields have been made using historical records for several decades (Thompson 1986; Changnon and Winstanley 2000). Most recently, Lobells and Asner (2003) investigated the relationships between climate trends and production of corn and soy bean in the United States between the periods of 1988–1998. Juan et al. (2008) used multiple regressions to analyze corn historical yields and weather variables for Southern Quebec from 1973 to 2005. Larson and Vanderlip (1994) also showed the dependency of sorghum yields on climate with a very high correlation between rainfall and yield. However, issues on climate change are only marginally entering into the development planning in the northern region of Cameroon and societal resilience so far is not improving. Besides, impact of climate change and historical climatic trends and patterns and their impacts on subsistent crop production remains a poorly investigated area in this region. Tingem et al. (2008) used CropSyst Simulation models in assessing crop growth vulnerability to climatic changes in Cameroon in its entirety and proposed sets of adaptation measures for a wide range of crops. Extensive literatures exist on the use of the Richardian cross sectional approach to measure the relationship between climate and the net revenues of some selected crops in a plethora of Africa countries with Molua and Lambi (2006) for Cameroon and (Mendelsohn 2006; Kurukulasuriya et al. 2006) for other African countries. The use of statistical models in climate impact studies on yields have been employed by Vasselin and Hoogenboom (2001), Jones et al. (2003), Lobells et al. (2006), Lobells and Field (2007), Tao et al. (2003) and Nicholls (1997). Moreover, studies pertaining to how subsistence farming communities have coped with climatic variability and change in order to guide or create benchmark for future adaptation strategies are still in its virginity. Most recently Witt and Waibel (2009) measured climate risk and its impact on livelihood outcomes in fishery-dependent communities in the Yaéres floodplain (Far North Province of Cameroon) proposing some adaptation options. Other studies in the determination of the ability of farmers in Africa to detect climate change and to ascertain how they adapt include works of Maddison (2006), Mary and Majule (2010) and Nhemachena and Hassan (2007).

A prerequisite for forecasting and projecting production based on observed measurements with future impacts changes is generally based on the understanding of climate subsistent crop relationships deduced from historical records. This is very crucial in the development of adaptive strategies since acquiring knowledge on recent climatic trends on crop productivity would be an important step towards predicting agricultural production. In addition, it is viewed that perspectives of the indigenous communities, the way they think, perceive and behave in relation to climate change as well as their values and aspirations have a preponderant role to play in addressing climatic variability and change adaptation issues (Doss and Morris 2001).

This study uses the top-down and the bottom-up approach of the TAR (the Third Assessment Report) of the UNFCCC (the United Nation Framework Convention on Climate Change) in the assessment of the sensitivity and vulnerability of crop production systems (UNFCCC 2006) for subsistence farming communities in the Sudano-Sahel of Cameroon. It employs statistical models in investigating the impacts of recent climatic changes on two staple crops, millet *(Pennisetum glaucum* L) and sorghum *(Sorghum bicolor* L) (Moench) in the North of Cameroon. It uses historical climatic data to analyze the severity of drought indices in the Sudano-Sahel and to assess the extent to which recent climatic variability has affected or influenced subsistent yields of millet and sorghum in this region between 1961and 2006. It also hypothesized that the current coping strategies in use by the subsistence farming communities shall be very crucial in the modern day quest for climate change coping and adaptation options.

9.2 Materials and Methods

9.2.1 The Study Area

Cameroon is situated in West Africa and extends between Latitude 2° and 13°North of the Equator and between Longitude 8° and 16°East of the Greenwich meridian. The country is highly vulnerable to climate change due to its geographical location (Fig. 9.1). It has a well-watered equatorial southern region and an increasing dry north, which falls within the Sudano Sahelian belt (Zaal and Dietz 2004). The Sudano-Sahelian zone alone extends from latitude 7°30′ to 13°North and longitude 9° to 15°East (Kengal et al. 2005).

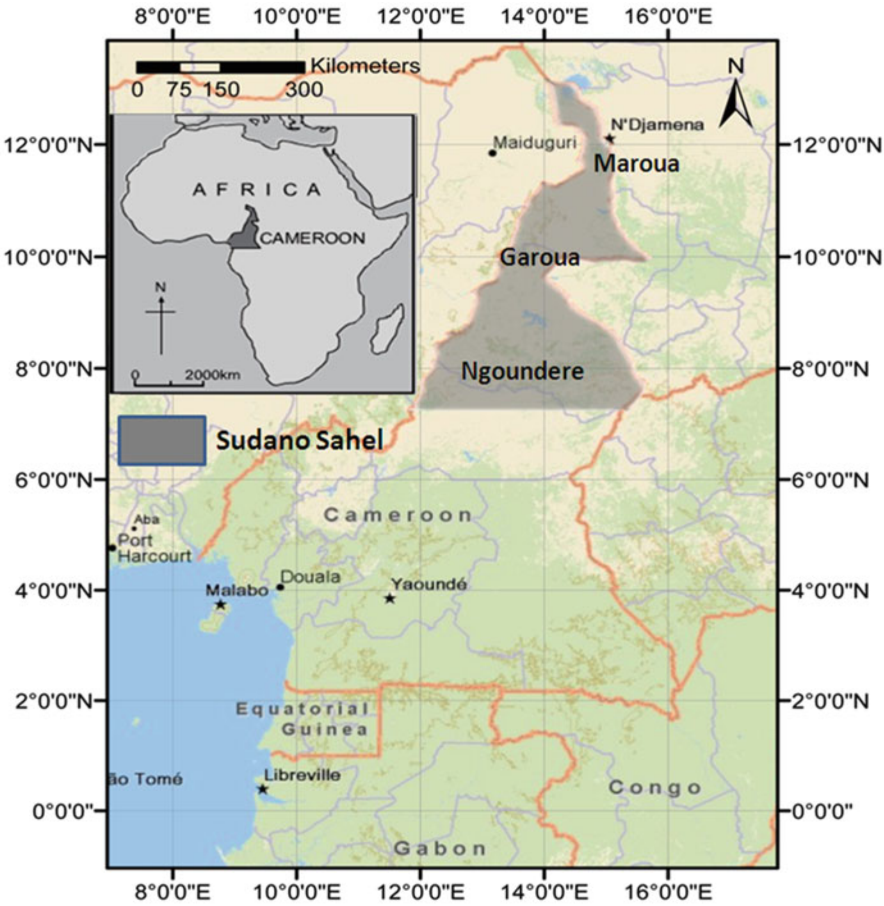


Fig. 9.1 Location map of Cameroon (*shaded area* shows Sudano-Sahelian study region)

The climate type is AW/BS according to Koeppen classification and is characterized by a pronounced dry season with the driest months having little or no precipitation (AW). The potential evapo-transpiration (PET) usually exceeds precipitation in its desert climate (BS) (Koeppen 1936). The region experienced a unimodal rainfall distribution and a long dry season. The rainy season lasts for about 5 months (May–September) acting as the growing season for crops with erratic rainfall patterns in April and October. Based on the FAO soil classification, three major soil types are distinguished. These are the Vertisols, the Planosols and the Lixisols (Kengal et al. 2005). The soils have characteristic of sandy to sandy loam textures, low in organic matter contents and low in native fertility, with limiting nutrients for crop growth (Manu et al. 1991). They are also structurally unstable and prone to crusting and hardsetting, and have a low water holding capacity (Valentin 1995). Cotton, millet, sorghum, maize, groundnut are the most suitable crops grown.

Crop types selected for this study were millet (*Pennisetum glaucum* L.) and sorghum (*Sorghum bicolor* L. (Moench)) since they constitute the most important food crops serving as sources of energy, protein, vitamin and mineral nutrients for approximately six million people living in this area. Millet and sorghum are genetically suited to hot and dry agroecology where other grains find it difficult to grow. The average yield of both millet and sorghum is approximated at 0.86 and 0.88 tons per hectare respectively. The total harvested area per year is 395,000 ha for sorghum and 86,000 ha for sorghum (FAO 2008).

9.2.2 Top-Down Approach

9.2.2.1 Climatic Variables and Calculating Standardized Precipitation Index (SPI)

Daily climatic variables-maximum and minimum temperatures and rainfall were obtained from the University Cooperation for Atmospheric Research (UCAR) (http://dss.ucar.edu/datasets) for the Sudano-Sahelian region of Cameroon. The choice of using the observed weather station data was based on the findings of Tingem et al. (2008). To avoid inhomogeneities in the data, quality control and homogeneity test procedures were performed using ClimDex Version 1.3 software developed by Byron Gleason from NCDC/NOAA, USA. (http://cccma.seos.uvic.ca/ETCCDMI/software.shtml). Time series for the mean monthly rainfall and mean yearly temperature from 1961 to 2006 for the entire region was computed.

Due to the over dependency on rain-fed agriculture in the study region, the computed rainfall time series was then used to determine the evolution and intensity of droughts in the three different regions. The 9-month standardized precipitation index (SPI) by McKee et al. (1993) was used for this purpose. In calculating the SPI, only the precipitation data were used. Other variables such as temperature, evaporation and humidity were not taken into account. Numerous papers have indicated that precipitation is the most important variable in rain-fed agricultural drought analysis (Oladipo 1985; Keyantash and Dracup 2002) since it is the variable that mainly determines the duration, magnitude and intensity of droughts.

SPI is a common index used to detect the change in drought. It is calculated on the basis of selected periods and its equivalent to the Z-Score used in Statistics and represents deviation in precipitation totals (Mckee et al. 1993). Firstly, a time series of the precipitation value of interest is generated. The SPI is calculated by deducting the precipitation difference from the mean for a time period and dividing this value by the standard deviation of the whole recorded precipitation. The precipitation data is assumed as normally distributed (Mckee et al. 1993). The index is based on an equi-probability transformation of aggregated monthly precipitation into a standard normal variable. Positive values in the SPI indicate greater than mean precipitation while negative values indicate less than mean precipitation. Nine Months Standardized Precipitation Trends and Patterns as well as the average monthly precipitation and the potential evapotranspiration (PET) for the three regions of the Sudano Sahel of Cameroon are shown in Fig. 9.2.

9.2.2.2 Crop Production Data

The historical crop statistics for the yield and harvested area data of millet and sorghum were obtained from the Food and Agricultural Organization (FAO) Agristat for same period of 1961–2006 (FAO 2008). The anomalies were computed for use in exploring relationships between yields and the above mentioned climatic variables (Fig. 9.3a, b).

9.2.2.3 Yield Functions

In order to study the impact of recent climatic trends on millet and sorghum in Sudano-Sahelian Cameroon, multiple regression models were developed using time series yield anomalies as the predictor. While anomalies in minimum temperature, maximum temperature and rainfall for the crop growing season from May to August acted as the predictor. The model was initially run with the said climatic variables. Thereafter, the harvested areas anomalies were included as the sole non climatic variable to assess which combination of factors accounted for the most variation in yields of the staple crops. The Pearson Product Moment Correlation Coefficient was also used in exploring individual climatic variables relationships with yields for the entire growing period in order to identify those variables that influenced a significant portion of the observed yield variance. The statistical software SPSS 17.0 was used and all analyses were carried out at a 95 % confidence interval level.

This model approach provides the option of investigating individual input effect variables that are capable of influencing crop yields while maintaining all other variables constant. The shortcoming of this model is that it does not explicitly

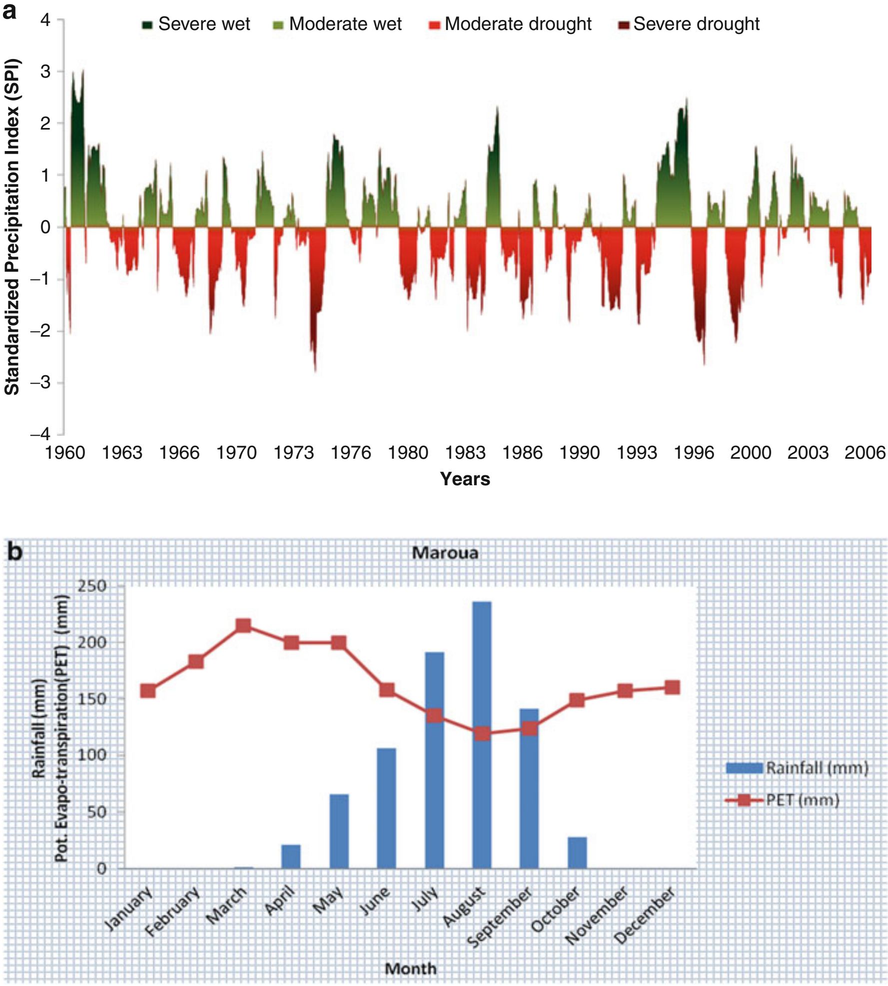
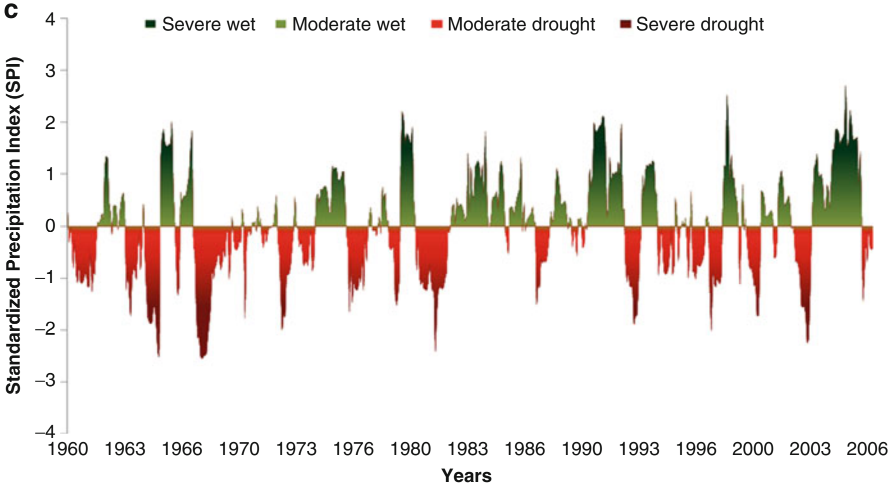
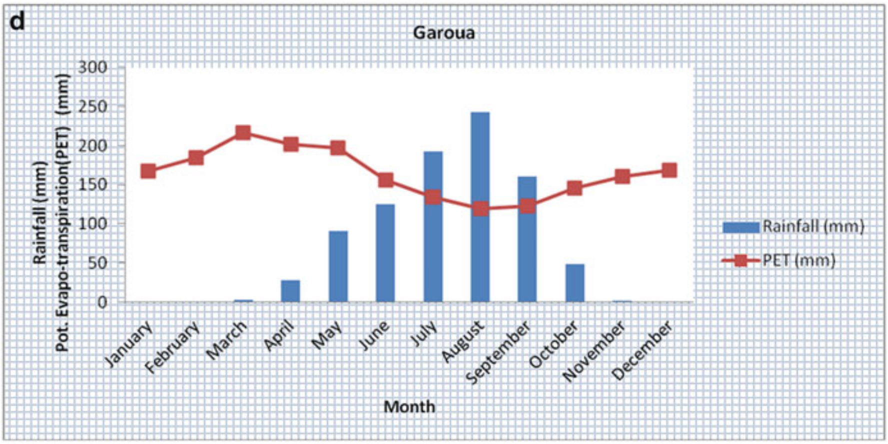


Fig. 9.2 Months Standardized Precipitation index, monthly precipitation and the potential evapotranspiration (PET) for the three regions of study area (Maroua, Garoua, and Ngaoundere) for the period of 1961–2006. (**a**) Nine months SPI for Maroua from 1961 to 2006. (**b**) Average monthly precipitation and the potential evapotranspiration (PET) for Maroua (Data Source: Computed from Sanders de Haas 2010). (**c**) Nine months SPI for Garoua from 1961 to 2006. (**d**) Average month precipitation and the potential evapotranspiration (PET) for Garoua (Data Source: Computed from Sanders de Haas 2010). (**e**) Nine Months SPI for Ngaoundere from 1961 to 2006. (**f**) Average month precipitation and the potential evapotranspiration (PET) for Ngaoundere (Data Source: Computed from Sanders de Haas 2010)





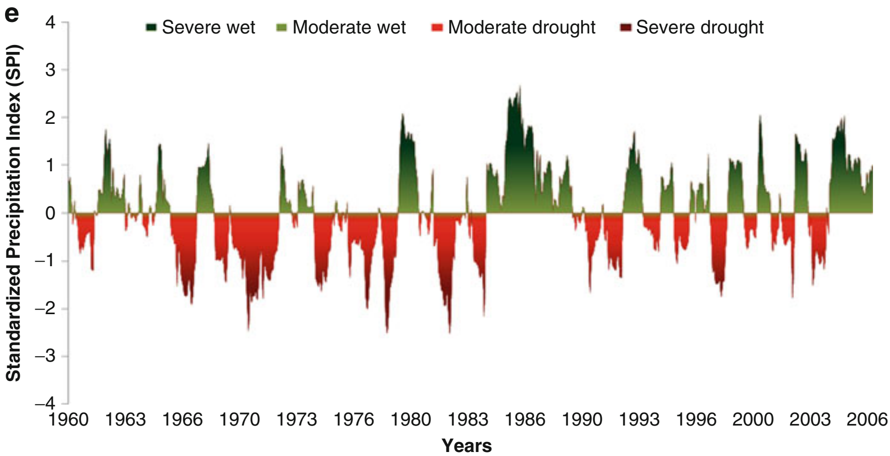
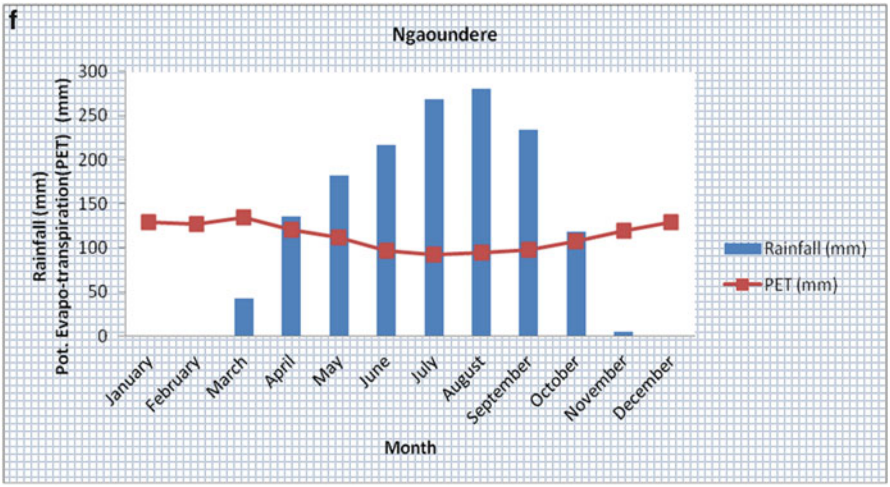


Fig. 9.2 (continued)



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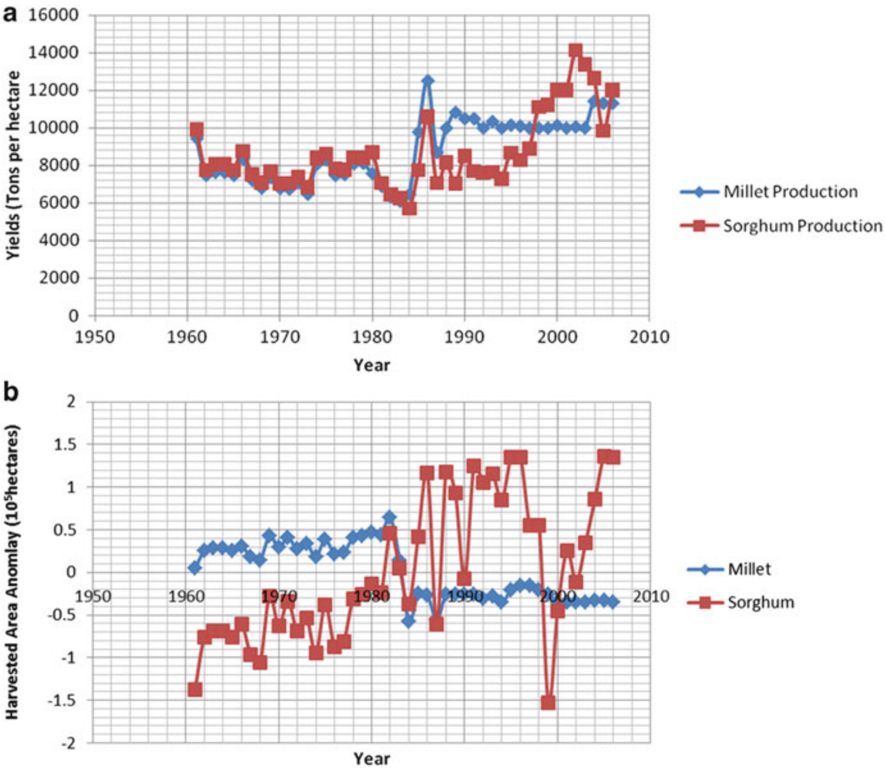


Fig. 9.3 Time series of average yields (**a**) and harvested areas (**b**) anomalies for millet and sorghum (1961–2006) (Source: FAO 2008)

consider management changes or other factors such as carbon dioxide impact that may alter the effect of climate on crop yields. It thus assumed a degree of uniformity in those factors other than climate that could influence crop productivity and yields.

9.2.3 Bottom-up Approach

It investigates the sensitivity and vulnerability of subsistence farmers, employing a participatory research approach in exploring the adaptation behaviour and pattern perceived by local communities in the face of variable conditions through key informant interviews and in-depth interviews via questionnaires.

9.2.3.1 Key Informant Interview

Two key informant interviews each were first conducted from each of the three different regions of the Sudano-Sahel zone of Cameroon. The key informants were mainly Agricultural Extension Service workers from IRAD (Institut de Recherche Agricole pour le Développement). Key informant interviews aided in the selection of the neighbourhoods where subsistence farming was the order of the day. Implying that respondents were selected based on the above premise and were also used in establishing the reliability and consistency that allowed findings from the household questionnaires to be compared with. The interviews were then used to explore and conceptualize approaches by subsistence farmers to adaptive capacity, and its perceived utility for decision making.

9.2.3.2 Household Questionnaires

The household questionnaires involved semi-structured open ended, closed ended questionnaires conducted across villages in the three regions of the Sudano-Sahel with Mayo Tsanaga (far north region), Mayo-rey (North) and Gbaya and Mbum (Adamawa) being the most surveyed areas due to subsistence farmers' population pool. These were the easily accessible villages chosen for the interviews. Questions covered a number of topics ranging from household information, agricultural dependency and crop types produced, the state of knowledge of subsistence farmers on climate change, currents adaptation practices, constrains and ways forward. A total of 300 questionnaires each were administered for each region. In some questions, respondents were given the options of multiple responses. The study was conducted at a face-to-face level and a respondent rate of about 81 % was obtained. Quantitative data were organized and facilitated for qualitative analysis. Analysis was based mainly on descriptive analysis and presentation. The statistical package (SPSS) 17.0 was used for analysis. Analysis of variance (ANOVA) was first used to check if there was significant difference between the mean responses to climate change perceptions, and adaptation strategies towards curbing the impacts at a 95 % confidence interval ratio in the three different region of the Sudano-Sahel.

9.3 Results

9.3.1 SPI Analysis

Table 9.1 shows the distribution of SPI class values for the 9-months interval. The 9 months was chosen since it covers in principle, the agricultural period of the natural cycle of the climate. 9-months SPI provides an indication of precipitation pattern over a medium scale, which covers land preparation, sowing, planting and harvesting season.

The differences between the frequencies of occurrence of the SPI range for the three regions of the Sudano Sahel of Cameroon are small. Extremely drought periods (SPI −2 or less) with potentially extreme drought occurred in about 3 % of the years. Severe drought periods (SPI values between −1.5 and −1.99) occurred approximately 5–6 % of the years. On the other hand, between 8 and 10 % accounted for the severe wet period (SPI value of +1.5 to +1.99). Extremely humid periods with potentially severe flooding occurrence were between 6 and 8.5 %.

9.3.2 Changes in Crop Production

There have been changes in both the yields and harvested areas for millet and sorghum in the Sudano-Sahelian region of Cameroon. Significant yield increases have been observed during the last four decades for both crops (Fig. 9.3a) with respect to climatic variability. Millet yields since the 1990s have increase from an average of 0.7 tons per hectare (t ha^{-1}) to about 1.0 (t ha^{-1}). In contrast, significant

Table 9.1 Standardized Precipitation Indices and categories combined with the percentage of occurrence over the period of 1961–2006 in the Sudano Sahelian region of Cameroon

		Percentage frequency of occurrences		
Drought category SPI range	SPI range	Maroua	Garoua	Ngaoundere
Extreme drought	−2.0 or less	2.4	2.7	1.5
Severe drought	−1.5 to −1.99	4.9	4.9	5.6
Moderate drought	−1.0 to −1.49	10.3	10.0	10.9
Mild drought	−0.99 to 0	34.2	31.5	35.1
Normal	+0.1 to +1.49	34.6	33.5	29.4
Severe wet	+1.5 to +1.99	7.8	8.9	10.0
Extreme wet	+2.0	5.8	8.5	7.6

dropping trends were observed for sorghum during the last decades. Nevertheless, below average yields were observed in the 1960s, 1970s and 1980s for all crops.

Harvested areas allocated to each crop shown variability with respect to climate as well. Millet harvested areas increased to about 120,000 ha till the 1980s and then dropped to about 50,000 ha (Fig. 9.3b).

9.3.3 Correlation Coefficient

The correlation analysis between yield anomalies for millet and sorghum were positively correlated with all the variables. Highest correlations were attained between maximum temperature whereby R^2 was 0.40 and 0.28 for both millet and sorghum respectively (Fig. 9.4). The correlation coefficients were never higher than 0.4. These overall weak correlations indicated a low percentage of yield variability explained by the different variables.

9.3.4 The Regression Model

Multi linear regression function using climatic variables (rainfall, maximum and minimum temperature) anomalies showed that the yield of millet was highly correlated to climatic variables compared to yield of sorghum. For millet, the predictors accounted for 24 % of the variations in yield at a 95 % confidence interval, unlike the 12 % in sorghum that was viewed as insignificant (Table 9.2). The inclusion of the sole non-climatic predictor variable (the areas harvested) into the model, R^2 value for millet increased to 0.59 while no changes were observed for sorghum. Harvested areas accounted for 59 % of the observed yield variance in millet. The intercepts of the regression represents the average yield change with climate held constant. For millet, the average yield change was +4.6 $\pm$ 165.6 (t ha^{-1}) for the time of study while that for sorghum was -0.52 ± 275.7 (t ha^{-1}).

9.3.5 Subsistence Farmers' Perception on Temperature and Rainfall Changes

About 84 % of the subsistence farmers interviewed perceived long-term changes in temperature. Figure 9.5a shows that 84 % of the subsistence farmers perceived that the temperatures in the Sudano- Sahelian zone of Cameroon have increased. Only 4 % noticed a decrease and 12 % on the contrary have observed no changes.

Figure 9.5b on the other hand, shows that some 8 % of the respondent perceived an increase in rainfall a huge 91 % responding that the amount of rainfall have

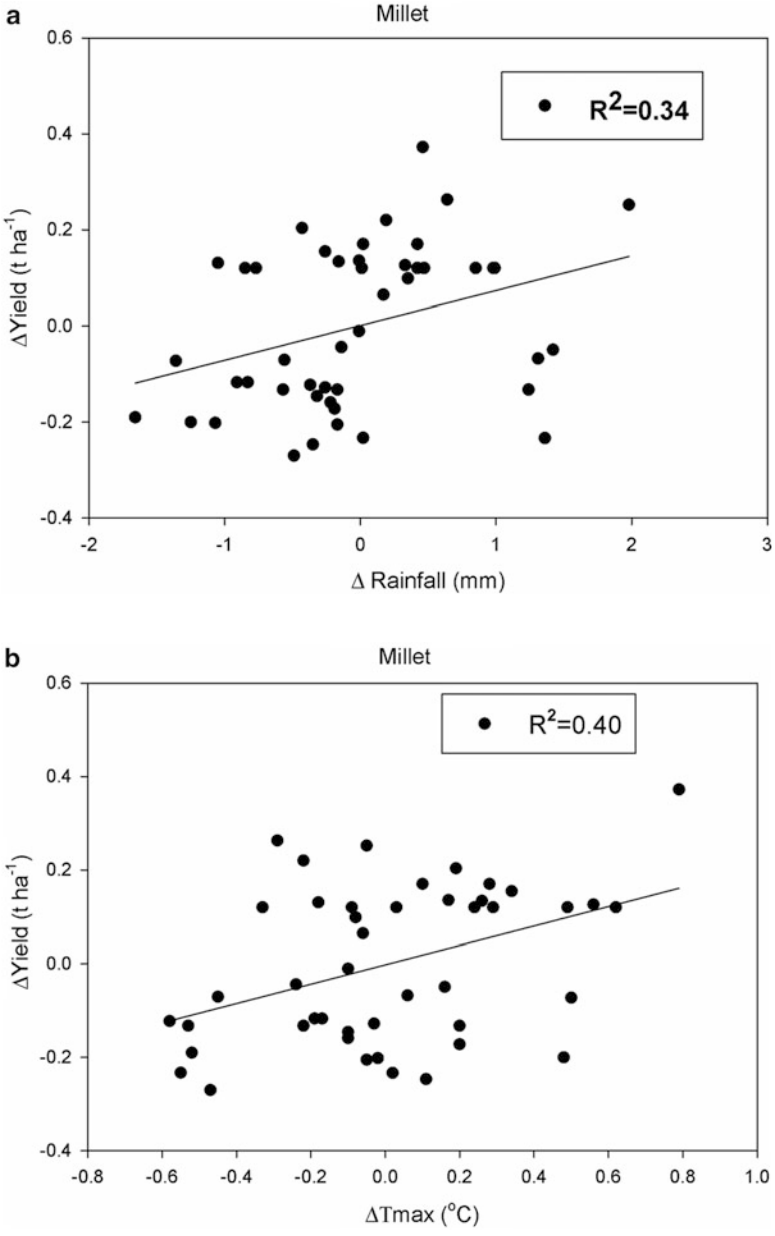
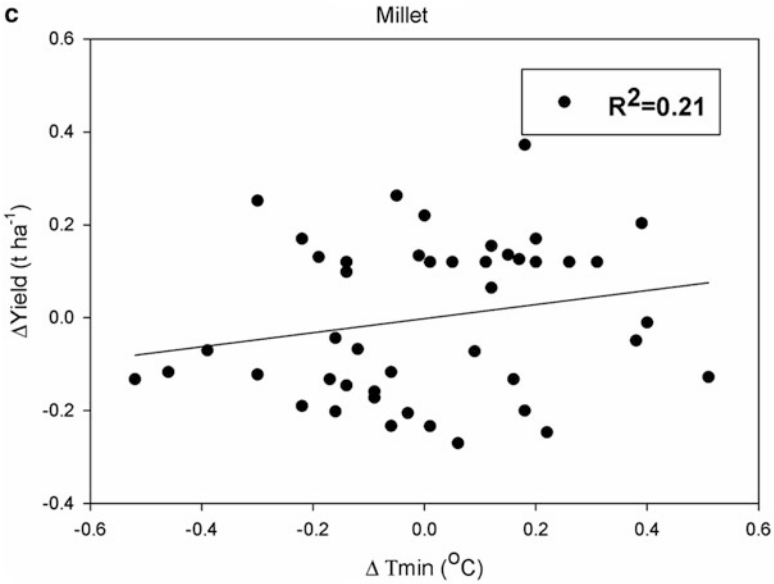
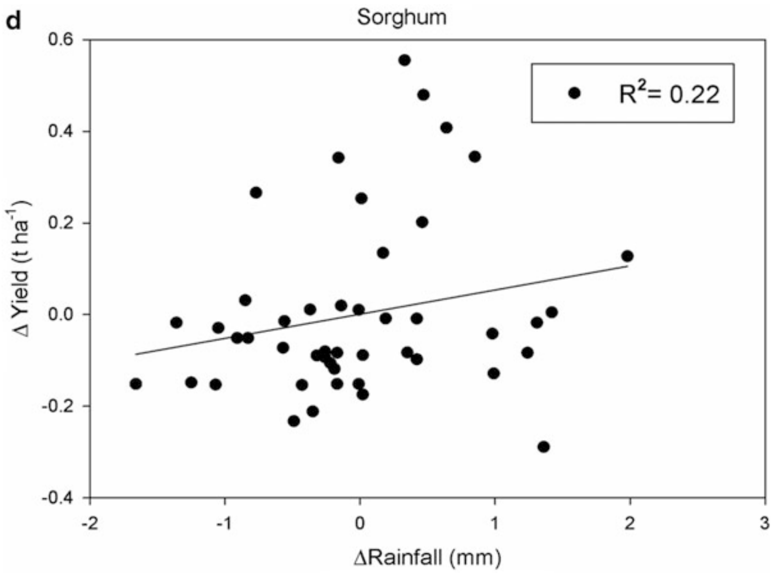


Fig. 9.4 Change in millet and sorghum yield Vs change in growing season minimum rainfall, minimum temperature and maximum temperature. Best fit regression line and R^2 are shown with significant correlations with yield changes ($p < 0.05$). (**a**) Change in millet yields Vs change in growing season rainfall. (**b**) Change in millet yields Vs change in growing season maximum temperature. (**c**) Change in millet yields Vs change in growing season minimum temperature. (**d**) Change in sorghum yields Vs change in growing season rainfall. (**e**) Change in sorghum yields Vs change in growing season maximum temperature. (**f**) Change in sorghum yields Vs change in growing season minimum temperature





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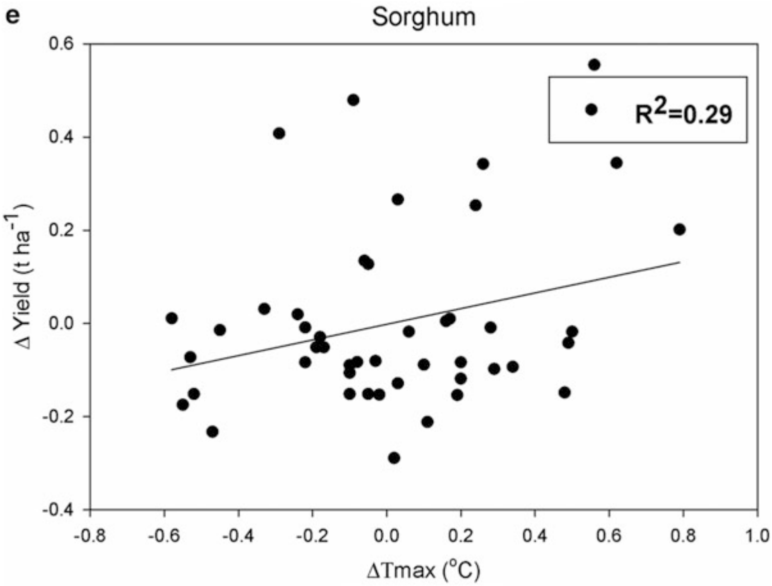

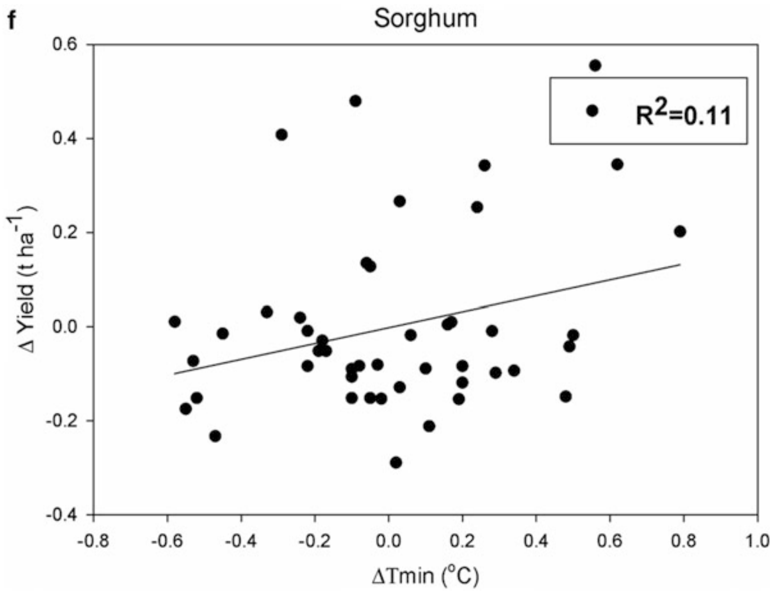

Fig. 9.4 (continued)

Table 9.2 Results of multiple linear regression model based on anomalies of yields and climatic variables for growing season from 1961 to 2006

	R	R^2	SE	df1	df2	Sign.F
Millet	0.48	**0.233**	1510.1	3	42	**0.010**
Harvested areas[a]	0.77	**0.588**	1120.5	4	41	**0.000**
Variables	**Intercept**	**Std. Error**	**Rainfall**	**Min. Temp.**	**Max. Temp**	**Harvested area**
	4.6	165.5	142.6	−1174.2	1143.4	0.04
Sorghum	0.35	0.119	1843.4	3	42	0.015
Harvested areas[a]	0.35	0.119	1186.7	4	41	0.257
Variables	**Intercept**	**Std Error**	**Rainfall**	**Min. Temp**	**Max. Temp**	**Harvested area**
	−0.52	275.7	411	−1063.7.8	−1117.8	−0.00

[a]Shows the inclusion of harvested areas as the sole non-climatic variables in the model. (Significance level at $p < 0.05$)

reduced considerably. Less than 2 % observed no rainfall changes. In Maroua for instance, a 0 % change in the rainfall pattern was perceived by the farmers.

9.3.6 Subsistence Farmers' Perceived Adaptation Responses

Quite a number of adaptation strategies have been adopted by subsistence farmers in the wake of the varying climate and are shown on Table 9.3. About 21 % of the respondent said they change planting dates as adaptation strategies. Some 20 % of the respondent cultivated different crop varieties. Another adaptation strategy perceived by the farmers was the migration from the rural suburbs to urban areas in search of greener pastures. Some 17 % of the farmers have increased their cultivation areas of land while about 16 % use local indicators. Some 14 % have perceived switching from crops to livestock as an option while 7 % of farmers have even hinged on daily prayers for better climatic conditions.

9.3.7 Constraints in Adapting to Perceived Climatic Changes

Results from subsistence farmers' interviews and the discussions with extension services workers on the question "*what were the main constrains in adapting to the perceived climatic variability and change?*" indicated that many factors hindered subsistence farmers' adaptation to the variations of climatic events in the Sudano-Sahel of Cameroon. Most of the responses were more or less the same. Those highlighted include:- Poverty (lack of money), the encroachment of the desert, the lack of information, shortage of manpower (labour) to work on the farms, farmers health status, non-availability of seeds, high prices and the inappropriate government policies such as supply of fertilizers and irrigation potentials. Public awareness and communication as well as high process of basic supplies and food were also some of the constraints.

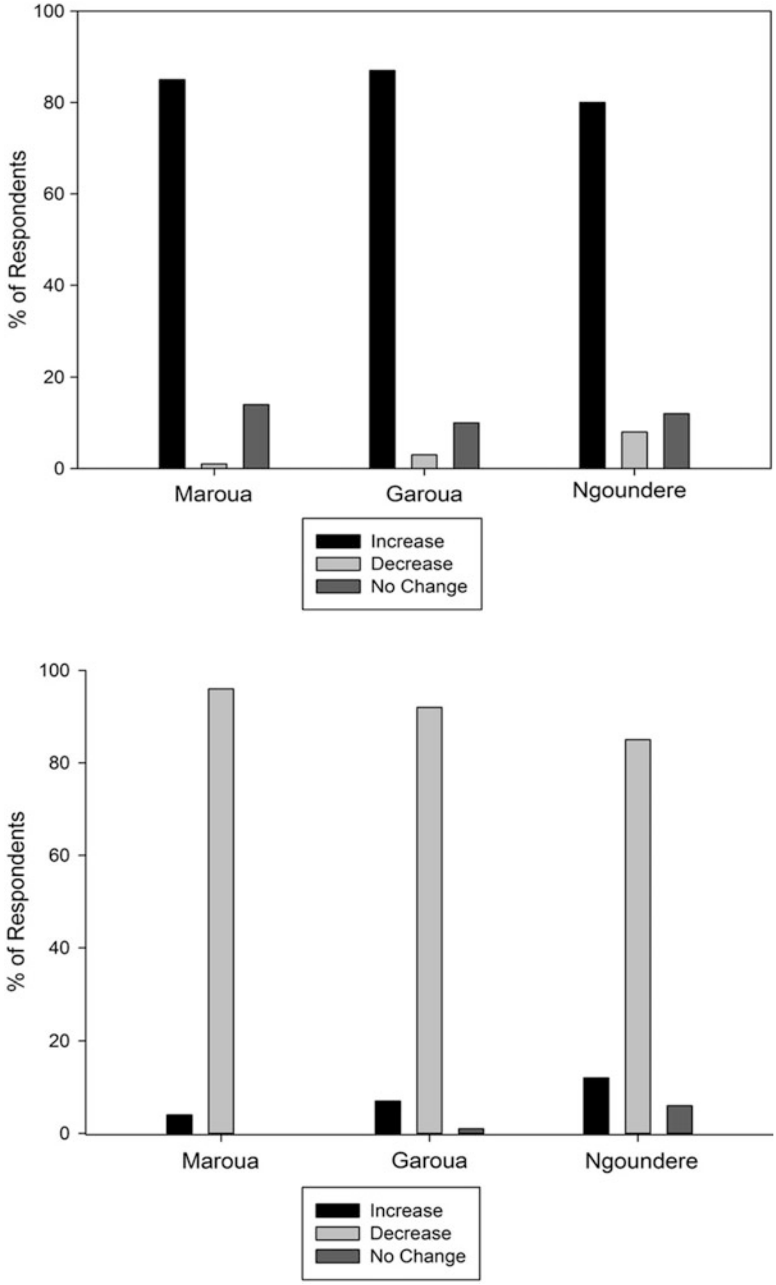

Fig. 9.5 (**a**) Farmers' perception of changes in rainfall in the Sudano-Sahel of Cameroon. (**b**) Farmer's perception of changes in temperature in the Sudano-Sahel of Cameroon

Table 9.3 Responses to perceived farmers adaptation practices

Variables	Number of practices including multiple answers	% of respondent
Change of planting dates	153	21
Change crop varieties	146	20
Movement to different sites	58	8
Reduction in cultivation	29	4
Increase in land area cultivated	124	17
Rural urban migration	146	20
Search for off farm jobs	44	6
Religious belief and prayers	51	7
Use of local indicators	117	16
Irrigation practices	29	4
Fertilizer use	51	7
Soil conservation	58	8
Crops to Livestock switch	102	14
Livestock to crop switch	7	1
Total responses	1,116	

9.4 Discussion

The results indicated a variation in the climate of the Sudano-Sahelian region of Cameroon. There have been very critical changes in the climate particularly, during the growing seasons from May-August for the study period of 1961–2006. This could be accounted for by the geographical location of the country; having a dry northern region where the Sudano-Sahel falls within and a well-watered southern equatorial region. Kengal et al. (2005) observed variations in the growing seasons of up to less than 120 days in this region. These results on variability in the climate also corroborate with the results of the interviews with the local farming pertaining to their perceptions on climatic variability and change in the Sudano-Sahel, whereby the majority of respondents perceived increasing temperatures and decreasing rainfall patterns. Maddison (2006) reported similar findings whereby a significant number of farmers in 11 African countries believed that the temperatures had increased while the rainfall intensity had dropped. Although in Maddison’s findings, Cameroon was an exception in the fact that most of those questioned believed that there had been no changes in temperature than that there had been an increase. The change in the agro-ecological zone from the Sudano-Sahel to the savannah type as one cruise southwards could be the reason for these changes. It should be noted that this research was based in the Sudano-Sahel and not in the whole Cameroon as he did. However, other scholars (Mertz et al. 2009; Thomas et al. 2007; Mary and Majule 2010; Gbetibouo 2009; Ishaya and Abaje 2008) have reported similar findings.

Droughts have a very pronounced impact because of the relative importance in the agricultural sector. Drought incidences have been prevalent in the Sudano-Sahel based on the results of the Standardized Precipitation Index (SPI). It does not take severe drought to affect crop yields. Even moderate lack of available water can drastically reduce crop yields. These types of droughty periods usually cause damage to rain-fed agriculture and the consequences are usually drastic and dramatic in that they render the agricultural soils very unstable, loss of fertility, prone to crusting and soil hard-setting (Valentin 1995) thereby making crop production very difficult. The possibilities of increase in desertification are also increased. The SPI droughts result analyzed were in accordance with the response of the subsistence farmers who responded that climate has been changing with many incidences of dry periods. In trying to understand why people may declare 1 year as a drought, it is important to recognize their needs in terms of rainfall – their dependency on rain-fed agriculture. This falls within the premise that people needs are used as kind of benchmark when they compare individual years. Drought is a very diffuse concept and the threshold identified for defining it is somewhat arbitrary (Agnew and Chappell 1999). The mid 1960s, mid 1980s, early 1990s, were droughty years characterized by severe famine in the Sudano-Sahelian. This coincides with the findings (Tingem et al. 2008; Molua 2008) who referred to this periods as years of the Sahelian drought.

The positive relationships between climatic variables and crop yields indicate their role in determining yields under changing climate. Higher correlations obtained for the maximum temperature with yield indicate just how important this variable might be in the growth period of the crops due to the rainfall variability and uncertainty between May and August in the Sudano-Sahelian region of Cameroon. Crop responses to temperature depend on the temperature optima for photosynthesis leading to growth and yield which may vary for different crops (Conroy et al. 1994). Changes in short term extremes can be essentially critical if they coincide with key plant development stages. The reproductive stage is very sensitive to temperature as it has an influence on the enzymes responsible for photosynthesis. Enzymes reactions and gene expressions might impact carbon assimilation and eventually crop yields (Gornall et al. 2010). Plant reproductive stage is very sensitive to temperature whereby at low temperatures enzyme activities are delayed causing antithesis which could affect final yields of crops (Bannayan et al. 2004). At higher temperatures, plant photosynthetic proteins may be denatured, with temperature extremes during flowering also reducing grain or seed numbers (Matsui and Horie 1992). These findings complement previous studies on drought impacts on crop yields where Dell et al. (2008) predicted that annual increase in temperatures by 1 °C have a far- ranging negative effects on staple crops of rural farmers. Changes in temperature also have an effect on the evapo-transpiration (Wheeler et al. 2000).

Differences in climate uncertainty between millet and sorghum yields reflect the fact that individual crops responds differently and develop different mechanisms under stress climatic conditions to continue their growth. Pierce and Raschke (1980) described that some plants have morphological characteristics which help to reduce absorbance of radiation. Some simply increase their root lengths density by penetrating deep into the soil to reach moisture thus enhancing water absorption. Climatic variables had more impact on yields of millet than for sorghum. Millet is considered more efficient in utilization of soil moisture than sorghum. It is hard and can grow in very hot dry areas and on soils too poor for sorghum. Generally it fits the same area of adaptation as sorghum, except that it is somewhat more drought tolerant and matures early. The attributes it has includes its fast root development, sending extensive root both laterally and downward into the soil profile to take advantage of available moisture and nutrients.

It should be noted that the addition of harvested areas as a predictor variable did not improve the yield variance for sorghum although an aggregated 59 % yield variance was observed for millet with the climatic predictors included. This is an indication that the unexplained variances in the regression analyses most probably were due to factors not evaluated in the model. This finding is in line with Lobells et al. (2006), who analyzed historical climate changing trends with yield trends and observed that just a little if any of the yields trends for a range of perennial crops in California could be attributed directly to climate. Such unexplained variables could include crop management practices, introduction of new cultivars and varieties, disease resistant controls, organic matter addition, possible technological changes as well as population influence. Since the start of the new millennium, both millet and sorghum yields have been showing downward trends. These crops are both C_4 crops and have optimum photosynthetic response at higher temperatures (30–35 °C). Elevated CO_2 levels would however benefit fewer of such crops. Most weeds for millet and sorghum are C_3 plants and at higher CO_2 levels C_3 outperforms C_4 plants (Ringius et al. 1996). So weed competition with millet and sorghum are likely to increase resulting in decrease in yields of both crops as it has been during the last 5 years.

Perception is a necessary prerequisite for adaptation. Perceptions are considered to be important as farmers' perceptions are regarded as critical determinant of necessary precondition for adaptation (Koch et al. 2007). From the findings, subsistence farmers' perception on climatic variability and change are based on assessments of mainly temperature and rainfall as they are experienced within the localities. Although they appear to be well aware of climate change, few seemed to actively take steps toward adjusting to the changing climate. Subsistence farmers in the Sudano-Sahel to an extent have been able to constantly cope with and adapt to the challenging environmental conditions. They have developed innovative responses to difficult or changing conditions. It must be reiterated that the strategies pointed out by the subsistence farmers are based on lessons learned from previous climatic stresses and have been handed down from generations to generations, with most of the strategies generally having some similarities for most SSA countries (Reij and Waters-Bayer 2001).

As an ex ante adaptation strategy, subsistence farmers have developed the tendency of switching crops varieties as climate changes. They seek to grow crop varieties that are with different sensitivity to climate. The reason for the positive farmers' perceived response that crop switching is a viable option for adaptation that could be associated to the conspicuous presence of the agronomic research institute although supplies have been limited. Moreover, over the past two decades, improved sorghum and millet technologies have been developed for West and

Central Africa that are high yielding, more productive, short cycle, pest-disease resistant as well as drought tolerant varieties by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Common in the study region were the High Yielding Varieties (HYV) of millet and the S35 varieties of Sorghum. Farmers in the Sudano-Sahel have substituted short duration S35 for their long cycle landraces (Djigari, Nadj-dadja, Kouran and Wakas varieties). Farmers' preferences for the S35 over the traditional varieties have been overwhelming due to its early maturing and high yielding with good fodder quality characteristics.

Shifts in planting dates are usually aimed at minimizing the effect if temperature-induced spikelet sterility that can be used to reduced yield instability by avoiding coincidence of the sensitive flowering stage with the hottest part of growing season. Farmers perception in the changing of planting dates as an adaptation option has also been reported in the finding by Bradshaw et al. (2004), Deressa et al. (2009), Tingem et al. (2008) and Molua (2008). The use of local indicators has a long stand traditional indigenous knowledge that enables farmers to live in a changing climate. Drought forecast indicator used have been the flower and fruit production of certain local trees, when less productive, it gave reasons for apprehension of poor climate. A good example of a drought forecast indicator plant were the shea tree *Vitellaria Paradoxa Gaertn*. Another indicator plant used in the Sudano-Sahel was the *Anogeissus leiocarpus* (Chewing stick plant). When it fails to blossom, it was an indication of harsh dry conditions.

Increase in the cultivation areas perceived by the farmers also corroborate with results obtained using the regression analysis whereby when harvested areas accounted for 59 % of the observed yield variance in millet. Implying that subsistence farmers do increase the areas they cultivate as an adaptive strategy. One of the reasons could be the decrease in soil fertility that makes farmers to perform other agricultural practices and shifting cultivation. This might have accounted for this adopted strategy. Since rain-fed crops are constrained by the harsh climate, further expansion of cultivated area is seen at the expense of livestock, which were more or less sensitive to climate factors than crop production. Therefore, there is a shift from crop cultivation to livestock. To supplement the recent shifts from crop to livestock as a perceived adaptation strategy, the increase use of cotton cake as feed for cattle has increased. The presence of para-statal organization Société de développement du coton du Cameroun operating in the North and the Far North regions (SODECOTON) provides a constant supply of these feeds. As an addendum to the above-mentioned, since 1994, the exportation of cotton seeds cakes to the Scandinavian countries stopped, implying that local cotton cake consumption produced by SODECOTON has been wholly local. Switching from crop to livestock is perceived as an invaluable strategy.

Sudano-Sahelian farmers like most African farmers have an in-built doctrine that emphasizes the overthrow of climate change concerns to fate. They have a long history about sacrificial obligations during prolonged droughts and when the rains fail to come. They offer goats, sheep or chicken for the soothsayers or witch doctors locally called "marabouts" to intercede the end of droughts. This is a common feature and does not surprise the researcher when some subsistence farmers hinge to prayers for better weather conditions. Mertz (2009), reported the same concerning Senegalese farmers while (Ajibade and Shokemi 2003) reported a similar situation with regards to attachments of famers to charlatans for better climatic conditions by rain-fed subsistent farmers inmost parts of Africa.

Of the many factors that hinder subsistence farmers' adaption to climatic variability and change, most if not all could be coined under the banner of poverty. Adapting to climate change is costly (Mendelsohn 2006) process. Availability of credit facilities would therefore imply that farmers would be able to afford the necessary equipment, seed varieties and fertilizers and indulge themselves in other off-farming activities. Studies by various researchers (Adger et al. 2007; Brooks et al. 2004; Downing et al. 2005; Ziervogel et al. 2006) found out that wealthier households in subsistence farming communities are better able to act quickly to offset climate risk than poorer households. Loss of labour and man-power highlighted by subsistence farmers as an obstacle to adaptation could be attributed to the mass rural migration within the Sudano-Sahel of Cameroon. Young locals leave the villages and migrate into towns searching for greener pastures or better leaving conditions. The HIV and Aids have also ravaged the working population and also accounts for the loss of labour and man-power.

9.5 Conclusion

This study was based on the impacts of climatic change and options for adaptation on some staple crops in the Sudano-Sahel of Cameroon. The Top-down and bottom-up approach was employed, with the quantification of the pressure indicators being droughts on crop productivity via SPI. State indicators were analysed using descriptive statistics (Regression Analysis). The bottom-up approach entailed the administering of structured questionnaires to subsistence farmers (response indicators) to deduce their perceived adaptation strategies and constraints encountered in coping with the changing environment.

Recent impacts of changing climate trends on yields show variability between millet and sorghum, indicating the influence of various climatic variables on different crops. Millet and sorghum yields in the Sudano Sahelian region of Cameroon have been affected by climatic variability as evident, during the Sahelian droughts of the 1960s, 1970s, 1980s and 1990s. Variability in the climate of the growing season between May and August appeared to have contributed to the differences in the yield trends for both millet and sorghum. This gives a clear suggestion that the diversification of Cameroon's agriculture could help in developing adaptation strategies in Sudano-Sahelian agricultural practices possibly via crop switching. Millet and sorghum crop yields are influenced by other external factors different from climatic variability. In the case of millet, increase in harvested areas turned to increase crop yields, but this wasn't the case for sorghum.

The analyses of subsistence farmers' perceptions on climate change indicate that farmers are aware of the climatic variability with temperature increasing and rainfall declining. Although subsistence farmers have developed coping strategies ranging from the changing in planting dates, and crop varieties, movement to from rural to urban areas, increment in cultivated lands, irrigation and soil conservation practices, the use of local indicators and switching from crops to livestock.

Adaptation by subsistence farmers should go beyond the above mentioned practices, else climatic variation and change will continue to increasingly have devastating impacts on subsistence farmers in the Sudano-Sahel of Cameroon. Policy makers should pay particular attention on the role of local and indigenous knowledge when adaptation is concerned. These are some of the type of experiences passed down from generation to generation and offer very invaluable information regarding coping options that would not be acquired through other channels. More importantly, special considerations should also be given in tackling the highlighted constraints perceived by subsistence farmers towards adaptation. Formal sources of credit, information access and full access to extension services should be improved upon by policy makers ensuring that they reach small scale subsistence farmers. Providing such support would be very crucial since they are the group most affected and most vulnerable with their resilience really not improving.

Furthermore all stakeholders should be involved when considering measures to reduce the adverse effects of climate change. The government, civil societies, private sectors, and above all the local communities, local farmers associations, non-governmental organizations (NGO) and the media should all actively participate and be more involved in promoting adaptation. Climate change has an impact on subsistence crop production in the Sudano-Sahelian zone of Cameroon. By using the top-down approach focusing on the biophysical aspects of vulnerability via the analyses of the climatic trends and their impacts on yields of subsistence crops and concomitantly the bottom-up approach paying emphasis on local communities and aspects of vulnerability, making use of indigenous knowledge relevant to community level responses. Both approaches could play a vital role in determination and promotion of integrated adaptation options to climatic variability and change.

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Part III
Food Security and Food Production and Consumption Patterns

Chapter 10
Productive Potential of Urban Agriculture Towards Food Security: Evidence from Southwest Nigeria

Oluremi Akintayo and Babatunde Oyewole

Abstract Increase in the rate of urbanization has been acknowledged to have effects on urban poverty and food security. Consequently, a notable strategy employed by urban dwellers in order to be and remain food secure is the practice of urban agriculture. Through a multi-stage random sampling technique, a total of 389 respondents were selected in Ibadan, Nigeria. Data were obtained through the use of structured questionnaire while analyses involved the use of descriptive statistics and stochastic frontier model for technical efficiency determination. The results showed that 66.3 % were involved in some form of urban agriculture, majority (90.7 %) of those involved were within the active productive age group of 20–59 years with relatively high literacy level. Most (94.2 %) of these urban farmers had agriculture as a supplementary activity which nonetheless constitutes a vital part of their livelihoods. With an average technical efficiency of 72.0 %, urban farmers can complement household incomes at significantly high levels sometimes as high as 80.0 %. Prospects for urban agriculture are high as the city continues to expand.

Keywords Food security • Urban agriculture • Urbanization • Livelihood • Technical efficiency

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O. Akintayo (✉)
Farming Systems Research and Extension Programme, Institute of Agricultural Research and Training, Moor Plantation, P.M.B. 5029 Ibadan, Oyo State, Nigeria
e-mail: oluremijay@yahoo.com

B. Oyewole
Land Sustainers, University of Ibadan, P.O. Box 20096, Ibadan, Oyo State, Nigeria
e-mail: toyewole7@yahoo.com

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10.1 Introduction

There is a consensus that the world's population would exceed the eight billion mark by the year 2025 and most of this increase would occur in developing countries (Wiebe 2003; UN 2009). The United Nations asserted that seventy-eight percent (78 %) of the world's population lived in developing countries in 1990. This figure increased to eighty-one percent (81 %) in 2000. By the year 2025, more than eighty-four percent (84 %) of the world's population will reside in developing countries (UN 2009). At present, the population of developing countries represents approximately eighty-two percent (82 %) of the global population.

The urban–rural population ratio has been changing as total population figures change over years and decades. World urban population as percentage of total population increased from almost forty-three percent (42.5 %) in 1990 to about fifty-one percent (50.5 %) in 2010 and it is estimated to reach fifty-seven percent (57 %) by the year 2025. The scenario is not different in Sub-Saharan Africa (SSA) where the proportion of population residing in urban areas increased from twenty-eight percent (28.3 %) in 1990 to almost thirty-three percent (32.7 %) in 2000 and to forty-two percent (42.2 %) in 2010. It is however projected that the proportion of population living in urban areas in SSA would be sixty percent (60.3 %) in 2025 and expected to reach seventy-five percent (75.4 %) by the year 2050 (UN 2009). All these imply that urbanization has been proceeding worldwide with Africa as no exception.

In Nigeria, the proportion of total population living in urban towns and cities has been on the increase since independence in 1960 when it was 16 %. The proportion increased to 35 % in 1990 and then rose to 43 % in the year 2000. It is also projected that the proportion of population in urban areas would increase to 57 % by the year 2020 from the current 50 %. In other words, people are migrating from rural areas to the urban areas (UN 2009). Rural–urban migration of course has implication for food security and urban poverty. Rapid urbanization goes together with rapid increase in urban poverty and urban food insecurity (RUAF 2009). It is interesting to note that the absolute number of urban poor and the proportion of poor people living in the urban areas of Nigeria have been on the increase over time (Haddad et al. 1999).

The major challenge posed by urbanization is the ability to make all urban dwellers food- secure. People certainly would not wait indefinitely for the government to make them food- secure, but would rather organize their activities in such a way to secure access to food. One notable activity engaged in by urban dwellers in order to be food-secure at various levels, is urban agriculture.

The objectives of this study were to determine the productive potential of urban agriculture towards the food security of urban dwellers and the level of efficiency of the respondents in their urban farming enterprises, with particular reference to Ibadan, southwestern Nigeria.

10.2 Conceptual Framework and Literature Review

Urban agriculture (UA) can be defined as the growing of food and the raising of livestock within and around cities. The main distinction between rural and urban agriculture is that the latter is integrated into the urban economic and ecological system (Maxwell 1999). It is embedded in, and interacting with the urban ecosystem (RUAF 2009). Worldwide, urban agriculture is growing because of its ability to assist with, resolve or cope with diverse urban development challenges. Urban agriculture tends to complement rural and foreign sources of food supply to cities and its most important asset is its contribution to food security and healthy nutrition (RUAF 2009). It has been noted that the main driving forces for farmers to become engaged in urban agriculture are food security and income generation (Baumgartner and Belevi 2001).

Although food security is a flexible concept as reflected in the several attempts at its definition in research and policy usage, the World Food Summit of 1996 defined food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life". Usually, the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences (FAO 2003; WHO 2009). Food security is established upon the three fundamentals:

– Food availability: sufficient quantities of food available on a consistent basis.
– Food access: having sufficient resources to obtain appropriate foods for a nutritious diet.
– Food use: appropriate use of food based on knowledge of basic nutrition and care, as well as adequate water and sanitation (FAO 2003).

Studies have shown that the rate of urban growth (urbanization) is increasing, and the consequent threat to food security for millions of urban dwellers thus merits particular attention. Therefore, given that rapid urbanization leads to increase in urban poverty and urban food insecurity, and that urban agriculture contributes to food security (RUAF 2009), it becomes imperative that urban farmers be efficient in the use of all production resources for maximum output.

The measurement of efficiency is important because it is recognized as the first step towards substantial resource savings which in turn has important implications for both farm management and policy formulation (Bravo-Ureta and Rieger 1991). Production efficiency has two components – technical and allocative efficiency (Rahman 2003). Technical efficiency refers to the ability of producing a given level of output with a minimum quantity of inputs, given technology. Technical efficiency is a relative concept, which means that the performance of the production unit(s) under consideration is (are) compared with a standard model (Obwona 2006). Allocative efficiency on the other hand refers to the choice of optimal input proportions given relative prices (Bravo-Ureta and Rieger 1991; Apezteguia and Garate 1997). Allocative efficiency also known as price efficiency, relates to the ability of a production unit (in this case, farm) to choose its inputs in a cost minimizing way and thus reflects whether a technically efficient unit produces at the lowest possible cost (Chavas and Aliber 1993).

Approaches to the measurement of efficiency: The efficiency of production units can be measured using the parametric or non-parametric approach. The former approach relies upon specific functional form while the latter does not. The non-parametric approach also referred to as the programming approach, requires the construction of a free disposal convex hull in the input–output space from a given sample of observations of inputs and output. The convex hull is generated from a sub-set of the given sample and serves as an estimate of the production frontier, depicting the maximum possible output. Production efficiency of an economic unit is measured as the ratio of the actual output to the maximum possible output on the convex hull, corresponding to the given set of inputs (Farrell 1957; Hanoch and Rothchild 1972; Obwona 2006). The major criticism of this approach is that the convex hull which represents the maximum possible output is not derived from all observations in the sample, but from marginal data thereby making the technical efficiency measures susceptible to outliers and measurement errors (Forsund et al. 1980). Also, being non-parametric, this approach does not allow for statistical inferences on its estimates (Obwona 2006).

The parametric approach can either take the form of deterministic or stochastic frontier model. The major difference between the deterministic and stochastic frontier models is that the deterministic model assumes that any deviations away from the frontier is due to inefficiency while the stochastic model gives room for statistical noise. The stochastic model incorporates a one-sided error component (u_i) which reflects inefficiency as well as a two-sided symmetric error component (v_i) which captures measurement errors and other statistical noise.

The stochastic frontier function is specified as

$$Y_i = f\left(X_i;\ \beta\right) \exp\left(v_i - u_i\right),\quad i = 1,\ 2,\ 3 \_\_\_\_\ N \tag{10.1}$$

Where

Y is output of ith farm

X_i is vector of inputs

β is a vector of parameters to be estimated

The possible production Y_i is bounded above by the stochastic quantity f (X_i; β) exp (v_i). The random errors vi are assumed to be independently and identically distributed as N (0, v^2) random variables and independent of the u_i's. The u_i's are assumed to be non-negative truncations of the N (0, v^2) distribution (that is, half normal distribution) (Stevenson 1980) or have exponential distribution (Meeusen and van den Broeck 1977).

Technical efficiency of a farm is defined in terms of the ratio of the observed output to the corresponding frontier output, given the levels of inputs used by the farm. The technical efficiency of farm i is therefore given as;

$$\mathrm{TE_i} = \exp(-\mathrm{u_i}) \tag{10.2}$$

$$\begin{aligned} \mathrm{TE} &= \mathrm{Y_i}/\mathrm{Y_i}^* && (10.3)\\ &= \mathrm{f}(\mathrm{X_i};\ \beta)\exp(\mathrm{v_i}-\mathrm{u_i})/\mathrm{f}(\mathrm{X_i};\ \beta)\exp(\mathrm{vi})\exp(-\mathrm{u_i}) && (10.4)\\ &= \exp(-\mathrm{u_i}) && (10.5) \end{aligned}$$

Studies on urban agriculture in Nigeria by Ezedinma and Chukuezi (1999) compared urban commercial vegetable enterprises and commercial floriculture enterprises in Lagos and Port Harcourt. The authors determined the profitability of the two enterprises and examined the differences and similarities between the production systems of both enterprises. Umoh (2006) stratified the farming population into three dominant farming systems – market-oriented vegetable farming, arable crop farming for home consumption and market/consumption oriented vegetable/arable crop farming systems and found the average technical efficiency of the farmers to be 72 %. Umoh (2006) further determined the cost and returns to urban farming as well as the technical efficiency of the farmers.

Okezie et al. (2008) determined the percentage contribution of urban agriculture to farming household income in Uyo metropolis using five urban farming systems – seasonal, backyard gardening, vegetable growing, small ruminants/poultry and commercial livestock. It was found that earnings from vegetable growing constituted 53 % while commercial livestock constituted as high as 73 % of household income.

Yusuf et al. (2008) examined the poverty status of urban farm households in Ibadan metropolis and found the highest poverty (50 %) to be among those engaged in crop farming while mixed farming households had poverty level of 37 % and livestock farmers 17 %. However, further analysis by the authors showed that livestock farming, educational status and years of experience in farming decrease the odd ratio of being poor.

10.3 Study Methodology

10.3.1 Study Area

The study was carried out in Ibadan (7° 22′N; 3° 54′E), the capital city of Oyo state situated in the southwestern part of Nigeria. Ibadan is the second largest city in Nigeria by population after Lagos and the largest in geographical area. Its population is 2,550,593 according to 2006 census and the population density in the city centre is 586 persons per square kilometre.

Administratively, Ibadan is divided into eleven local government areas (LGAs), five of which constitute the city centre home to 67 % of the entire city population (Jaiyebo 2003).

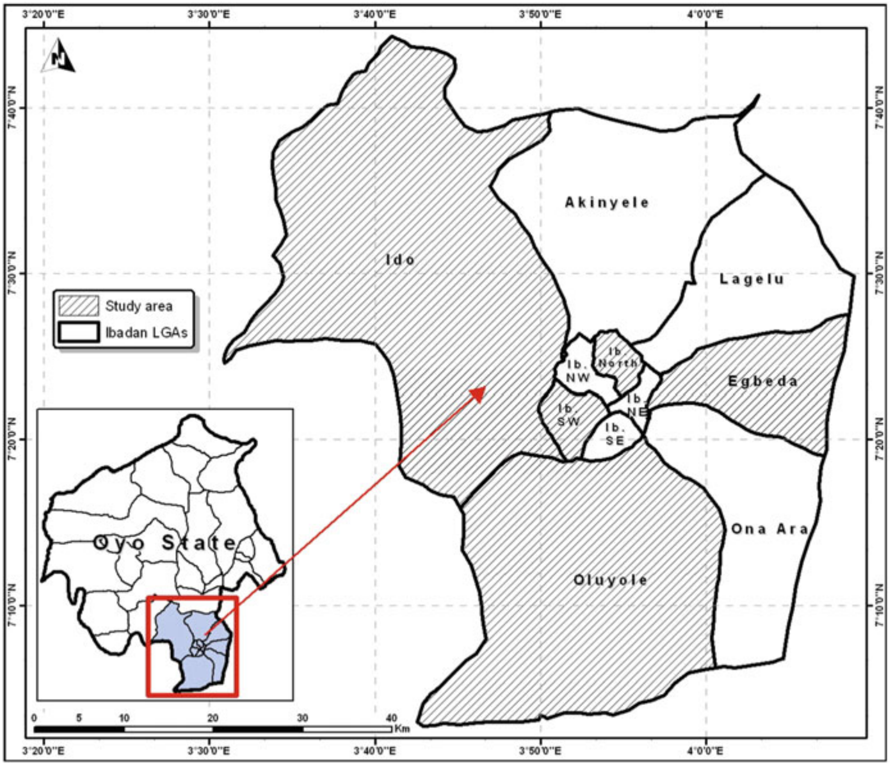

Fig. 10.1 Map of Oyo state showing Ibadan and the local government areas within Ibadan

10.3.2 Sample Selection

The sampling procedure for the study is the multi-stage sampling technique. The first stage involved the random selection of five LGAs from the eleven local government areas in Ibadan giving rise to the selection of Ibadan north, Ibadan southwest, Egbeda, Oluyole and Ido LGAs. The second stage of sampling was the random selection of electoral wards from each local government area based on the number of wards in each LGA (sampling proportionate to size). The next stage involved the random selection of households from the wards. A total of 389 households were randomly selected from the wards. Household heads of the selected households constituted the respondents for the study.

10.3.3 Data Collection

Data were collected with the aid of pre-tested and validated questionnaires which were administered to the selected respondents. Questions asked covered aspects of respondents' social and economic characteristics, farming inputs, costs of production as well as output quantities.

10.3.4 Analytical Techniques

Descriptive statistics such as frequencies and percentages were used to describe respondents' socioeconomic characteristics and their production units. In order to determine the level of efficiency of the respondents in their urban farming enterprises, the stochastic production function frontier model was employed.

Empirical model: The empirical model employed in this study is the stochastic frontier model using Cobb-Douglas functional form.

The linearized form of Cobb-Douglas functional model is

$$\mathrm{Ln}\, Q = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + vi - ui \tag{10.6}$$

Where
lnQ is natural log of farm output
Ln X_1 is natural log of garden/farm size in square metres
lnX_2 is natural log of labour use (mandays)
lnX_3 is natural log of planting material (seed/stem cutting) (kg)

It is important to note that the major farm inputs were planting materials and labour. None of the respondents used pesticides or herbicides on their farm plots.

The coefficients β_i are interpreted as elasticities of output with respect to the corresponding input. The sum of the output elasticities ($\sum\beta_i$) gives the function coefficient as well as the returns to scale (RTS) of the production unit(s). RTS is a technical property of production which examines changes in output due to a proportional change in all inputs.

v_is are assumed to be independent and identically distributed normal random errors having mean zero and variance $\sigma_v{}^2$ and are also distributed independently of u_i.

u_is are non-negative technical inefficiency effects representing management factors and are assumed to be independently distributed with mean μ_i and variance σ^2 (Battese et al. 1996; Munir et al. 2002)

The technical inefficiency model however, is specified as;

$$\mu_1 = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 \tag{10.7}$$

where
μ_1 is technical inefficiency term
Z_1 is main reason for urban farming (1 = commercial, 0 = home consumption)
Z_2 is educational level of farmer
Z_3 is age of farmer
δ_i are parameters to be estimated.

10.4 Results and Discussion

10.4.1 Socioeconomic Characteristics of Farming Respondents

Out of the 389 respondents selected for this study, 258 (66.32 %) were involved in some form of urban agriculture while 131 (33.68 %) were not. Major reasons given by 131 (33.68 %) of the respondents for not engaging in urban agriculture are summarized below with percentages in parentheses.

1. No time to spare for agricultural activities (38.17 %)
2. Non access to land/space required (31.30 %)
3. Lack of interest (16.79 %)
4. Prohibition by landlord (13.74 %)

Forty-five percent of respondents not engaged in urban agriculture however indicated interest and readiness if and when conditions are appropriate. Such conditions include access to the required space/land and lift of embargo on agricultural activities in rented apartments by landlords.

More than half (53.10 %) of the farming respondents were females. It has however been noted by authors such as Anosike and Fasona (2004) that UA is a major livelihood asset for both men and women. Majority (90.70 %) of respondents engaged in UA were between 20 and 59 years old. This age group is recognized as the active productive age group (Simatupang 1994).

Most (75.58 %) of the respondents involved in urban agriculture were married indicating that the pressure to attain food security is more acute for married people. This was also noted by Ezedinma and Chukuezi (1999) who reported a high percentage (91 %) of married commercial vegetable entrepreneurs in Lagos. This is understandable as married couples may have more mouths to feed in the household (at least a spouse and one child).

The literacy level of the respondents appears relatively high with an average of 7 years as the minimum cumulative years of schooling for 80.24 % of the respondents (Table 10.2). Only 5.81 % of the respondents engaged in urban agriculture had farming as their main occupation while the majority (94.19 %) had urban agriculture as a supplementary activity to improve household income and consumption.

10.4.2 Motivations for Engaging in Urban Farming

Major reasons given by respondents for engaging in urban agriculture could generally be grouped into seven categories which are arranged in order of importance (Table 10.1).

Table 10.1 Seven categories of importance

Major reason for urban farming	Respondents (%)
Home consumption	37.98
Income enhancement	22.87
Income diversification	16.67
Easy access to fresh foods	8.14
Lack of employment	6.98
High prices of market food	4.65
Hobby	2.71

Table 10.2 Socioeconomic characteristics of respondents engaged in urban agriculture

Variable	No. of respondents	Percentage (%)
Age		
20–29	52	20.16
30–44	117	45.35
45–59	65	25.19
60 and above	24	9.30
Total	258	100.00
Gender		
Male	121	46.90
Female	137	53.10
Total	258	100.00
Marital status		
Single	42	16.28
Married	195	75.58
Divorced	8	3.10
Widow(er)	13	5.04
Total	258	100.00
Educational status		
None	23	8.91
Primary education	28	10.85
Secondary education	88	34.12
Tertiary education	119	46.12
Total	258	100.00
Main occupation		
Trading	47	18.22
Artisan	28	10.85
Civil servant	95	36.82
Private business	30	11.63
Farming	15	5.81
Teaching	43	16.67
Total	258	100.00

An overview of the motivations to farm include both the cash income earned from any sales or employment in urban farming as well as the 'in-kind' income flow in the form of farm produce consumed by the individual/household.

10.4.3 Foods Produced in the Study Area

The variety of foods produced in the study area is considerable, ranging from livestock such as rabbits, poultry, snail and fish to vegetables and food crops such as maize and cassava. Production for sale typically comprised of perishable commodities such as vegetables, fish, eggs and poultry for which proximity to consumers provides a cost advantage.

Common vegetables grown by respondents are Amaranths species, Cochorus species, pumpkin leaves (ugwu) and tomatoes. While some of the farmers produced vegetables throughout the year, others specialized in dry season production when the produce is scarce and sold at premium prices. More than forty percent (45.35 %) of respondents engaged in vegetable production solely or in combination with other crops/livestock as shown on Table 10.3. Sole vegetable gardening respondents made up twenty-four percent (23.64 %) of total farming respondents. Vegetables are grown on small plots of lands, in all the cases less than half of an acre. These plots are located in backyards (compound plots), undeveloped residential plots, and along the banks of streams and swamps. None of the farmers applied chemical inputs such as fertilizers and herbicides to their vegetable plots. However, seven (5.98 %) of the vegetable growers applied organic manure on their plots. Vegetable products are sold right on the farm directly to consumers, hawked or sold at the market.

Maize and cassava are the most common staple crops grown, but some farmers also cultivate fruit crops such as pineapple, pawpaw and bananas in their backyards for home consumption. In addition to being cultivated in backyards, staple crops such as maize and cassava are also cultivated on undeveloped private land plots and along stream banks.

Among the livestock raised by the farmers, poultry was the most common. Respondents involved in poultry farming made up fifty-two percent (51.67 %) of sole livestock farming respondents and twenty-four percent (24.03 %) of total farming respondents. Three categories of livestock production (subsistence, semi-commercial and commercial) were observed among the farmers. The subsistence production category included poultry, snails, goats and fish reared solely for home consumption. In the semi-commercial production category were animals such as poultry, rabbits, snails, sheep and fish which were raised for sale and home consumption. In this category, the proportion of animals sold is larger than the proportion consumed at home. Three animal types were found to be raised under the commercial category – poultry, fish and grass-cutters.

Also observed was the fact that only a small proportion (5.81 %) of the urban farmers was involved in UA on a full-time basis, making it their primary occupation. However, majority (94.19 %) did so on part-time basis (Table 10.3). In other words, most of these urban farmers had other major income sources to which their farming activities were supplements but nonetheless still regarded urban farming as an important part of their livelihoods.

Food production plays direct roles in the food access of urban households. Some of the respondents practiced purely commercial food production while others had

Table 10.3 Urban agriculture participation by respondents

	No. of respondents	Percentage (%)
Mode of farming		
Full-time	15	5.81
Part-time	243	94.19
Total	258	100.00
Purpose of farming		
Home consumption	142	55.04
Commercial	17	6.59
Both	99	38.37
Total	258	100.00
Type of food produced		
Livestock	120	46.51
Vegetables	61	23.64
Staple foods	15	5.81
Livestock and veg	44	17.05
Livestock and crops	6	2.33
Staple crops and veg	12	4.66
Total	258	100.00

varying degrees of commitment to the market which ranged from routine sales to occasional sales, and sometimes zero sales (subsistence production). Table 10.3 shows that more than half of the farming respondents produced food for home consumption alone while about 38 % produced food for both home consumption and market. Respondents who practiced purely commercial food production were engaged in routine sales and also take advantage of seasonal markets to earn occasional extra income. Seasonal markets are created mainly during religious festivals such as Easter, Christmas and Ed el Kabir when the demand for high value livestock such as poultry and rams is very high. From an economic point of view, food production yields direct income through sales and employment, as well as indirect income through savings on food expenditures.

10.4.4 Contribution of Urban Agriculture to Household Income

The contribution of urban agriculture to the income of respondents is summarized in Table 10.4. Urban agriculture contributes cash income for people whose activities are market-oriented while it contributes to savings on food expenditure for people whose activities are directed towards home consumption. For respondents who were involved in pure commercial agricultural production, the income represents the value of produce sold. For those who produced solely for home consumption, income represents the cash value of total produce consumed while respondents who produced for both sale and consumption had their income

Table 10.4 Percentage distribution of respondents by average monthly income from urban agriculture enterprises

Income (naira)	Vegetable gardening	Livestock production	Staple crop production	Vegetable and staple crop production	Livestock and veg/staple crops
≤5,000	9.84	0.00	40.00	16.67	0.00
5,001–10,000	39.34	13.33	26.67	66.66	36.00
10,001–15,000	21.31	5.00	13.33	0.00	42.00
15,001–20,000	8.20	17.50	20.00	16.67	4.00
20,001–25,000	13.11	34.17	0.00	0.00	10.00
≥25,000	8.20	30.00	0.00	0.00	8.00
Total	100.00	100.00	100.00	100.00	100.00

154.00 naira = $US 1.00

contribution calculated by adding the value of produce sold with the cash value of produce consumed.

It is observed from Table 10.3 that the average monthly contribution of urban agriculture to farmers' income varies across enterprise types. For instance, approximately thirty percent (29.51 %) of respondents engaged in sole vegetable gardening had an average income of over 15,000 naira per month while eighty-two (81.67 %) percent of respondents involved in sole livestock production had an average income of over 15,000 naira ($US 100.00) per month. Thirteen percent (13.33 %) of respondents engaged in sole staple crop production, seventeen percent (16.67 %) in mixed cropping (vegetable and staple crops) and 22 % in mixed farming (livestock and vegetable/staple crops) had average monthly incomes of more than 15,000 naira.

With regards to the percentage contribution of urban farming to total household monthly income, this ranged from 8 to 100 %. Approximately nineteen percent (18.61 %) of the urban farmers had between 8 and 29 % of their monthly income coming from UA. Forty-five percent (44.96 %) got between 30 and 49 % of their monthly income from UA while UA contributed 50–99 % to the monthly income of thirty-one (30.62 %) of the urban farmers. However, 5.81 % of the urban farmers derived all their monthly income from UA.

It is important to note however that none of the urban farmers sold 100 % of his/her farm produce. On the other hand, some (55.04 %) consumed 100 % of their farm produce. Fifteen percent (15.11 %) consumed between 5 and 29 % of what they produced, twenty-four percent (23.64 %) of the farmers consumed 30–69 % of their farm produce and six percent (6.20 %) of farmers consumed 70–99 % of what they produced.

10.4.5 Efficiency of Urban Crop Farmers

Technical efficiency analysis of urban food crop production was carried out using vegetable gardening and arable crops as proxy in order to examine how productive

Table 10.5 Estimated maximum likelihood parameters of the production function frontier with inefficiency model (Eqs. 10.6 and 10.7)

Variable	Parameter	Coefficient	t-ratio
Constant	β_0	−0.1180	−2.03
Farm size	β_1	0.0261	0.48
Labour	β_2	−0.2997	−10.22***
Planting materials	β_3	0.8461	12.39***
Inefficiency model			
Constant	δ_0	0.1643	1.77
Farming purpose	δ_1	−0.5048	2.36**
Educational status	δ_2	−0.4491	2.66***
Age	δ_3	−0.2294	1.87*
Sigma squared	σ^2	0.2300	
Gamma	Υ	0.4556	
Log likelihood function		−92.887	

*Significant at 10 %
**Significant at 5 %
***Significant at 1 %

these farmers are in food production for food security in the study area. Coefficient (β_1) for farm size was positive but not statistically significant. This indicates that all things being equal, an increase in the size of land devoted to UA by the respondents would not lead to a significant increase in output. With regards to labour, the coefficient was negative and significant ($p = 0.01$). This implies that labour is over-utilized and increase in labour input would result in lower farm output. This might be due to the availability of and easy access to family labour which was highly utilized by respondents. The coefficient (β_3) for planting materials was positive and significant ($p = 0.01$). This implies that more output would be obtained from additional use of planting materials (seeds/stem cuttings). In other words, increased plant standings and plant population through higher seed rates would bring about an increase in output.

The estimated gamma parameter (Υ) indicates that about forty-six percent (45.56 %) of the variation in the vegetable and crop output was due to differences in their technical efficiencies which ranged between 29.76 and 92.18 % with a mean of 71.86 % (Table 10.5 and 10.6).

With regards to the inefficiency model, all the variables (main purpose for farming, educational level and farmers' age) had negative and significant effects on inefficiency levels. The dummy/indicator variable for farming purpose was significant ($p = 0.05$) and implies that all else equal, farm output would be 50.48 % higher if farm is mainly commercial. Also, being a commercial farm has a negative effect on inefficiency – the more a farm tends to being commercial, the lower the inefficiency. Farmers' educational level and age contributed negatively to inefficiency. In other words, the higher the farmers' educational level, the lower the efficiency and the older the farmers are, the higher the efficiency. Results from the stochastic frontier model show that there is considerable scope for efficiency improvements towards greater output that would lead to increased farm incomes and enhanced food security for the urban populace.

Table 10.6 Technical efficiency score distribution of vegetable and crop farming respondents

Efficiency score range	Frequency	Percentage
0.20–0.49	30	21.74
0.50–0.79	86	62.32
0.80–0.99	22	15.94
Total	138	100

10.4.6 Farmers' View on Future Prospects for Sustainable UA

All the respondents involved in UA acknowledged the potential benefits associated with the proper practice of UA. These include good and regular income for the farmers as well as the availability of fresh and healthy farm produce for consumers at affordable prices thus ensuring food security. However, one major constraint mentioned by respondents is the issue of market access as most of them had to seek buyers for their produce thereby becoming mobile vendors. For instance, none of the respondents sold farm products at any farmers' markets because there were none in the study area, as opposed to countries like Australia and USA where farmers' markets abound.

10.5 Conclusions and Recommendations

It can be concluded that prospects for urban farming are good in the study area. As the city continues to urbanize in the context of national urbanization process, greater local food self-reliance must be regarded as an important aspect of sustainable urban development. However, there is need for better understanding of how urban food systems work in order to comprehensively assess and promote the role of urban agriculture. Although there were no functional by-laws governing the practice of urban agriculture in the study area at the time this study was conducted, it is expected that the impact of urban agriculture on the welfare of urban communities will ultimately depend on policies and program instruments that encourage efficient and sustainable urban food systems.

As found in the study, urban agricultural production can complement household incomes at high levels. Urban planners and local government should therefore consider how to incorporate environmentally sound urban agriculture in their policies.

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Chapter 11
The Role of Bahrain Local Food Production System in Ensuring Sustainable Food Security

Salma Saeed Ahmed Bani

Abstract Bahrain, severely constrained by limited agricultural resources such as limited water resources, poor and declining quality of the soil, and unfavourable climate as a result of which the country has low food sufficiency rates for the main food commodities, with the exception of some fruits and vegetables. As result of which agriculture sector contributes less than 1 % to Bahrain's real GDP, which means Bahrain remains heavily dependent on imports to meet its domestic demand for most agricultural products. In view of this therefore, with the world facing perfect storm of food scarcity, Bahrain needs to focus on lowering its food imports and increasing agricultural production in order to boost the contribution of agricultural sector to its Gross Domestic Product. The aim of this paper is to review the role of local production system in ensuring food security, focusing on the incentive framework aimed at diversifying the economies and increasing the level of food security. From the discussion it is therefore clear that Bahrain's Agricultural Policy is towards the right direction of creating impact on the role of local food production system embracing diversified production base focusing on strategic option for a sustained growth of productivity and diversification of economies in general. In specific it significantly emphasizes on non-traditional methods of production which in turn spells out a sound strategic option for ensuring sustainable food security in Bahrain.

Keywords Bahrain food production system • Food security • Policy approach to food security

S.S.A. Bani, Phd Scholar (✉)
Senior Executive Strategic Planning, Planning Department,
Ministry of Municipality and Urban Planning, Manama, Bahrain
e-mail: Salmabani@yahoo.com

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11.1 Introduction

The Kingdom of Bahrain is an islands nation in the Arabian Gulf and consists of an archipelago of 36 low-lying islands. Due to arid climatic conditions the country is characterized by high temperatures, erratic and often scanty rainfall, high evapo transpiration rates and high humidity levels due to the surrounding Gulf waters. Temperature averages from 17 °C in winter (December–March) to 35 °C in summer (June–September). The rainy season runs from November to April, with an annual average of 83 mm, sufficient only to support the most drought resistant desert vegetation. The total arable land in Bahrain is estimated to be 64,000 dunam (Agricultural Statistics Year book 2009), in other words it is about 10 % of the total area which amounts to 622 km2 square. Two thirds of this arable land is cultivated.

Agriculture in the Kingdom of Bahrain witnessed in recent years many obstacles that affected its role in the development process and achieving food security in the country. The value of agricultural output is 16.2 million dinars at a contribution rate of 23 % of the GDP. The value of food imports amounted to more than BD202 million Bahraini dinars, and the deficit of the balance of commodity trade in the Kingdom of Bahrain up to the borders of almost BD173 million dinars. Therefore, with the world facing perfect storm of food scarcity, Bahrain needs to focus on lowering its food imports and increasing agricultural production in order to boost the contribution of agricultural sector to its Gross Domestic Product.

The government applies an economic incentive strategy to enhance crop productivity. The productivity and sustainability of the Bahrain food system, especially under more severe climate change scenarios is a major concern for the government. Also, to ensure food security since the 1970s of last century, government of Bahrain becomes responsible for providing basic food commodities to the nation. However, t since 2001 the government opened the doors for local merchants to import, store, distribute and sell these commodities in the local market. Besides, for food security purpose Bahrain government has established safeguard mechanisms for three strategic food commodities, including flour, imported Australian meat and locally produced chicken through rates of constraint put by the government.

Consequent to brief profile of Bahrain economy, the paper reviews and highlights the role of local production system in ensuring food security. A strategic option for sustained agricultural growth and increased food production will be laid out. Food security conceptual framework will be used to evaluate how government food policy interacts with the local food systems to produce food security. It will analyze the impact of these policies on sustainable agricultural development and will highlight the main achievements in terms of enhancing the level of food security.

11.2 Food Production System in Bahrain

Bahrain was one of the richest countries in the Arabian Gulf prior to the discovery of oil resources in 1932. Its' pearl was the famous and best in the region, an important agriculture and trading centre. But due to urbanization and expansion of new towns and communities, as well as industrial sector land consumption, the pressure on agricultural land in Bahrain becomes enormous. The biggest challenges Bahrain agriculture is facing are limited agricultural lands and shortage of water resources. The total arable land in Bahrain is estimated to be 64,000 dunam (Agricultural Statistics Year book 2009), in other words it is about 10 % of the total area which amounts to 622 km^2 square. Two thirds of this arable land is cultivated. The agriculture products produced locally covers only 12 % of total consumption needs. The major crops grown are dates and fruit trees with a yield of 7.5 tons/ha, vegetables, mainly tomatoes, with a yield of 11.7 tons/ha, and fodder crops, mainly alfalfa, with a relatively high yield of 74.5 tons/ha. The government assists agricultural producers mainly by offering subsidies for a number of inputs, such as pesticides, veterinary drugs, machinery services, and irrigation material.

11.2.1 Concept of Sustainable Food Security

At the very centre of concern about overall economic development there must be a concern for food, agriculture, and people. The concept of sustainable food security combines above three elements in to a major objective that is fundamental to economic development. Achieving sustainable food security will require more than improving farm productivity and profitability while minimizing environmental impacts. The concept is broader than sustainable agriculture; it aggregates the goals of household food security and that of sustainable agriculture.

Various definitions of food systems and food security have been developed over time, which reflect particular worldviews expressed by both economists and food security analysts. Analysts have shifted from a focus on agricultural production towards including the question of access to and affordability of food into the notion of food security. Today both food utilization and stability of food systems are also, recognized as determinants governing the food security status of a household or a nation (Maxwell 2001; Ericksen 2008). Food security is not just a poverty issue; it is a much larger issue that involves the whole food system. Food security is the outcome of food system processes.

Food systems encompass all activities from production through to consumption, along with other key determinants of food security. The outcomes of these activate contribution to food security (food availability; food access; and food use). The food system operates within and is influenced by social, political, economic and natural environments. A country is said to be food secure when its food system operates in such a way as to remove the fear that there will not be enough to eat.

In particular, food security will be achieved when household have access to the food they want.

Food security arises when all people at all times have access to enough food that is affordable, safe and healthy, culturally acceptable, meets specific dietary needs, produced in ways that are environmentally sound and socially justified. Thus food security should be treated as a multi-objective phenomenon. Considering complexity of the food system, it is easy to see that many factors determine food security.

Food security historically referred to food supply and shortfalls in supply compared to requirements. However, the term has been broadened beyond notions of food supply to include elements of access (determined by food entitlements, Sen 1981), vulnerability (Watts and Bohle 1993), and sustainability (Chambers 1989).

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit 1996). This widely accepted definition points to the following dimensions of food security: Food availability; Food accessibility; Utilization; and Stability or Sustainability.

Deriving from this definition, achieving food security requires that the aggregate availability of physical supplies of food is sufficient, that households have adequate access to real food supplies through their own production, through the market or through other sources, and that the utilization of such food supplies is appropriate to meet the specific dietary needs of individuals. Therefore, food security needs to be ensured at national, household and individual level.

11.2.2 Government's Policy Approach to Food Security

Despite aiming for food security since a long time, Bahrain is able to produce only a quarter of the total food demand due to unfavourable climatic conditions and limited availability of arable land. As result of which the high dependence on imports for the country is going to continue and this makes the issue of food security critical for the country. The governments realized the need to undertake the necessary steps to secure food imports for the growing population.

Bahrain's environment is hostile to agriculture, characterised by extreme heat, water scarcity and high soil salinity as result of which domestic production is insufficient to meet the current food requirements for consumption. Bahrain, like the other Gulf States, imports up to 90 % of its food requirements for consumption. as result of which food imports in the kingdom of Bahrain stood at USD 1.7 billion in 2010. High dependence on imports makes the country food supply very vulnerable and highly dependent on the world food market. Disruption in food imports, either due to policy restrictions by exporting countries or natural calamities has affected the region significantly. As a result, foodsecurity is an important issue for the country and government of Bahrain has taken initiatives to enhance domestic production and at the same time to secure food imports through international agricultural investments.

Food security is a concern to the governments in the region as a whole. Bahrain governments along with other Gulf Cooperation Council (GCC) countries are currently pursuing a strategy in order to secure their food supply. First, investing in agriculture in countries where there is surplus land and has favourable climate. Secondly, encouraging the domestic food processing industry so that imports of processed food decrease. The aim is to source domestic and foreign raw materials from outside and then processes them within the region. Thirdly, building strategic food reserves along the lines of energy reserves in the US and food stockpiles in India.

The government of Bahrain offers subsidies on three basic commodities: red meat, poultry and flour. According to the Bahrain Chamber of Commerce and Industry (BCCI), the country provided subsidies totalling BD 4.2 million in 2010; the figure is estimated at BD 6.5 million in 2011. Ministry of Industry and Commerce encourages the foodstuff processing industry to preserve agricultural and animal products through processing. According to the ministry of industry and commerce, more than 112 factories manufacture various food products in Bahrain. Also, in order to ensure food security the country is undertaking various initiatives, such as a scheme that encourage the private sector to produce leafy vegetables in greenhouses. It is also supporting the private sector to produce fish, poultry, sugar and dates. Both the government and private sector firms are investing in the overseas markets to acquire farmland for the production of fruit, vegetables, rice and corn in an attempt to meet the rising demand. Bahrain has purchased farmland in India, Pakistan, Philippines, Thailand, and Turkey and Sudan.

11.2.3 Interactions with the Local Food System to Ensure Sustainable Food Security

People are food secure when they have regular access either through production or purchasing power to sufficient food for healthy and productive life. Framework in Fig. 11.1 shows that the major activities and actors involved in various food systems. The four major components of food security are availability, accessibility, utilization and stability. These four elements are influenced by food system activities.

Food availability refers to the physical existence of food, be it from own production or in the markets. On national level, food availability is the function of the combination of domestic food stocks, commercial food imports, and domestic food production, as well as the underlying determinants of each of these factors. The three elements of production, distribution, and exchange contribute to food availability. The determinants of availability from local production include land holding sizes, resource tenancy arrangements, economic returns to labour, human capital; the determinants of distribution include transportation and infrastructure, public safety nets, storage facilities and the determinants of exchange include income levels and purchasing power, markets, and subsidies.

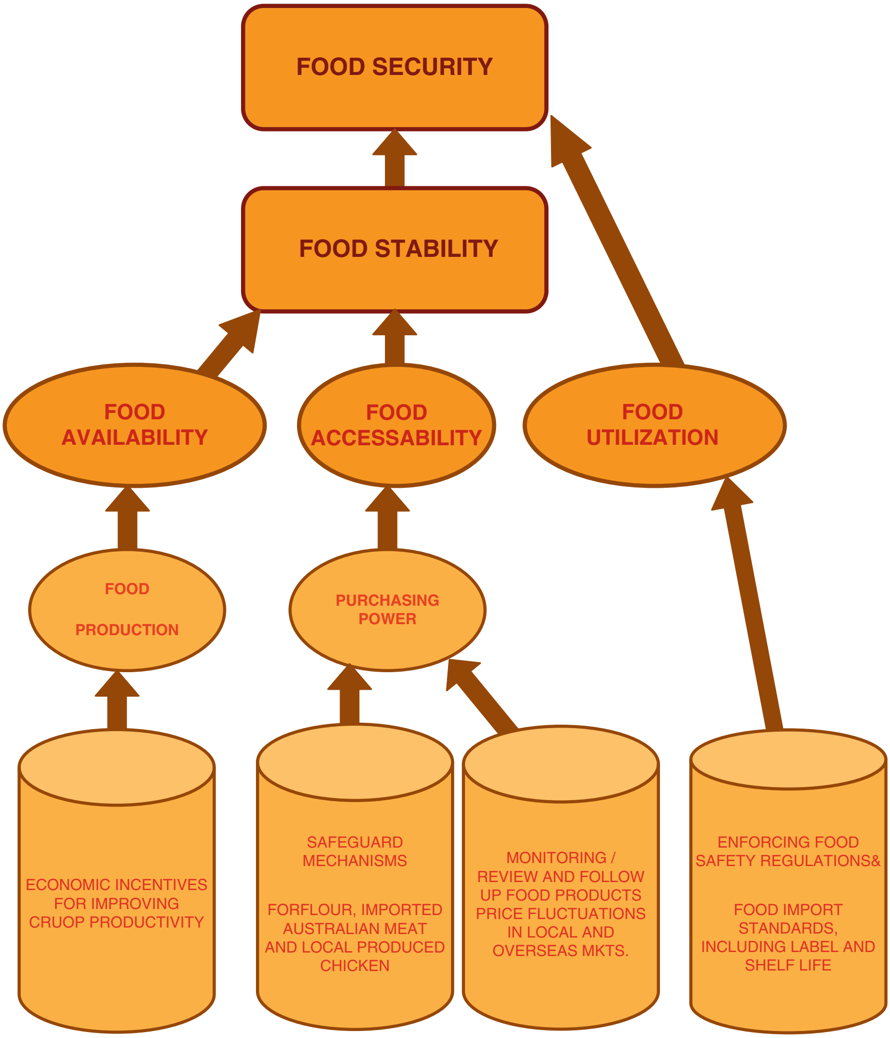

Fig. 11.1 Interactions with the local food systems to ensure sustainable food security

Food availability is achieved when sufficient quantity of food is consistently available to all individuals within a country. Such food can be supplied through household production, other domestic output, commercial imports or food assistance. Despite limited land and water resources and constraints of climatic conditions, the government of Bahrain has been encouraging agricultural development in both public and private sectors by providing various facilities, and strengthening research and extension activities. This comes within the government's long-range aims of achieving a higher level of self-sufficiency in various agricultural products and in particular high-quality fresh vegetable crops.

The policy of Bahrain government to diversify its economy and to increase the level of food self-sufficiency focused on economic incentives for improving crop productivity. Government provides subsidies in several forms. The agricultural production is supported through provision of subsidies such as 84 % of the cost of machinery services; 40 % of the price of modern irrigation equipments; and 50 % of the price of pesticides; 40 % of the price of plastic sheet; 50 % of the price of veterinary drugs and animal vaccines; and 5 % of the price of local poultry meat. Low interest Loans are also, provided to farmers intending to launch programmes to protect date palms, and other farming activities.

To ensure food availability Bahrain government has taken a number of actions regarding food subsidy since late 1970s of the past century. In 1975, the government established a directorate to control the subsidy through the Amiri Decree No. (7)-1975 to establish the Department of Supply and Price Control within the Ministry of Commerce, Agriculture and Economy, which among other things is responsible for direct provision of food to the merchants and achieve the following:

– Monitor implementation of the provisions of the legislative Decree No.18 – 1975 regarding Price setting, Control, and its implementing decisions and to demonstrate a violation of crimes that happen to them.
– The Implementation of policy measures to prevent monopoly and to compel merchants to adhere to specific and non-price manipulation.
– Control of local markets in terms of prices or quantities and the pursuit and study of developments in world prices in order to propose foundations for determining a fair price and to combat the root of the adjournment unjustified in the country.
– To regulate payment of subsidy by differences in prices the government decided to pay a subvention to the differences in prices, determined by a resolution issued by the Ministry of Commerce, Agriculture and Economy, as well as overseeing the way of sales to achieve justice in the distribution of reduced prices to consumers.

Since 2002, Bahrain government has established safeguard mechanisms for three strategic food commodities, which are: flour, imported Australian meat and local produced chicken through rates of constraint put by government. The other imported food commodities ministry of commerce is responsible for, is to monitor the markets; review and follow up food products price fluctuations in local and overseas markets; supervise commodities price specifications, which are under mandatory pricing; maintain information regarding national stocks of essential goods and commodities to form the basic data for rationing in times of national emergency.

Food access is ensured when all households and all individuals within such households have sufficient resources to obtain appropriate foods for nutritious diet (Riely et al. 1995). Food access depends upon income available to the household, distribution of income within the household and on the price of food. Three elements describing the accessibility of food are affordability, allocation, and preference.

Affordability is the purchasing power of households relative to the price of food. The determinants of affordability include pricing policies and mechanisms, seasonal and geographical variations in price, local prices relative to external prices, income, and wealth levels.

Allocation is the mechanisms governing when, where, and how consumers can access food. Markets are key determinants of food allocation; government policies often are designed to correct market failures. Ministry of commerce is responsible for monitoring the markets; review and follow up food products price fluctuations in local and overseas markets; supervise commodities price specifications, which are under mandatory pricing; maintain information regarding national stocks of essential goods and commodities to form the basic data for rationing in times of national emergency.

During 1970s of last century, the Government was responsible for providing the basic food commodities to the nation, but since 2001, the government opened doors for the local merchants to import, store, distribute and sell these commodities in the local market. Nevertheless, the ministry of Industry and commerce has established the Consumer Protection Directorate to:

– Review and translate statistical publications regarding food products which are issued by international organizations.
– Review and follow up food products price fluctuations in local and overseas markets.
– Supervise commodities price specifications which are under mandatory pricing.
– Maintain information regarding national stocks of essential goods and commodities to form the basic data for rationing in times of national emergency.
– Scrutinize and maintain companies' budgets of companies receiving government subsidy.

The government ensures right of access to food for its people and it has established different social and welfare programs by implementing its social policy targeted towards affecting life of the society individuals of all categories where in the first place it adopts the development of human being, upgrading him, realizing his capabilities, ensuring equal opportunities, and fairness in the distribution of society gains among all of its elements. The ministry of industry and commerce is active in protecting the market from unfair trade practices, which includes eradication of monopoly and restrictive trade practices such as cartels and resale price maintenance, as well as ensuring that sufficient quantity of strategic supplies is available for local consumption.

The Policy on the right to adequate food for Bahrainis, government intervenes in the market by assuring low prices of basic food commodities; stability in retail prices and availability in all seasons during the year. There is solid coordination among all related ministries like Ministry of Industry and Commerce, Ministry of Social Development, Ministry of Municipalities Affairs and Agriculture, Ministry of Health and the National Commission for price control.

Food utilization is the proper biological use of food, requiring a diet providing sufficient energy and essential nutrients, potable water, and adequate sanitation.

The three elements of food utilization are nutritional value, social value, and food safety. Food safety encompasses the dangers introduced from addition of chemicals during production, processing and packaging, and food-borne diseases. The main determinants of this are procedures, standards, and regulations for food production, processing, and packaging.

Regarding the Policy of Food Standards in Bahrain, since January 1995 Bahrain has been WTO member on food trade, including the Sanitary and Phytosanitary Measures (SPS) and Technical Barriers to Trade (TBT) agreements. The Public Health Directorate (PHD), Ministry of Health (MOH), in conjunction with the Directorate of Standards and Metrology, Ministry of Commerce (MOC) are all responsible for formulating food regulations.

The Public Health Directorate, Food and Water Control Section (FWC), MOH, is responsible for enforcing food safety regulations. For example, the FWC is responsible for visually inspecting all imported fresh and processed food products, verifying compliance with label regulations and, if deemed necessary, drawing samples for laboratory testing by the MOH. However, not all shipments are subject to laboratory analysis. In general, new-to-market products and products that failed previous inspections are targeted for thorough examination at the time of import. The Food Safety Committee (FSC), an inter agency committee composed of representatives from MOH, Directorate of Standards and Metrology, MOC, and Directorate of Agriculture, Ministry of Municipal Affairs and Agriculture (MMAA), decide all food safety and control issues, including ban imposition. The Directorate of Agriculture, MMAA, inspects live animals and plants, feedstuffs and horticultural products at port of entry.

11.3 An Incentive Framework Aimed at Diversifying the Economy and Increasing the Level of Food Security

Despite limited land and water resources and constraints of climatic conditions, the government of Bahrain has been encouraging agricultural development in both public and private sectors by providing various facilities, and strengthening research and extension activities. Development efforts in agriculture have included the promotion of intensified farming and further development of existing agricultural resources according to National strategy for sustainable agricultural development (2010). Bahrain is implementing a 2004–2015 plan for sustainable agriculture development to improve production and raise productivity. This development plans for improved agricultural production aim to enhance the productivity and competitiveness of Bahrain's agricultural products in domestic and regional markets. Framework in Fig. 11.2 shows that Bahrain's Agricultural Policy is towards the right direction of creating impact on the role of local production system embracing diversified production base focusing on strategic

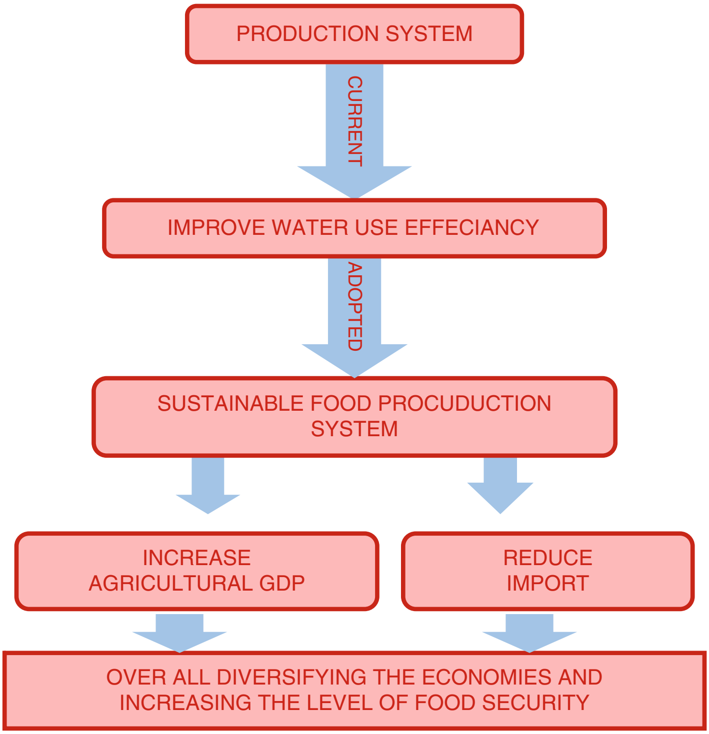

Fig. 11.2 An incentive framework aimed at diversifying the economy and increasing the level of food security

option for a sustained growth of productivity and diversification of economies in general. In specific it significantly emphasizes on non-traditional methods of production which in turn spells out a sound strategic option for ensuring sustainable food security in Bahrain.

11.4 Conclusion

The biggest challenges Bahrain agriculture is facing are limited agricultural lands and shortage of water resources. As result of which, domestic production is insufficient to meet the current requirements and food imports in the kingdom. Thus Bahrain, in order to overcome the deficit between food production and imports need to achieve relative food security relying on local production of certain strategic items and to encourage agricultural investment and optimise the role of the private sector in developing the sector.

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Chapter 12
General View Point, Perception and Acceptance of Organic Food Products Among Urban Consumers in the Thai Marketplace

Seksak Chouichom, Lawrence M. Liao, and Masahiro Yamao

Abstract This study aims to determine consumer knowledge about organic foods and the reasons why buyers patronize or reject organic food products in Bangkok. It also relates such consumption patterns with the consumers' understanding and points of view towards organic food as well as their demographic and socio-economic profiles. Data were collected from 130 randomly selected organic food consumers in a huge Bangkok supermarket using semi-structured questionnaires. Results showed that more than half of the respondents have purchased organic fruits, rice and vegetables in the past. The key reasons given for these purchases include expectations of healthier lifestyle and long-term contribution towards a more sustainable environment. Results have shown that surveyed organic consumers tend to have higher educational and family income levels, bigger family size and older than those who have never bought any organic products. The primary obstacles cited in the purchase of organic products include persistent confusion in interpreting organic food labels and the general lack of organic product information.

Keywords Buying behaviour • Consumer education • Consumption patterns • Product perception • Organic food • Organic products labels • Thailand

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S. Chouichom (✉)
Department of Bioresource Science, Graduate School of Biosphere Science,
Hiroshima University, 1-4-4 Kagamiyama, Higashi Hiroshima, Hiroshima 739 8528, Japan

Marketing Division, Technology and Innovation, Management Department,
Thailand Institute of Scientific and Technological Research (TISTR),
35 Mu 3, Technopolis, Tambon Khlong Ha, Amphoe Khlong Luang,
Pathum Thani 12120, Thailand
e-mail: joys-tistr@hotmail.com; joys.tistr@gmail.com; seksak@tistr.or.th

L.M. Liao • M. Yamao
Graduate School of Biosphere Science, Hiroshima University, 1-4-4 Kagamiyama,
Higashi Hiroshima, Hiroshima 739 8528, Japan
e-mail: lliao@hiroshima-u.ac.jp; yamao@hiroshima-u.ac.jp

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12.1 Introduction

The organic movement has rapidly swept across the world alongside a growing awareness of perceived environmental and health benefits that can be derived from organic products. The shift from conventional farming methods into organic farming and agricultural genetic engineering has occurred in many countries in widespread efforts to promote sustainable agriculture (Wheeler 2008). Many developed countries in the West have stepped up their organic farming efforts while in most Third World countries such a shift is just beginning to take effect (Chouichom and Yamao 2010) although there are inherent problems attributed to various socio-economic factors.

The intimate link between organic farm products and good human health is well known, likewise with the perceived environmental impacts of organic production. Organically produced food has shown a growing role in the evolving consumption patterns among today's households. One major concern is chemical residues in fruits and vegetables which have caused widespread anxiety among consumers especially those in developed countries. Moreover, promoting greater environmental awareness coupled with food safety concerns has caused many people to favour sustainable agricultural practices (Chen 2007). It is well known that chemical and pesticide residues found in food are linked to deleterious, long-term as well as unidentified effects on human health (Wilkins and Hillers 1994; Miles and Frewer 2001; William and Hammit 2001).

In Thailand, as well as in many Southeast Asia countries, the rapid socio-economic development is ushered by the industrialization and modernization of agricultural food production. The Thai government is particularly keen in pushing agricultural export targets to supply world demands. As such, the use of fertilizers and pesticides has increased dramatically in recent years (OAE 2008). While pushing up agricultural productivity, the Thai government is slowly realizing the need to promote organic approaches to address issues of food safety to maintain its competitiveness in the global market. Domestically, traditional food production schemes are still deeply rooted but will need to be re-examined in the light of growing awareness among Thai consumers towards environmentally friendly and healthy eating patterns. The demand for safe food imports from developing countries is likely to increase for social and political reasons. In many Western countries, health concerns among the general public appear to be the main reason driving the organic food industry (Schifferstien and Oude Ophuis 1998), thereby exerting pressure on exporting countries to re-evaluate safety options.

Organic food consumption represents a new lifestyle trend among the urban population of developing countries as the benefits of organic agriculture are only starting to be realized. A strong organic food manufacturing and marketing system will obviously rely on a stable organic food production source, i.e., organic farms. In Thailand, the organic food supply chain is only beginning to be defined (Kramol et al. 2006). In a study on consumer perceptions of organic vegetables and fruits, only one-third of respondents have purchased organic produce due to various reasons and constraints (Roitner-Schobesberger et al. 2008). Among Thai consumers surveyed in that study organic food labelling has been cited as confusing although respondents showed some degree of awareness of food safety and environmental issues. In neighbouring Malaysia, a preliminary survey among a group of academics revealed a health consciousness factor exerting a greater influence on organic food choices rather than environmental preservation (Salleh et al. 2010).

The recent years have witnessed increased global spending on organic food which exceeded US$86 billion in 2009, with the perceived human health benefits dominating consumers' preferences for organic food. Alongside these human health concerns, Poulston and Yiu (2011) surveyed the increasingly popular concept of organic dining in some New Zealand and U.S. restaurants who found the higher prices of organic food as a main obstacle to increased consumption among customers. Price sensitivity plays a significant role in consumer preferences even in developed countries (Stolz et al. 2010) and expectedly more so in countries with lower incomes. Despite these setbacks, it is suggested that the highest trend of organic food production and consumption has not been reached yet, and that there is still plenty of growth capability within the global organic market (Ebrahimi 2007). The gap between organic food production and demand growth rates is wide: production growth rates in European countries and in China are about 15–25 % (Briz and Ward 2009) and 30 % per annum (Sheng et al. 2009), respectively, while in New Zealand and Australia a growth rate in the demand for organic products could run up to 50–60 % per annum and as much as 75 % per annum in the U.K. (Poulston and Yiu 2011). The world organic market is more vigorous than ever.

Thus far, there has been very little information about organic food consumption trends in Asia compared to industrialized countries such as the U.S., Australia, New Zealand and the European Community (Zhang 2005). Asian countries are set against unique socio-cultural backgrounds which might influence the collective mindset of its people, and thus present complicated trends of consumer behaviour and preferences. Therefore, the aims of this study were to assess the level of consumer knowledge about organic foods, determine some socio-economic and cultural factors affecting their decision-making and the reasons why buyers patronize or reject organic food products in Bangkok. It also relates such consumption patterns with the consumers' understanding and points of view towards organic food as well as their demographic and socio-economic profiles. Moreover, some correlation between consumers' attitudes towards organic food consumption and their socio-economic background will be explored.

12.2 Study Area and Methodology

This study was conducted mainly within Siam Paragon Shopping Centre in downtown Bangkok, one of the largest organic food markets and presumably the destination of most organic consumers in Thailand. The survey and pre-test were carried out in late February 2010. The total sample size was 130 consisting of randomly selected consumers. The interviews employed semi-structured and structured questionnaires. In order to complement both quantitative and qualitative data, more information is collected through focus group discussions among target groups and also by one-on-one interviews. Some questions elicited quantitative data as well. The data were analyzed using descriptive statistics to determine percentages, arithmetic means, and standard deviation. A significance of $p < 0.05$ was set for statistical analysis in this study. F-test values were computed and used for comparing means. A Likert-type scale also was used when respondents were asked to point out their opinions and attitudes.

12.3 Results and Discussion

12.3.1 Demographic Characteristics of Respondents

As shown in Table 12.1 the bulk of respondents included in this study were female (70.8 %), had an average age of 39.77 years (middle-age in this study); most of them were able to read and write fluently. The majority of the interviewees earned bachelor degrees from universities (63.1 %) and some of them had some form of graduate education (23.8 %).

Compared to the respondent group of an earlier survey conducted in Bangkok (Roitner-Schobesberger et al. 2008), the current group is younger, included more women and have higher educational attainment. The latter may imply that surveyed consumers have potentially better knowledge and information about organic food products than the previous sample. Clearly, education significantly influences the level of awareness for organic products (Briz and Ward 2009). Interestingly, Ghorbani and Hamraz (2009) found women consumers in Iran to be more willing than men to pay for organic products owing to their higher levels of awareness towards food nutritional issues, a pattern similarly seen by Byrne et al. (1994) among American respondents. Bartels and Rienders (2010) opined that gender has a profound effect on organic buying behaviour, and contrary to the findings of Ghorbani and Hamraz (2009), they identified men in U.K. spent more money on organic products than women without offering an explanation. The average family composition of respondents was 3.90 persons/household, and mainly with young children. Their average total income was 57,877 ThB/year/household (1 US$ = 36 ThB).

Besides, respondents received organic food information from various sources at around 3.78 times a month. The Internet printed advertising leaflets and television commercials were their primary sources of information about organic products. The media have important roles in disseminating information as illustrated in the case of Australia wherein negative media portrayal hindered the further adoption of genetic engineering (Wheeler 2008).

Table 12.1 Demographic characteristic of respondents (n = 130)

Variables	No.	Percentage (%)	S.D.	Mean	Sig.
Sex			0.47	–	
Female	92	70.8			
Male	38	29.2			
Age (years)			8.72	39.77	
≤30	21	16.2			
31–40	48	36.9			
41–50	51	39.2			0.032*
>50	10	7.7			
Highest educational attainment			0.82	4.03	
Vocational school	17	13.1			
Bachelor degree	82	63.1			0.041*
Master degree or higher	31	23.8			
Family composition (persons)			1.40	3.90	
1–2	22	16.9			
3–4	69	53.1			0.038*
5–6	36	27.7			
>6	3	2.3			
Total income (Baht/year/household)			6.02	57,877	
≤ 20,000	30	23.1			
20,001–40,000	33	25.4			
40,001–60,000	35	26.9			0.034*
> 60,000	32	24.6			

$*P < .05$

12.3.2 Consumers' Concern with Pesticide Residue and GMOs

Table 12.2 shows that more than half of respondents (70 respondents or 53.8 %) showed concerns about harmful chemicals and potential risks as a result of genetic manipulations.

This is not entirely surprising since health risks, aside from environmental hazards, are recurring themes within the consumer world. Chang and Zepeda (2005) revealed that many consumers are far more anxious about the kinds of chemicals used and how they affect their health than anything else. These anxieties about chemical residues drive consumers into buying organic products as observed by Ghorbani and Hamraz (2009). While organic foods are perceived as healthier for the consumer and environmentally friendly as well, these two positive benefits have different acceptance levels in different societies. Green consumption by way of purchasing locally and organically produced foods is often based on an ethically centred consumer behaviour directed towards the general welfare of the society and the environment and is widespread in Europe (Pieniak et al. 2010). In the richer societies of Europe and North America, such altruistic values play a significant role in organic food consumption (Vermeir and Verbeke 2008) as food prices do not

Table 12.2 Participants' concern with pesticide residue and GMOs (n = 130)

Questions/concerns	Very much	Often	Sometimes	Not at all
Are you concerned with pesticide residues on vegetables, meat and fruits?	46 (35.4 %)	70 (53.8 %)	12 (9.2 %)	2 (1.5 %)
Are you concerned with the use of GMOs in foods?	27 (20.8 %)	54 (41.5 %)	36 (27.7 %)	13 (10.0 %)

rank as high a concern as that in poorer societies. In many countries of East Asia which witnessed a number of recent food crisis like mad cow disease, foot-and-mouth disease, avian influenza, etc., there is understandably a far greater concern on the effects of consumed food on their personal health and well-being (Miles and Frewer 2001). In Malaysia, the 'health consciousness factor' exerts a greater impact on food preferences than environmental concerns (Salleh et al. 2010). The same could be said about the respondents of the present study. When asked about chemical residues in foods and foods made with GMO, only 10 % said that these issues do not matter to them, but the great majority are worried and directly link such concerns with personal health and well-being with only a faint impression for environmental concern at best.

When asked to compare their concerns, more respondents were more worried with pesticide residues (35.4 %) than GMO in foods (20.8 %). Farming practices like fertilizer and pesticide applications with their corresponding residues are apparently more well- known in an agricultural country like Thailand than genetically engineered foods and the processes that go into making them. In addition, genetically modified crop seeds are banned in Thailand. In the local media, GMOs have received very limited coverage and public discussion. Roitner-Schobesberger et al. (2008) mentioned that only 10 % (n = 848 respondents) of organic food production consumers surveyed in Bangkok stated that they were 'very much' concerned with GMOs food product, a trend also seen in the present study.

12.3.3 Consumers' Knowledge Level of Organic Farming and Agriculture

The interviewees were asked about their level of knowledge of organic farming and agriculture (Table 12.3) with most of them (94.6 %) having heard the statement 'organic food/organic product' but are not certain what it meant. Most interviewees (70 %) have some knowledge but only 5.4 % claimed having very good knowledge about organic foods. It can therefore be said that there is a moderately low level of organic food products knowledge of consumers in the study area. It has been pointed out that consumers who have more information and knowledge about organic products will show a higher willingness to purchase organic products and that this understanding about organic food is based upon perceptions and state of

Table 12.3 Participants' knowledge level of organic farming and agriculture

Statements	Yes (%)	No (%)
Having heard the statement organic food/organic product	94.6	5.4
Having know some knowledge about organic food/organic product	70.0	30.0
Having very good knowledge about organic foods	5.4	94.6

Table 12.4 Participants' satisfaction with organic food products in supermarkets (n = 130)

Questions	Yes	No
Do you think organic food products are expensive?	103 (79.2 %)	27 (20.8 %)
Are you satisfied with the variety of organic foods in the supermarkets?	57 (43.8 %)	73 (56.2 %)

knowledge, both of which contributed to the final decision to buy or not to buy organic products (Briz and Ward 2009). Consumers' preference towards organic food purchase is in turn positively determined by their attitude towards organic foods. Consumers are influenced by information about organic production and manifest their acceptance in the direction of the expected link, especially among consumers in developed countries where awareness of the ethical value of organic farming and its effects on product safety are high (Napolitano et al. 2010).

12.3.4 Consumers' Satisfaction with Organic Food Products in Supermarkets

Table 12.4 showed that a big number of respondents (79.2 %) thought that organic products are still expensive and that most (56.2 %) are not satisfied with the variety of organic products available in Bangkok supermarkets at the time of the survey. Price and charge variables seem to affect the consumers' decision-making process, whether they will purchase or not. This is not surprising as the respondents belong to a fairly affluent urban community. The organic and non-organic food product prices in Bangkok are quite divergent; with organic food products priced as premium products almost 100 % more than non-organic products. Roitner-Schobesberger et al. (2008) cited that despite the price difference, approximately 60 % of organic food shoppers said the high prices of organic food do not cause a significant problem or a strong deterrent towards their purchase. Mondelaers et al. (2008) and Stolz et al. (2010) found that organic consumers are much less price-sensitive compared with non-organic shoppers in general. In addition, respondent shoppers expressed general dissatisfaction with the variety of organic food products, especially fruits and vegetables, found in supermarkets at the time of the survey. The results of Roitner-Schobesberger et al. (2008) also confirmed that shoppers would like to see more variety from where they can select products to purchase.

Table 12.5 Reasons for buying organic food products

Statements	Yes (%)	No (%)
Organic food is fresher than other common products	82(63.1)	48(36.9)
The taste of organic food is better	78(60.0)	52(40.0)
Organic foods are good for the health	149(87.7)	16(12.3)
Organic food does not have pesticide residue	110(84.6)	20(15.4)
Organic food has organic certification	88(67.7)	42(32.3)
Just want to try organic product/something new	71(54.6)	59(45.4)
It is fashionable to buy organic food	31(23.8)	99(76.2)

12.3.5 Consumers' Reasons for Buying Organic Food Products

The respondents were presented with seven statements asking for the reasons why they buy organic foods (Table 12.5). Results showed that the most important reason cited is the positive health impact (87.7 %). Consumers always considered health reasons as directly impacting on them. Physical well-being and egocentric values are the most important motives for consuming organic foods because of the perceived health benefits of organic food over and above those derived from conventional food products (Grankvist and Biel 2001; Makatouni 2002; Naspetti and Zanoli 2002). Health concerns also constitute a more important incentive even among incidental or infrequent patrons of organic food products (Schifferstien and Oude Ophuis 1998).

Furthermore, consumers surveyed bought organic products because there is proper organic certification in them (67.7 %). The issue about organic certification is contentious. Certification and organic labels are confusing to many consumers. For example, Roitner-Schobesberger et al. (2008) found that respondents presented with six different food labels such as hygienic food, pesticide-safe, organic, etc. found no difference among them and equated all of them into a simplistic and convenient definition of organic products which is of course incorrect. The term 'organic' as found in food labels has been shown to influence behavioural changes brought about by altered brain activity (Linder et al. 2010). Chen (2007) has hypothesized several factors that can affect consumer choices, and one of these is product labelling which was found to be confusing for surveyed consumers in Taiwan. It is apparent that consumers who possess the right information about labels will show more effectiveness and more discrimination towards buying organic foods (Ghorbani and Hamraz 2009). Awareness of organic labels can increase the probability that consumers would be willing to pay a premium for organic food products (Battle et al. 2005). In contrast, consumers experiencing more difficulty in identifying organic foods labels will likely show a drop in their intention to purchase organic foods (Chen 2007).

More than half of surveyed consumers (63.1 %) felt that organic food is fresher than other products while most of the respondents (60.0 %) agreed that organic foods

Table 12.6 Reasons for not buying or rejecting organic food products

Statements	Yes, I agree	No, I do not agree
Organic food product is not a special product compared to any ordinary products, its price is just higher	33(25.4)	97(74.6)
I do not know sufficient information about organic food product and what it stands for	46(35.4)	84(64.6)
I do not believe in the certification system of organic food products	33(25.4)	97(74.6)
It is difficult to find and there are only few organic food products sold	89(68.5)	41(31.5)
Organic food has higher prices than the more common non-organic products	82(63.1)	48(36.9)
The taste of organic products is not good	14(10.8)	116(89.2)

have better taste than non-organics although numerous sensory assessments have yielded inconsistent results (Fillion and Arazi 2002; McEachern and McClean 2002; Zhao et al. 2007). Moreover, two quality aspects of food product (taste and visual attractiveness) are factors related to the frequency of buying organic fruits and vegetables (Ghorbani and Hamraz 2009). Wholesomeness, absence of chemicals, environment friendliness, and a better taste have been cited as primary reasons to justify the purchase of organic foods (Schifferstien and Oude Ophuis 1998).

Other respondents just wanted to try new organic products (54.6 %) while some (23.8 %) wanted to go with the organic food lifestyle trend. Roitner-Schobesberger et al. (2008) declared that the important motive to purchase organic food is the consumer's search for new, trendy and fresh products. On the other hand, food neophobia, defined as the behavioural and personality style shift wherein consumers are reluctant to try new foods (Chen 2007) also figures prominently in our survey results. Poulston and Yiu (2011) have seen a significant and noticeable trend towards organic food and also a noticeable switch towards healthier eating of organic food of respondents in what they called organic dining in restaurants. Generally, the key factor for purchasing fruits and vegetable is the freshness of the products (Pénau et al. 2006; Sakagami et al. 2006) and this is likewise an issue among the present respondents who hinted that Thai organic vegetables must show such qualities to merit their continued patronage.

12.3.6 Consumers' Reasons for not Buying or Rejecting Organic Food Products

The consumers were also asked about some of the reasons which prevented them from buying organic foods. The survey (Table 12.6) showed that consumers were generally satisfied with the variety of organic foods in the supermarket with only 31.5 % complaining that it was difficult to locate organic products. Interestingly, Chen (2007) found that inconvenience has a negative impact on consumers' attitude to organic foods. With the distribution channels of organic foods still limited in

Taiwan, this causes inconveniences to consumers in the purchase of organic foods there. On the other hand, providing a more visible place for organic products in a shop may increase consumers' familiarity with the products and simultaneously improve their image (Aertsens et al. 2009).

Another reason for the rejection of organic foods was the far higher prices compared to non-organic products as cited by 63.1 % of the respondents who also suggested introducing lower cost organic products to the market. From our field survey, we found that the price of organic food product is higher than conventional food by almost 100 % or more. The price premium (generally 50–70 % more than conventional food) is a determining factor for a lot of shoppers (Brown and Sperow 2005; Duffort 2006; Willer et al. 2008). McCoy (2002) and Pearson (2001) opined that the price premium is the most significant reason limiting the demand for organic foods. Baltzer (2003) and Corsi and Novelli (2003) mentioned that consumers' willingness to pay high prices for organic food reflects their appreciation for organic food production quality.

Some respondents (35.4 %) cited poor product information as another reason for not purchasing them. About a quarter of respondents (25.4 %) did not trust organic certificates or banners or became confused with too many kinds of certificates. Mann (2003) argued that the physical image and presentation of organic produce are good enough to hasten consumption and social acceptance. However, due to budget restrictions, the market share for organics is still low. Roitner-Schobesberger et al. (2008) revealed that organic consumers have become more sensitive of food labels and read label more carefully. The current respondents also knew very little about the information on organic product labels. Thus even if the respondents mentioned that they 'know' the label, it does not necessarily denote that they understood the specified data on the label. Marshall and Bell (2004) found that people with a higher level of food involvement have capabilities to make finer discriminations among foods, including what kind of food is healthier. Yet, the best policy for the institutions concerned is to make it easier to identify the certificates of organic foods so as to promote purchasing intentions of organic foods.

12.3.7 Organic Products Most Commonly Purchased by Respondents

The results in Table 12.7 showed most of organic products that were purchased by consumers are organic rice and lettuce (48.5 %). The other organic product commonly shopped by Thai organic consumers is swamp cabbage/water spinach (33.8 %). This kind of vegetable is quite popular in Southeast Asia countries and in other tropical countries. Approximately 26.9 % of respondents frequently bought Thai herb products such as kaffir lime leaf, lemon grass, galangal, ginger, turmeric (curcuma), chili, spicy basil leaf and so on. The organic status of these herbs is

Table 12.7 Organic products most commonly purchased by respondents

Organic products	Yes (%)	No (%)
Cabbage	23.8	76.2
Chinese kale	25.4	74.6
Swamp cabbage/water spinach	33.8	66.2
String bean/long bean	13.8	86.2
Pumpkin	4.6	95.4
Papaya	12.3	87.7
Lettuce	48.5	51.5
Thai culinary herbs	26.9	73.1
Rice	48.5	51.5

uncertain but because they are standard ingredients in Thai cuisine their organic origins have not been scrutinized. In Germany as well as in many parts of Europe, vegetable products have a higher share of organic production than animal products (Mann 2003). These results showed a similar situation in the Thai marketplace surveyed in the present study.

12.3.8 Correlation Between Consumers' Socio-Economic Data and Their Perception of Organic Food Production

In Table 12.1, statistical results illustrated that consumers' age, educational level, family size, and total income were strongly correlated to and influenced their perception of organic food production at the 5 % level. Moreover, the respondents who are between 41 and 50 years old, have educational level of at least the bachelor level, have family members between 3 and 4 persons, have monthly family income between 40,001 and 60,000 ThB are more likely to buy and shop organic food products than other consumers. Bartels and Rienders (2010) revealed that age and income were significant positive predictors of consumer behaviour. Additionally, their results confirmed that the younger generation spent more money for organic food than did older people. This observation disagreed with our present results. Napolitano et al. (2010) pointed out that consumers with a higher education level are more concerned with ethical issues and other sensitive information related to the organic production system. The results of Ghorbani and Hamraz (2009) found that with increasing family size, willingness to pay for organic products will increase.

12.3.9 Consumers' Constraints Towards Organic Food Consumption in Bangkok

Table 12.8 showed some of the consumers' constraints towards organic food consumption in Bangkok. Majority of consumers (64.61 %) cited the lack of

Table 12.8 Consumers' constraints towards organic food consumption

Constraints	Yes (%)
Lack of organic label information	84 (64.61 %)
Low diversity of organic products	76 (58.46 %)
Higher price of organic products	68 (52.30 %)
Small organic market niche	65 (50.00 %)

organic label information as a major problem. They expressed that they still need more information details than what is currently available in the labels. Also, they are still confused with too many organic labels in supermarkets, an observation shared by respondents polled earlier by Roitner-Schobesberger et al. (2008). In Taiwan, consumers are likewise confronted with a confusing array of organic food certificates and labels, with at least 14 different kinds of certification in the market (Chen 2007).

Obviously, greater understanding of information in organic labels can help consumers make intelligent decisions (Ghorbani and Hamraz 2009). Although organic food labelling presents recognition and decision problems, surveyed consumers (58.46 %) stated that the diversity of organic food products is low to allow for greater and wider product selection. German shoppers surveyed by Mann (2003) also expressed dissatisfaction over the low variety of organic products in stores. Approximately 52.30 % of organic consumers surveyed cited the high price of some organic products in the supermarket as constraints.

Napolitano et al. (2010) revealed that the major obstacle to buying organic food is the higher price because of higher production costs. In addition, consumers (50.0 %) felt that the current organic food market niche is restricted with limited patronage, but they were left without any options but to buy at higher prices anyway. There is obviously a need to narrow the gap between the prices of conventional and organic foods in order to stimulate the growth of the organic food sector. To initially address this concern, shoppers expressed the need for businessmen to expand the organic market and for the government to grant subsidies and incentives to achieve the same effects and to reduce the price of some organic products. This way a major constraint revolving around high costs would have been eliminated. This is not a new idea but is a feasible and temporary intervention step until socio-economic conditions can allow the usual market forces to set in.

12.4 Conclusions

The results of this study showed that most of the respondents have purchased organic rice, vegetables and fruit, among other organic items available in Thai marketplaces. The key reasons given to support these purchases include expectations of healthier lifestyle as primary reasons and long-term contribution towards a more sustainable environment as secondary reasons. However, purchasers still need more information on organic labels. Consumers faced a number of issues that restricted them from further patronizing organic foods, foremost of which is the limited market niche that hinders greater product variety and product competition. Consumer preference for organic products is observed among consumers with higher educational attainment and greater family income, bigger family size and greater age than those who have never bought any organic products. Our results showed a steady growth of the organic market share in Bangkok; organic patrons have risen to about 50 % among the respondents (February 2010) compared to about only a third during an earlier survey conducted April-May 2005. This comparative figure points to a growing organic food market in the urban Thai setting. The main obstacles cited by respondents that prevented them from patronizing organic products were the lack of information by way of organic product labelling. This study strongly suggests that new, easily accessible information and knowledge on organic products be more widely disseminated, particularly within the general shopping areas and urban population centres by agencies supporting the organic movement in the country. In this case, public education is clearly a potent factor towards increasing consumer awareness that will help them make informed decisions. It is also a crucial factor that could result in the rise and fall of the growing organic industry of the country.

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Chapter 13
Food Diversity and Nutritional Status in School Children in Morocco

Youssef Aboussaleh, Ahmed Ahami, and Mohamed Afechtal

Abstract In Morocco about 20 % of children under the age of 15 years are stunted or delayed in growth. Dietary quality is much associated with dietary diversity. Recent FAO/WHO recommendations emphasized food diversification intake to combat many nutrition related diseases. Dietary diversity is used for the assessment of diet quality and food security. Morocco still bears a heavy burden of many micronutrient deficiencies and child stunting. Stunting reflects chronic under nutrition and nutritional insecurity. The purpose of the study was to assess dietary diversity by comparing a dietary diversity score (DDS) and a weekly food frequency score (WFFS) and study their relationship to stunting in school-age children in the province of Kenitra (Morocco). The study was carried out in urban and rural areas of Kenitra. After administrative authorizations and parents' clearance and children's consent. The study team surveyed seven different schools representing all the principal communities of Kenitra and its region. A structured questionnaire composed of different items: Household demographic data, socio-economic data, anthropometric measurements, food and nutrition evaluation was delivered to get answers. A stratified random sample of 263 pupils with average age of 12.9 ± 0.9 years including one-third from rural schools were administered a weekly food frequency questionnaire. A health team assessed the anthropometric status. Dietary diversity was appraised with two types of indices: a dietary diversity score (DDS) based on the number of food categories consumed over a week, and a weekly food frequency score (WFFS) which also takes into account the frequency of food intake. The DDS was significantly higher in rural than in urban children, whereas the WFFS was lower, in rural children owing primarily to less frequent intake of fruits and vegetables than in the urban children. Maternal level of instruction was also

Y. Aboussaleh (✉) • A. Ahami
Nutrition and Health Laboratory, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco
e-mail: abou_85@yahoo.fr

M. Afechtal
Department of Agriculture and Pest Management, Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (Bari), Italy

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positively associated with a higher consumption of fruits and vegetables and milk, and with a higher WFFS. Both indices were significantly associated with stunting. The study suggested that diet quality is associated with height status and food diversity indices that take food frequency into account which may provide a better reflection of diet quality.

Keywords Diet • Diversity • Stunting • Schoolchildren • Morocco

13.1 Introduction

Malnutrition is widespread in Morocco, as it prevails in many developing countries and in Africa in particular. The 1990–1991 survey on living standards in Moroccan households reported a stunting rate (height-for-age z-score < -2.0) of 23.9 % among children under the age of 11 (Ministère chargé de l'incitation à l'économie 1992). Among pre-school age children, the rate went from 28.3 % in 1990 to 23 % in 1998 which is the latest national survey that comprises anthropometrical data in Morocco (Benjelloun 2002). The most recent national study, conducted in 1998, also revealed that 5.4 % of adults are underweight (Ministère chargé de l'incitation à l'économie 2000) while isolated studies reveal the progression of obesity in adulthood, especially among women, with the nutritional transition experienced by the population in Morocco (Mokhtar et al. 2001; Rguibi and Belahsen 2004; Aboussaleh et al. 2009). Studies on the prevalence of malnutrition in school-age children are almost non-existent in Morocco.

A varied diet rich in fruits and vegetables is among the strategies recommended by WHO in its report on diet and health in order to prevent both deficiencies and chronic diseases linked to nutrition (WHO 2004). Dietary diversity is not a new concept, but its operationalisation is more recent, at least in developing countries. An indicator of quality of food intake, dietary diversity is an assessment tool that has been used in industrialized countries for close to two decades (Kant et al. 1991). It can be defined as the number of different foods or groups of food consumed over a period of time, most often a day or a week (Ruel 2002). Studies associating dietary diversity with nutritional status and growth in particular have been mainly involved in pre-school age children in developing countries and a positive association has generally been observed (Haltoy et al. 1998, 2000; Novotny 1987).

There have been some studies that focused on children over the age of 5 and on adults. Indeed Torheim et al. (2004) reported a positive correlation between dietary diversity and the mean nutrient adequacy score in subjects aged 15–45. The only study that includes school-aged children was carried out in Iran by Mirmiran et al. (2004) and it revealed that in subjects age of 10–18, a more diversified diet was associated with a higher body mass index (BMI).

Recently in another study it was reported that stunting and underweight were associated with DDS while no correlations were found with wasting. The absence of correlation with other nutritional status indicators could be due to other factors that maybe more important, such as socio-economic status and others (Moikabi 2011).

In rural Bangladesh a reduced dietary diversity was a strong predictor of stunting and the inclusion of a variety of food groups into complementary could improve child nutritional status (Rah et al. 2010).

In another study about 3.6–8.1 % of changes in stunting and wasting, respectively, could be attributed to changes in dietary diversity. An r^2 of 0.284 was obtained between nutrition status and morbidity (Nakhauka et al. 2009).

This study, was conducted on a school-aged population of pre-adolescents in north-western Morocco, with objective to evaluate dietary diversity and to develop a score that reflects presence/absence of different food groups as well as the frequency of food intake. A comparison between the two indices was reported in relation to the prevalence of stunting.

13.2 Methodology

13.2.1 Population and Study Subjects

The present study was performed in Kenitra (North Western Area of Morocco) as shown in the map (Fig. 13.1). The sample of pupils was stratified for municipalities and for schools. From a list of all the schools a systematic sampling was done. Among the seven schools in the sample, four were drawn from the urban network of municipalities of Kenitra and three belonged to the rural area, out of a total of 10 municipalities and 50 elementary schools. All the children in their final year were included in the study. They were aged from 12 to 16 years old. The study includes a total number of 306 children.

13.2.2 Variables and Data Collection

With the agreement of the public health and education authorities in the region, the students' parents were made aware of the study by the school principals. The contact visit of the study team was conducted 1 week prior to the date set for data collection. The study involved an administration of a questionnaire to the students and their parents, containing a medical examination and anthropometric measurements of the children.

13.2.2.1 General Questionnaire

This questionnaire was tested and validated by an urban school. The staff was trained by a nutritionist 1 week before the survey. During the interview, the questionnaire was filled by the trained PhD students and allowed the researchers

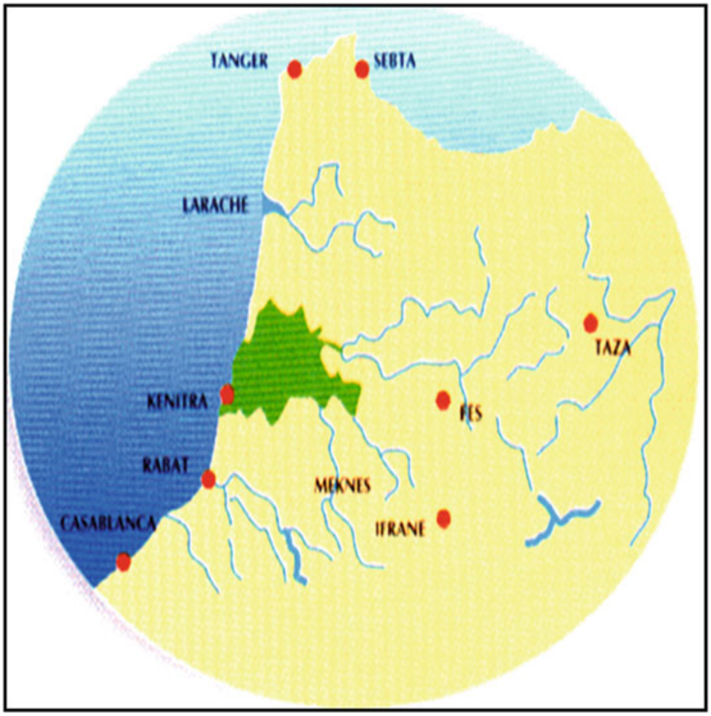

Fig. 13.1 Province of Kenitra (Green area in the map above)

to collect a variety of information about the child and his/her family, as well as on food frequency. Demographic and socioeconomic data was obtained from the children and their parents or guardians, in particular, age, sex and ranking of the child in the family, parents' level of education, as well as household size. Level of education was defined by a score ranging from 0 to 3, according to an ascending scale (0: no education; 1: elementary; 2: secondary; 3: post secondary).

13.2.2.2 Questionnaire on Food Frequency

The food frequency questionnaire (FFQ), based on food groups, was administered to the child and covered the previous week. The food groups to be included in such studies depend on the objectives. Stunting can be a manifestation of several deficiencies (Allen 1994; Allen et al. 2001). Thus, we classified foods according to their nutritional composition. The following 12 categories of foods were listed: meat, poultry, fish, legumes, green and other vegetables, fruits that are a source of vitamin C, other fruits, cereals and derivatives, dairy products, fats, sweets and sweetened tea.

13.2.2.3 Anthropometry

The students' height and weight were measured according to standard techniques using a beam balance platform scale and a locally manufactured height measuring board. The indices of nutritional status selected were body mass index (BMI) and height for age, evaluated according to National Center for Health Statistics /World Health Organization reference values (WHO 1995).

13.2.3 Data Processing and Analysis

13.2.3.1 Calculation of Dietary Diversity Indices

In many developing countries, due to lack of specific food guidelines based on nutrition adequate servings, the majority of studies have used the counting of food groups alone to estimate diet quality based on diversity (Ruel 2002). Such a dietary diversity score has been validated, in particular in Mali, in adults (Hatloy et al. 2000). We drew on this for our dietary diversity score (DDS). Based on the presence or absence of consumption of the food category, as recalled for the last week, a code of 0 was assigned if the food is not consumed or 1 if consumed and the sum gives the DDS, with a maximum possible of 12. We also calculated a partial dietary diversity score (PDDS) by excluding the three categories of foods that could be considered superfluous (sweets, sweetened tea and fats).

In addition, we calculated an index of dietary diversity that takes into account the weekly food frequency, which we call the Weekly Food Frequency Score (WFFS). For each item the WFFS score is the number of times the child consumed this item during a week. Every child was asked how often he consumed last week the different foods: A score from 0 to 7 was affected in the ascendant order 0: not consumed 1 once a week and 7 for every day. These scores are summed up to build the food category scores and then summed up to have the WFFS.

This index was calculated for each of the 12 food categories and for all of them together, as well as for four major groups: meat, fruits and vegetables, cereal products, and milk. This choice of four groups is in accordance with most food guides and in particular to Canada's Food Guide (Santé Canada 2008). Thus, red meats, poultry, fish and legumes, sources of protein and iron, were grouped together in the "meat" group.

13.2.3.2 Interpretation of Nutritional Parameters

Stunting suggests chronic malnutrition. It is evaluated by low height for age. Wasting is an acute form of malnutrition. It is evaluated by a low body mass index (BMI) for age. In both cases, the cut-off point is a Z score < -2.0.

13.2.3.3 Statistical Analyses

Statistical analyses were carried out using the Epi Info 2000 software (Centre for Disease Control and Prevention 2000) including the Nutstat module for the calculation of the Z-scores of the anthropometric indices and Statistica. In addition to the descriptive statistics, t- test, chi-square and ANOVA were applied.

13.3 Results

There were a total of 306 subjects, 263 of whom answered the food frequency questionnaire (FFQ). Only those who answered the FFQ are considered in this article. In this sample, 97 of the students or 37 % were from rural areas.

13.3.1 Characteristics of the Sample

Table 13.1 shows that the average age of the children was 12.9 years ± 0.9 and that the number of boys and girls in the sample was balanced, with 49.5 % girls. On average, the children observed were third in birth order. The average size of the households was 7.7 people with a higher number in the rural areas (8.95 vs 6.76) with a $p = 0.00001$, while the parents' level of education there was lower. These scores for fathers are 1.12 in rural vs 0.41 in urban areas with a $p = 0.001$. Mothers in rural area are very undereducated with only 0.05 as a score.

Table 13.1 Children's socio-economic status in urban and rural areas

	Total[a]	Urban		
	Mean ± SD	schools	Rural schools	probability
Age (years)	12.98 ± 0.90 (n = 262)	13 ± 1	12.97 ± 0.68	0.77
Rank of birth	3.26 ± 2.20 (n = 222)	3.3 ± 2.0	3.26 ± 2.34	0.89
Household size (number of people)	7.72 ± 3.89 (n = 260)	6.76 ± 2.13	8.95 ± 5.58	0.00001*
Fathers' education[b]	0.93 ± 0.90 (n = 244)	1.12 ± 0.89	0.41 ± 0.68	0.001*
Mothers' education[b]	0.36 ± 0.65 (n = 244)	0.48 ± 0.75	0.05 ± 0.28	0.0001*

[a]N = 263 with 130 girls and 133 boys
[b]No schooling = 0, Primary school = 1, Secondary level = 2, Post secondary = 3
*Difference is significant ($p < 0.05$)

Table 13.2 Food consumption more than twice a week

	Rural	Urban	Probability
Meat	73	75	0.74
Fish	49	52	0.71
Poultry	74	66	0.19
Legumes	58	31	0.00001*
Green vegetables	76	83	0.23
Fruits Vit C	89	76	0.01*
Other fruits	55	58	0.57
Milk	79	77	0.68
Cereals	93	97	0.11
Fat	73	75	0.74
Sweeties	81	79	0.71
Tea with sugar	99	93	0.03*

*Difference is significant ($p < 0.05$)

13.3.2 Food Frequency

Food frequency is illustrated in Table 13.2 where we can see the proportion of subjects who ate each of the food categories at least twice the previous week. We can see that cereals and tea come first. The foods eaten least often are legumes in urban areas with 31 % and fish in rural ones with 49 % of the children who ate them at this frequency. The other food groups ate least by twice a week by over 50 % of the children. Comparing urban to rural food frequencies, results showed that green legumes ($p = 0.00001$), rich vitamin C fruits ($p = 0.01$) and tea ($p = 0.03$) were more frequently consumed in rural Knowing that this region is a high citrus farming area.

13.3.3 Nutritional Status

Chronic under nutrition expressed by stunting touches one fourth of the sample with 26 % of girls and 24 % for boys as shown on Table 13.3.

Concerning current malnutrition the same trend found with 10 % wasting in girls against 8 % in boys.

13.3.4 Dietary Diversity and Malnutrition

Dietary diversity indices according to nutritional status indicators are shown in Table 13.4. There was no significant difference observed between wasted vs non wasted children for any dietary diversity or frequency score. No trend could be detected either. Some differences were observed between stunted and non-stunted children. Mean DDS and one weekly frequency score, that for fish, were significantly higher in stunted than in non-stunted children, which appears paradoxical.

Table 13.3 Nutritional status of children

	All	Boys	Girls	Probability*
HAZ score	−1.12 ± 1.15	−1.09 ± 1.23	−1.18 ± 1.03	0.53
Stunting %	25.00	24.00	26.00	0.70
BMIZ score	−0.44 ± 1.12	−0.41 ± 1.10	−0.47 ± 1.15	0.67
Wasting %	8.36	8.00	10.00	0.57

*Means are compared by *t*-test and proportions by Chi-square test

Table 13.4 Dietary diversity indices and stunting

	Stunted (n = 63)	Non-stunted (n = 200)	Probability
DDS	10.66 ± 1.20	10.4 ± 1.29	0.17
DDS without superfluous items	8.06 ± 0.96	7.75 ± 1.08	0.03*
WFFS	42.18 ± 9.66	44.34 ± 9.59	0.13
WFFS without superfluous items	26.98 ± 7.34	29.14 ± 7.29	0.06
WFFS meat	2.18 ± 1.53	2.50 ± 1.53	0.17
WFFS fish	2.13 ± 1.76	1.65 ± 1.40	0.04*
WFFS poultry	2 ± 0.90	2.36 ± 1.92	0.16
WFFS legumes	1.45 ± 1.44	1.82 ± 1.95	0.18
WFFS meat and substitutes	7.77 ± 2.54	8.34 ± 3.02	0.19
WFFS vegetable	3.79 ± 2.49	3.95 ± 2.70	0.63
WFFS vitamin C fruits	3.25 ± 2.14	3.40 ± 2.46	0.62
WFFS other fruits	1.97 ± 1.67	2.05 ± 1.64	0.09
WFFS fruit and vegetable	7.77 ± 2.54	8.34 ± 3.02	0.26
WFFS milk and dairy	3.62 ± 2.74	4.34 ± 2.72	0.08
WFFS cereal products	6.40 ± 1.75	6.48 ± 1.61	0.69
WFFS fats & oils	4.79 ± 2.96	4.48 ± 2.93	0.48
WFFS sweets	3.60 ± 2.81	4.37 ± 2.82	0.07
WFFS tea with sugar	6.80 ± 1.07	6.34 ± 1.85	0.07
WFFS superfluous items	15.20 ± 4.71	15.20 ± 4.50	1.00

*Difference is significant ($p < 0.05$)

However, non-stunted children had a slightly higher total WFFS (without superficial items) but not significative ($p = 0.06$), and tended to have a higher frequency score for milk. This effect of dietary score on stunting does not persist when we control for either area of residency ($F = 1.3$ and $p = 0.25$) or parent education ($F = 2.22$ $p = 0.08$) as performed by ANOVA/MANOVA.

13.4 Discussion

Dietary diversity is a measure of dietary quality, as it is predictive of nutrient adequacy (Ruel 2002), and therefore, for food security in terms of quality rather than quantity. However, there is still much debate as to what indices to use, what food categories, and for how long a reference period.

13.4.1 Indices of Dietary Diversity

The observation of 263 pre-adolescents in rural or urban areas revealed that their diet is relatively diversified since the mean dietary diversity score (DDS) was 10 out of a maximum of 12 (food categories) and a total weekly food frequency score (WFFS), without superfluous foods, of 84.

It is not easy to compare our results on dietary diversity with other studies, since they did not use the same food groups or the same reference period. In fact, this problem has been raised by Ruel (2002). The selection of food categories depends in part on the study objectives and the length of observation, on local customs. The reference period was chosen for a reference period of 7 days because it includes the market day (weekly *souk*), which has a considerable influence on intake, in particular of vitamins A and C, as we observed in 1988 (Aboussaleh 1988). The percent adequacy of dietary intakes increased by 60 % on the day of the *souk*. As for food categories, in the present study we combined poultry and eggs as common sources of protein. By separating meat and fish, we were taking the different composition in fatty acids into consideration. In addition, we distinguished between fruits that are a source of vitamin C. In their study, (Tarini et al. 1999) grouped eggs together with dairy products. It was reported that an average DDS of 5 (out of 11 food groups) in children aged 2–4 in Niger over a period of 9 days, three per season. They also found a weak, but significant relationship between DDS and the children's anthropometric status (Tarini et al. 1999). Since there have not been any studies on dietary diversity in relation to nutritional status in school-age children, no comparisons can be made with other age groups.

Our results are comparable to an adult Vietnamese women (Ogle et al. 2001). Their average DDS was 9 out of a maximum of 11 over a 7-day period (Ruel 2002). It should, however, be noted that the food groups were not the same because of different contexts.

With the additional index of dietary diversity, which includes food frequency (WFFS), more information is derived than with the DDS, which does not take food frequency into account. Theses scores seemed complementary and indeed both have their value in terms of food quality. Even when using the DDS alone, some kind of breakdown by food groups is essential to identify the differences between diversified and non-diversified diets (Savy et al. 2004). The drawback presented by the total WFFS is that a high score can be achieved even when a limited number of food groups are consumed if there is a high frequency of consumption of some groups. It is therefore essential to present the partial WFFS by food groups as well. For instance, mean DDS was significantly higher in rural than in urban children (with or without superfluous items). However, the WFFS was significantly higher in urban children and, when considering the partial scores, it can be seen that there was no food group for which the frequency of consumption was higher in rural children. Indeed, the WFFS for fruits and vegetables was significantly higher, and that for meat tended to be higher in urban as compared to rural children. This suggests a better quality of diet in the urban areas of the study when not only the presence but also the frequency of the food groups is taken into account. The DDS may overestimate the dietary quality in rural areas where the diet is known to be more monotonous than in cities. In fact during this season of cereal harvest (for market exchange), food security is more important than the other season where only cereals and tea are the main foods eaten in low income families. However, the weekly food frequency scores need to be validated against quantitative food intake data.

When food is eaten from a common pot, as is usually the case in our population, individual intake is not easily quantified, and this was a major reason for resorting to non-quantitative assessment. Counting the number of mouthfuls and assessing the average weight of these has been used to validate semi-quantitative food scores (Tarini et al. 1999), but this is a costly and invasive approach, and there is the risk of altering normal intake patterns.

We also observed that the total WFFS (without superfluous items), and the partial scores for fruits and vegetables, and for milk, were significantly higher among children whose mothers were better educated. When mothers had reached at least the secondary level of schooling, the frequency of fruits and vegetables increased by 50 % as compared to mothers without any schooling. Parents' level of education may be confounded with rural–urban residence since the level of education is higher in cities.

13.4.2 Nutritional Status

The fact that girls seem to be more stunted may be due to early pubertal maturation in girls than boys. There is a fall in the age that correspond to the 3rd and 97th percentiles for onset of puberty in girls while the ages at these percentiles remain practically unchanged in boys (Papadimitriou and Chrousos 2005).

13.4.3 Dietary Diversity and Nutritional Status

A relationship between dietary diversity and anthropometric nutritional status was detected only in the case of stunting. However, opposite results were observed with DDS and WFFS. While DDS (without superfluous items) was significantly higher in stunted children, total WFFS (also without superfluous items) was significantly higher in the non-stunted children. Furthermore, the WFFS for fish was significantly higher in stunted children. This likely reflects the substitution of sardines for meat for economic reasons, particularly in rural areas, where we observed twice the rate of stunting compared with the urban sample (Aboussaleh et al. 2007). These apparently paradoxical findings could be better explained with a multivariate analysis model, but sample size precluded such analyses. Nonetheless, the DDS by itself did not appear as a reliable index of dietary quality in the rural sample of school children.

This study has also limitations such as the lack of food intake reports and the length of the period (a week) concentrated in only one season. This may not reflect the real consumption behaviour especially in the rural area where food consumption is very closely related to the season.

Seasonality may be affected by climate change. In fact it was estimated that climate change will lead to a relative increase in moderate stunting of 1–29 % in 2050 compared to a future without climate change. Climate change will have a greater impact on rates of severe stunting, which we estimate will increase by 23 % (central sub-Saharan Africa) to 62 % (South Asia). Climate change is likely to increase child undernutrition in South Asia and sub-Saharan Africa, even when economic growth is taken into account (Lloyd et al. 2011).

13.5 Conclusion

In the absence of quantitative measurements of food intake, the concept of dietary diversity operationalised by indices can inform on nutritional quality. Of the two indices that we used, the DDS has been validated in other contexts, but it has proven to be of little relevance in the framework of the study of school children in Morocco with regard to growth assessment. The other index WFFS which take food frequency into account is associated to chronic malnutrition or stunting.

Given these dietary trends, the food frequency approach can be a valuable tool for nutrition education and dietary guidance in school nutrition evaluation or in rapid nutrition assessment in other fields.

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Chapter 14
Local or Indigenous Chicken Production: A Key to Food Security, Poverty Alleviation, Disease Mitigation and Socio-Cultural Fulfilment in Africa

Kolawole Daniel Afolabi

Abstract Political instability, economic crises, war, food insecurity or hunger, poverty, diseases, pestilence and religious and socio-cultural crises are problems confronting and militating against African development. The role of local or indigenous or rural/scavenging chicken in food security, alleviating poverty, disease mitigation and meeting the socio-cultural fulfilment towards ensuring political, economic and socio cultural stability in Africa is hereby reviewed. The Local or indigenous chicken of any country are better adapted to local conditions as they are hardy, can thrive under minimal supply of feed, more resistant to local pests, parasites and diseases than the exotic breeds or hybrids. The potentials of local or indigenous chickens include 460–1,840 g mature body size in 30 weeks 40–200 eggs production per annum and egg weight of 29–45 g per egg. Meat and eggs from local chicken are very palatable, taste better with strong flavour, have low cholesterol and are nutritious as they furnishes energy, essential amino acids, vitamins and other micro nutrients of animal source to the poor rural and urban dwellers and sick people at cheaper, affordable and manageable quantities. They are preferred delicacies for entertainment besides their therapeutic values. Income or money from the sale of local chicken and eggs are often used to pay for other needed commodities, services and obligations (seed, salt, cloth, fuel, medicine, school fees and books, transport fare, taxes etc.); and it encouraged cash flow, savings, investments and insurance against absolute poverty. Satisfaction in African religious/ spiritual and socio-cultural values cannot be attained except local chicken and eggs were used to entertain visitors, make sacrifice or rituals to appease gods and during family celebration or traditional ceremonies. Other roles of local or

K.D. Afolabi (✉)
Livestock Unit, Rubber Research Institute of Nigeria Iyanomo, P. M. B. 1049, Benin City, Nigeria
e-mail: kaydafl@yahoo.com

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indigenous chicken production in pest and weed control, as sanitizing agent and converter of household waste and left over grains to meat and eggs, in healing, recreation, local timing and as sources of manure for gardening cannot be under estimated.

Keywords Local or indigenous chicken • Food security • Poverty alleviation • Socio-cultural value • Disease mitigation

14.1 Introduction

Human and livestock populations have increased considerably over the last three decades at different rates. Since 1960, the total human population had increased by 75 % but developing countries population had grown by 97 %, compared to 28 % in industrialized world (Branckaert 1997). The world population is predicted to increase from 5.4 billion to at least 7.2 billion within the next two decades and this increase will take place largely in the developing countries. As the population grows annually there is no corresponding compensation in food supply increase, especially dietary animal protein. The frequent occurrence of various forms of protein-calorie malnutrition such as kwashiorkor, marasmus, and mental deficie-ncies is an evidence of inadequate quality of food especially dietary protein in developing countries. The problem is that of insufficient food production, poor road networks, transportation problems, inadequate distribution, and glut of produce during production seasons which often lead to spoilage and wastage as a result of poor storage and preservation of farm produce. Most African countries are either underdeveloped or developing whose citizens or dwellers are poor with low income and cannot adequately acquire quality food that will satisfy their needs.

Political instability, economic crises, war, food insecurity or hunger, poverty, diseases, pestilence and religious and socio-cultural crises are the major problems confronting and militating against African development. Local or indigenous or rural, village or scavenging chicken (as it is often referred to) has been playing a significant role for ages in food security, alleviating poverty, disease mitigation and meeting the socio-cultural fulfilment towards ensuring political, economic and socio cultural stability in Africa.

The local or indigenous fowl is believed to have originated from the red jungle fowl of India. The birds are adapted to different environmental conditions of the regions where they exist as indigenous in different localities. They are better adapted to local conditions than the hybrids as they have good flight skills and more likely to escape predators besides their scavenging ability. The indigenous chickens are of small body size, with different colours of plumage, and of dual-purpose type, with variable body conformation and physical characteristics. Market weight of 1–1.5 kg is reached in 4–5 months. They have been reared extensively for generations in almost every village and towns in Africa, in free range or integrated farming systems (Aini 1990). They are hardy and can thrive under minimal supply of feed and are more resistant to local pests, parasites and diseases than the exotic breeds or hybrids.

Local or indigenous chickens breeds of Africa and other part of the world include the Bisaya in the Philippines, the indigenous fowl of the Polvaba province of Ukraine, the golden-speckled native fowl of Czechoslovakia (Oluyemi and Roberts 2003), the non-descript Deshi, Asel, Naked neck and Hilly chicken of Bangladesh (Bhuiyan et al. 2007), the large Baladi, Bare-neck and Betwil chicken of Sudan (Mohammed et al. 2005), Noi and Tau Vang breed of Vietnam (Thuy and Ogle 2007), the Ayam Kampong of Malaysia (Aini 1990), the Fayoumi reared in Egypt and Bangladesh (Islam et al. 2004) and local or indigenous chicken or village poultry of other countries like Nigeria, Senegal, Cameroon, Kenya, Malawi, Mozambique, Tanzania etc. Others are the Sampav or bantam, Kandong (slow feathering), skoeuy (Bicolour) and Kragnos (frizzle) breeds of Cambodia (Vathana and Keo 2006), Tikur (Black plumage), Kei (red plumage), Gebsima (greyish mixture plumage) and Netch (white plumage) genotypes of Ethiopia (Mebratu 1997).

The Nigerian indigenous or local chicken is a light strain or breed possessing a small body size with extremely variable plumage colour, early maturing of rather nervous disposition and produces white-shelled eggs (Oluyemi and Roberts 2003). Hill (1954) described the local or indigenous chicken of Nigeria as being similar in conformation and plumage pattern to the native fowls found in other parts of West Africa. They have live weights of 460–1,380 g for females, and 690–1,840 g for males, average weight of 29–45 g per egg with egg yield or production of 40–80 eggs per annum when raised under the extensive or free range, and 100–200 eggs per bird when reared under intensive system of management.

Despite the rapid development of commercial poultry systems worldwide, it has been estimated that still more than 80 % of the global poultry production occurs in local or traditional family-based production systems and it constitute up to 90 % of the total poultry products in many countries (Mack et al. 2005). The estimated population of local or rural poultry in Africa is as shown in Table 14.1 below.

Pictures of Nigerian local chicken are shown in Figs. 14.1 and 14.2 below.

The local or indigenous fowl outnumbered all other livestock species in Nigeria and was estimated at 123,900,000 in 1977 and 1978, about 92.8 % of the total chicken population Akinwumi et al. 1979). Family or backyard poultry or scavenging chicken or local chicken as may be called was put at 104 million in 1992 (RIM 1992) and 115,880,864 (FMARD 2006) in 2006. Indigenous chicken production in Nigeria for the year 2005 was estimated at 212,430 metric tons, about 247 million dollars in value and it ranked 19th among Agricultural Commodities produced in Nigeria in 2005 (FAOSTAT 2006). The economic importance of local chickens to contemporary African dwellers' political, economic and socio-cultural settings is hereby highlighted and reviewed.

Table 14.1 Estimated population of local or rural poultry in Africa

Country	No. of rural poultry (millions)	% Local or village poultry of national flock
Africa	1,500	70
Cote d'Ivorie	–	53
Ethiopia	53.2	99
Kenya	16	70
Lesotho	1.6	–
Nigeria	120	80
Tanzania	–	86
Uganda	16	80
Zimbabwe	–	30

Source: Awan (1993)

Fig. 14.1 Nigerian local cock

14.2 Importance of Local or Indigenous Chicken in Africa

Food Security/Nutritional Value: The contribution of local or indigenous chicken production to household food security is indicated by the quantity and quality of poultry products, mainly meat and eggs emanating from this type of poultry that is consumed. Meat and egg of local chicken are sources of protein in village diets and have been described as "cheap and valuable protein in convenient, readily harvestable and manageable quantities" (Adene and Oguntade 2006).

Meat from native or local chicken is popular among local people for making delicious soup. The average protein content of poultry meat is about 20 % and it also contain relatively little fat (±7 %), especially under the skin (Eekeren et al. 2004). In all places there is usually a strong preference for the meat of local chicken breeds. This has improved the nutritional status of rural dwellers and checked malnutrition. Village chicken products are often the only source of animal protein for resource-poor households.

Fig. 14.2 Nigerian local hen

In households headed by widows, children or grandparents, chicken represent the easiest specie to rear for home consumption thus providing a source of high quality protein and micronutrients which play an important role in the nutrition of people living with HIV/AIDS. A study in Mozambique (Alders et al. 2005) showed how village poultry play a key role in the local economy, and how increased production has the potential to improve food security, assist in poverty alleviation and mitigate the adverse economic impacts of HIV/AIDS for rural populations.

Hen eggs have been an important part of the human diet since the dawn of recorded history and they are one of the few foods that are used throughout the world. Chicken egg in particular, offers a great nutritional bargain as it contains approximately 315 kJ of energy and is of the best quality protein source known coupled with the fact that it supplies an array of vitamins such as A, E, B_{12} and Vitamin K, a bone-boosting nutrient; unsaturated fatty acids, iron, phosphorus and trace minerals (Alders et al. 2005; Watkins 1995). Egg also provides choline, a B vitamin that plays a role in brain development. Chicken egg provides a unique well-balanced (100 % Biological value) source of nutrients for all ages (Mine 2002). The general consensus in Nigeria is that local or indigenous meat and eggs are more palatable than imported exotic breeds (Hills 1954). The meat and eggs of local/indigenous chicken have low cholesterol, taste better and have a stronger flavour than those of exotic and commercial chicken, and they have therapeutic values (Poultry International 2003; Oh 1987). Thus the price of indigenous chickens is not affected by the fluctuating market price of intensively produced commercial birds. The carcass traits of Nigerian local Chicken reared under intensive system of management is as shown in the Table 14.2 below.

A local chicken producing company, Tanaosree, Thai Chicken Co, in Thailand had embarked on commercial production of native chicken and raises about 400,000 indigenous chickens a year for the local market, with a turnover of 400 million baht, or half of the total market value (Poultry International 2003).

Table 14.2 Carcass traits of Nigerian local chicken

Carcass parameters	Local cockerels (28 weeks old)	Local hens after 12 weeks in-lay (35 weeks old)
Live weight (g)	1,662 ± 122	914–1,025
Dressed weight (g)	1,155 ± 106	460–510
Dressing percentage	68.12–70.68	48.93–50.89
Gizzard (g)	37.74 ± 1.73	15.85–28. 07
% Gizzard	2.32	1.77–2.30

Source: Afolabi (2009); Olawoyin (2006)

It is high time similar production of local chicken on a large scale commenced in Africa to meet the ever increasing demand for local meat and satisfy the taste of the inhabitants.

Religious and Socio-Cultural Value: Tradition often dictates that local chickens are used during customary or religious festivals, to honour visitors or during family celebrations or traditional ceremonies. African households are usually on the top of their spirits and emotionally elated as Christmas and other festivals are approaching just because it's on such occasions they are sure of eating the delicious local chicken *ad libitum*. In some rural areas with lower household incomes, consumption of poultry product is reserved for special occasions (Adene and Oguntade 2006). In some parts of Kenya, chicken meat is highly valued to the extent that one would not consider him/herself a distinguished guest if a chicken is not slaughtered for him/her on a visit (Nyange 1997).

In a study on the relationship between tested organoleptic qualities and the consumption pattern for selected poultry meat in three Nigerian cities, Joseph et al. (1995) observed that local chicken was the most preferred by their respondents followed by guinea fowl, bush fowl, exotic chicken and lastly the duck in that order. Local fowl are even used as sacrifices to gods since no exotic fowl will be accepted in its place. Local chicken and their eggs are often used by priests and traditionalists medicinally, spiritually and for rituals.

Economic Value/Poverty alleviation: Despite the rapid development of commercial poultry systems worldwide, it has been estimated that more than 80 % of the global poultry production occurs in traditional family-based production systems and that the latter constitute up to 90 % of the total poultry products in many countries. The objective of alleviating or reducing poverty and malnutrition cannot be achieved alone by commercial poultry production but with the integration of local or rural chicken production into rural and urban farming system and mode of life (Mack et al. 2005). In many developing countries nearly all families at the village level, even the poor and landless are owners of poultry. Mack et al. (2005) also affirmed that targeting small scale family-based poultry system as an effective entry point for poverty alleviation programmes is gaining widespread acceptance. Livestock, especially poultry species have shown to provide a practical and effective first step in alleviating abject rural poverty. Chickens are more easily sold as source of income by the local farmer/dwellers or used to barter. Chicken has been described as small disposable asset or the only disposable resource of the rural poor. In south-east Asia, village chickens and their eggs are often demanded by wealthy urban residents, who are willing to pay a premium price for them. Proceeds from the sale of local chicken allow cash flow to meet essential family needs such as medicine, clothes, cooking fuel, salt etc., to pay school fees, buy school books for the children, buying seed rice, maize etc. at planting seasons, as poll taxes etc. Indigenous or local chicken provide the critical cash reserve and cash income for many small farmers who grow crops or rear other animals like sheep and goat for subsistence purposes. A relatively small number of chickens are being exchanged for a goat (Spradbrow 1997). Chickens therefore offer one means of redressing the inequalities that exist between rural and urban incomes and may help prevent the movement of populations from villages to cities. According to Alders et al. (2005) Nomsa Nkomo, a member of Junior Farmer Field Schools (JFFS) in Vukuso village in Zimbabwe reported the importance of local chicken thus:

> We raise chickens for their eggs and so that they increase in number, so that we can sell and get money. This money will help me to buy what I want. If I have a visitor I can slaughter them and get relish. If a child fails to get school fees, the chicken can be sold to get money. Money to buy sadza comes from chickens. Chickens give manure that we use in our gardens for green vegetables and tomatoes. The other thing I can do is to buy clothes using chickens. When celebrating a birth I can also use a chicken as a gift. When I want someone to work in my fields, I can slaughter a chicken. I can also eat the eggs with sadza.

The prices of local chicken in Nigeria in 2001, 2003, 2005 and 2010 were NGN 423.75, NGN 403.70, NGN 507.59 and NGN 500 – NGN 700 ($3.33–$4.67) per chicken respectively. From households own slaughter and consumption in 2005 the estimated value of live local chicken and the total dressed weight (70 % of live weight) were NGN 6.17million and NGN 12.76metric tones respectively (Adene and Oguntade 2006).

Annually, family poultry or local chicks represents a significant part of the national economy as it contributes 43 and 89 % of the national egg and poultry meat production with an annual output of 67,000 metric tonnes of meat and 82,000 metric tonnes of eggs (Sonaiya 2000). These amounts to a turnover of 2,693 million Naira from a standing asset of 3,120 million Naira that the family poultry population represents. Rural poultry represent significant household savings, investment and insurance, and poultry products which are sold, contribute about 15 % of the annual financial income of poor rural households (Sonaiya 2000). Local fowl can be used as a savings account and the offspring like eggs and chicks are the interest on the savings.

Sonaiya (2000) also stated that under the present circumstances in Nigeria, research and development activities that will increase productivity of family/indigenous poultry by 10 % will contribute far more poultry products than a 10 % increase in industrial poultry which will require far more capital investment. Family poultry is an effective way of transferring wealth from the high-income urban consumers to the poor rural and peri-urban producers.

Table 14.3 The average composition of chicken manure

Composition	Fresh manure	Litter manure
Dry matter (%)	20–22	50
Nitrogen (%)	1–1.5	1–2
Phosphorus (%P_2O_5)	1–2	2
Potassium (K_2O)	0.7	1
Calcium (%CaO)	2.2	3

Source: Eekeren et al. (2004)

Indigenous or local or family poultry development has been found to be ideal for rehabilitation of refugees and victims of disasters and wars. Somali Nomads, who lost most of their cattle to droughts accepted poultry and its products as substitutes for cattle and beef respectively. Widows of the Ugandan civil war were rehabilitated by the Catholic Church of Uganda through a rural poultry programme initiated in 1987 (Sonaiya 2000).

Pest and weed Control: Local or indigenous chicken are active in controlling pests as they feed on pests like grasshopper, termites, crickets, snails, weevil, cockroach, other insects, worms (earthworms) and larvae (e.g. maggots). Scavenging local chickens are useful in weed control by grazing young grasses and other vegetation. They feed on green leaves and sieve weeded plant debris in the field in search of food (seeds, grains, insects and worms etc.); and thus assist in preventing regeneration and quick emergence of weeds after weeding especially during the rainy days or season.

Source of Manure: Excreta or droppings from local chickens or their litters which are good sources of plant and animal nutrients are obtained cheaply by farmers who may not be able to afford to purchase or access inorganic fertilizers. According to Aini (1990), 15 chickens can produce 1–1.2 kg of chicken manure per day. Chicken manure is very rich in nitrogen and other minerals, especially phosphorus, calcium and potassium (Eekeren et al. 2004). The average composition of chicken manure is as shown in Table 14.3 below. This manure is valuable fertilizer for the vegetables, fruit trees and other crops of the compound and the village. The manure can also be put into fish ponds to serve as direct food for fish or indirectly serves as food for plants which will grow to be eaten by the fish. Dried chicken manure in combination with grains and molasses can be fed to cattle or goats. The sale of fish, cattle, goats, vegetables and fruits gives the farmer another income and indirectly contributes to the village economy. Perches can be constructed for the bird to rest or sleep at night and sometimes during the day. A space is needed under the perches to catch the birds' droppings as the litter will get less moist and it is also easier to collect for use on the farm. In a mixed farming system, chicken droppings are released into the soil as chickens scavenge for feed on the farm. Local chickens are therefore an important component in an integrated farming system.

Sanitizing agents and waste converter: They also provide sanitation service by feeding on household refuse, crop waste, kitchen craps such as rice, bread, beans, yam, other foodstuffs etc., and the gleanings from gardens, fields and waste land.

They convert every left over grains into valuable protein for the owner (Aini 1990). Eekeren et al. (2004) had asserted that local chickens are more suitable to be kept around the home as they make better use of garbage than hybrid chickens. Local, indigenous, scavenging, village or rural poultry gleans the fields for grains dropped by the wayside during the processes of threshing, drying and transportation; and are known to make productive use of household leftovers into valuable protein for the owner (Sonaiya et al. 2011; Aini 1990).

Local Timing: In the ancient settlements and towns, and even in villages up till this century, indigenous chickens especially cocks serves as the clock for the inhabitants especially the farmer. The cock crow early in the morning signifies the emergence of a new dawn or day. People embarking on a long journey or going to distant farms to do important operations like planting, weeding and harvesting or transportation of farm produce to nearby or distant markets normally wake up to set out/off on hearing the cock crowing so that that they can get there on time. Thus at first cock crow, they wake up to prepare and at the second and third cock crow they embark on their journeys. In fact, cock crow is a good timer in villages and farms up till this moment or age.

Conservation of genetic germplasm: The indigenous stocks serves as reservoir for important genetic traits or genetic germplasm or gene bank which can be useful for future breeding programmes and improvements. The indigenous stocks in developing countries are disappearing and their gene pool adulterated following crossbreeding and invasion of imported stocks from developed countries. FAO (1984) therefore suggested a thorough study of the different indigenous population and conserving them, if found worthy. The indigenous birds have great potential for a meaningful genetic improvement. For instance Akinokun and Dettmers (1977), Akinokun (1990), Oluyemi (1979), Omeje and Nwosu (1983), Ibe (1990), Adebambo et al. (1999) etc. agreed in the production of locally adaptable stock from the local chicken as genetic base. Oluyemi (1986) suggested the investigation into the potentialities of indigenous birds as layers, with or without crossing with light breeds such as Leghorn as the material or product may be useful as a substitute for scarce, exotic grandparent stock.

Healing: In the ancient African world especially in Nigeria and up till this day in the rural areas or villages, the next thing after giving drugs or herbal preparations to a sick person is to make a local chicken dish for him or her to hasten recuperation from such ailment. There is the belief that local chicken is rich in nutrients that hastens blood formation and can quickly replace the lost blood cells during sickness. Local chickens are also used traditionally in making sacrifice or appease gods and spirits for quick recovery from sickness.

Research, Sport and recreation: They also play a crucial role in fundamental and applied research, and provide an enjoyable source of human entertainment and leisure time activities (Delany 2000) as evident in cock shows or displays and cock fights in the ancient world. About 150 varieties of bantams (small chicken weighing from 16 to 30 oz or 0.45–0.85 kg as adults) that are of the same breeds as the larger chickens are generally used for show and as pets in the Orients or East Asian world as dated back to about 3,000 years ago (Gillespie 1998).

Improvement on local chicken performance or production: Various researchers (Sola-Ojo and Ayorinde 2010; Afolabi 2009; Oluyemi 1974, 1978, 1979; Akinokun and Dettmers 1977; Akinokun 1990; Omeje and Nwosu 1983; Ibe 1990; Adebambo et al. 1999 etc.) have carried out various researches to improve the performance of local or indigenous chicken via breeding, nutritional, health and management studies. Thus the performance and survival ability of local chickens have been improved by supplemental feeding with grains and concentrates, feeding compounded rations or mash, administration of vaccines especially against the deadly Newcastle disease and rearing under intensive system of management in battery cages and in the deep litter. Hybrids from crosses of indigenous chicken with exotic breeds have shown superior traits over their ancestor or sires.

Gunaratne (2008) reported improvements in the performance of scavenging local or village chicken when fed commercial feed under intensive deep litter system. The weight at point of lay increased from 1,227 ± 170 to 1,600 g. Egg production at 20 weeks increased from 23 to 33 %, while the egg weight decreased from 48.0 ± 0.03 to 46.05 ± 0.04 g. Mortality also decreased from 40 to 7.7 %. Olawoyin (2006) also observed similarity ($p > 0.05$) in the Feed Conversion Ratio (FCR) and Efficiency of Feed Utilization (EFU) of the Nigerian local cockerels (0.32 ± 0.01 and 4.21 ± 0.76 respectively) and the exotic harco cockerels (0.39 ± 0.03 and 4.44 ± 0.50) in the humid tropical zone. It was also observed that the local cockerel had numerical advantages of 0.07 for FCR and 0.23 for EFU over the exotic strain meaning that they both possess similar potentials for efficiency of gain.

The performance characteristics of the Nigerian local chicken at different stages of growth reared under intensive system of management derived from series of research investigations is as shown in Table 14.4 below to substantiate the

Table 14.4 Performance characteristics of the Nigerian local chicken reared under intensive system of management

Performance characters	.Chicks (0–9 weeks old)	Grower/finisher (10–21 weeks old)	Hens (24–35 weeks old)
Weight at day old (g)	25–32	–	–
Feed intake (g/bird/day)	24.92–29.86	49.25–54.28	58.24–71.97
Weight gain (g/bird/day)	3.55–3.87	7.38–7.75	–
Final body weight (g/bird)	250.00–270.63	920.66–962.50	914.00–1,025.00
Feed conversion ratio (feed/gain)	7.00–7.69	6.58–6.91	2.63–5.56
Efficiency of feed utilization (gain/feed)	0.13–0.14	0.14–0.16	0.18–0.38
Metabolisable energy intake (kcal/bird/kg)	76.13–94.69	151.66–155.67	172.75–198.32
Protein intake (g/bird/day)	5.56–6.69	8.27–9.44	12.81–14.54
Hen-day production (%)	–	–	32.93–63.33
Egg weight (g)	–	–	29.00–45.00

Source: Afolabi et al. (2007, 2010); Afolabi (2009) potentials of local or indigenous chicken production under improved health and management system. A body weight of 914–1,025 g, 0.13–0.38 EFU, 32.93–63.33 % egg or hen-day production and 29–45 g egg weight were thus reported.

14.3 Conclusion

Local or indigenous or rural or scavenging chicken in Africa ensures food security, alleviates poverty, contributes to disease mitigation and meets the socio-cultural fulfilment towards ensuring political, economic and socio-cultural stability in Africa. It's importance cannot be under estimated and it's potentials need to be explored and harnessed.

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Chapter 15
Responding to Food Production Challenges in the Face of Global Warming at Community Level in Kenya: The Role of a Local University

Jokastah Kalungu, Walter Leal, and Moses Mwangi

Abstract Africa's population is expected to rise to 1.8 billion by 2050 (Gregory 2009). In Kenya the population was 15.3 million in 1979 and by 2009 it had grown by 23.3 million to reach 38.6 million (MOP 2009) population and housing census results. Projections indicate that the country's population will stand at 51.3 million by 2025 representing a growth rate of 1 million people per year (1.45 %) (UNFPA 2011). This increase is due to enhanced fertility rate, poverty and high illiteracy levels (Masci 2007). The population increase has already amounted to unprecedented pressure on land, environmental degradation and strained water resources. The situation has been aggravated by effects of global warming. The circumstances have made the people poorer. There is a correlation between environmental degradation and poverty (Ramshackle 2010) resulting into many poor people engaging in environmentally destructive practices which only lessens survival chances. The arid and semi arid environments are particularly vulnerable by virtue of their ecological conditions and neglect by the government development systems. This chapter analyses the role of the South Eastern University College (SEUCO), a constituent college of The University of Nairobi, Kenya in acting in response to the challenges of food production at the

J. Kalungu (✉)
School of Water Resources, Science and Technology, South Eastern University College, P.O. Box 170-90200, Kitui, Kenya

Research and Transfer Centre Applications of Life Sciences, Hamburg University of Applied Science, Lohbruegger Kirchstrasse 65, D-21033 Hamburg, Germany
e-mail: jwanzuu@yahoo.com

W. Leal
Research and Transfer Centre Applications of Life Sciences, Hamburg University of Applied Science, Lohbruegger Kirchstrasse 65, D-21033 Hamburg, Germany
e-mail: walter.leal@haw-hamburg.de

M. Mwangi
School of Water Resources, Science and Technology, South Eastern University College, P.O. Box 170-90200, Kitui, Kenya
e-mail: mnmwangi2000@yahoo.co.uk

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community level in light of global warming. The institution has made major strides in developing technologies and measures that are adaptable by local communities as well as raise community awareness and community participation in living with climate change. Knowledge on sustainable improvement in water availability through rainwater harvesting, soil and water conservation measures, harnessing the use of drought-tolerant crops and adopting crop diversification have been found to be important adaptation strategies for the people in the arid and semi-arid environments. The results of the interventions by the university in the local environment reveal a need to increase the use of emerging technologies and the enactment of appropriate policies on climate change by all stakeholders.

Keywords Global warming • Climate change • Food security • Adaptation • Local community • University

15.1 Introduction

Scientists have predicted that global warming could result in adverse effects if current warming trends continue (Rosenzweig and Iglesias 1993). This could cause severe food and water shortages for millions of people by 2100 as well as trigger melting of polar ice that could keep ocean levels rising for centuries (UN 2007). According to the IPCC (2007), the unfavourable temperatures and flooding of lands will lead to refugees fleeing in search of alternative habitable land. Sub-Saharan Africa and Asia will be the most affected since they lack the capacity to deal with negative impacts of climate change. Farmers near the equator will be most likely to suffer falling crop yields even with small temperature rises, while farmers living nearer the poles might see some immediate benefits (UN 2007).

With the existing water crisis, 1.2 billion people lack access to safe and affordable water for their domestic use (WHO 2003). The water crisis is weightier for the poorest of the poor who in addition lack access to water for production purposes thus resulting in a vicious cycle of malnutrition, poverty and ill health (Allan 1999). Moreover, an estimated reduction of cropland of between 10 and 50 % will occur due to climate change (Stevens 1989). There is also a likelihood of alteration of production of rice, wheat, corn, soybeans, and potatoes which are staple food for billions of people and major food crops in both North America and Africa (Pimentel 1993). The unprecedented production challenge is more complicated with farming systems which are complex with heterogeneous mixtures of annual plants, livestock and forests that are most likely to be affected by global warming (FAO 2010). The way forward is to confront and manage the changes while modernizing farming and food infrastructure to ensure continued growth and development.

Despite the campaign for use of environmentally friendly products like ethanol fuels, this will have devastating effects on food prices hence worsening world hunger as the boom of ethanol threatens to divert massive amounts of corn and other food crops into biofuels (Braun 2008). Food shortages have been manifested by decline in per capita food availability, malnutrition, death, poor health, civil wars and collapse of economy through food imports. In order to meet food future demands there is need for far sited international planning and investment decisions that put policies and procedures to support it across the world. However, this should be supported by local initiatives for sustainable and tangible impacts especially in rural areas. This will ensure not only more provision of diversified and nutritious food but also ensure improved food security with less environmental impacts (Runge et al. 2000).

At the community level the impacts felt include severe food and water shortages, malnutrition and in some cases, deaths (WFP 2011). These impacts are severe in rural communities based in semi-arid and arid regions compared to their counterparts in productive areas as well as in urban set ups. In the Kenya arid and semi-arid lands, this has been manifested by massive deaths of cattle and human beings in localities such as the North Eastern of Kenya. For the last 60 years, there has not been such a drought in the Horn of Africa which has sparked severe food crisis and high malnutrition rates as the 2011 one (WFP 2011). Ten districts in Kenya have been mapped as vulnerable spots (UNICEF 2011). This is a further clear manifestation of impacts of climate change in the arid and semi arid regions. This includes Eastern region which has an average annual rainfall of 500–1,050 mm with 40 % reliability (Kinga 2010). The periods falling between June to September and January to March are usually dry. In addition, the rainfall is unreliable. These rainfall characteristics make farmers vulnerable to food shortage thus relying on relief food. The food crisis is more severe for the farmers surrounding the South Eastern University College (SEUCO) as some are squatters on government land. The squatters rely on subsistence farming for a living at small sized farms. The inadequacy in production have resulted in to other destructive economic activities that include charcoal burning, brick making, selling of trees and sand from the seasonal rivers as survival strategies.

Global warming refers to the rising average temperature of earth's atmosphere and oceans and its projected continuation. In the last 100 years, Earth's average surface temperature increased by about 0.8 °C (1.4 °F) with about two thirds of this increase occurring over just the last three decades (NAP 2011). Warming of the climate system is unequivocal, and scientists are certain most of it is caused by increasing concentrations of greenhouse gases produced by human activities such as deforestation and burning fossil fuels. An increase in global temperature will cause sea level to rise and will change the amount and pattern of precipitation, and a probable expansion of subtropical deserts. Likely effects of the warming include more frequent occurrence of extreme weather events including heatwaves, droughts and heavy rainfall events, species extinctions due to shifting temperature regimes, and changes in agriculture yields. As such, warming and related changes will vary from region to region around the globe, with projections being more robust in some areas than others. With increased temperatures, the limits for human adaptation are likely to be exceeded in many parts of the world, while the limits for adaptation for natural systems would largely be exceeded throughout the world. Hence, the ecosystem services upon which human livelihoods depend would not be preserved (Warren 2011).

It is acceptable that global warming would lead to an 11 % decrease in rain fed land in developing countries and in turn a serious decline in cereal production (Kinga 2010). This has necessitated the use of emerging technologies such as precision agriculture that has proved to increase yields in low-potential areas such as the dry lands and market-marginalized areas (Fraisse et al. 1992). The precision agriculture requires specific information such as mapping the geo-referenced soil variations, the metrological data and the high-tech water application systems that can be adjusted to the specific operation tasks and accurate positioning systems (Ehsani et al. 2003).

15.2 Study Area

SEUCO is located in Lower Yatta District, Kitui County of Kenya, about 40 km from Kitui town (Fig. 15.1). The University College lies on an expansive 10,000 acres of land classified as semi arid. The area has low and unreliable rainfall. While the University land is occupied by squatters, the communities surrounding the University land are characterized by smallholder land parcels that generally depend on subsistence farming as well as charcoal burning and deforestation coupled with poor farming practices. Food insecurity is experienced throughout the year.

In normal circumstances, the communities walk on an average of some 3 km to fetch water from shallow wells and sand dams constructed by Nyumbani village in Mwita-syano and Mikuyuni seasonal rivers. However, with the current drought situation, the access to water has become a nightmare as the other sources of water are as far as 10 km from the village. The community has to walk to Kwa Vonza town to access piped water from a water kiosk which flows irregularly.

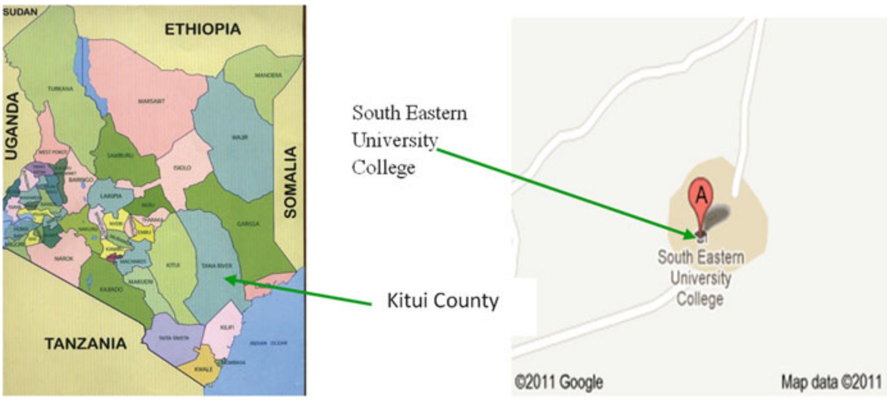

Fig. 15.1 South Eastern University College location site

Charcoal burning and poor farm practices due to lack of alternative economical activities particularly characterise the rural poor environments in Kenya. Lack of knowledge and skills have had the biggest contribution to poverty extents and trends. Reckon is taken that agricultural advisory services can play a key role in helping the largely smallholder producers to access information about crop and animal production and tap into new research, technology and market opportunities. But the extension services are in a state of crisis as a result of privatisation and structural changes in the country. Recent years have seen serious under- investment in extension, research, education and training, as publicly funded services have dwindled. All too often, state run extension services are organised on a centralised basis which does not filter out to the farmers who need them, especially in remote areas. The trend has left the small scale producers on their own, at times when they critically need guidance on how to adapt to rapidly shifting conditions such as climate change and biodiversity loss. The gender balance in the extension staff services is frequently skewed. The other problems include poor linkages with education and research, with the result that technology often fails to be generated or adapted.

Since the start of the SEUCO in 2007, numerous activities have been initiated aimed at making the semi arid region more productive in full realisation of adverse effects of climatic change and its consequences. On its part, SEUCO has established fish ponds, use of mulching systems, diversification technique in green houses and outdoor farming using drought tolerant and short duration crops. Emphasize has also been given to rainwater harvesting, earth dams, sand dams, shallow wells as well as the use of planting pits. Introduction of improved breeds, dairy goats and development of raised access to husbandry has been enhanced.

15.3 Study Methodology

The research has applied desk studies and field surveys in relation to food security in light of effects of global warming. A survey questionnaire was administered to 350 respondents between December 2010 and February 2011. The choice of respondents was based on the proximity to the University. One set of the interviews was comprised of the people living on University land as squatters. This was aimed at providing responses on practices in insecure land tenures. The second set was made of farmers on land owned by individuals in the area surrounding the university and with secure land ownerships. A comparison on the two land tenures was aimed at showing sustainability of adapted technologies and factors applying. Overall, the questionnaire sought to find out the effect of SEUCO growth and, the effects of its research and extension programmes to the surrounding environments. The data and information gathering was supplemented by transect walks and community meetings with the female and male genders for direct participatory observation in the areas of interest in the selected localities. The data was subjected to SPSS analysis to build frequencies and correlations.

15.4 Results and Discussions

Overall, the people acknowledge advent of climate change which is explained in terms of more unpredictable rainfalls, drought coupled with strong winds. The change has been most prominent in the last 15 years. It was observed that 100 % of the farmers living on the University are squatters. This makes engagement in permanent investments impossible as they have no right to the land. Ninety percent live in semi permanent building, grass thatched houses with earthen floor. The 2 % cluster with permanent buildings had the wrong assumption that they have permanent rights to the land parcels they occupy which they have had to reckon with. The squatters believe that they have contributed to the effects of climate change through engaging in unfriendly environmental activities. Compared to the neighbouring lands, the University land has less fauna. Before the establishment of the University, the community relied on subsistence farming as well as other unfriendly environmental activities so as to generate income. It was established that 55 % engaged in charcoal burning, 65 % in brick making along the Mwita-syano dry river bank, 70 % engaged in sand harvesting and 85 % engaged in poor farming practices which led to soil erosion and degradation as shown in Fig. 15.2. The farmers reported that the activities they are involved in are for survival purposes as most of them could not get tangible employment near their homes or from urban areas due to high illiteracy level. It was also observed that the higher the poverty level, the more the community engaged in land degradation activities. Households with members in employment sector engaged less in environmental destructive activities.

With the establishment of the University college, there has been a remarked change on the survival tactics of the community albeit slowly. All the households interviewed said that the emergence of the University has transformed their lives. The institution has given alternative options to the people in both social and economic terms. A populace of about 120 people is employed within University. Others practice knowledge provided by the University at the household levels to make ends meet. Fish ponds with funding from the University, National Council of Science and Technology and the Economic Stimulus Funds have been constructed. The interest of the local communities in fishing is seen by the influx of farmers to the University to acquire knowledge on the fish ponds. Though the technique has not picked up within the communities, largely due to funds problems and water inadequacy, efforts are going on to assist people living in the surrounding communities. There are demands for knowledge on fishing with a view to poverty alleviation and food security. Of keen note is of the fact that the relevant government departments are getting attracted to offer extension services.

The University has made it its mandate to contribute towards transforming the arid lands to green. With this, it has embarked on a massive activity on tree planting within the University involving both the staff and the surrounding communities. In the process, it has planted 1,500 tree seedlings with appropriate holes to harvest rainwater and pests control measures that are appropriate to the local environment.

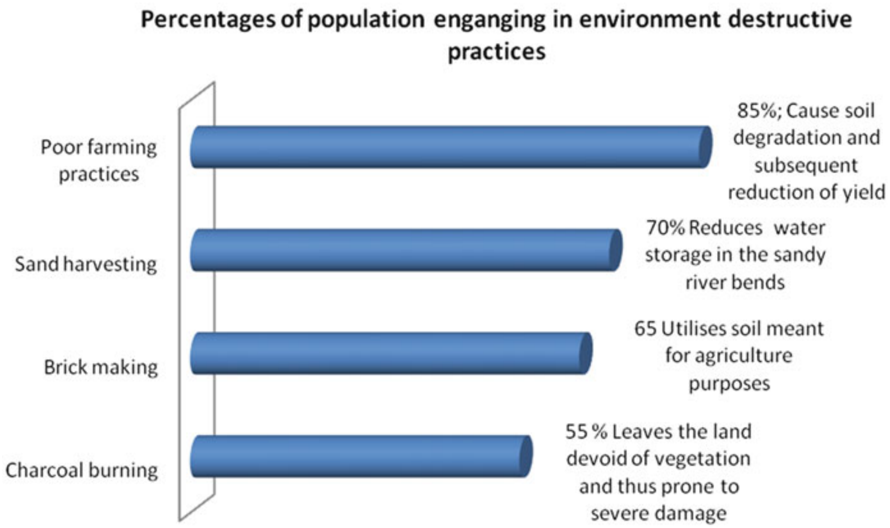

Fig. 15.2 Percentages of population engaged in different activities

The University has established the various tree nurseries where the local communities can access trees seedlings at a fee. Encouraging the local people to plant trees is becoming an important undertaking of the University College. Among the 350 households interviewed, 70 % have started planting fruit and aesthetic trees in their compound and farms as a way of diversifying their food production, source of wood fuel and for income generation purposes. Among the fruit trees adopted are grafted mangoes and pawpaw. This activity is supplemented by use of mulching system around the trees and farm land as well as recycling kitchen water for watering the trees since the area is hard hit by water crisis. Mostly the farmers are using grass from the bush while others use maize stalks for mulching. It has been proven that mulches can save soil water from evaporation by up to 50 % (Yi et al. 2010).

The University has roof water, sand dams and is in the process of developing rock water catchment harvesting technologies. While the appropriate roofwater harvesting techniques have been picked up by all the surrounding communities, the other technologies adoption are threatened by the land tenure problems. All the squatters on university cannot develop sand or rock catchments for lack of tenure security. In 92 % of the responses in the land-secure tenures in the surrounding environment, sand dams and rock catchments adoption and application are thwarted by the economic reasons. Lacks of access to common resources such as the seasonal rivers are sighted by 58 % of the respondents' impediments to developing sand and rock catchments. Seventy-three percent of respondents have adopted to growing of crops with can irrigation along the seasonal rivers which has raised food security and incomes at the household levels.

15.4.1 Influence of the University to the Local Community

The presence of the University has led to food security, improved diet, income generation as well as employment. More influence of SEUCO will be seen in the coming days. In its new 10 years strategic plan, the University has deliberately included the community component that will see partnerships between the University and the communities in the region. Through this arrangement, the institution will be able to look for solutions towards existing problems for both social and economic development.

Notably, since the inception of the University, it has been able to build an influence on sustainable land uses to rhyme with climate change. A driving force has been the known fact that the harmful outcomes of climate change will probably increase the gap in wealth, access to food, and health between the rich and the poor. SEUCO reckons that everyone has the responsibility of avoiding any activity or practice that will prejudice environment in the long term. It is only by this conscience that a combination of global policies as well as local initiatives can have a positive effect thus ensuring a safe future for the coming generation in terms of food production and water availability.

The research established that SEUCO's presence and proactive engagement with the local community has contributed towards reduction of poverty. Thirty percent of the households interviewed have accessed employments as casual or temporary workers which have raised their incomes. This has made the households engage less in the destructive and environmental activities such as charcoal burning and cutting trees to sell firewood. 0.1 % indicates that the university growth has encouraged them to have their children access advanced education to access employments and raise their living standards and food security. Among the 30 % who have accessed employment as casual workers, 18 % are women who are mostly employed as casuals in activities such as trimming grass, cleaning, manual labour or as cleaners. The low percentage of men being employed at the University is explained in terms of outward migration in search of employment and engagement in drinking of illicit brews.

Among the farmers, women comprise 59 % of the farmers adopting food security techniques from the University especially the low cost ones. These include mulching, change from maize planting to sorghum crop, use of planting pits as well as harvesting of surface runoff to their small sized farms. With extension services rendered by the University, the local community is ready to combat and contribute to the counteracting effect of climate change. The university college is planning to set a station for reference on sustainable agriculture practices made available through geographical information systems which can provide emergency plans, calculate emergency response in the event of a natural disaster like flooding, rescue of victims at unbearable habitable regions or determine when drought is most extensive in a particular region. It will also be useful in the management and sharing of data across the world. The University College has also devised rainwater harvesting courses on the technology which it plans to pass on to the people in the region. It plans to set up a course on early warning systems that will assist the local people on drought preparedness. The University College is in the process of applying biotechnology in food security and downloading it to users. If fully implemented, biotechnology will reduce farmers' production costs and boost yields without changing the commodity (Bongaarts 1996).

15.5 Conclusions and Recommendations

Universities have a major role to play both as knowledge centres and as community mobilisers for proactive actions to play rightful roles as agents of change. This can be enhanced more effectively through wider reach of local communities by identifying focal points that can replicate innovations. It should further conduct training needs analyses so that they can address the other felt needs by community in an integrated way. The institutions need lobby and advocate for stronger linkage of farmers with the government and institutions that can support them in adapting to global warming. With the enactment of law and policy for enactment of county government in Kenya and, the setting up of local Universities in each County, there can be food production increase and diversification within the 47 counties. A message from this study is that local initiatives need be supplemented with external interventions for significant outputs. Appreciation of initiatives from local universities, Non Governmental organizations and all other stakeholders need to be appropriated and appreciated. For the rural arid lands, cost-effective carbon sequestration on farms and in forests is an important undertaking. What is clear is that this cannot be accomplished by any single agency but linkages at various levels through the use of defined policies. This collaboration and international links may solve problems of many complex agricultural issues by providing new knowledge especially those related to present global climatic changes, provide agricultural innovation and help in distribution of food and health care in disaster stricken countries facing food shortages. Modern agriculture requires many agencies working together and sharing diverse human and physical resources to create sustainable food supply chains, which are environmentally, socially and economically sustainable in the long term (FAO 2004). Promoting global partnership for agricultural development will require recognition of the need to base these partnerships on good governance structures and practices. The real risk for investment in developing countries is in the arbitrary behaviour that flows from weak institutions and systems. If scarce resources are diverted from this task, offering guarantees will be akin to pushing on a string.

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Part IV
Enhancing Food Security by Innovation: Selected Successful Practices

Chapter 16
Food Security in Knowledge-Based Economy: Role of Trans-national Seed Corporations

Sangeetha Parthasarathi

Abstract Increasing preference is given for technologically mediated solutions to solve developmental issues, such as hunger and scarcity of food. A classic example of this kind is the introduction of 'Green Revolution' in the early 1960s. To increase global food supply in order to feed the growing population has been a dominant policy discourse ever since but the emerging controversies over agricultural biotechnology and genetically modified Foods show how this remains a key issue. Is intensified 'production at all costs', a sustainable and viable method/solution to attain global food security? The following chapter is an attempt to present debates around food security in general, and linkages between agricultural biotechnology, intellectual property rights and trans-national seed corporations and implications to food security. Two concurrent trajectories mould this chapter. First, it conceptualizes food security with an elementary approach: from the perspective of SEED. Seeds are knowledge intensive goods with direct linkages to food entitlements at all levels of the socio-economic sphere. Second, the chapter seeks to contextualize food security in an expanding 'knowledge-based economy'. A knowledge-based economy is understood as production and services based on knowledge and technology-intensive activities that contribute to an accelerated pace of production and economic growth. Biotechnology for example is seen as an arena where knowledge is effectively turned into capital. Commodification[1] of genetic modified seeds on a global scale reveals that seeds are regarded as private property, which can be bought and sold especially by trans-national seed corporations, contrasting traditional ways of seed saving and farming methods. Simultaneously, internationalization of the Patency regime has set rules on the ownership, control and usage of seeds. Biotechnology research is resource intensive; hence most of the breakthroughs lie in the private sector. The Intellectual

[1] The process of turning into a commodity: commercialization.

S. Parthasarathi (✉)
Global and European Studies Institute, University of Leipzig, Leipzig, Germany
e-mail: parthasa@rz.uni-leipzig.de

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property Rights over transgenic seeds transfer full control of seeds over to the corporations. Farmers having to pay royalty or 'monopoly rents' in exchange of replanting seeds, to corporations signifies that these rules not only protect innovation and determine the 'who' but also the 'terms' of usage and control. This phenomenon has alterations on the entire chain of food: from mode of farming, production, nutrition, distribution to sale of food, which are all significant elements contributing to a general wellbeing and food secure situation. At this point a very fundamental question arises: Is Knowledge capital embedded in the current international proprietary framework a driver for 'sustainable' development in agriculture and food security? As a way of conclusion, the chapter with aid of statistics and graphics presents a potential and possible future scenario of a monopolized global food market, where due to extensive consolidation processes in the private sector, monopoly power can come into play with total control over the food chain and food prices.

Keywords Food security • Seed • Corporations • Sustainable • Intellectual property rights • Knowledge • Economy

16.1 Introduction

16.1.1 Food Security: A Debate in Transformation

"The power of population is indefinitely greater than the power in the earth to produce subsistence for man. Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio. A slight acquaintance with numbers will shew the immensity of the first power in comparison of the second by that law of our nature which makes food necessary to the life of man, the effects of these two unequal powers must be kept equal. This implies a strong and constantly operating check on population from the difficulty of subsistence. This difficulty must fall somewhere and must necessarily be severely felt by a large portion of mankind" (Malthus 1798).

Talking about the dangers of population growth, Malthus posited a theory as a causal process for famines in general: a constant decline and eventual scarcity in food availability due to over population (Malthus 1798). Malthusian optimism (Dreze and Sen 2007) as it is termed is the observation that, if there is surplus of food, meaning if food production is either equal to or more than the population or the rate of food production is either equal to or faster than the growth of population, then there shall be no food insecurity. The Malthusian 'optimism' refers to the dichotomist perspective of preventing famines by way of producing food in abundance. Another argument in relation to famines put forth by David Ricardo: in a situation of 'superabundance', a famine cannot occur. The approach towards understanding famines and causes of food insecure situation was dominated by the discourse of producing abundant food on a global scale. A classic example of such a discourse translated into an international policy discourse is the Green Revolution of the 1960s introduced in many parts of Asia and Latin America. The term 'Green' referred to the agrarian sector while 'Revolution' was to imply a drastic change in growing food crops and producing food, using intense industrial and technology based means and solutions (Gaud 1968). The post years of the Green Revolution (GR) opened up a series of socio-economic-ecological issues and controversies. The GR was inherently capital intensive and favoured rich farmers with large landholdings resulting in enhancing the class differences in the country side (Yapa 1977). On the other hand, the GR was water intensive and detrimental to soil nutrition as it relied heavily on chemicals. The biggest success of the GR is however the desired increase in crop production. What can be noted from this example is that an international agriculture development program such as the GR had a single dimension of focus which was to multiply agricultural output. The local agrarian realities[2] were however, not considered and hence the side effects are not included in the mainstream narratives around the Green Revolution.[3] However, the Food Availability Decline (FDA) hypothesis was dominant until early 1980s. World Bank report of 1986 included, for the first time, the element of nutritious food while describing individual wellbeing, thereby broadening the dimensions of understanding food-insecurity. By 1996, another dimension of food 'accessibility' was established in synergy with food 'availability' to combat food-insecure situations. 'Accessibility' was explained in terms of food 'distribution' at a larger level and at the individual level as the 'economic' capability of procuring food (FAO 1996). Eclectic debates around agricultural development and food security have surfaced since the GR and the controversies which it resulted. 'Sustainability' was introduced in debates around agriculture production. Sustainable agriculture production called for a more 'pro farmer' approach which integrated traditional and indigenous knowledge of cultivation with small scale organic farming methods. A 'production at all costs' approach was heavily criticized from an environment protection perspective (Scoones 2002). Minimizing chemical based agriculture and subsidizing organic farming methods was announced to be the way towards renewable agriculture. However the biggest criticism to this approach based on the FDA hypothesis, was simply, 'Is this enough? Can such methods of farming produce enough to feed the world?' (Scoones 2002) Perspective of 'Trade' was applied to agriculture development. It was argued that importing cheap food while growing higher value commodities for the external market had better consequences in preventing food insecurity. Import substitution methods for agriculture sector were criticized and growing cash crops for export was advocated profusely. This perspective gained momentum and culminated in increased trade liberalization in the late 1980s.[4] On the one hand economic benefits at the national level can be

[2] Unequal Land distribution and Feudal character of agrarian society.

[3] For example India and many other countries give high credit to the Green Revolution and owe it to preventing famines.

[4] Uruguay Round of trade talks between 1986 and 1994 within the framework of General Agreement on Tariffs and Trade in Punta Del Este, Uruguay.

enhanced if a country utilizes its comparative advantages over others, the pitfalls of export driven and dependent economies are strong. Long term availability of cheap food is questioned. For example due to higher transportation costs on food imports, consumers might have to pay higher prices. Sudden changes in the international market over food preference could decrease the demand over a certain commodity affecting the country producing it extensively. This happens under situations of alternative choices: like root sugar over cane sugar. Also, the assumption of "efficient markets" facilitate efficient distribution is challengeable. Another insight into deconstructing causes for food-insecurity is the 'livelihoods approach'. Food-insecurity was no longer seen as a failure of agriculture to produce sufficient food at the national-international level, but instead a failure of livelihoods to generate stable access to sufficient food at a household/individual level. Food availability and accessibility were considered to be one part of the equation. Holistic rural dynamics have to be included to ensure food security in the poorest of places (Scoones 2002).

The discussion above points out to Food-in/security enmeshed in a macro, mesa and micro narratives weaved over time. This debate in its entirety was, if not deconstructed but definitely challenged by a mega narrative via the 'entitlements approach' (Sen 1982) In describing the entitlements approach, Amartya Sen argues that food supply and accessibility are however major influence factors of a famine developing but what is not considered is the food 'acquirement'. It is not merely about not having enough food to eat or not having enough food to go around, rather of people having or not having enough command over food. The command over food is based on 'endowment',[5] 'entitlement mapping'[6] and 'entitlements'[7] (Sen 1982). Sen draws upon the great Bengal famine example amongst others to support his argument, that cause of famine was not due to decline of food availability, rather due to decline in food entitlements. Sen pointed out that famines can even occur in booming economic and 'abundance' conditions as well. "Economic disparities might lead to a large section of the population losing its command over food because of the worsening of their relative position vis-à-vis the groups favored by the boom" (Dreze and Sen 2007).

The above discussion is an attempt to conceive a brief historical debate around the question of food-insecurity. The changing understandings and approaches evolved through time, place the issue in perspective and oblige a question to be asked: what is the current narrative around preventing hunger and food-insecurity?

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[5] Endowment: A combination of all resources legally owned by a person, both tangible and intangible assets like land, animals, equipments and knowledge, skill, labor power, membership in a community respectively.

[6] Entitlement mapping: Relationship between endowment set and entitlement set. Basically indicates the rates at which the resources of the endowment set can be converted into goods and services included in the entitlement set: fall in wages, loss of employment, and rise in food prices.

[7] Entitlement: A combination of goods and services that a person can legally obtain by using the resources from his/her endowment set.

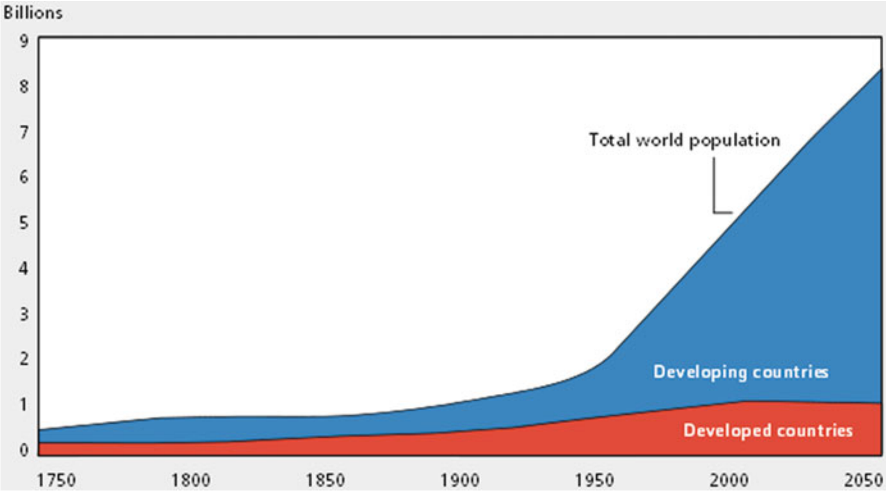

Fig. 16.1 World population development. Source: http://www.worldbank.org/depweb/beyond/beyondco/beg_03.pdf

The question diverts attention back to the population issue highlighted by Malthus. There has been a series of reports and studies about population growth over the past decade. Numbers and charts indicating a rapid, almost alarming growth rates are published. The web-pages of FAO and WB announce in big bold letters, how to feed the world in 2050 (fao.org). These projections indicate that developing countries especially India and China are major contributors to accelerated population growth (Fig. 16.1).

Malthusian prophecy of unchecked population culminating in a doom seems to be coming back. Current mainstream discourse is dominated by the Food Availability Decline hypothesis and recommends persuasively large scale food production as a solution in preventing future famines.

A question which strikes out at this point is a methodological one: – To neglect any part of the 'macro-meso-micro-mega' narrative means asymmetric and undesired impacts. An integrated perspective approach is required. Denying any one of the perspectives is to romanticize the question of food security.

The next part of this chapter looks upon a more contemporary solution seeking trajectory. There has been increasing preference towards knowledge based-technologically mediated solutions to solve hunger and prevent famines. The section attempts to not only discuss this trajectory but also analyze the impacts of such a phenomenon.

16.1.2 The Green Revolution Revisited

When discussing the intervention of technology in agriculture sector, the Green Revolution comes back in the picture. The GR is probably the earliest and the most dominant policy narrative (Scoones 2002) associated strongly with the benefits of realizing such a method.

The Rockefeller foundation and Ford foundation together focused research in upgrading agriculture techniques: especially at the ‘seed’ level. New varieties of cross bred Wheat seeds were produced and first planted in Mexico. In 1962, an International Rice Research Institute was established in the Philippines with a focus on producing new varieties of Rice seeds. Simultaneously the foundation pressed the issue of intense population growth to the governments and thereby creating a necessity to grow Rice much faster than traditional means and hence increase Rice production. The new varieties depended heavily on chemical fertilizers and pesticides. A ‘fertilizer supply project’ was set up from the Agency for International Development (A.I.D). As part of the project either direct loan were provided to countries involved in the GR or fertilizers and pesticides were supplied on a loan basis. $60million was to be allotted to Pakistan in 1969 just for the purpose of buying fertilizers. $200million worth fertilizers and related raw materials on loan basis was to be offered to India in 1969. The GR technology in conjunction with A.I.D’s projects was extended to major parts of Asia and Central America. In order to gain the ‘trust’ of the farmers to plant new seeds and to buy expensive fertilizers and chemicals for an unknown effect and result, the foundations worked closely with the national governments. Community based groups would go into villages and households and demonstrate the project. In the Philippines for example, the A.I.D designed a “Do It Yourself” Rice kit for farmers. As a persuasion strategy, the first 100kits were financed by the A.I.D. More than 20,000 were sold soon after (Gaud 1968).

The post GR period saw great distress cropping up from almost all parts of the developing world. Ecologists pointed out to the negative effects on soil nutrition and depleting water tables due to thirsty ‘miracle seeds’, threat to biodiversity due to mono-cropping (Shiva 1997). A growing alliance of peasants, activists, researchers voiced out harsh criticisms. The criticisms circled mainly around persisting ‘colonial’ and ‘exploitative’ tendencies also towards nature: ‘Telling the farmers and the governments of the poor world, what to do and to have found a viable market for post World War II technologies and research by extending it to agriculture especially indirectly via the sale of agricultural inputs like seeds, equipments, chemicals, fertilizers (Shiva 1991).

16.1.3 Concluding Remarks

The Green Revolution throws out two trajectories with respect to agriculture development: (1) A dichotomist ‘practical’ solution to prevent hunger and famines and (2) the first steps towards drawing solutions from intense Research and Technological innovations: Shift from traditional knowledge and conventional methods of farming and growing food towards more industrial, scientific- knowledge based methods.

The following part of this chapter brings about new implications to food security by discussing genetic modification of seeds and Intellectual Property Rights.

16.2 Biotechnology – Knowledge-Based Economy

The application of bio-technology to agriculture is not a new phenomenon. Tissue culture was long used as a low technology method to increase productivity. Biotechnology is not a new stream in science either. Biotechnology can be talked about in various forms like 'traditional technology' like brewing beer and bread making, Louis Pasteur's Production of antibiotics, tissue culture, modern plant and animal breeding to the more contemporary, sophisticated, 'new biotechnologies' which implies various genetic engineering techniques for transferring DNA from one life-form to another to make transgenic organisms which might possess new and desired traits (Scoones 2002). An important point to mention here is that research and development of applications in the contemporary new biotechnology is generally capital intensive/extensive and therefore most of the Research and Development (R&D) stays with the private sector. Since the liberalization of agriculture sector and institutionalizing of patency in the international trade regime at the World Trade Organization- Uruguay round[8] under the section of Trade Related Intellectual Property Rights (TRIP), there has been a rapid increase in the concentration of trans-national Corporation in the agribusiness sector. Using genetic engineering, miracle seeds and the infamously known 'terminator seeds' (Mooney 1979)[9] have been engineered by the corporations. Since genetic modification of seed gives rise to an altered form of seed, it falls under the category of new invention. Intellectual Property Rights is a legal protection framework under Patent Law, granted to the owner of a creation or innovation. In which the owner is granted a limited monopoly for a fixed duration of time. The rights exclude others from making, using, selling and offering for sale (O'Donnell et al. 2008). Since a terminator seed, for example was genetically engineered by an agri-business corporation, the corporation now has complete ownership over the seed. "IPR provides the IP holder with the possibility of charging monopoly rents over the invention that not only compensates for inventing and developing the invention but that allows him or her to profit" (Richard Gold et al. 2007). Farmers could no longer 'save' their seeds or 'replant' saved seeds and neither 'exchange' seeds.

Diverse debates have surfaced regarding impacts of Genetic modified seeds. Fears regarding hidden health risks from consuming gene modified food and polluting nature with heavy chemicals. From the dimension of Patency it is argued

[8] Uruguay Round of trade talks between 1986 and 1994 within the framework of General Agreement on Tariffs and Trade in Punta Del Este, Uruguay.

[9] Coined by activist Pat Mooney in a report: Seeds of the Earth, 1979. Plants growing out of terminator seeds yield sterile seeds.

that the entire concept of growing patented GM crops is based on: (1) reductionist science ideology which stops farmers from saving seeds (2) thereby creates closures and monoculture by destroying seed diversity and (3) Exploits indigenous and traditional knowledge.

16.2.1 Concluding Remarks

Seeds are not only the first links and basic building blocks in the food chain. Seeds indicate food security. Moreover, Seeds symbolize ‘knowledge’. Farmers have carried out natural pollination methods and have bred multiple varieties of Rice, Corn etc. This knowledge has been ‘transferred’ over generations and farmers today have inherited it from their ancestors. In this perspective, knowledge about farming and its application is a ‘public’ good. The Intellectual Property Rights stands in contrast to the notion of public good. Intellectual Property Rights works on the principles of exclusion and constructs individual/group ownerships. In this perspective, ‘knowledge’ is seen as a commodity with immense economic value and profit.

With the Intellectual Property Rights framework in action, a fundamental shift and transfer of seed sovereignty – ownership has taken place which has given rise to structural imbalances in agriculture and unequal and limited distribution of production power and wealth to the farmers. The impacts of imposing conflicting ideologies on each other are evident. The important question to be asked is not simply of: Is it necessary to have genetic modified seeds and therefore food? Or: Should life forms be even patented? But more so a question arises as a consequence of acknowledging the elementary differences in the two knowledge systems of producing food: Should there even be attempts of interference between the two systems?

Seeds can indeed be altered but should Intellectual Property Rights be applied to seeds? By definition, IPR is applicable to a product of the intellect and clearly the Seed is a product of nature: Are Seeds a Public good or Private Property?

16.3 Trade, Agriculture and Food Security: Emergence of New Actors in Agriculture and Implications to Food Security

With relevance to the chapter, this section provides a brief historical overview of major developments in agriculture which heralded new (international) actors in the sector, their implications to food security and the essential restructuring of social and ecological relations.

Based on the premise of comparative advantage put forth by the economist David Ricardo[10] international trade was perceived as a viable tool for economic development. Reduced policy distortions and market failures was believed to pave way to more efficient allocation of resources and more sustainable patterns of production. Discourses were constructed to link trade with environment, sustainable development and food security. Agriculture trade was argued and advocated a key to attain food security. The agriculture trade fact sheet released in 1999 reads: "It augments domestic supplies to meet consumption needs; reduces supply variability; fosters economic growth; permits global production to take place in those regions most suited to it" (WTO Agricultural Trade Fact Sheet 1999). In 1944, a Bretton Woods Conference resulted in the need for an International Trade Organization to have a rule based international trading system. Succeeding a series of rounds the General Agreement on Tariffs and Trade- GATT[11] came into being instead.

16.3.1 The Uruguay Round[12] of GATT: A Critical Juncture for Agriculture and New Implications to Food Security

"It took seven and a half years, almost twice the original schedule. By the end, 123 countries were taking part. It covered almost all trade, from toothbrushes to pleasure boats, from banking to telecommunications, from the genes of wild rice to AIDS treatments. It was quite simply the largest trade negotiation ever, and most probably the largest negotiation of any kind in history." (wto.org)

The Uruguay round of GATT is important because the trading system and most trade agreements of today are based on the structure, rules and agreements finalized during the Uruguay round.

Two important reasons placed agriculture at its critical phase which paved in dramatic transformations in the sector especially in the non-industrialized countries or the so called developing countries. (1) Comprehensive liberalization reforms for the first time were applied to agriculture and (2) Trade Related Intellectual Property rights were formalized and extended to agriculture.

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[10] 1772–1823 proponent of free trade and most known for his law of comparative advantage. Basic premise of comparative advantage is that countries can gain by specializing in the good where it has comparative advantage and trading that good for the other.

[11] GATT part of the international monetary system was created at the end of second world war and lasted until it became the World Trade Organization in 1995.

[12] September 1986, in Punta del Este-Uruguay talks were launched to extend the trading system multi laterally touching several new areas prominently intellectual property, trade in services, reforming sensitive sectors of agriculture and textiles. The talks ended in April 1994. GATT was replaced by the World Trade Organization.

16.3.2 Comprehensive Liberalization Reforms

Prior to the Uruguay round of General Agreements on Tariffs and Trade, agriculture enjoyed a special status. Trade rules were applicable to manufactured and industrial products where as for agriculture; countries could offer subsidies or use other forms of non-tariff measures. This aspect was perceived as a distortion towards effective international trade. Agriculture was for the first time formally introduced in multilateral agreements which then underwent comprehensive reform process (wto.org). The agriculture sector was perceived to be a viable tool for economic growth via the means of a well sketched out trade rules. The key word was ‘liberalization’. All barriers to successful agriculture trade had to be phased out. Domestic support and protection of internal markets, subsidies required to be cut down and eventually phased out within a set time period. Countries were asked to pursue domestic policies in favour of international markets for example growing cash crops of demand and favour free trade. To improve conditions for maximum market access there should be: less protectionism, reduced tariffs, impose import food requirement and reduce export subsidies. The following table offers numerical details on this matter (Table 16.1).

Most parts of the non-industrialized world thrive on agriculture for sustenance and contribution to national economy. With less than two hectares of land holdings small farmers and landless peasants form the majority in most parts of the non industrialized world. Nations states like India where agricultural policies have been pursued with a motive of national self sufficiency, the agrarian sector has been in distress due to structural adjustments as a result of the GATT. Companies like Pepsico, Cargill and Monsanto created channels for capital flow in Indian agriculture especially in the realm of biotechnology research and harvesting biogenetic resources. The national policies pertaining to seeds, agriculture exports, growing cash crops underwent major changes to match with the “discipline” of the international market rules. These changes needless to say only strengthened the roofs of uncertainty over the agrarian sector. A side effect was the increase in agrarian populism in the country side. Populist farmer groups split into factions, either supporting the free market ideology by mobilizing farmers to participate affirmatively in the developments or to oppose and show dissent in the name of nationalism (Gupta 1998).

16.3.3 Trade Related Intellectual Property Rights

“The completion of the most recent round of GATT negotiations is significant for many reasons, not least because “TRIPS” (Trade Related Intellectual Property Rights) – such as patents, copyrights, trademarks, trade secrets – have been accepted as an area to which internationally-recognized rules and disciplines apply. Protection and enforcement of these rights are critical to many global

Table 16.1 Numerical targets for cutting subsidies and protection in agriculture agreed in the Uruguay Round

	Developed countries (%)	Developing countries (%)
Tariffs		
Average cut for all	–36	–24
Agricultural products		
Minimum cut per product	–15	–10
Domestic support		
Cuts in total "AMS"	–20	–13
Support for the sector		
Exports		
Value of subsidies	–36	–24
Subsidized quantities	–21	–14

WTO Agricultural Negotiations. The issues, and where we are now, December 2004: http://www.wto.org/english/tratop_e/agric_e/agnegs_bkgrnd_e.pdf
AMS aggregate measurement of support

industries, including research based pharmaceuticals, whose livelihood and ability to contribute to the world depend upon innovation" (Pratt 1996).

In 1986, 6 months before the Uruguay round commenced, an Intellectual Property Committee (IPC) was formed. It consisted of 12 chief executive officers from U.S based firms: Bristol-Meyers, CBS, Du Pont, General Electric, General Motors, Hewlett-Packard, IBM, Johnson & Johnson, Merck, Monsanto, and Pfizer. The purpose of the IPC was to develop an IPR framework (patents, copyrights, trademarks and trade secrets) and gather international support for it. Backed by their associates in Europe and Japan, the drafted proposal was put forth in the GATT-Uruguay round which later came to be the Trade Related Intellectual Property Rights (Sell 1999).

Knowledge and ideas were considered to be a vital part of international trade. By definition, "Intellectual property rights are the rights given to persons over the creations of their minds. They usually give the creator an exclusive right over the use of his/her creation for a certain period of time" (wto.org). Creators are given rights to prevent others from using their inventions, designs or other creations and to use that right to negotiate payment in return for others using them.

Apart from Trademarks, copyrights, trade secrets etc. falling under the purview of TRIPS, the clause on Patency is of interest in this paper. According to the agreement Patency should be grated for inventions for at least 20 years subject to renewal. Patent protection must be available for both products and processes, in almost all fields of technology provided that they are novel and have capabilities of industrial application. In addition, patents should be available and patents rights enjoyable without discrimination as to the place of invention, the field of technology and whether products are imported or locally produced (wto.org).

The consequences of such a mandate would on the one hand offer protection to the producers but not necessarily to the rest involved in the societal chain. The producers in this case would be resource intense large firms, trans-national corporations who possess the know-how and advanced scientific capabilities to have novel 'creations' with varied industrial applications. This is where bio-technology gets its heightened recognition as a tool for capital advancements.

Biological matter became raw materials to produce something unique. The new produce or 'creation' is eligible for patent protection. Usage and application of Biotechnology lays in the hands of a privileged few corporations in the private sector: BASF, Monsanto etc. This obviously leads to a threat of monopoly creation, price exacerbation and devastating results on crucial essentials like some life saving drugs/medicines.

The entire IPR framework favours the industry. According to Susan K. Sell, noted author on the subject of TRIPS, "the industry identified a trade problem, devised a solution, made a concrete proposal, advanced it to the governments for agreement which now enjoys the status of public international law" (Sell 1999).

The other consequence would be mainly to the parts of non-industrialized/industrializing world where there is no well-established patent system and governing laws falling in lines with the TRIPS standards. This posed a restriction on those countries to impose subject matter exclusions that many European countries had in their patent laws such as on pharmaceuticals and food products. For example, France only allowed pharmaceuticals to be patented from 1960, Ireland from 1964, Germany from 1968, Japan from 1976, Switzerland from 1977, Italy and Sweden both from 1978 and Spain from as late as 1992 (Bellman et al. 2003).

The Uruguay round of trade negotiations and agreements has been extremely controversial from the start. Debates around the necessity and credibility of the IPR framework have surfaced from multiple standpoints. Critics enunciate that currently contoured IPRs have devastating effects: for example with higher prices on essential drugs; availability of educational materials for developing country schools and university students; legitimizing the piracy of knowledge and undermining self sustenance of small and resource poor farmers. Apologists argue that effective usage of the IPR which remains in the purview of the states and government institutions can bring benefits to all countries.

The article 27.3(b) of the Uruguay round agreement pertains to exceptions in patentability in the area of biotechnology and plant breeding. According to this subparagraph: "Members may exclude plants and animals other than micro-organisms and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes. However, any country excluding plant varieties from patent protection must provide an effective sui generis system of protection" (wto.org).

This basically means that plants and animals can be excluded from being patented but patents must be provided on micro-organisms and microbiological processes for producing plants or animals; for example the genes of a seed would be considered products necessary to create alterations at the microbial level so as to enhance the robustness/qualities of a given crop and its qualities and hence needs to be patented. Countries which exclude patenting plant varieties are however, obliged to offer some form of protection system. This could either be on the guidelines of

UPOV- International Union for the Protection of New Varieties of Plants or a unique alternate system needs to be devised.

The evident challenge resulting from this especially for non-industrialized countries which did not have an effective patent system or a system in lines with the TRIPS framework, now had to integrate development policies in crucial areas of health, food security, education etc. into IPR policies. At this point critics point out that costs incurring from administration, enforcement of such a complex system catering aspects of patents, trademarks, copyrights, designs etc. outweigh the benefits of the IPR system (Bellman et al. 2003).

As the industry was involved in formulating the TRIPS, it is obvious that the successful completion of the GATT negotiations paved in the entry of numerous corporations to expand purview into and explore new international markets and especially into the agriculture sector. Corporations like Sygenta, Limagrain, DuPont, and Cargill were traditionally chemical and pharmaceutical companies, nothing remotely to do with agriculture. The chemical and pharmaceutical firms were producing large quantities of chemicals and chemical based applications: for example the notorious defoliate, ‘Agent Orange’ used by the US army during the Vietnam war is a product of Monsanto which was one of the largest chemical producing company. Fifty percent of Agent Orange composition is 2, 4, 5-T which Monsanto used in its leading herbicide called Roundup. The herbicide was first tested on crops of soya bean in the United States of America. The Roundup herbicide is a toxin which should do no harm to the actual soya bean crops but kill only the weeds. How would the Roundup herbicide which is purely a chemical product be able to recognize what to harm and what to let live? The answer lay in bio-technology. Soya bean seeds were genetically altered with a gene obtained from a bacterium. The gene produced a protein which showed resistance to the Roundup substance. Therefore when sprayed around the fields of soya bean crop, only the weeds were affected. In addition to Soy, Roundup ready Corn was introduced in parts of the USA. Sales of Roundup ready Corn, Soy seeds and the herbicide: brilliant product of unknown consequences rose rapidly. First quarter of 2008, Monsanto made a profit of 1billion USD just by the sales of Roundup herbicide in Latin America (Monsanto.com). Least to mention this application underwent a heavy controversy. According to Vandana Shiva, environmentalist and prominent scholar on the issue of bio technology-Genetic modified agriculture and its societal implications: weeds contribute to bio-diversity. They are part of a symbiotic relationship within their eco-system contributing significantly to bio-diversity and hence wellbeing of the crop. The farmers who used the Roundup could do away with the weeds much easily and save time. It also meant that the farmers had to not only buy the herbicide from Monsanto but also the herbicide tolerant soya bean seeds from Monsanto. Monsanto, on the other hand by producing and selling the herbicide created a necessity for GM soy bean seeds. It was able to expand its market share and profits. The technology and knowledge behind the Roundup and GM soy bean is brilliant and a mark of advancement but the point of contention here is its application, regulation, use and misuse. The soya bean has been infused with immunity towards Roundup but what about the rest of the environment? How about the effects on soil, air, water, birds, animals, humans? Would they all need to be infused with the resistant as well? The story of the roundup continues. Over time and regular usage of the herbicide, the weeds developed immunity towards Roundup. 'Superweeds' (guardian.co.uk) was how it came to be known as they spread across rapidly through the fields. A solution to stop the superweeds and put an end to it could not be devised overnight! "Since the scientific and industrial revolution, technology and economics have mutually reinforced the assumption that nature's limits must be broken for the creation of abundance" (Shiva 2010).

Traditionally manufactured and industrial goods had the status of most economic value and return. Given the raw materials and certain degree of infrastructure necessary for production and storage, desired goods are manufactured in a quantity and quality of desire. They can be stored and transported long distance with lesser risks. Agriculture and farm production on the other hand depended on a lot of external factors like climate and weather conditions, rain, diseases and pest attack thereby making it highly unpredictable. Agriculture was time consuming and relied on crude methods for cultivation. Due to the perishability of food products, not all what was produced could be traded long distance (Mann and Dickinson 1978). Moreover, agriculture was taking place on a small scale with most peasants and farmers having small landholdings aiming for self-sustenance. These factors posed restrictions to the capitalist logic of accumulation (Kautsky 1988). The sphere of agriculture posed risks to seek profit. The limits and hurdles had to be stretched and overcome by restructuring agriculture towards a factory model (Goodman et al. 1987). The restructuring process was fuelled by the application of post world war two technologies indirectly to agriculture. The sale of agricultural inputs like herbicides, pesticides, fertilizers, enhanced hybrid seeds, new equipments; have all favoured the process of accumulation (Lewontin and Berlan 1986). The perception of Nature as the provider of raw materials and resources expanded to the one where Nature became the raw material. Commoditization of Nature in its entirety reaches a new dimension with the introduction of Intellectual Property Rights. When analyzed on purely ethical and moral grounds, questions arise on the ownership over Nature, who has more rights over Nature, who is entitled to have more rights over Nature.

Coming back to food security, agricultural biotechnology is globally recognized as a highly beneficial tool to create food abundance and thereby food security. The natural species barrier to regulate reproduction and maintain integrity has been perceived as limits and hindrances of nature towards efficiency and abundance creation (Shiva 2010). The transgenic technology is argued to enhance linkages between increased efficiency in farming practices and environmentally sustainable development. In this view, biotechnology promotes ecologically sustainable way of food production by reducing the application of chemicals and pesticides to the soil since transgenic insertion leads to the development of crops with reduced dependency on pesticides, water, fertilizers. It is supposedly more sustainable than any other form of farming in the sense of decreased soil erosion and gas emissions and improving the production capability of a small cropland. In addition to the above another widespread reasoning by those in favour of the above discourse is the 'population pressure'. It is said that rapidly growing population especially in countries like India and China is exerting an immense pressure on the limited resources in those regions. Therefore in order to match the order of current times, agriculture has to be intensified and food needs to be produced using the limited resources yet in a sustainable manner.

In lines with the discussion of the chapter, the next section offers an example of Bt Cotton- the first transgenic crop commercialized in India and implications to the seed sector and how it translates to the international level impacting food security.

16.4 The Case of Bt Cotton in India

The Green Revolution period in India during the 1960s made way to trans-national corporations like Cargill and Monsanto in India. However transgenic seeds or genetically modified seeds were introduced in 2002 for large scale agriculture. The involvement of private sector in the Indian seed industry has been at bay until the period of rigorous economic reforms in India starting from 1991 onwards co-relating to the agreements made in the Uruguay round of trade.

As part of the liberalization and economic reforms, India pursued progressive industrial policies. Pertaining to agriculture, the policy identified, especially the seed sector as a "high priority industry" (Gadwal 2003). Amongst other developments in the seed sector, the policy facilitated foreign investments and overtly encouraged trans-national seed companies to enter the seed business in India. Due to the GATT agreements on assuring proprietary rights, more than 24 international agriculture oriented companies initiated research and development activities in India (Gadwal 2003).

Being the second largest cotton producer in the world, cotton is one of the most important cash crops in India. At the same time, cotton is prone to frequent pest and insect attacks which prompted farmers to use large quantities of pesticides. The international market price for cotton inhibits fluctuations impacting cotton farmers with high risks. As a solution to maximize cotton yield by controlling pest attacks, in 2002, the Government of India approved its very first large scale cultivation of genetically modified cotton from the Bt cotton seeds.

Bt stands for Bacillus thuringiensis. It is a naturally occurring soil bacterium which releases a toxin showing resistance capabilities towards controlling pests. Traditionally farmers have used the soil containing this bacterium as a natural pesticide. Monsanto, the US based agro-chemical trans-national company engineered the Bt cotton. The gene in the bacteria responsible for producing the toxin was harvested and introduced into the genes of cotton seeds using advanced bio-technology applications (frontlineonnet.com).[13] The new improved seeds were called Bt Seeds by Monsanto which were tested and approved to work

[13] http://www.frontlineonnet.com/fl2011/stories/20030606006012600.htm, accessed on 06.09.2011.

against particular pest specie: the Bollworm. The transgenic Bt cotton also came to be known as Bollgard cotton seeds. With the official sanction in India, the Bt cotton seeds were almost offensively advertised. Local Indian religious deities were pictured bringing into the homes of farmers a bag of miracle seeds which would put an end to their woes, reduce costs of pesticides and multiply yields. Sales of Bt cotton in India went up. The cultivation began in South and Central Indian states and gradually covered the rest of the regions as well. Monsanto set a price on the Bt cotton seeds. The price included a 'trait fee' and an additional 'technology provider fee'. The total price came to Rs.1,600 for 450 g of Bt Seeds. Current exchanges rates converts to Euro 24.5 0 for a 450 g. The cost of similar amounts of non Bt seeds were in the range of Rs. 200–300 which is Euro 3 to Euro 4.5. Despite the high price cotton farmers were convinced of the promised output and financial return. From various sources it is gathered that the farmers who indulged in Bt cotton cultivation did experience a growth in their overall production: from 189 and 212 kg/ha in 2001–2002 and 2002–2003 it increased to 307 kg/ha in 2003–2004. The success did not last long as signs of pest resistance to Bt cotton by the bollworms surfaced and quickly spread like wild fire destroying the mature cotton crops. Monsanto in 2006 released a second generation of transgenic Bt Cotton seeds which included an additional protein to resist pest attack. The BollgardII were tested and authorized to be more the fix for the cotton farmer's distress. The newer and improved varieties have an improved price as well. A packet of 450 g of BGII seeds were sold at Rs. 1,700.

This time around, the farmers had no choice than to opt for the newer version of cotton seeds as they had already invested in the BGI. Falling under the auspices of the TRIPS, Monsanto is the sole owner of the transgenic Bt seeds. Breeding and production of further Bt seeds are done by authorized farmers only for the purpose of seed production and sales. Monsanto acquired a 50:50 partnership with India's biggest seed corporation becoming Mahyco-Monsanto Biotech (India). Mahyco has the legacy since the Green Revolution period as it acted as a major distributor of hybrid seeds in association with the Rockefeller foundation (mahyco.com). With this partnership Monsanto-Mahyco Biotech has the largest share in the Indian seed market.

16.5 Analysis and Conclusion

The extensive usage and production of transgenic cotton seeds parallelly brought in a closure to the production of non-transgenic cotton seeds. Monsanto with its subsidiary in India successfully established a niche in the agriculture industry becoming the biggest supplier of pesticides, fertilizers and the most important transgenic seeds. The cotton crop in general has many natural enemies. The transgenic varieties of cotton showed resistance to only the bollworm and precisely American bollworm and not to others in the species like pink bollworm and spotted bollworms most common in India. Farmers continued to invest in pesticides in spite of the transgenic variety to keep the numerous other pests away: Aphids, Thrips, Jassids etc. What can be noted here is the asymmetry of information dissipated in general. Complex advertisements and partial information confuses the audience and makes decision making hard (Karihaloo and Kumar 2009). Farmers have not been counselled with risk assessments and there have been no noted instance of any information talks where the marketing involved the dangers of transgenic seeds. The transgenic seeds markets are under the monopoly of Monsanto which has patency over its Bt cotton seeds. According to statistics of 2006 (IFPRI 2008), a total area of 3,800,000 ha was used to cultivate Bt seeds with an overall production of 24 million bales. As the dependence on transgenic cotton seeds and thereby on Monsanto increased, in the year of 2006–2007, some of the federal states in southern India acknowledging the plea of farmer associations filed a case against Monsanto's monopolistic market control and ordered the company and its distributors to bring down the prices. After a long court trial the prices did decrease to Rs. 410 and Rs. 660 for BGI and BGII respectively. The price control was successfully implemented in three federal states. In other states the price control had to be withdrawn as the Monsanto Mahyco group defeated the case. In the states where there are no price control, the price of BGI and BGII are Rs. 750 and Rs. 925 respectively (Pray and Nagarajan 2010).

This is a classic case of imbalance in power between the state and non-state actors (Trans-national corporations plus national companies which act trans-national due to mergers: ex. Monsanto with Indian Mahyco) and control over crucial segments of the economy like food. The intervention of state which takes over the role of maintaining the welfare of its population in other cases failed to compete and resist the corporate power.

As the seeds are produced solely by the corporation and as the knowledge behind the production is tightly protected by the corporation the Indian farmers have no other choice than to purchase the high priced seeds from Monsanto. It is also claimed that the preference of farmers to expensive Bt seeds represents their satisfaction and continued indulgence in transgenic cotton cultivation. What is ignored or rather left obscured in mainstream sources is that the farmers are now facing a severe shortage of non Bt seeds or other hybrid seeds (hindu.com).[14] This is due to the process of consolidation taken place since 1991. There have been a series of mergers and acquisitions in the private seeds and agriculture sector with two major actors: Monsanto and Mahyco.

Currently 80 % of the cotton produced in India is with transgenic Bt seeds. The dependency on private sector and the monopoly of Monsanto is represented in its recent subtle threat/announcement of a potential shortage of Bt seeds.[15] The announcement can be interpreted in the way that if the governments do not back off with the price control order, the corporation would decrease the supply of transgenic seeds. In this case negatively impacting the production of India's most

[14] http://www.hindu.com/2010/11/14/stories/2010111458980100.htm, accessed on 06.09.2011.

[15] http://www.business-standard.com/india/news/shortagebt-cotton-seeds-may-hit-2011-12-production-able/125831/on

important cash crop and hence its status in the international economy simultaneously having a brutal impact on the cotton farmers in India.

Moreover the situation takes dangerous inclinations as the same pattern can be traced in other transgenic seeds which are not a cash crop but are seeds of basic food crops like Brinjal and tomatoes in the case of India and many other varieties of vegetables, fruits and milk globally. For example in 2005, 60 % (Gomez-Barbero 2006) of the total soya bean production in the world was genetically modified. The consumption of soya bean is rapidly increasing and the above number denotes serious implications to food security. Moreover soya bean, maize, corn, cotton etc. forms part of cash crops in the countries of production. These crops relate to a high consumption and international demand hence more and more farmers are shifting cultivation towards growing cash crops. Such a tendency is leading to mono-cropping as opposed to traditional ways of multi cropping which helped the soil maintain its fertility, avoiding erosion and maintaining a vibrant bio-sphere. Intense indulgence in mono-cropping is a tendency with transgenic crops and reveals detriments towards sustainable agriculture which in turn has a negative impact on food security.

The following table is a compilation of top 5 trans-national corporations who are also the leading biotechnology based solution providers. Their net sales give an idea of their financial might and hence power: (Table 16.2).

The following table offers a comprehensive global picture of the amount of transgenic crops produced. It becomes clear that production of transgenic crops has increased and these are not only non consumption crops like Cotton but most are for regular direct consumption (Table 16.3).

The following is a graphic representation of global distribution of genetically modified crops. The numerals have a unit of million hectares and indicate growing of GM crops (Fig. 16.2).

The most important element here is not only the increasing inclination towards production, distribution and consumption of transgenic food. As transgenic foods are considered creations of the mind under the current international proprietary framework, there exist clear definitions of ‘who’ the owners are, thereby rendering them the privilege of defining the ‘terms’ of usage and control.

The following graphic is perhaps the most important one to indicate the concentration of economic- international market power and a potential creation of monopoly at an international level. The graphic represents the process of global consolidation process which has taken place since 1998 until 2008 in the seed sector. The solid lines represent full ownership while the dotted lines indicate partial ownership. The graphic represents acquisitions between various firms over the years while it is clear that Monsanto Corporation has undergone an immense consolidation[16] process and is occupying the biggest share in the seeds and agriculture inputs market (Fig. 16.3).

[16] Consolidation process indicates to mergers or unions of corporations.

Table 16.2 Top 5 global seed corporations

Monsanto (US)	Pharmaceutical company. World's biggest seed company. Net sales (2009): US $11,724 million (homepage)
DuPont (US)	Chemical industry. Net sales (2009): US $1,755 million (home page)
Sygenta (Switzerland)	Chemical industry. Net sales (2009): US $1,374 million (home page)
Groupe Limagrain (France)	Horticulture industry. Net sales (2009): US$ 1,240 million (home page)
Land O' Lakes (US)	Agriculture products. Net sales (2009): US$ 10.4 billion (home page)

Table 16.3 Comprehensive global picture of the amount of transgenic crops produced

Rank	Country	2010 –Area (million hectares)	2009–Area (million hectares)	Biotech Crops
1	USA	66.8	64.0	Soybean, Maize, Cotton, Canola, squash, Payaya, Alfalfa, Sugarbeet
2	Brazil	25.4	21.4	Soybean, Maize, Cotton
3	Argentina	22.9	21.3	Soybean, Maize, Cotton
4	India	9.4	8.4	Cotton
5	Canada	8.8	8.2	Maize, Soybean, Canola, Sugarbeet
6	China	3.5	3.7	Cotton, Tomato, Poplar, Payaya, Sweet Pepper
7	Paraguay	2.6	2.2	Soybean
8	Pakistan	2.4	-	Cotton
9	South africa	2.2	2.1	Soybean, Maize, Cotton
10	Uruguay	1.1	0.8	Maize, Soybean
11	Bolivia	0.9	0.8	Soybean
12	Australia	0.7	0.2	Cotton, Canola
13	Philippines	0.5	0.5	Maize
14	Myanmar	0.3	-	Cotton
15	Burkina Faso	0.3	0.1	Cotton
16	Spain	0.1	0.1	Maize
17	Mexico	0.1	0.1	Cotton, Soybean
18	Colombia	<0.1	<0.1	Cotton
19	Chile	<0.1	<0.1	Maize, Soybean, Canola
20	Honduras	<0.1	<0.1	Maize
21	Portugal	<0.1	<0.1	Maize
22	Czech Republic	<0.1	<0.1	Maize, Potato
23	Poland	<0.1	<0.1	Maize
24	Egypt	<0.1	<0.1	Maize
25	Slovakia	<0.1	<0.1	Maize
26	Costa Rica	<0.1	<0.1	Cotton, Soybean
27	Romania	<0.1	<0.1	Maize
28	Sweden	0.1	-	Potato
29	Germany	0.1	-	Potato

Self compiled from: http://www.isaaa.org/resources/publications/pocketk/16/default.asp & http://www.isaaa.org/resources/publications/briefs/41/executivesummary/default.asp

Fig. 16.2 Representation of global distribution of genetically modified crops (Source: http://chartsbin.com/view/578)

Such a concentration of market power transfers control of price setting over to the corporation. When the concentration reaches a certain threshold, it hinders market competition. Such a large cluster and concentration of power can "simply signal their intention to raise prices or restrict output, with others following suit" (Philip 2009). This would unleash a stark dependency jeopardizing the availability and affordability of basic and important food and food security. In addition to the risk of price setting which could either fluctuate or just remain high, there is also a potential artificial creation of abundance or scarcity of a certain crop or food product. Such a monopoly and concentration of power is an instrument of political power possessing very serious potentials to undermine the state. Whether national laws relating to monopoly control and price discrimination can resist and control such activity is an interesting aspect for further study.

The issue calls for re-structuring the current regulatory framework and IPR at the international level while at the national level adequate protection needs to be observed and implemented. A more balanced public – private sector relation needs to be established where national companies have more leverage in their partnerships with trans-national actors. In countries like India where agriculture still plays a vital role in the economy, offers employment and where the farmers as both producers and consumers form the biggest chunk of the society are faced with a dilemma of choice with serious implications on their food security.

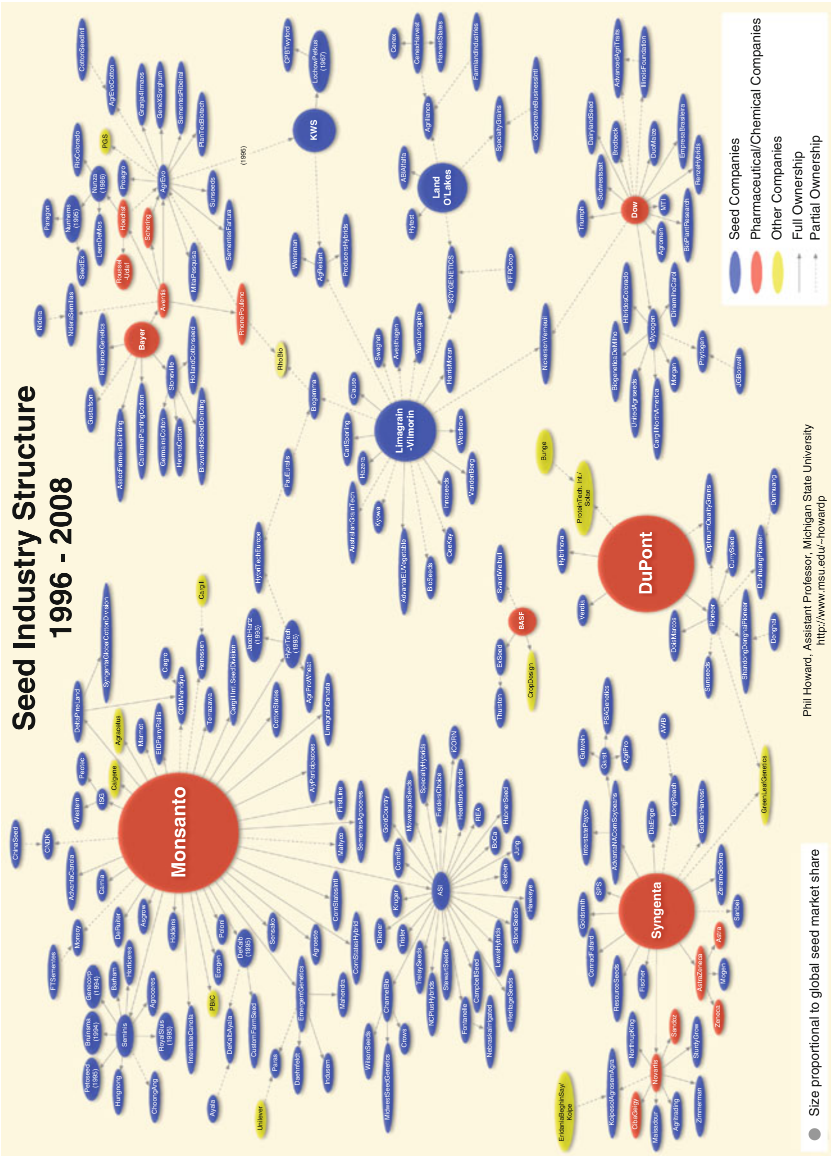

Fig. 16.3 Seed industry structure 1996–2008 (Source: https://www.msu.edu/~howardp/seedindustry.html)

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Chapter 17
Food Security Constraints and Role of Biosaline Agriculture in Meeting Food Demand in the Gulf States

Shahid A. Shabbir

Abstract The combination of limited fresh water supplies, poor soils and hyper-arid environment (dryland system), and climate change impact in Gulf States (GS) constrains the local economic agricultural production of many crops grown for food and fodder. The difference between the Ecological Footprint of Consumption and the Biocapacity of GS, suggests a net deficit between the eco-resources generated and those consumed and wasted. Given these existing and predicted challenges, it would be hard for the GS to achieve food security unless there are considerable technological innovations in agriculture and water research to boost local production. To meet food security, GS may be seeking options of acquiring land abroad for agriculture. Leasing prime land in poor developing countries is questioned by many actors, so the sensible option is to acquire marginal (saline) lands in these developing countries, over one billion ha available globally, or acquire prime land in countries where there are resources surpluses (abundant soil and water resources) concentrated in ecological creditors' countries, which currently do not utilize their full biocapacity and the production cost is lower. In the former case, ICBA can significantly support GS in growing salt-tolerant crops (Biosaline Agriculture) in the marginal land acquired abroad and by bringing them into crop production through an integrated approach of reclamation of salt-affected lands, thus, paving the way forward for food security. Over the last 13 years ICBA has developed a world-wide reputation for its expertise in the development of salt-tolerant germplasm and applied research and development in many of the 57 IDB-member countries including the GS. The groundwater in the GS is mostly saline or brackish and biosaline agriculture is the best approach.

Keywords Biocapacity • Biosaline agriculture • Ecological footprint • Climate change • Food security

S.A. Shabbir (✉)
Salinity Management Scientist, Innovation and Research Program, International Center for Biosaline Agriculture, 14660, Dubai, United Arab Emirates
e-mail: s.shahid@biosaline.org.ae

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17.1 Introduction

The Gulf Cooperation Council Countries (GCC countries) include Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. In this chapter they are referred as ***Gulf States 'GS'***. The GS are located in a water-scarce region, and thus most water demand is met through non-conventional water resources, that are from high-cost desalination. In addition, most of the native soils are low in fertility (low organic matter and clay contents) and productive capacity. The combination of limited fresh water supplies, poor soils and hyper-arid environment (Fig. 17.1) constrain the economic agricultural production of many crops grown for food and fodder. In addition to these existing poor resources, it is projected that the GS will be impacted greatly by the climate change through rises in temperature, decline in rainfall and an increase in evapotranspiration, e.g., the climate change impact to Abu Dhabi coastal zones, water resources and dryland ecosystem is discussed in detail (Dougherty et al. 2009).

The GS Ecological Footprint of Consumption and Biocapacity (Ewing et al. 2010) suggests a net deficit between the eco-resources generated and those consumed and wasted. Under current circumstances and with business as usual (BAU) approaches the GS will continue to be food-importing countries and seeking new options of food security and perhaps will be in the forefront of new investments in farmland abroad. There are strengths, weakness, opportunities and threats (SWOT) with such an approach. In this chapter these issues are discussed and linked with

Dryland Systems	P/PET
Hyper-arid	< 0.05
Arid	0.05-0.0.2
Semiarid	0.2-0.5
Dry sub-humid	0.5-0.65

P = Annual precipitation; PET = Potential evapotranspiration

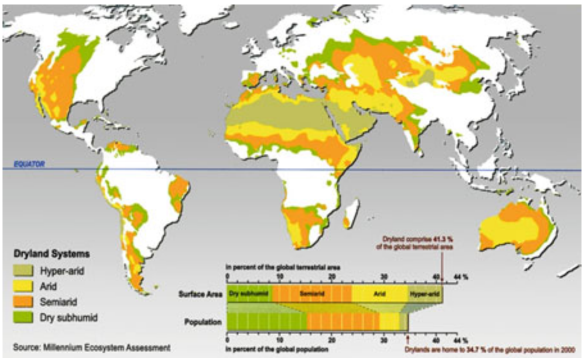

Fig. 17.1 Gulf States are in Hyper-arid Dryland Systems (Source: MEA-Millennium Ecosystem Assessment 2005)

adoption of biosaline agriculture on leased marginal lands abroad, where ICBA can significantly support the GS in bridging the gap to meet food demand.

Most of the groundwater in the GS is saline or brackish and the best option to exploit these marginal waters is through growing salt-tolerant plants (biosaline agriculture). Biosaline agriculture means growing salt-tolerant plants on salty soils using salty water. In 1999 the International Center for Biosaline Agriculture (ICBA) was established in Dubai to conduct biosaline agriculture research and to implement applied research in Islamic Development Bank (IDB) member-countries including the GS. Over the last 13 years ICBA has developed a world-wide reputation for its expertise in the development of salt-tolerant germplasm and applied research and development in many of the 57 IDB-member countries including the GS. Particularly in the GS, salt-tolerant forage production is the best approach to provide fodder and thus minimize its importation.

Significant efforts have been made in GS to narrow gaps between local food production and total food import. Water scarcity; hyper-arid climatic conditions, climate change impact, poor soil resources and poor suitability of soils for arable crops are considered the main constraints to food security.

17.2 Objectives

This chapter aims at:

– Reviewing the status of GS countries to support local agricultural production to meet food demand;
– Reviewing the ecological footprint and biocapacity of GS and relate to food security;
– Recommending the ways by which GS can explore means to meet food demand.

17.2.1 Dryland Systems

The GS (Fig. 17.1) are situated in the Dryland Systems (lack of water) area. Dryland Systems include cultivated lands, scrublands, shrublands, grasslands, savannahs, semi-deserts and true deserts like in the GS. Drylands refer to land areas where the mean annual precipitation (P) is less than two thirds of potential evapotranspiration (PET = potential evaporation from soil plus transpiration by plants). Hyper-arid areas are considered as true deserts like those in the GS. The lack of water constrains the production of crops, forage, wood, and other ecosystem services.

Four dryland subtypes are widely recognized: dry sub-humid, semiarid, arid, and hyper-arid, showing an increasing level of aridity or moisture deficit as below.

Table 17.1 Levels of water stress in the Gulf States

Levels of water stress			
Critical	**Serious**	**Significant**	**Slight**
More than 10,000 persons per million cubic metre	Between 5,000 and 10,000 persons per million cubic metre	Between 2,500 and 5,000 persons per million cubic metre	Less than 2,500 persons per million cubic metre
Kuwait and UAE	**Bahrain and Qatar**	**Saudi Arabia**	**Oman**

Source: UN-Economic and Social Commission for Western Asia-ESCWA (2007)

17.2.2 Water Stress and Water Scarcity

The GS are situated in the Dryland Systems (Hyper-arid), so they face various levels of water stresses; these are varying based on the available and renewable water resources of each country. Kuwait and UAE are under critical water stress and Oman slight water stress (Table 17.1).

One third of the world's population lives in basins that have to deal with water scarcity. Based on the map shown in Fig. 17.2 (Areas of Physical and Economic Water Scarcity 2008), the GS in general fall under physical water scarcity (water resources development is approaching or has exceeded sustainable limits. More than 75 % of river flows are withdrawn for agriculture, industry, and domestic purposes (accounting for recycling of return flow). This definition – relating water availability to water demand – implies that dry areas are not necessarily water scarce), except most of Kuwait which is approaching physical water scarce status.

17.2.3 World Population Since 1950 and Projection for 2050

Global population (Table 17.2) is continually growing at an alarming rate, doubling in the past half century; it is likely to plateau at some 9.19 billion by about the middle of this century, that is 272 and 362 % increase by 2010 and 2050 respectively compared to that in 1950 (Charles et al. 2010; UN 2007). The highest population growth is in the resource-poor developing African countries. In the GS, annual population growth rate of 3.5 % is reported in 2008. Continuing population and consumption growth will mean that the global demand for food will increase for at least another 40 years (Charles et al. 2010). This calls for renewed efforts to efficiently manage natural resources (soil and water) to enhance food security and safety.

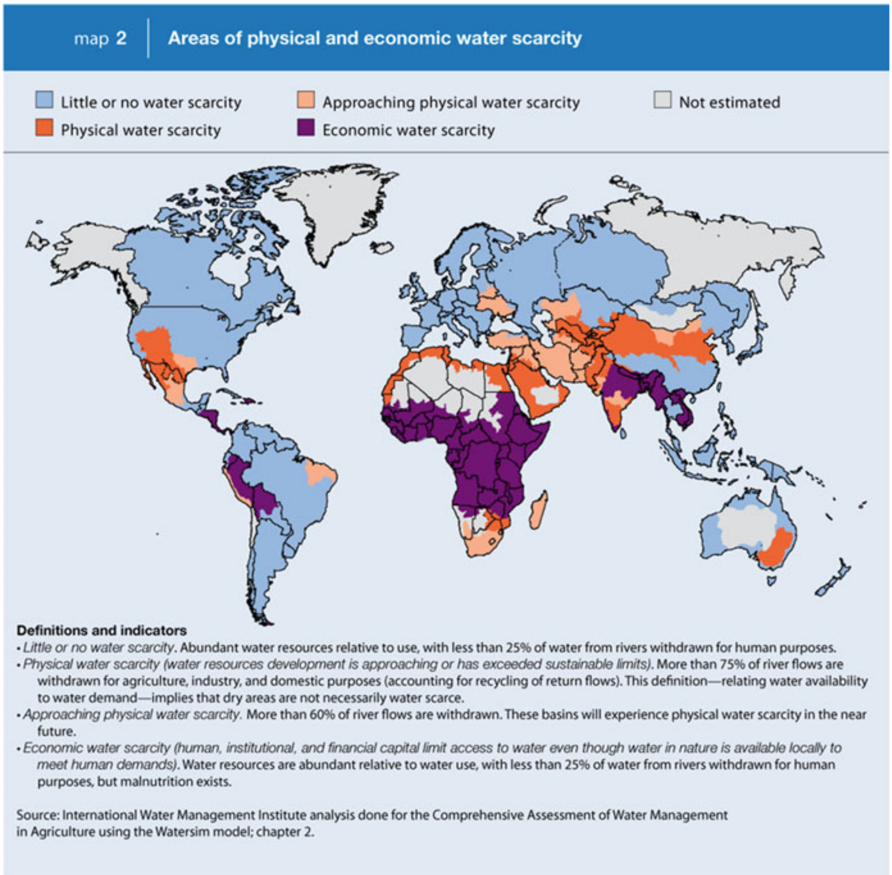

Fig. 17.2 Areas of physical and economic water scarcity (Source: Areas of Physical and Economic Water Scarcity 2008; IWMI 2007)

Table 17.2 World population since 1950 and projection for 2050

Year	Total population (billions)
1950	2.54
1960	3.03
1970	3.70
1980	4.45
1990	5.29
2000	6.12
2010	6.91
2020	7.67
2030	8.31
2040	8.82
2050	9.19

Adapted from UN (2007)

17.2.4 Global Saline Wastelands

Planet earth consists of land surface of about 13.2×10^9 ha, of which 7×10^9 ha are arable and only 1.5×10^9 ha are cultivated (Massoud 1981). Of the cultivated lands, about 0.34×10^9 ha (23 %) are saline and another 0.56×10^9 (37 %) are sodic. The sodic soils are non-saline and present exchangeable sodium percentage (ESP) on soil exchange complex more than 15. Older estimates (Szabolcs 1989) suggest 10 % of the total arable land to be affected by salinity and sodicity, and extending over more than 100 countries occupying different proportions of their territory. Salt-affected soils occur practically in all climatic belts, from the humid tropics to beyond the polar circle. They can be found in different altitudes, from territories below sea level, e.g., the district of the Dead Sea, to mountains rising over 5,000 m as the Tibetan Plateau of the Rocky Mountains (Szabols 1995). The description of the types of salt-affected soils, causes of formation and hypothetical salinization cycle has recently been reported (Shahid et al. 2010; Shahid and Rahman 2011).

Currently the exact extent of salt-affected soils is unknown due to unavailability of updated information. Based on the FAO/UNESCO Soil Map of the World (1974), Massoud (1977) made an estimate of 880 million ha (M ha) of salt-affected soils, of which 316 M ha are in developing countries. These are the potential areas where land can be leased for food security or alternate energy sources. It is also sensible to lease land in countries where biocapacity is higher than the ecological foot print of consumption. Balba (1980) gave a global estimate of only 600 M ha as salt-affected soils (Africa 30 M ha, Asia 340 M ha, Australia 140 M ha, Europe 1 M ha, North America 26 M ha and South America 60 M ha), these estimates may include soils which are not currently in use and have the potential for biosaline agriculture to meet food demands for the host countries and options for lease for other countries seeking land for agriculture. Recently Pessarakali and Szabolcs (2010) have quoted 954.8 M ha of salt-affected soils (Kovda and Szabolcs 1979) available worldwide (Table 17.3).

Table 17.3 Salt-affected soils of the continents and subcontinents (Kovda and Szabolc 1979)

Continent	Area (million ha)
North America	15.7
Mexico and Central America	2.0
South America	129.2
Africa	80.5
South Asia	87.6
North and Central Asia	211.7
South-East Asia	20.0
Australasia	357.3
Europe	50.8
Total	954.8

17.2.5 Scientific Soil Inventories

The value of scientific soil inventories for rational use of soil resources has long been recognized in the GS. Such soil investigations identify land parcels at the national level for broad land use planning including agriculture activities. In the GS, the Kingdom of Saudi Arabia published a reconnaissance soil map covering the entire Kingdom (Ministry of Agriculture and Water 1985). A similar soil map was completed in the Sultanate of Oman (Ministry of Agriculture and Fisheries 1990). Kuwait was the third country to asses its soils for broader land use planning at scales of 1:100,000 (KISR 1999a) and an area of 200,000 ha was assessed on a semi-detailed level (1:25,000) for irrigated agriculture purposes (KISR 1999b), and the first order soil survey at the farm level (Shahid and Omar 1999). The State of Qatar has completed a detailed survey and published soil and other interpretative maps (Ministry of Municipal Affairs and Agriculture 2005a, b; Scheibert et al. 2005). Recently Abu Dhabi Emirate completed a soil survey at two levels, the extensive for the entire emirate and the intensive survey of 400,000 ha area for irrigated agriculture (EAD 2009).

17.2.6 Land Suitability for Irrigated Agriculture

In the GS the soil survey results were evaluated for the suitability of irrigated agriculture using the FAO framework for land evaluation (FAO 1976) for local food production, to be self sufficient in basic agricultural commodities. However, the results are not encouraging as only small areas have been found suitable for irrigated agriculture (arable land). The above reports show, in Saudi Arabia only 13.8 % of the survey area is suitable for large-scale irrigation farming; in Oman (7.07 %), Kuwait currently 2.71 % area is under agriculture and about 35 % area has the potential for irrigated agriculture (KISR 1999a), Abu Dhabi emirate (5.44 %) area is highly-moderately suitable for irrigated agriculture (EAD 2009), in the State of Qatar such an area is less than 4 % (Ministry of Municipal Affairs and Agriculture 2005a, b).

17.2.7 Arable Land

Summary of arable land in the Arab countries by regions is shown in Fig. 17.3, which clearly illustrates that arable land per capita in the Arab region has been continuously declining since 1961. Such a decline is due to hot climatic conditions and land degradation that has declined the resource capacity for agriculture production since 1961. As of 2003 the GS have less than 0.15 ha arable land per person. This shows, currently, GS has insufficient arable land to meet food demand of its population.

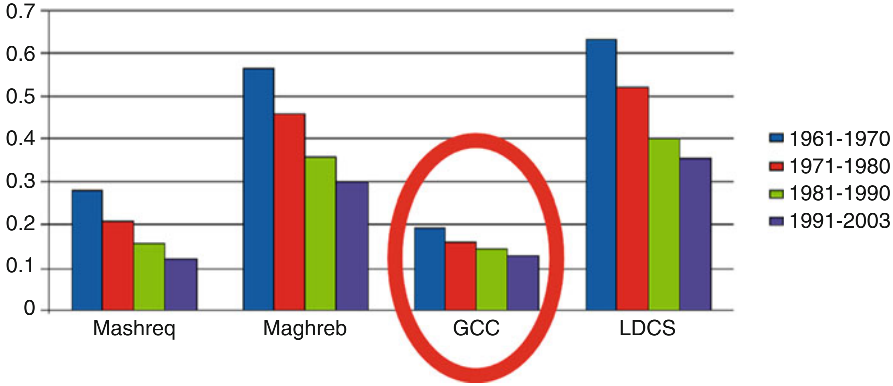

Fig. 17.3 Arable land (in hectares) per capita (1961–2003) (Source: Adapted from World Bank)

17.2.8 Ecological Footprint

Ecological Footprint (EF) analysis measures human demand on nature. It compares human consumption of natural resources with planet Earth's ecological capacity to regenerate them. The EF is a resource accounting tool that helps countries understand their ecological balance sheet and gives them the data necessary to manage their resources and secure their future. In 2007, global humanity's total EF was 18 billion global ha (gha) with world population at 6.7 billion people, the average person's footprint was 2.7 gha, with 11.9 billion gha biocapacity (1.8 gha per person). Thus, it is apparent that humanity uses the equivalent of 1.5 planets to provide the resources we use and absorb our waste (Table 17.4). Moderate UN scenarios suggest that if current population and consumption trends continue, by the 2050s, we will need the equivalent of more than two Earths to support us (Fig. 17.4), and of course, we only have one. This means it now takes the Earth 1 year and 6 months to regenerate what we use in a year, and in 2050 more than 2 years (Ewing et al. 2010).

The overexploitation of earth necessitates saving ecological assets for future generations. Many countries are using more resources than they are generating and hence they are ecologically deficit countries and depend heavily on resources from other countries through food imports. If these are poor developing nations then the implications of ecological deficits can be devastating, leading to resource loss, ecosystem collapse, debt, poverty, famine and war. Currently more than 35 nations are engaged directly with EF analyses for better management of resources. Seventeen nations have completed reviews of the Footprint and Japan, Switzerland, UAE (Gulf State), Ecuador, Finland, Scotland and Wales have formally adopted this methodology.

The Ecological Footprint is measured in global hectares (gha). The gha is a productivity weighted area used to report both the biocapacity of the earth, and the demand on biocapacity (the Ecological Footprint). The Biocapacity is the capacity of the ecosystem to produce useful biological materials and to absorb waste

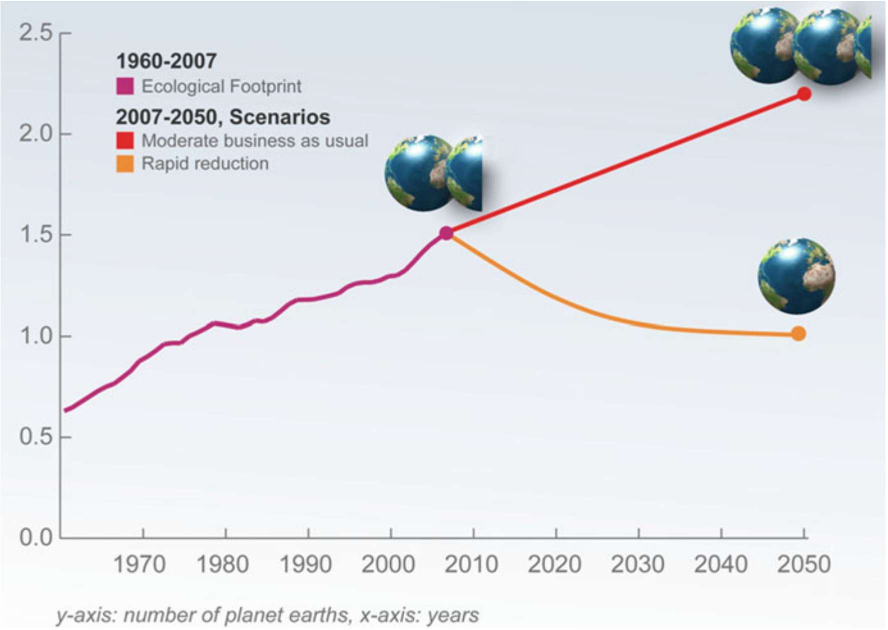

Fig. 17.4 Number of Earth Planets required by 2050 to feed nine billion peoples (Source: Ewing et al. 2010)

materials generated by humans, using current management schemes and extraction technologies. The gha is normalized to the area-weighted average productivity of biologically productive land and water in a given year. Because different land types have different productivity, a gha of, for example, cropland, would occupy a smaller physical area than the much less biologically productive pasture land, as more pasture would be needed to provide the same biocapacity as 1 ha of cropland. As the world bioproductivity varies slightly from year to year, accordingly the value of a gha changes slightly from year to year. Reader is referred to Ewing et al. (2010) for more information regarding the subject matter.

17.2.9 Ecological Creditors and Debtors

Today, more than 80 % of the world's population lives in countries that use more resources than what is renewably available within their own borders. These countries rely for their needs on resource surpluses concentrated in ecological creditor countries, which use less biocapacity than they have. Recently, Ewing et al. (2010) has reported ecological footprint and biocapacity of high-income 36 countries, including from GS (Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates) and these are shown in Table 17.4.

Table 17.4 The world, Gulf States (high-income) ecological footprint, biocapacity and the difference

Country	Population (millions)	Ecological footprint of consumption (gha per person)	Biocapacity (gha per person)	Nominal difference between EF and biocapacity (gha per person)	Percentage difference between EF and Biocapacity
World	6,670.80	2.70	1.78	0.92	51.70
Kuwait	2.85	6.32	0.40	5.92	1,580.00
Oman	2.73	4.99	2.14	2.85	233.18
Qatar	1.14	10.51	2.51	8.00	418.73
Saudi Arabia	24.68	5.13	0.84	4.29	610.71
United Arab Emirates	6.25	10.68	0.85	9.83	1,256.47

Adopted and modified from Ewing et al. (2010)

Table 17.4 shows all reported GS countries use more resources than are generated; the deficit is compensated through food importing from other countries. According to Ewing et al. (2010) in the GS, the UAE has the highest ecological footprint, the EF trend Ewing et al (2010) in the GS, the UAE has > Qatar > Kuwait > Saudi Arabia > Oman, however, the trend of percent deficit between EF and biocapacity is Kuwait > UAE > Saudi Arabia > Qatar > Oman. The data from Bahrain is currently not available.

17.2.10 Gross Domestic Product and Natural Reserves

The GS has no foreign exchange limitation for food imports. The GS region has also benefitted immensely from the recent sharp increase in oil prices. The increase in the hydrocarbon sector resulted in lifting real GDP in the GS by around 5.5 % in 2010–2011 compared with 5.2 % in early 2010. The collective nominal GDP of GS up by almost US$133 billion in 2010 and is expected to rise in 2011. The GS nominal GDP is expected to hit US$ 1,010 billion in 2011. The GS has almost 1 quarter of the world's natural gas proven reserves. Of the total world natural gas reserves, Qatar shares 14.9 %, Saudi Arabia 3.9 %, Kuwait 0.9 %, UAE 3.5 %, while Oman has made natural gas the chief focus of its diversification and economic growth strategy. In 2008 the percentage contribution of agriculture to GDP in GS was less than 1 % (Bahrain, Kuwait, Qatar), and 2.0, 2.8 and 3.9 % in Oman, UAE and Saudi Arabia respectively. Similarly, the percentage of the population engaged in agriculture varies in different countries e.g., Qatar (0.8 %0), Bahrain (1 %), Kuwait (1.1 %), UAE (3.2 %), Saudi Arabia (5.5 %), and Oman (29.2 %).

17.2.11 Food Import Dependency and Food Security

Despite the GS being capital rich nations, the GS face challenges regarding sustainable use of natural resources, combating desertification and enhancing local food production. In addition to poor existing soil and water resources and harsh climatic conditions, it is projected that the GS will be impacted greatly by climate change through a rise in temperature, decline in rainfall and increase in evapotranspiration (Shahid and Taha 2010). Given these existing and predicted challenges, it is apparent that it would be hard for the GS to achieve food security locally unless there are considerable technological innovations in agriculture research to boost production.

Figure 17.5a shows that almost all countries in the world are importing food to various extents based on their local production and food demands. All GS countries are net food importers, and it is apparent that the GS are importing more than 70 % (Fig. 17.5a), and currently even more than 90 % (Fig. 17.5b). The UAE imports 85 % of its food (Daniel 2011). In the GS the total bill for food imports ballooned from US$8 to US$20 billion from 2002 to 2007 (GRAIN 2008; Daniel 2011). The GS have moved quickly to extend control over food-producing land abroad (Daniel 2011).

Food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Important dimensions of food security are: food availability, food access, utilization (state of nutritional well-being), affordability and stability. Food importing has various aspects of benefits and impact on economies, it gives an opportunity to trade with other countries and build up relationships, however, long term food importing raises some concerns: significant financial obligations – capital flow from food importing counties can affect national economies, lack of control on food quality – production, high risks of food insecurity during wars and when food import demand increases.

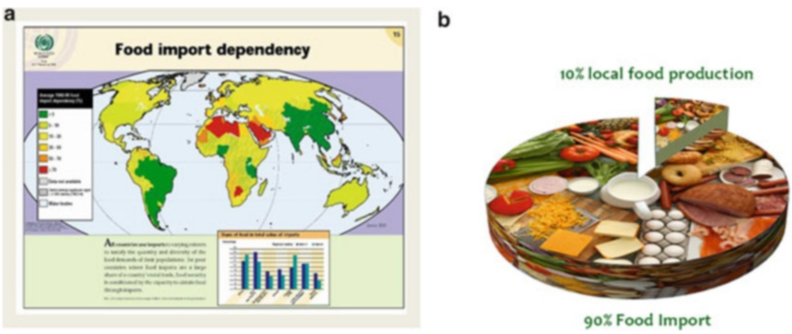

Fig. 17.5 Food import dependency and actual food import by Gulf States. (**a**) Worldwide food import dependency. (**b**) Share of Gulf States to total food import

Water scarcity, poor soil resources and the hyper-arid environment lead the GS to have a high deficit between EF of consumption and Biocapacity (Table 17.4), and thus it is highly likely that the GS (capital rich and food insecure nations), to meet the demand of continuing population growth, will continue to import food and may be seeking new options of food security and perhaps will be in the forefront of new investments in farmland abroad.

While the food is imported, at the same time the countries are also importing virtual (or embodied) water. This is a measure of the total water used in production of goods or services, e.g., 1 kg of wheat requires about 1,000 l of water, and 15,500 l of water is required to produce 1 kg of beef (D'Silva 2011). The concept was initially used to illustrate the advantages to water scarce nations of trade with other nations, rather than attempting to produce all goods locally.

17.2.12 Farmland Investment in Developing Countries

There are many ways by which economically prosperous but food insecure nations can achieve food security, like intensification in local food production using high-tech (rationale use of soil resources, modern irrigation systems, protected agriculture, water conservation, sector wide water reforms, use of alternate water sources); continuing food import; outsourcing food production to countries which have comparative advantage for agricultural expansion; and through creation of GS-FOOD RESERVES to be used in case of emergency and lasting for at least 2 years. In addition to the above options, it is likely that GS may be in the forefront of new investments in farmland abroad. However, the purchase, lease or acquisition of land in the poor developing countries by foreign investors for sources of alternative energy and food crops has led to the so called "***land grab***".

17.2.13 Main Driving Forces for Land Lease Abroad

There are three main driving forces for land lease abroad; (1) to secure food supply by increasingly food-insecure nations; (2) the surging demand for agrofuels and other alternate energy sources and; (3) the sharp rise in investment in both the land market and the soft commodities market.

17.2.14 Major Concerns of Land Lease

The major concerns of Activists, Researchers and Environmentalists are; (1) private land investments only increase monoculture-based, export-oriented agriculture, arguably jeopardizing international food security; and (2) domestic to foreign control over crucial food-producing lands. Acquisition of farmlands in such resource-poor countries may provoke food insecurity. If land lease is the potential way to meet food demand, then it is sensible to lease land where there are resource surpluses (abundant soil and water resources) concentrated in ecological creditors' countries, which currently do not utilize their full biocapacity and where production cost is lower. However, this is not the present scenario and there have been land deals in poor developing countries by foreign investors (von Braun and Meinzen-Dick 2009) eg for biofuels (Congo, Ethiopia, Mozambique, Tanzania, Zambia), Rice (Angola, Cambodia, Cameron, Indonesia, Mali, Mozambique, Tanzania,), Wheat (Egypt, Sudan), Maize (Madagascar) and general agriculture projects (Africa, Malawi, Nigeria, Pakistan, Turkey, Ukraine, Vietnam) etc. Perhaps such deals are a global re-alignment of political economic relations through diverse trajectories and neo-liberalisation.

17.2.15 Gulf Deals of Land Leasing Abroad

There have been reports (von Braun and Meinzen-Dick 2009) of Gulf deals for farmland abroad e.g., **Saudi Arabia** (Sudan-wheat, vegetables, animal feed; Indonesia-rice; Egypt-barley, wheat, livestock feed; World-agriculture projects); **UAE** (Sudan-corn, alfalfa, wheat, potato, beans; Pakistan-agriculture; Ethiopia-tea); **Qatar** (Kenya-fruits, vegetables; World-food and energy; Vietnam-agriculture); **Kuwait** (Cambodia-rice); **Bahrain** (Philippine-agroforestry; Turkey-agriculture); Dubai World Trading Company (Ethiopia-tea).

17.2.16 FAO-IFAD-IFPRI Perception of Land Grab by Gulf States

The land lease (land grab) trend has come under heavy scrutiny since mid-2008. On the one hand, investment in agricultural land is thought to be an answer for boosting food production in a world plagued by food shortages; on the other hand, many claim that this large-scale, private-sector-led approach conflicts with the urgency of increasing domestic food supplies in the world's poorest and most vulnerable countries.

The FAO Director General Jacques Diouf, while having clearly expressed his concern about the potential consequences of swift land grabbing on political stability, has said "he supports the proposed Gulf food deals as a means of economic development for poor countries. If the deals are constructed properly, he said, they have the potential to transform developing economies by providing jobs both in agriculture and other supporting industries like transportation and warehousing" (Coker 2008; *cf* Daniel 2011).

Similarly the President of the International Fund for Agricultural Development (IFAD) expressed hope for possible development opportunities through land purchases. "*When such deals take into account interests of both parties they help increase agricultural production in developing countries, provide jobs, boost export and bring in new technologies to improve farm efficiency there*" (Kovalyova 2009; *cf*. Daniel 2011). Despite calls from several organizations including the UN for an international code of conduct for land acquisition, most of the land deals to date lack transparency and offer little or no concession to small farmers. The IFPRI calls for a code of conduct both for foreign investors and the host countries in order to protect the interests of small farmers, as well as address environmental concerns on biodiversity and water and land resources stemming from the impact of large-scale farmland investments. No matter how convincing the claim that the global land grab will bring much-needed agricultural investment to poor countries, evidence shows there is simply no place for the small farmer in the vast majority of these land grab situations (Daniel 2011).

17.2.17 Win-Win Scenario for Both Investors and Host Countries

Farmland investment in developing countries can be a potential "*win-win*" situation in which *food-insecure* nations increase their access to food resources and "*host*" nations benefit from investments in the form of improved agricultural infrastructure and increased employment opportunities. There are, however, strengths; weakness, opportunities and threats (SWOT) in such an approach. In the authors' opinion if the foreign investors acquire marginal lands (saline land resources) which are set aside and currently are either not under production or cannot be brought into production due to poor economic resources of the host countries (refer to Table 17.3), and the investors bring them into production, with the condition that the prime agricultural lands are left for the host country, and this practice does not upset the local market, farmers rights and food policies, and arrangements are properly negotiated, local manpower receive training on high-tech in agriculture production, practices are sustainable, and benefits are shared by the investors and the host countries, it is only then the investment abroad has a positive case and both the investors and the host countries are in a win-win situation. Under such circumstances and choices ICBA can significantly support Gulf States in growing salt-tolerant crops (Shahid et al. 2011; Shahid and Rahman 2011) in farmland acquired abroad and through the reclamation of salt-affected lands, paving the way forward for food security. If this scenario is widely supported, then there are worldwide opportunities to lease marginal lands to achieve food security by GS countries.

17.2.18 Biosaline Agriculture and ICBA

In 1999 the International Center for Biosaline Agriculture (ICBA) was established in Dubai to conduct biosaline agriculture research and implement in Islamic Development Bank (IDB) member-countries including the Gulf States (GS).

Since ICBA's inception in I999 and until 2009, ICBA's mission was to demonstrate the value of saline water resources for the production of environmentally and economically useful plants and to transfer the results to national research services and communities regionally and globally. In the second strategic plan (2009–2014) ICBA is focusing on helping water-scarce countries improve productivity, social equity and environmental sustainability of water use through an integrated water resource systems approach, with special emphasis on saline and marginal quality water. ICBA is unique in the world as it is full time involved in Biosaline Agriculture activities.

17.2.19 Agricultural Production Systems and Marginal Quality Waters

ICBA is contributing to various Research and Development activities related to the use of marginal quality waters (saline/brackish waters) in developing agriculture production systems and introducing to various NARS (National Agricultural Research Systems) and through building capacity of national manpower in many countries (Bangladesh, Bahrain, Egypt, Iran, Jordan, Kazakhstan, Kuwait, Libya, Morocco, Niger, Oman, Pakistan, Palestine, Qatar, Saudi Arabia, Tunisia, Turkmenistan, UAE, Uzbekistan, Yemen etc.). ICBA achievements over the past 10 years have been documented by Shahid et al. (2011). ICBA business in biosaline agriculture is based on:

- Collection of germplasm from around the world and screening at ICBA.
- Identification of new and improved salt-tolerant germplasm (conventional crops and halophytes) to sustain ecosystem productivity.
- Developing alternative production systems and technologies to improve productivity in marginalized environments.
- Developing low-cost technologies for low-quality water-use by small scale farmers.
- Promoting policies, legal and institutional frameworks for sustainable resource management.
- Establishing stronger partnerships with NARS to test and adopt new technologies for ecosystem resilience.
- Provide training (capacity building) to staff from National Agricultural Research Systems (NARCS) in Islamic Development Bank (IDB) member countries.

17.3 Conclusions and Recommendations

The Gulf States are facing a number of constraints (hyper-arid climate, scarce water resources and arable lands, poor soils, high ecological footprint of consumption, climate change impact) limiting sufficient local food production to meet the food demand of the existing and continuing growing population. Therefore, it is believed that food import by GS is likely to continue. This is the time that GS must act urgently to improve food security and therefore need a multi-pronged approach including expansion of future agriculture activities on soils suitable for irrigated agriculture based on scientific soil information, protection and management of the limited water resources, efficient use of water to increase production, exploring alternate water sources (treated waste water) for agriculture, increasing investment in agricultural research and technological innovation, developing a comprehensive strategy including creation of regional food reserves sufficient for at least 2 years, leasing marginal lands and bringing then into production through reclamation and biosaline agriculture, or leasing prime land in resource surpluses concentrated in ecological creditor countries, which uses less biocapacity than they have. The above are the basic recommendations which can be viewed by GS as a whole and the individual countries where appropriate on case by case basis.

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Chapter 18
Land Use Change and Food Security: Has Introduction of Rice Production in Cotton Zone in Benin Met Optimal Allocation of Resources by Households?

Sènakpon E. Haroll Kokoye, Silvère D. Tovignan, and Rosaine Nérice Yegbemey

Abstract Land use is one of the major source of soil fertility decline and food insecurity. In Benin where cotton is the main cash crop, the potential of cultivating rice exists even in cotton cultivation zone. Rice is seen nowadays as a staple food and the national production is insufficient to meet national consumption. Change in land use becomes obvious and the farmers cultivate several crops during the agricultural campaign which enter in competition in terms of resources use. This study has investigated the allocation of resources to different crops in cotton zone using primary data collected from a sample of 71 farmers randomly selected in two villages in the Northern region of Benin (West Africa). The model built showed that rice is the most profitable crop while cotton gross margin is low. It reduces then the area of cotton for about 56 %. It allows the production of maize, sorghum, peanut and the soy bean for ensuring the food availability of the household whereas rice and the bean have an economic importance. It gives a possibility to farmers to cultivate the same amount of land with less amount of labour force and gain 18 % more income than previously. From these results the agricultural policy need to be orientated to the training of farmers on practices and on the best way to allocate resources in order to achieve a good production. The arrangement of inland valley needs to be done to allow farmers to have more areas of inland valley for rice cultivation.

Keywords Land use • Food security • Rice • Cotton • Benin

S.E.H. Kokoye (✉) • S.D. Tovignan
Department of Agricultural Economics and Rural Sociology, Faculty of Agronomy, University of Parakou, BP: 123 Parakou, Republic of Benin
e-mail: kharsene@yahoo.fr

R.N. Yegbemey
Department of Agricultural Economics and Rural Sociology, Faculty of Agronomy, University of Parakou, BP: 123 Parakou, Republic of Benin

Institute of Project and Regional Planning, Faculty of Agriculture, Nutrition, and Environmental Management, Justus-Liebig University of Giessen, Senckenbergstrasse 3, D-35390 Giessen, Germany

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18.1 Introduction

The rural world faces nowadays several problems such as food insecurity, climate change, deforestation, decline of soil fertility. Food security is an issue of great and growing concern in many countries, particularly in Sub-saharan countries. Despite global pledges, the recent report of the United Nations Special Report on the Right to Food highlighted that the number of people suffering from hunger has increased every year since 1996 (UNCTAD 2008). For the first time ever the number of hungry people passed the one-billion mark in 2009 (EED 2009). All these problems compromise the rural development and put rural population into the situation of vulnerability and poverty.

Benin is confronted to food insecurity as well and the problem exists with acuteness. In order to tackle the situation a lot of agricultural policies were launched. One of the most important is the diversification of agriculture in order to vary the source of income and improve the food security by producing food crops.

Indeed agricultural sector in Benin contributed to about 39 % of GDP and employed about 80 % of population in 2002 (PNUD 2003). Cotton is the main cash crop in this sector which contributes to around 64 % of export revenue, 90 % of agricultural revenue and 24 % of state revenue (OBEPAB 2002). The farmers found its cultivation as an opportunity and changed the land use consequently in order to increase the production with intensive use of chemicals. This situation causes a decline of the soil fertility and exposed farmers to food insecurity and environmental risks and damages. The production of food decreased and made farmers vulnerable to food security.

The agricultural policy in order to solve this problem proceeded to the introduction and the promotion of rice production in different regions of Benin. This introduction of rice was done also in cotton production zone due to the fact that the cotton zone has important inland valley appropriate for rice production which are not farmed or not properly.

The department[1] of Alibori, first producer of cotton, is also one of the departments which produce a big quantity of rice (34 % of the national production). The municipality of Banikoara[2] is located in this agro-ecological zone with important inland valley covering 4,756 ha in 2006 (CeCPA, 2006) appropriate to the cultivation of rice. However, the producers of this zone regularly complained about the low performance of their farm which has a negative impact on their income. The launch of rice production in this region is based on all these advantages for rice production. The possibility to re-change the land use becomes obvious and the farmers cultivate then several crops during the agricultural campaign which enter in competition in terms of resources use. The management of the new land use system need to be

[1] Benin is divided into 12 regions or sub-states called departments (In French: departement).

[2] First municipality producer of cotton in the Alibori region and the whole country.

investigated in order to find out which allocation of resource allow farmers to increase their income and ensure the availability of food.

This study carried out in township of Banikoara in Benin, by using the linear programming analyses the rationality that guide the producer in the management of his farm and finds out the allocation of resources that allow him to maximise his profit.

18.2 Study Area

The Republic of Benin is located in West tropical Africa, between 6°30 and 12° North Parallels and 1° and 3°40 East Meridians. Data were collected in two villages belonging to the municipalitie of Banikoara, (11°18′0″ North and 2°25′60″ East), located in the Northern region of Benin (Fig. 18.1). This zone has been chosen because of its importance in agriculture in Benin and the problem it faced nowadays in term of low agricultural productivity and food security.

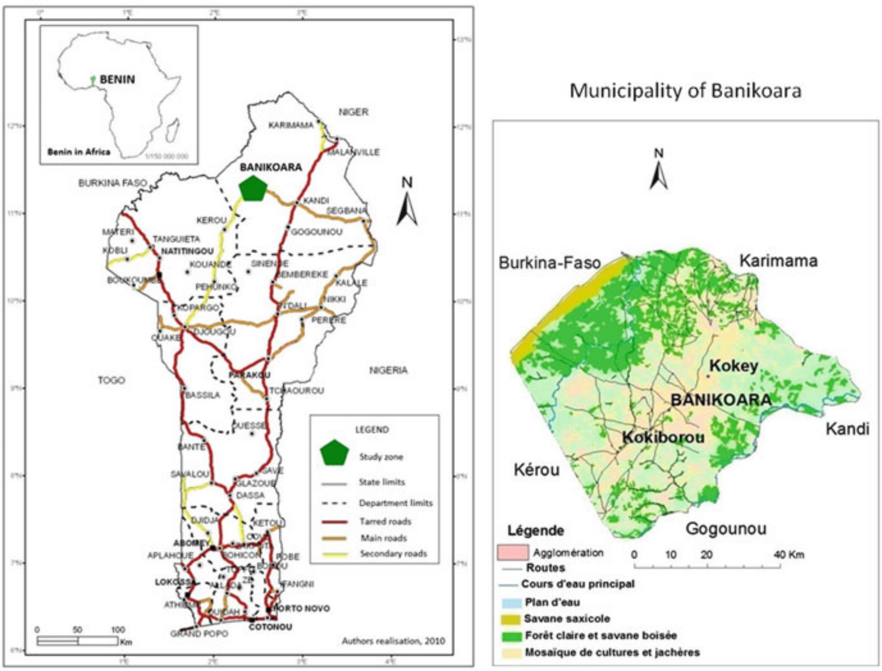

Fig. 18.1 Study area

18.3 Methodology

Data were collected in two villages (Kokey and Kokiborou) in Banikoara by using a two stage sampling technique for selecting the respondents. The first stage was a purposeful sampling of two representative village – Kokiborou and Kokey – with the support of agricultural extension officers following the criteria of the relevance of the subject for the village, the easiest accessibility during the survey time and the availability of financial resources. The second stage of sampling involved the purposeful random sampling of cotton and rice farmers in the two villages. In total 71 households were surveyed. The approach used for analysis consists of determining the average farm which cultivates rice and cotton. Therefore the average farm is formed by five active persons of whom two men, two women and one permanent farm worker.

Seven activities (crops) were retained within the framework of the elaboration of the model. These activities are the main crops cultivated by the farmers (rice, cotton, maize, sorghum, bean, soybean and groundnut).

$C = (\text{Rice, Cotton, Maize, Sorghum, Bean, Soybean, Groundnut})$ with C the set of crops;

$F = (\text{Rice, Maize, Sorghum, Bean, Soybean, Groundnut})$ with F the set of food crops;

$DL = (\text{Cotton, Maize, Sorghum, Bean, Soybean, Groundnut})$ with DL the set of crops cultivated on dry land;

$R = (Rice)$ with R the set of crops cultivated on inland valley.

18.3.1 Availability and Constraints of Land

The available land is represented by the area of land effectively cultivated by the average farm in 2006 and not the area of land it owns in total. Two types of land were distinguished by taking into account the physical characteristics of the land. It is about inlands valley for the cultivation of rice and the dry land for cotton, maize, sorghum, bean, groundnut and soybean. Hence the available land is limited to the average area of inland valley and dry land cultivated by the average farm (Table 18.1).

The following constraints are formulated on land:

$$Area\,(R) \leq dsps1;$$

$$\sum Area\,(DL) \leq dsps2.$$

With dsps1 the area of inlands valley available for rice cultivation and dsps2 the total area available for the cultivation of crops on dry land.

Table 18.1 Availability of land expressed in hectares

Type of land	Availability (ha)
Inland valley	0.515
Dry land	9.77

Source: authors' estimates from field study data.

18.3.2 Availability of and Constraints of Labour

The labour is a major constraint and its management is one of the pillars of the agricultural production. Two types of labour were considered: family labour and agricultural wage labour. Regarding the family labour three periods were considered by taking into account the cultivation calendar:

Period 1(April to June): during this period the cleaning of land, ploughing and sowing for maize, cotton, sorghum, soybean, groundnut, rice and bean are done. The application of herbicide for cotton, maize and sorghum begins during this period.

Period 2(July to August): It is the period of weeding for rice. Most of the crops receive the fertilizers. The hoeing and the application of insecticides for most of the crops are also done during this period.

Period 3(September to January): it corresponds to the period of harvesting.

The constraints of labour are: $\sum\sum mo\,(p.C) \times x(C) \leq dspmo\,(p)$.

With $mo\,(p, C)$ the quantity of labour required for cultivating 1 ha of crop C during the period p; $x(C)$ is the area of crop C to be cultivated.

$dspmo\,(p)$: Labour available during the period p.

In order to determine the available labour the coefficient defined by Norman (1973) has been used. The labour unit quantified in man-day is equivalent to the work which would have been done during a day by a worker paid according to the task-work.

The man-day is used by considering 8 hours of work per day. It is important to notice that in Benin in general and in the study zone in particular, the agricultural worker is paid according to the task-work. Therefore the price per man-day for cleaning is not equal to the amount of money paid per man-day for ploughing. If a farmer works during 3 days to accomplish the work which could be finished (according the norms in the zone) in 1 day by an employee, his labour force is not equivalent to 3 men-days but 1 man-day. Likewise a child, who works during 1 week and has accomplished the work which could be finished by a worker in 2 days, has only 2 men-days of labour force.

Regarding the agricultural wage labour the number of workers to be hired is not a constraint but the money for acquiring is the constraint (Table 18.2).

Table 18.2 Availability of family labour expressed in man-day

Period	Availability (man-day)
Period 1	318
Period 2	219
Period 3	427.5
Total	964.5

Source: authors' estimates from field study data.

Table 18.3 Expenditures related to the purchase of manure, insecticide and herbicide (FCFA/hectare)

Types of expenditures	Expenditures (FCFA/ha)						
	Rice	Cotton	Maize	Sorghum	Beans	Groundnut	Soybean
Manure	42,359.15	55,902.39	32,083.81	463.38	–	–	9,212.44
Insecticides	–	34,515.28	–		7,937.84		404.35
Herbicides	28,646.85	13,044.05	10,534.85	1,885.72	1,284.51	864.32	1,539.31

Source: authors' estimates from field study data
Note: 1 Euro = 655.957 Franc CFA.

18.3.3 Constraints Related to Input-Credit Payments

Cotton cultivation allows farmers to have access to the input credit. The farmers have the possibility to request for the quantity of inputs corresponding to their forecast of area to be cultivated. There is no limit in the wanted quantity. The most important issue is to be able to pay back from the revenue gained after the selling of cotton. If this revenue does not cover the inputs cost they should be able to pay from other sources. The GV[3] is the local institution responsible for the collecting of the debts related to inputs. In this study it was supposed that only the revenue gained from the selling of cotton is used for paying back the inputs credits. Let us indicate that the inputs are supposed to be used only for cotton but it has been noticed that the farmers overestimate the quantity of inputs for cotton and use the surplus for the food crops. But this situation is not expressed in the model. The model considers that all credit is reimbursed by cotton revenue.

The constraints are as followed:

$$\sum (prfum \times qfum + prins \times qins + prher \times qher) \times x(cot) \leq REC;$$
$$REC = prv(cot) \times prod(cot);$$

$prfum$: Price of sale of 1 kg of chemical manure expressed in FCFA[4]/kg;

$qfum$: Quantity of manure used for 1 ha of cotton expressed in Kg;

$prins$: Price of sale of 1 l of insecticide expressed in FCFA/L;

$qins$: Quantity of insecticide necessary for 1 ha of cotton expressed in litre;

$prher$: Price of sale of 1 l of herbicide expressed in FCFA/L;

$qher$: Quantity of herbicide requested for 1 ha of cotton expressed in L;

REC: Revenue from cotton expressed in FCFA;

$prv(cot)$: Price of sale of cotton expressed in FCFA/Kg;

$prod(cot)$: Production of cotton expressed in Kg;

$x(cot)$: Area of cotton to be cultivated expressed in ha (Table 18.3).

[3] GV means "Groupement villageois", group of farmers.

[4] FCFA = Franc CFA is the currency of Benin; 1 euro = 655.957 FCFA.

18.3.4 Use of Stock for Seeds

Farmers often keep seeds for the next season from the available harvest of current year. Therefore a relationship between the quantity of seeds to be stored and the area of production it has been stored for is written as followed:

$$SMNCE(F) = sem(F) \times Area(F)$$

$sem(F)$: Average quantity of crop F to be stored for sowing 1 ha expressed in kg;
$Area(F)$: Area of crop F to be sowed expressed in ha;
$SMNCE(F)$: Quantity of crop F to be stored in kg;

18.3.5 Production Available for Sale and Consumption

$$PRO(F) = rend(F) \times sup(F);$$

$$PROD1(F) = PRO(F) - SMNCE(F) + STOCKO(F)$$

$STOCKO(F) = 0$ by assumption;
$sup(F)$: Area of food crops F expressed in ha;
$rend(F)$: Yield of crop F expressed in kg/ha;
$PRO(F)$: Harvested production of crop F expressed in kg;
$PROD1(F)$: Harvest of crop F available for consumption expressed in kg;
$STOCKO(F)$: Stock of crop F from previous season expressed in kg.

18.3.6 Availability and Constraint of Capital

The available funds are the capital used by the producers to pay the workers. These available funds are part of the income of harvest.

18.3.7 Constraints of Self Consumption

These constraints are the minimal quantities of each food crop which are produced to satisfy the food needs of the household. To identify these needs, the parts of the production self consumed were considered. With regard to the declared

Table 18.4 Foods consumption needs expressed in kilogramme

Crops	Self consumption needs
Rice	328.928
Maize	2,723.512
Sorghum	1,108.032
Bean	82.488
Groundnut	53.384
Soybean	59.592

Source: authors' estimates from field study data.

consumptions, the households are supposed self-sufficient. The needs of household are presented in Table 18.4.

Twenty percent of raise was made for all products because of the losses and the gifts as well as the food given to the occasional farm workers.

$$sup(F) \times rend(F) \geq P;$$

$rend(F)$ = yield of food crops F expressed in kg/ha;

$sup(F)$ = area of food crops F expressed in en ha;

P = self consumed production expressed in kg.

18.3.8 Model

The objective function is written as followed:

$$\begin{aligned} Max\,Z &= \sum (prv(C) \times Q(C) - sup(C) \times C(C)) \\ &= \sum (sup(C) \times prv(C) \times rend(C) - sup(C) \times C(C)), \end{aligned}$$

$prv(C)$ = Price sale of one unit of product C expressed in FCFA;

$Q(C)$ = Quantity of C produced expressed in kg;

$C(C)$ = Cost related to the production of 1 ha of product C expressed in FCFA/ha;

$sup(C)$ = Area cultivated for crop C expressed in ha;

$rend(C)$ = Yield of crop C expressed in kg/ha;

$PROD1(F) = PRO(F) - SMNCE(F) + STOCKO(F)$:

$PRO(F) = rend\ (F) \times\ sup(F)$;

$$SMNCE(F) = sem(F) \times Area(F);$$

$$Area(R) \leq dsps1;$$

$$\sum Area(DL) \leq dsps2;$$

$$REC = prv(cot) \times prod(cot);$$

$$\sum (prfum \times qfum + prins \times qins + prher \times qher) \times x(cot) \leq REC;$$

$$\sum \sum mo\,(p, C) \times x(C) \leq dspmu\,(p);$$

$$sup(F) \times rend(F) \geq P;$$

$$Area(C) \geq 0;$$

$$mo\,(p, C) \geq 0;$$

18.4 Results and Discussions

No particular condition was put for this model. It is about the first model run with the collected data. This model constitutes the basic model. The model was built and run in GAMS (General Algebraic Modeling System).

18.4.1 Area Cultivated

The model gives a total area of available dry land equal to 9.77 ha corresponding to the total dry land area available for the average farm. As for the inlands valley the total area given in the model was also completely used. The optimal production used consequently all the area belonging to the average farm. This result shows the importance of agricultural activity in this zone. Land seems to be a major constraint for agricultural production. The producers in that case are capable to use more area, even if they are able to rent the land. The opportunity costs of one unit of land are respectively to 296940 FCFA for the inlands valley and 75488 FCFA for the dry land (Table 18.5).

As for the allocation of the resource for each crop the results of the model appear as follows:

All the available land for rice (0.515 ha) is used by the optimal plan of production. It explains the current desire of farmers to cultivate this crop. Similar results are obtained by Adégbidi (2003) who noticed from a model of programming that all the available area (0.78 ha) for rice was completely used by the optimal plan of

Table 18.5 Area cultivated expressed in hectares

	Observed results	Results of model
Rice	0.515	0.515
Total 1	0.515	0.515
Cotton	5.12	2.256
Maize	2.88	1.262
Sorghum	1.06	0.801
Beans	0.26	5.290
Groundnut	0.29	0.058
Soybean	0.16	0.103
Total 2	9.77	9.77
Total	10.285	10.285

Source: authors' estimates from field study data.
Total = Total 1 + Total 2

production. The model allocated a part of the production (just the quantity which is needed by the farm for self-consumption) for the consumption and the major part (3/4 of the production) for the selling. Indeed rice is a very profitable crop and its selling presents an economic interest not only for farmers but also for the entire region.

The model proposes a decrease of about 56 % of the area of cotton. This result demonstrates that in the current conditions of production, the cotton is not profitable for the farmers. This confirms the strong decrease of cotton production and the crisis in the sector nowadays. Studies carried out in 2002 by the OBEPAB in the municipality of Glazoué in Benin showed that the cotton presented a negative gross margin, what justified the debts of the producers and the decrease of production. Similar results are obtained by Adidehou (2004) in the municipality of Glazoué in Benin. He noticed that in the present state of production, cotton is not a profitable speculation for the farmers.

Areas assigned to the crops such as maize, sorghum, groundnut and soybean by the model are lower than the observed situation. The quantities allow by the model are only intended to the satisfaction of the needs of the household. But in the real situation farmers sell a part of these products. These crops do not present an economic importance for the region, at least in the current conditions of their production.

As for the cultivation of bean the optimal solution is about 20 times superior to the observed situation. The model has suggested the production of more beans for marketing. This situation is due to the fact that among the crops cultivated on dry land bean is the one which has high gross margin. It is to say that apart from rice, bean is a profitable crop which can supply monetary resources for the household. The difference between the observed situation and the optimal solution can be explained by parasitic problems. Bean is subject to a strong parasitic pressure which is difficult to manage. According to Adégbidi (2003) the yields of beans are good every 2 years, because of the parasitic problems. In spite of its important profitability the farmers assign few areas because of the risks connected to the parasitic attacks. As this risk is not included in the model, bean has benefited from the reduction of area of maize, sorghum, groundnut and soybean.

Table 18.6 Labour force in man-days

	Observed results		Results of model	
Period	Family labour	Agricultural wage labour	Family labour	Agricultural wage labour
Period 1	318	78	251.176	–
Period 2	219	52	219	39.831
Period 3	427.5	130	104.622	133.693
Total	964.5	260	574.798	173.524

Source: authors' estimates from field study data.

From the model it can be inferred that the resources are mobilized first of all for the satisfaction of the needs of consumption, then, the available factors are used for the production of the crops which are profitable for farmers by taking into account available resources and requirements of every crop. Rice and bean are the crops of which areas proposed by the model are superior or equal to those observed. Given that they present the best margins, the model suggested to produce them within the limits of the available resources. Similar results are obtained by Madi (2000) in an entitled study: the prices of products and the productive system in the cotton zone of the north extreme of Cameroon. His results showed that since the production is sufficient for the consumption, the crops such as cotton, mouskwari and bean appear in the model because presenting the best economic opportunities.

18.4.2 Family and Agricultural Wage Labour

The model has showed that there are some rush periods of activities during which the family labour constitutes a major constraint in the production. The concerned periods are: July–August. During this period producers need to hire labour force (Table 18.6).

On 964.5 men-days of family labour available in the farm, the model gives a use of 574.798 men-days. As for agricultural wage labour, instead of 260 work days paid on average by a farm the model has given 173.524 men-days. In total a global labour of 748.322 days would be sufficient to obtain a better income by keeping at the same time its independence towards the market of the food crops. This surplus of labour force could be used for other activities in order to vary income source.

18.4.3 Capital

18.4.3.1 Use of Own Capital

The use of the capital is the same in the observed situation and that of the model. The capital available is only intending to the hire of labour force. The model thus used this capital in its limited availability.

Table 18.7 Credit allocated to crops expressed in FCFA

	Observed results	Results of model
Credits		
Inputs rice	36,568	36,568
Inputs cotton	529,724	233,409
Inputs maize	122,741	53,784
Inputs sorghum	2,490	1,881
Inputs bean	2,397	48,786
Inputs groundnut	250	50
Inputs soybean	1,784	1,149
Total	695,954	375,627

Source: authors' estimates from field study data.

Table 18.8 Gross margin of crops expressed in FCFA

Gross margin	Observed results	Results of model
Rice	149,695	170,823
Cotton	230,121	100,665
Maize	167,514	79,796
sorghum	68,009	48,120
Bean	36,051	423,217
Groundnut	39,019	3,275
Soybean	15,734	5,894
Total gross margin	706,143	831,790

Source: authors' estimates from field study data.

18.4.3.2 Credit

The credit is only available for the cotton; however the farmer use this credit for others crops by overestimating the quantity of inputs. The revenue from the sale is thus used to pay off this credit. Therefore the model uses this credit proportionally to the cultivated cotton area. The reduction of credit (from 695,954FCFA to 375,627 FCFA) is proportional to the decrease of the cotton area given by the model (2.256 ha instead of 5.12 ha) (Table 18.7).

18.4.4 Income

The gross margin of the crops such as cotton, maize, sorghum, groundnut and soybean decreased with regard to the observed average situation, because of the decrease of area used. Only gross margin of rice and bean increase and carry the agricultural gross margin from 706143 FCFA to 831790 FCFA, corresponding to 18 % increase (Table 18.8). Therefore with the same total area and with less work, the model gives an increase of the income of 18 % with a complete independence towards the market of the food crops for the household's consumption. In this situation we could ask ourselves why farmer does not choose to work less and gain more money. The answer to this question is that the farmer who has experience in his business knows well that he can gain more money by producing for example less maize and enough of beans and rice with the resources he has. The model does not allow farmers to produce more because the risk of a bad harvest is not taken into account here, what is against the farmer's logic. Even if the maize is less profitable, the farmer wants to be assured that in case of insufficient rain or bad harvest due to insects, he can survive without going to the market.

The various results given by the model on the utilization of land, labour force and the capital showed that the obtained basic model is optimal. Consequently, the hypothesis of this study to see whether allocation of the factors of production is not optimal is confirmed. Indeed, the model presents a better use of the factors of production to optimize the income.

18.5 Conclusions

This study has investigated whether the introduction of rice for diversification of crop allow farmers to reach the optimal production. The linear programming was used to achieve this objective. It has been found that rice is the profitable crop for farmers and is able to allow them to reach food security in term of availability and food accessibility. Cotton cultivation in the current situation is not interested for the farm. It becomes interested with an increase of more than 40 % of his actual yield. Less labour needs to be used to attain with the same amount of land 18 % more income than previously. The surplus of labour may be engaged in others activities in order to earn extra revenue for households expenses.

This study has confirmed the potential of cultivation of rice in the cotton zone. Rice is an interested crop which needs to be promoted intensively. The agricultural policy must be orientated to the training of farmers on practices and on the best way to allocate resources in order to achieve a good production. The arrangement of inlands valley needs to be done to allow farmers to have more areas of inlands valley for rice cultivation. In order to avoid some post harvest losses some measures need to be taken to improve the processing of rice for ensuring the utilization.

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Chapter 19
Oil Palm Expansion: Competing Claim of Lands for Food, Biofuels, and Conservation

Ari Susanti and Paul Burgers

Abstract At about 20 % of total GHG emissions, land use, land use change and the forestry (LULUCF) sectors contribute significantly to global green house gas (GHG) emissions. This percentage may be significantly higher in countries with huge forest resources, like Indonesia. In Indonesia, forests are increasingly converted to satisfy the growing demand for commercial agricultural products, most notably oil palm *(Elaeis guineensis),* not only for food but also for biofuels. Although forest losses caused by oil palm expansion are considered to be one of major contributors to land use change (LUC), oil palm expansion has less visible additional indirect effects in accelerating forest transformation. These are hardly studied, as they require an in depth knowledge and understanding of socio-economic changes caused by oil palm expansion at the grass-root level, the household level. These complex indirect effects receive no or only scant attention. This is striking to note, since they may become a major cause of forest conversion in the (near) future. Oil palm production leads to complex population redistribution. Local people are displaced not only by large scale investors, but also sold out by in-migrants. Large numbers of migrants are entering the Indonesia oil palm producing regions, hoping to benefit from the economic opportunities oil palm plantations provide. The search for arable land by a fast growing population puts increasing pressure on remaining (protected) forest areas, when they start investing in land for small scale oil palm plantations. Many of the remaining areas consist of peatlands. GHG emissions are therefore expected to rise

A. Susanti (✉)
Faculty of Geoscience, International Development Studies, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands

Faculty of Forestry, Gadjah Mada University, Jl. Agro No. 1 Bulaksumur, 55281 Yogyakarta, Indonesia
e-mail: a.susanti@uu.nl; asusanti@ugm.ac.id

P. Burgers
Faculty of Geoscience, International Development Studies, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands
e-mail: P.P.M.Burgers@uu.nl

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tremendously. Analyzing these indirect socio-economic land use effects associated with oil palm expansion is therefore urgently required and is the main objective of this chapter.

Keywords Oil palm • Food • Biofuels • Conservation • Landuse change • Emission • Migration

19.1 Introduction

The Land Use, Land Use Change, and Forestry, usually referred to as LULUCF sectors, contribute to global GHG emissions in a dualistic way. On the one hand, LULUCF sectors are responsible for around 20 % of total global emissions (Pearson et al. 2005; Schlamadinger et al. 2007; Watson et al. 2000). These consist mainly of the expansion of agricultural land into forested areas, due to ever increasing demand for agricultural products at a global scale. On the other hand, the LULUCF sectors also have special characteristics in removing GHG emissions from the atmosphere. The pledge of the international legally binding biodiversity convention in 1992 forced each country to develop national strategies for the conservation and sustainable use of biological diversity and for sustainable development. Since then, the LULUCF sectors have been seen as the key component of conservation and sustainable development (Convention on Biological Diversity 2010). Ever since the Kyoto Protocol, the LULUCF sectors have been more intensively discussed under the United Nation Framework Convention on Climate Change (UNFCCC) because of its important roles in reducing Green House Gas (GHG) emissions from the atmosphere as a result of biomass growth (Schlamadinger et al. 2007).

There is however huge differences among countries in the share of how much the LULUCF sectors contribute to GHG emissions. Especially in countries where agriculture is an important part of the GDP, and where large forest areas are still available, this figure may be much higher. Brazil is one such country, where deforestation adds to about 70 % of national GHG emissions (Cerri et al. 2009). However, number one in this respect is Indonesia, where deforestation contributes to around 85 % of the national GHG emissions (PEACE 2007). In particular the conversion of peatland forests, into oil palm plantations contributes significantly to this percentage.

Currently most of the oil palm produced in Indonesia is for food purposes. Besides being an important export commodity, palm oil accounts for up to 80–85 % of the domestic edible oil consumption in Indonesia (Goenadi et al. 2005). Furthermore, to comply with international negotiations to reduce GHG emissions and the problematic situation of the national energy supply, the government of Indonesia has developed a national energy policy in the recent past. Palm oil as a biofuel will play an important role in this energy policy. By 2025, biofuels should have a share of at least 5 % (Wirawan 2006) in the domestic fuel supply. These commitments were strengthened by the statement of the President of the

Republic of Indonesia in the G-20 summit 2009 in Pittsburg, saying that Indonesia will reduce national emissions by 26 % by 2020 from BAU (Business As Usual) with international support (Yudhoyono 2009). Looking ahead, the trend shows an increasing global demand for biofuels in between 2010 and 2020. The supply must double to meet the demand (Klein et al. 2011). The push for biofuels is not only linked to the international climate negotiations to reduce GHG emissions, it is also pushed by the problematic situation in the Middle East, and coming shortages of affordable oil, driving up prices of crude oil. These developments push governments to search for alternative fuels.

These rather strong policy directions of high emission reduction targets and the fact that palm oil is viewed an alternative low carbon fuel, adds to an acceleration of oil palm expansion in Indonesia. Oil palm is a logic choice. It thrives well in tropical countries and produces by far the highest yields compared to other vegetable oils as shown in Table 19.1 (Journey to Forever 2010).

A growing body of literature is beginning to show controversies in relation to oil palm production. Many of the newly planted estates have been established on former forest lands. If the carbon losses from deforestation are included in the so-called low carbon equation, biofuels contribute more to GHG emissions compared to the use of fossil fuels (Block 2013). Several studies in East Kalimantan on forest degradation and above ground forest biomass found that tropical natural forest seems to be the greatest reservoir for biomass or a carbon sink (Basuki et al. 2009; Hashimoto et al. 2000; Tangki and Chappell 2008). Depending on the converted forest type, the payback time to recapture the carbon released from forest conversion to oil palm varies. A study done on the payback time for the loss in carbon for establishing oil palm plantations on degraded grassland is a mere 10 years, while for rainforests, cleared with burning is 93 years. Most dramatic is however the conversion of peatland forests, estimated to be around 692 years (Danielsen et al. 2009). Carbon losses are not the only controversial aspect related to oil palm expansion. A number of studies also revealed that forest conversion to oil palm estates leads to serious biodiversity declines (Fitzherbert et al. 2008; Koh 2007). Figure 19.1 clearly shows that oil palm plantations mostly overlap with areas of high biodiversity value (a), especially in Indonesia. Moreover, the government of Indonesia plans to expand the oil palm plantations up to around 20 million hectares in 2020 to satisfy the demand in the global market. The expansion will focus on Sumatra, Kalimantan, Sulawesi and Papua Barat (Colchester et al. 2006). However, these are also hotspot areas for most of the world's high biodiversity.

Although these environmental issues have received widespread attention for good reasons, socio-economic indirect effects of oil palm expansion receive only scant attention. With regard to social issues, the debate is limited to labour circumstances on plantations or to conflicts between local communities and investors, when local communities are being displaced from their land. There are more complex indirect effects on the rise, which until today are hardly or not at all studied nor understood. As most arable lands have been taken into production, while ecologically vulnerable forest lands are set aside for conservation purposes, there only little land remains to absorb not only displaced communities, but also an

Table 19.1 The vegetable oil yield/ha (Journey to Forever 2010)

Crop	Oil palm	Coconut	Jatropha	Sunflower	Sesame	Soybean	Corn (maize)
Litres oil/ha	5,950	2,689	1,892	952	696	446	172

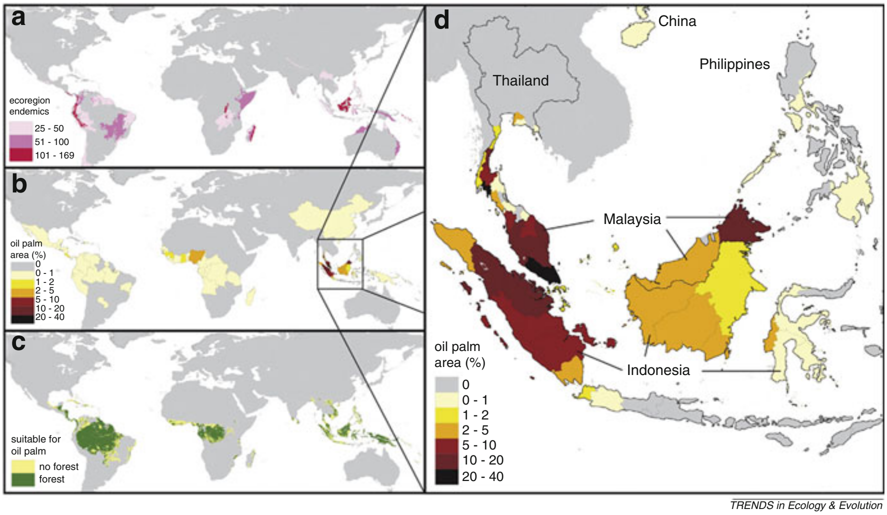

Fig. 19.1 The distribution of current oil palm plantations and biodiversity rich areas in Indonesia (Fitzherbert et al. 2008)

increasing number of migrants. All in search for land to develop their own small scale oil palm plantation. This puts additional pressure on the remaining, usually protected forest areas. In addition, where forest land cannot be accessed, high potential profits from oil palm cultivation is also altering the way people perceive on farm food cropping. Food cropping land is also beginning to feel the pressure put on land to grow oil palm.

19.2 Conceptual Framework

A growing body of literature reveals a great interest in the effects how increased palm oil demand leads to deforestation and carbon losses. However, most studies on LUC are focused on the unintended consequences of releasing carbon emissions due to land use changes around the world induced by the expansion of croplands in response to the increased global demand for specific products, e.g. palm oil. Relatively few studies focus on the social consequences of these large scale land use changes, let alone the impact of these changes on population dynamics, caused by oil palm expansion.

Our research project aims to unravel how changing population dynamics may cause another wave of deforestation, and its associated carbon losses. A redistribution of population is not only caused by displacement, but also by the migration attracted by the development of new economic centres with oil palm as main commodity. These economic centres attract large numbers of migrants who wish to set up their own (small scale) oil palm plantation (usually less than 5 ha). In areas where most of the suitable land is already taken into production, e.g. Riau province, displacement in combination with migration may put additional stress on the remaining forest areas. In our research project, we combine social and bio-physical research to find regular patterns in what are often viewed as irregular processes of encroachment into forested areas. Here, we will focus on how voluntary and involuntary migration induces deforestation and carbon losses, caused by the growing global demand for palm oil. We present our findings from fieldwork in Riau Province, Sumatra. This is a province, where since the early 1970s, land use patterns have been largely influenced by oil palm investments.

19.3 Study Area

Riau province lies in Sumatera Island, Indonesia. Geographically, it is located in 01°05′00″ S–02°25′00″ N and 100°00′00″–105°05′00″ E. The size of the province is 8,867,267 ha. The province hosts around 4.7 million inhabitants with a population density of 50 per km^2. Around 49.3 % of the labour force in the area finds employment in the agricultural sector. This includes cash crop cultivation, estate crops, live stock production, fishery, and forestry, both large scale and small scale enterprises (Badan Pusat Statistik Propinsi Riau 2010).

The province is blessed with large supplies of natural resources below and aboveground. The most important natural resources include oil, natural gas, charcoal, gold, peat, forest (timber), wildlife, and fish. Oil exploitation started already as early as the beginning of the nineteenth century (Uryu et al. 2008). Natural forest has been harvested (logging), mostly for timber, also from this time onwards (Sumardjani 2005). Forest exploitation was followed by the establishment of large scale pulp and paper industries, turning large forest areas into industrial tree plantations.

In the early 1970s, Riau was still covered with extensive forest areas. Over 95 % was classified as state forest area at that time (Ministry of Forestry of the Republic of Indonesia 1986). From the early 1980s, the paper and pulp industry developed in Riau province. Large areas of natural forest areas were converted into tree plantations, now occupying around 1.6 million hectares (Directorate General Estate Crop Ministry of Agriculture 2010).

Huge investments were made in road construction to bring logs to the processing facilities which were established along the coast and rivers. The enormous amounts of labour needs were satisfied through various trans-migration programmes and by setting up settlements. In recent decades, many of these tree plantation settlements

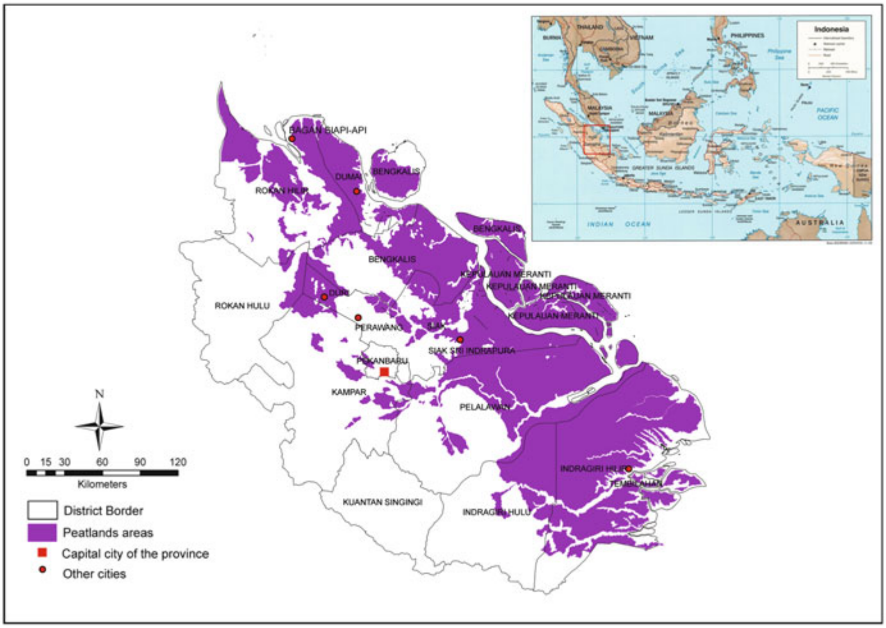

Fig. 19.2 The administrative and soil type maps of Riau province (Center for Soil and Agroclimate Research and Agency for Agricultural Research and Development 1990; Pemerintah Provinsi Riau 2011)

have developed into relatively large towns. For example, the Tualang district with Perawang town and Pangkalan Kerinci district with Pangkalan Kerinci town, have 93,118 inhabitants or 271 inhabitants/km^2 (Badan Pusat Statistik Kabupaten Siak and Badan Perencana Pembangunan Daerah Kabupaten Siak 2010) and 71,219 inhabitants (370 inhabitants/km^2) (Badan Pusat Statistik Kabupaten Pelalawan 2010) respectively. Although tree growing remained mostly a large scale activity, smallholder involvement in large scale agricultural activities completely changed when oil palm came to Riau (Fig. 19.2).

Oil palms emerged as one of the most important cash crops in Riau province since the mid 1970s, out-competing coconut, rubber, and coffee which had always been the main commodity crops in the area. Since 1995, oil palm occupied the largest area compared to other estate crop commodities (Directorate General Estate Crop Ministry of Agriculture 2010). Palm oil production really took off in the late 1990s, when the global demand for more healthy fats in the food processing industries increased. More recently, the demand for palm oil in Riau is once more increasing, now caused by the growing demand for palm oil as a biofuel.

Nowadays, the total area covered with oil palm plantations in Riau (including state-owned, smallholder and private enterprises) is about 1,925.341 ha of land (Dinas Perkebunan Provinsi Riau 2010). Smallholder involvement mainly consisted of so-called supported smallholders, who cultivate oil palms with direct support from either the government through state-owned companies or the private sector through private companies. Based on loans, the companies provide technical assistance; inputs feed stock, fertilizers and pesticides.

To control the expansion of oil palm, it was stipulated by regulation that the processing mill could only be established in combination with oil palm plantation. However this regulation was abandoned in 1995, and from that time onwards, it really became an independent smallholder crop. These independent growers cultivate oil palm without direct assistance from government or private companies and are not linked to one specific processing mill. Brokers or middlemen become the intermediary for them, buying the fruits from individual households, and provide loans to set up their own plantation. The farming household become highly dependent on them especially with the fact that they are lacking of access to bank loans. In addition, most of the individual farmers could not meet the requirements to get delivery orders (DO) for fresh bunch fruits from the mills. This requires specific minimum requirements on area harvested and available transportation means to get a DO from the mill. Middlemen can get these DOs, as they collect large enough quantities from the individual small scale producers. This situation creates in one hand can maintain the price of oil palm in the local market, but on the other hand it creates high competition among oil palm mills which do not have their own plantation to maintain the continuous supplies of the raw materials. With this situation, in 2005 the government set the requirements for integrated oil palm processing industries, in which a new processing mill have to be established integratedly with the oil palm plantation. This is in particular to maintain the sustainability of the raw material supplies which is from their own plantation.

It is estimated that both supported and independent smallholders nowadays consist of about 377.183 families, who have their own small scale oil palm plantation. In total they occupy around 996.199 ha or around 52 % of the total oil palm plantation in Riau (Dinas Perkebunan Provinsi Riau 2010). These are registered smallholders. There are however, large numbers of unregistered smallholders entering the market nowadays. It is especially this group of smallholders, on which we focus as they are viewed to become a major driver for deforestation in the near future.

19.4 Methods

This research combines biophysical and social aspects and quantitative and qualitative methods of analysis. Biophysical data were collected from the field in February – April 2009 and in November 2010 – February 2011. Samples were selected based on the NDVI (Normalized Difference Vegetation Index) value and accessibility. Two permanent sample plots and 92 temporary sample plots were measured for biomass estimation and 405 points were visited to identify the type of actual land use/land cover. The coordinate of each point was recorded using Garmin

GPSmap 76CSx. In total, 499 points were visited to check the actual land use in the field to support the development of land use/land cover classification map. Longitudinal spatial data (remotely sensed data and GIS data) were collected from relevant offices and websites. Spatial analyses were applied to remotely sensed data (Landsat TM) in combination with GIS and field checking data. Using ArcGIS version 9.3.1 software, projection and transformation, visual classification, map editing, and map lay outing operations were conducted. The actual land use/cover map from 2010 was than compared to the land use/cover map based on forest land use by the consensus map of the Ministry of Forestry from 1986. In this way, we were able to gain insights into the more direct impacts of land use change processes over the past 20 years in the area.

In order to factor in socio economic evidence, focus group discussions and semi structured interviews through questionnaires using closed and open questions among randomly chosen household members in villages were conducted to understand the context of oil palm development in the area. More qualitative information was collected by interviewing key informants. These included community representatives, community leaders, company representatives, government agencies representatives, experts (scientists) and staff from various NGOs, working in Riau province. Non spatial secondary data were collected to support the analysis on the dynamics of socio economic developments in the area. A descriptive statistic analysis was conducted using Microsoft Excel to report the distribution and to summarize specific socio-economic characteristics observed in the research area. A descriptive analysis on association and causation was conducted to understand the inter-relation among the observed variables.

19.5 Results and Discussion

19.5.1 Direct Effects of Oil Palm Development

Among others, the expansion of oil palm is triggered by the market price (Basiron 2002). The trend of the international market price of palm oil tends to increase over time (Index Mundi 2011). In Riau, the increase of the palm oil price in the global market was followed by a significant increase of oil palm plantation establishment. In contrast, only a slower growth in oil palm plantation development was a response to the decrease of palm oil prices. This is illustrated by Fig. 19.3a, while Fig. 19.3b (below), shows that Riau province is the largest producer of palm oil in Indonesia (Directorate General Estate Crop Ministry of Agriculture 2010).

Forest conversion into oil palm plantations accelerated during the early phases of decentralization in Riau province (from 2000 onwards) in which local governments were given more authority in regulating resources management on their jurisdiction (Barbier 2007; Barr et al. 2006; Resosudarmo 2004). In addition local governments were also given wider responsibilities to create a larger regional income (PAD) for

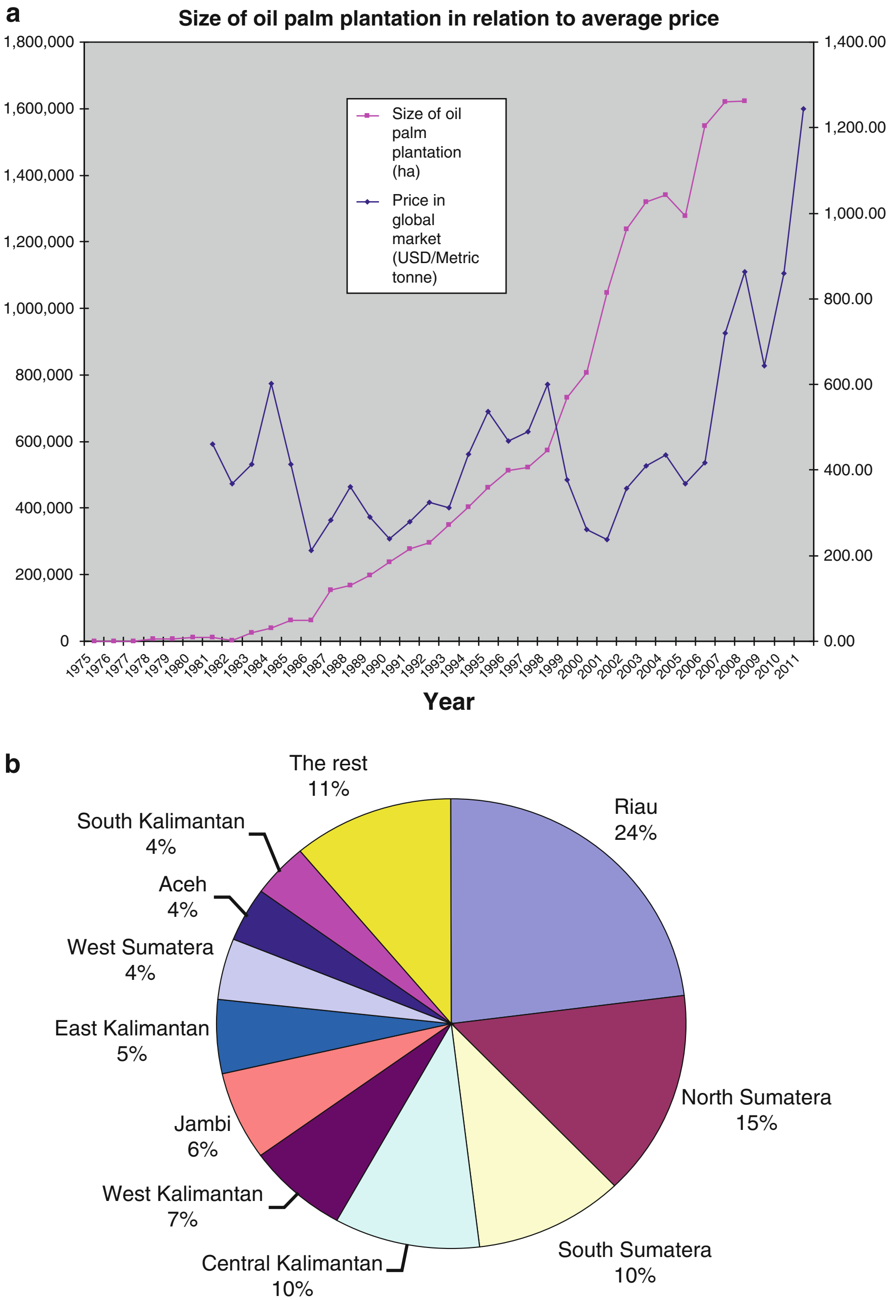

Fig. 19.3 (**a**) The development of oil palm plantation in Riau province in relation to global palm oil price; (**b**) The distribution of major oil palm plantation by province in hectares (Directorate General Estate Crop Ministry of Agriculture 2010; Index Mundi 2011)

themselves and maintain their existence as an autonomous region (Saad 2001). This has resulted in cashing in from forest resources for quick income (Obidzinski and Barr 2003; Palmer and Engel 2007). With the issuance of the regional autonomy laws which gave more authority to regional governments, licenses for natural resources utilization were rapidly issued at district level. This included small-scale forest concessions up to 100 ha and forest conversion (either from convertible or production forest) for oil palm plantation, rubber plantation, and settlement. In 2010, registered oil palm plantations contributed around 1.9 million hectares. This includes 52 % smallholders, 44 % private company, and 4 % state-owned company (Dinas Perkebunan Provinsi Riau 2010). However, there are many unregistered spontaneous smallholders who spontaneously establish oil palm plantations (usually less than 5 ha each). Our research is analyzing these oil palm plantation developments of independent smallholders, as they will be some of the main players in deforestation in the near future.

With the introduction of industrial forest plantation and intensive estate crop plantation, there have been significant changes during the last three decades. In 2010, the remaining forest is around 47 %. This is divided into 36 % of primary and secondary forest and 11 % of industrial plantation forest. Estate crops are dominated by oil palm plantations, and consist of about 31 %, while dry-land agriculture, shrub, and grassland account for up to 14 %. Mining takes 0.12 % of the land use. Surprisingly, there is still 7 % of bare land in the area (Fig. 19.4).

Although it brought prosperity to the province at large, it has also caused major controversies. Its production has been associated with extensive clearance of tropical forest areas and consequent loss of habitat for endangered species, and huge carbon losses. In addition, oil palm plantations compete directly for food cropping land and forest areas. Not only will food cropping land be converted into oil palm plantations, many local communities living in and around these forest areas depend to some extent on the forest for their livelihood. Cakrabortty (2008) reported that according to an unpublished World Bank report biofuels have forced global food prices to rise by 75 % through three main ways: (a) it has diverted grain away from food for fuel, (b) small scale farmers are being encouraged to set land aside for biofuel production, and (c) shortage in food production has sparked speculation in grains which is driving up prices further.

19.5.2 Food and Fuel Compete for Scarce Land Resources in Riau

Changes in crude oil prices also affect the rice production. External inputs, such as fertilizers and pesticides use oil for their production processes. Such fluctuations in costs for inputs and market prices for rice alters the way oil palm expansion takes place, not only for the large scale investors, but also for small scale producers of rice and oil palm. At a global level there seem to be contrasting opinions about the

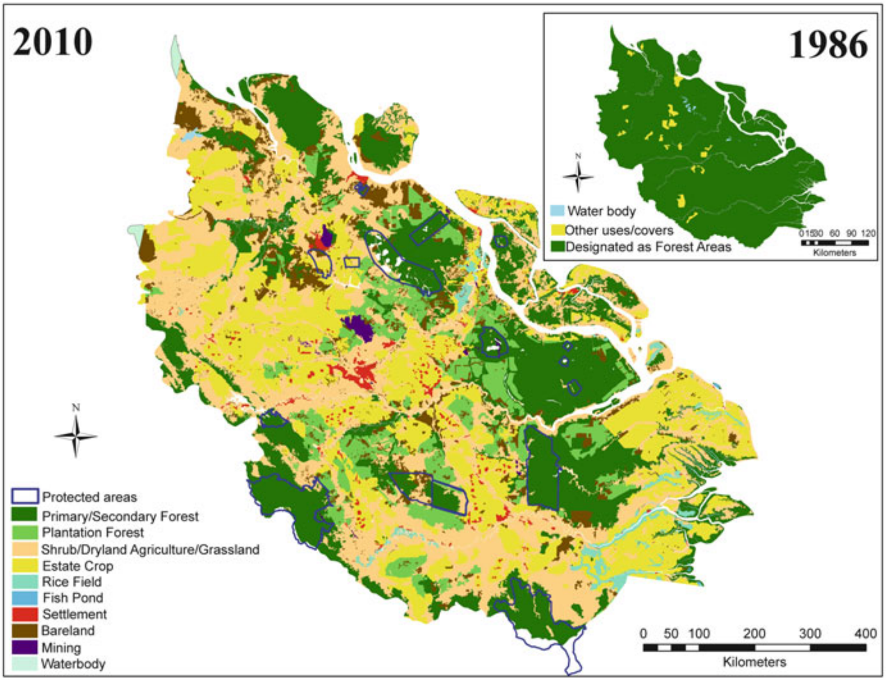

Fig. 19.4 Planned land use by consensus in Riau province 1986 (Ministry of Forestry of the Republic of Indonesia 1986) and actual land use cover map derived from mosaic of Landsat TM satellite images from 2010 and ground data overlaid with map of protected area 2005 (Ministry of Forestry of the Republic of Indonesia 2005a)

relationship between the increasing demand for palm oil as a biofuel and rising food prices. It ranges from no effect as biofuel is said to represent only 7 % of global supply of palm oil, while others stress the neglect of investments in the agricultural sector in general and in the food sector in particular as a main cause for growing food prices (Koswanage et al. 2011). However, in order to feed the growing population, food production is estimated to increase by 70 % (FAO 2011). Although the exact amount of additional land required to meet the demands for food is unsure, the FAO estimates it to be around 70 million ha in 2050. It is said to be possible. However, these figures do not yet take into account the need for land required to satisfy the growing demand for biomass for other purposes than food. The International Energy Agency (IEA) estimates that land requirements for biofuel production under the IEA Alternative Policy scenario will amount to 52.8 million ha in 2030 (IEA 2006). Hence, competition for the remaining land base increases (Burgers and Susanti 2011). However, to what extent there might be an effect depends largely on the region we are dealing with.

With most of the suitable land for agriculture already in production, Riau province is beginning to experience the dramatic effects of competition between oil palm and food crops, in particular rice production. Riau has become a food

Table 19.2 Rice field conversion 2002–2009 (Dinas Tanaman Pangan dan Hortikultura Provinsi Riau 2011)

No	Rice field conversion	Size (Ha)	(%)
1	Rice field – fish pond	81.80	0.41
2	Rice field – dryland agriculture	1,901.12	9.47
3	Rice field – bare land	1,319.30	6.57
4	Rice field – mining	90.39	0.45
5	Rice field – mix estate crop	1,545.68	7.70
6	Rice field – rubber plantation	720.26	3.59
7	Rice field – coconut plantation	1,102.36	5.49
8	Rice field – oil palm plantation	8,052.76	40.12
9	Rice field – settlement	1,895.59	9.45
10	Rice field – shrub	3,360.40	16.74
	Total	20,069.66	100.00

importing province, and this is expected to worsen in the years to come. Whereas large areas have been converted into oil palm plantations, the euphoria of possible profits from oil palm in combination with low profit margins for rice increasingly makes small scale farmers in Riau decide to convert their rice fields into oil palm plantations. Small scale farmers nowadays increasingly view oil palm plantation a better solution compared to engaging in food cropping and they assume that with the opportunity to get high profit margins from oil palms people can easily buy food. Table 19.2 shows that from 2002 to 2009, in total around 15 % of the small scale rice fields were converted into other uses. The main conversion has been the conversion of rice fields into small scale oil palm plantations (40 %).

This is a controversial development in a country that has always been self sufficient in rice production. Figure 19.5 shows that rice consumption in Riau is twice as high compared to rice production. Self sufficiency in rice remains however a major political issue and critical to national security, being the major staple crop for over 90 % of the Indonesian population. For these reasons, the government of Riau province plans to control rice field conversion to other land uses/covers through legal and economic mechanisms (Badan Ketahanan Pangan Provinsi Riau 2011). Rice is however not the only food item that is imported. Figure 19.6 shows that Riau province is also a net importer of various food items including fruits and vegetables.

Obviously, oil palm expansion has caused an unbalanced growth of agriculture. Where rural Indonesians always kept a piece of food cropping land as a fall back mechanism for hard economic times (Burgers 2008), The high profit margins that can be earned from oil palm cultivation have not remained unnoticed among inhabitants from other provinces or islands. A growing number of migrants are moving into Riau, adding significantly to population growth in Riau, and to pressures on land and food resources.

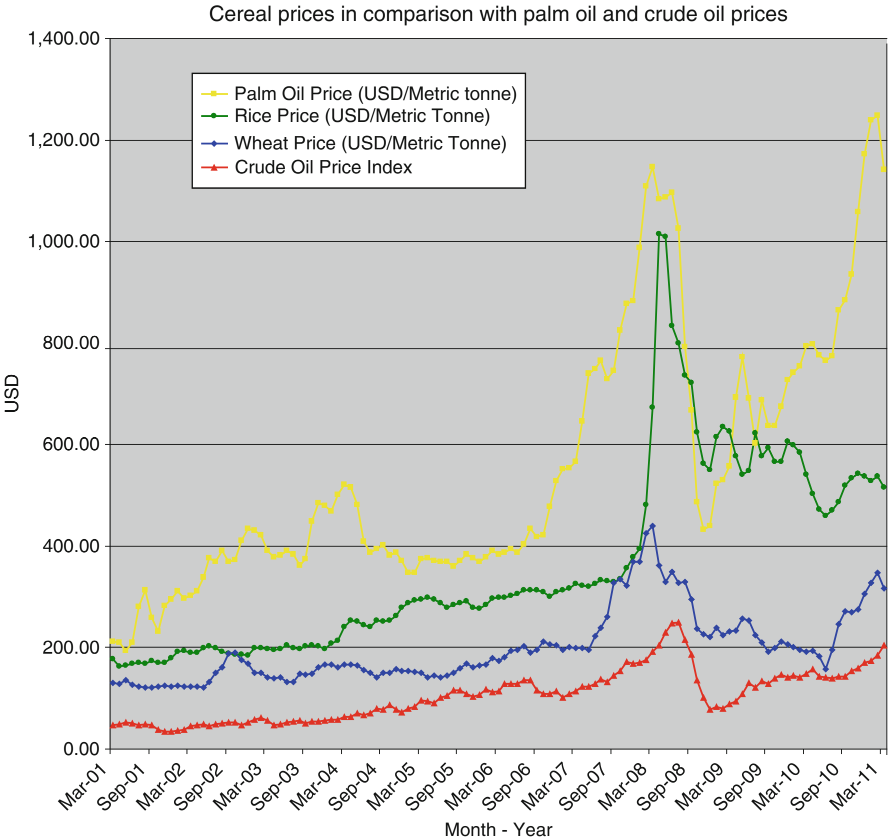

Fig. 19.5 Global cereal prices in comparison with oil palm and crude oil prices (Index Mundi 2011)

19.5.3 The Redistribution of People Caused by Oil Palm Expansion in Riau Province

Oil palm plantations have been an important crop to promote economic development in the outer islands (outside Java). The Dutch colonial government established the first oil palm plantations in North Sumatra in the early 1900s. In most cases, Javanese migrants were brought to Sumatra to work on these plantations (Jelsma et al. 2009). More recently, in the period 1968–1988 oil palm development, logging and tree plantation development for the paper and pulp industry in Sumatra was also largely supported by transmigration programmes to provide labour for the new estates. This was mainly caused by the fact that Riau was sparsely populated, and the huge labour demand made many forest concessionaries and industries to decide to bring their labour from other islands, mostly from Java and Madura (Sumardjani 2005). This programme was supported by the government of Indonesia, the World Bank, and the

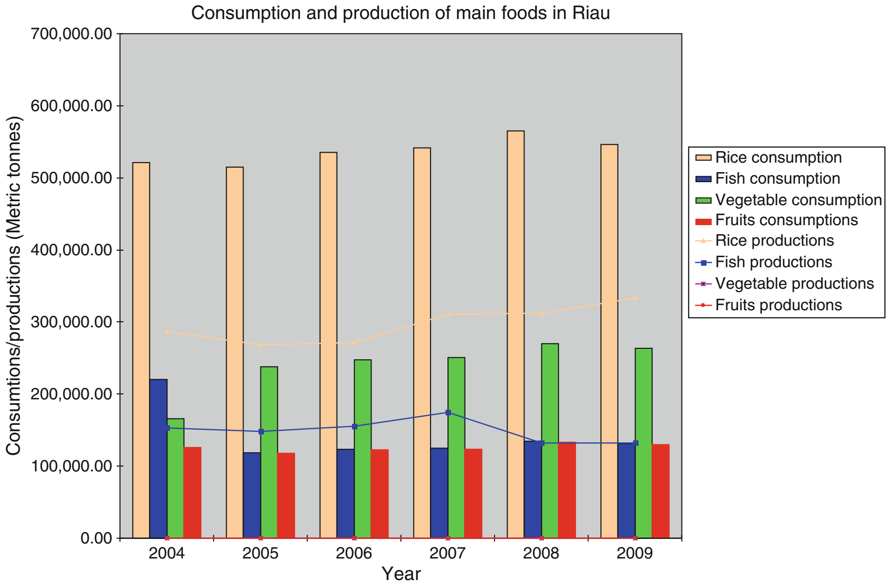

Fig. 19.6 The comparisons between production and consumption of main food commodities in Riau province (Badan Ketahanan Pangan Provinsi Riau 2011)

Asian Development Bank as it promoted development in outer islands (Jelsma et al. 2009). Sumatra has therefore always been a major destination for people from Java, who follow the social networks of transmigrated Javanese families.

In the early 1990s, most of the forest concessionaries were threatened by illegal logging and encroachment. The issues of sustainable forest management, deforestation, forest degradation, and depletion of local resources for livelihood emerged. As a consequence, the forestry business decreased. Coincidentally, during this time the establishment of estate crops especially oil palm in nucleus-plasma scheme started which inevitably needed large tracts of lands. Forests could be cut down completely and converted into oil palm plantations, getting maximum profits from timber. Initially, the oil palm plantations were also connected to transmigration programmes, and again, brought many people from Java, Madura, and Bali (Jelsma et al. 2009). In general, the influx of migrants, first through transmigration programmes, and more recently spontaneous migrants, has tremendously increased the total population in Riau (Fig. 19.7).

However, these developments would not have been possible, if it would not have been associated with widespread infrastructural works and development of service centres. Where the road system in Riau province was considered to be very poor in the 1980s, in the last 25 years, this has changed, and the road density per 1,000 km^2 has significantly increased (Table 19.3). This is especially important for bulky and heavy goods, such as logs and oil palm bunch fruits.

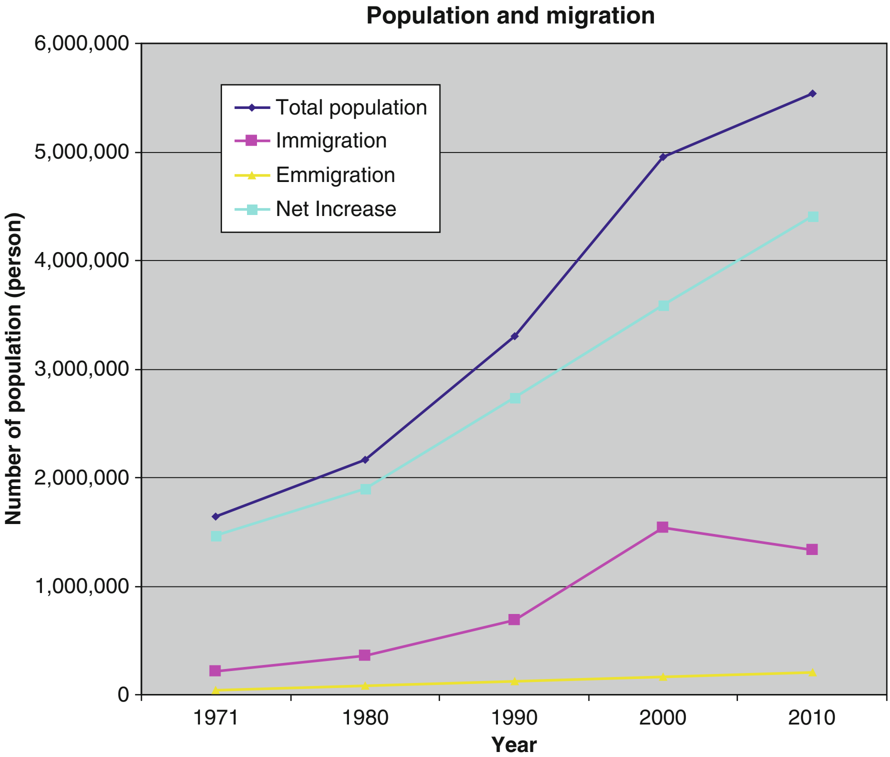

Fig. 19.7 The population growth, immigration and emigration in Riau province (Badan Pusat Statistik Propinsi Riau 2011)

Besides lowering the transportation costs and connecting the business centres, this road system development also opened up many remote areas, often protected forest areas, and triggered the development of dry land agriculture and spontaneous settlement along the roads (Fig. 19.8). It became increasingly easy for migrants to move along these roads into these newly accessible areas. Settlements and new economic activities evolved. With most of the suitable arable land being taken by large scale agricultural activities and existing local communities, roads allowed people to reach new forest frontiers easily.

This is a process that is currently becoming a major problem as population growth is faster than employment generation in the agricultural sector, both formally and informal employment. In order to survive, many individuals will develop their own agricultural employment by converting the last remaining lands, most probably still covered with forests. Forest areas are increasingly converted into food cropping land for survival, but in most case become small scale oil palm plantations. This has raised competition and conflicts between the indigenous communities and the migrants. The migrant groups are often well connected to migrant groups with the same cultural background, who arrived in the early days of

Table 19.3 Road density in Riau province 1984–2009 (Badan Pusat Statistik Propinsi Riau 2011; Rice 1991)

Roads	1984	2009
Length (km)	1,287.00	23,725.36
Km/1,000 population	0.53	4.47
Km/1,000 sq km	13.60	267.56

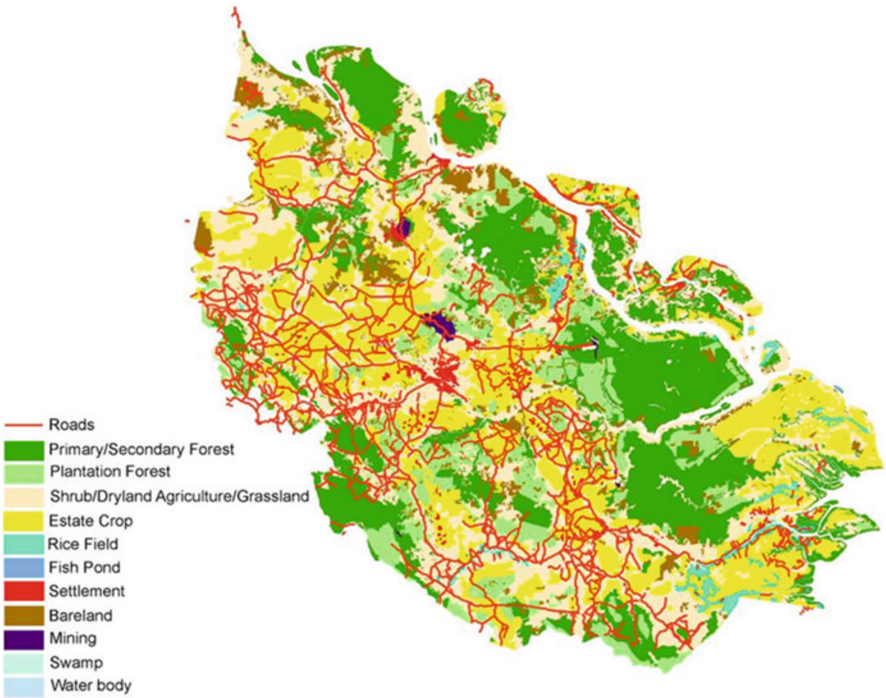

Fig. 19.8 Road network between economic centres and settlements map (Ministry of Forestry of the Republic of Indonesia 2005b) overlaid with land use cover map derived from mosaic of Landsat TM satellite images from 2010 and ground data

plantation development, often as part of the transmigration programmes. As these groups have established themselves firmly, through support from transmigration programmes, they have accumulated knowledge of oil palm cultivation. They transfer this knowledge to newcomers with the same cultural background (both Javanese or Madurese for instance) by becoming a worker on the plantation of the established groups. In a rather short period of time, these migrants are able to accumulate knowledge and capital. Local communities are increasingly sold out from their land by these migrants, who are seeking maximum profit. Once they are sold out, the local communities will move to the forest frontier, where they open up new areas, often claiming the forest area as being part of their ancestral lands.

This second wave of LUC more and more develops into a very intense way of forest encroachment. Since most unprotected areas have been occupied already, the small scale farmers target the last remaining lands, in many cases forest areas. Most recently, small scale households increasingly target the peatland areas in Riau, being the only areas left. The conversion of peatland forests could cause enormous carbon losses and other environmental disturbances. Since most of these areas are not suitable for agriculture, low profit margins are compensated by enlargement of the planted area. In other word, further encroachment into new peatland areas.

19.6 Conclusion

Since several decades, the forest areas in Riau province have been the target for conversion into other land use types. In just over 20 years, massive changes have occurred in Riau. Tree plantation development has driven land use change in the 1970s. Since the late 1980s, oil palm expansion has made Riau Province the largest palm oil producer in Indonesia. The need for labour was satisfied for a long time through the transmigration programmes of the Indonesian government (mainly from Java to Sumatra). Ever since, the migrants have served as a haven for spontaneous migration from their homes areas on Java and Madura. This employment–driven migration has increased.

As one of the biggest oil palm producers, Riau province provides these opportunities from oil palm cultivation. Nowadays, not only migrant from Java and Madura, but also migrants from the other provinces in Sumatra move into Riau. Where transmigration had to fill the gap, nowadays the enormous influx of migrants is leading to competition for the jobs available or lands. Where tree cultivation did not match the livelihood system of rural small scale producers, the regular, and possibly high earnings from oil palm really took off among small scale producers. Most of the migrants have set up their own small scale plantation, often less than 5 ha. But as most of the suitable land has been occupied in Riau, new, more complex LUC processes are taking place. These new LUC processes are caused by small scale farmers who are in search of better livelihoods. These involve not only conversion of forest area into agricultural lands, but recently also the conversion of food cropping lands (rice fields) into oil palm plantations. Although done by small scale farming households, it does not mean the problem can be ignored. On the contrary, with almost half of the oil palm producers being recognized as small scale oil palm producers, encroachment into remaining (protected) forest and peatland areas is unlikely to stop in particular with unregistered smallholders being many. Not only displaced people, also large numbers of migrants both from outside Sumatra and from provinces within Sumatra are joining the rush for land. These last forest frontier areas in Riau which are mostly peatland and conservation areas are getting very high population pressure and increasingly targeted for conversion.

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Chapter 20
Performance of Raised Beds and Conventional Planting Method for Wheat (*Triticum Aestivum* L.) Cultivation in Punjab, Pakistan

Ijaz Rasool Noorka and Saba Tabasum

Abstract Pakistani farmers have adopted an over century old flat sowing conventional planting system. There exist other planting systems which are not common in Pakistan. In order to meet food demand of growing population in Pakistan there is a great need to explore alternate planting systems for better crop production and to improve livelihood of the poor farmers. In an effort of such exploration an experiment was conducted to study the effects of planting methods for varieties of spring wheat (*Triticum aestivum* L.) for grain yield and yield components. Experiment was conducted using a randomized complete block design (RCBD) with four replications to compare the planting methods viz., raised bed and conventional planting method. The results revealed significant effect of planting methods on yield and yield contributing characters. Interactions between planting methods and varieties were also significant for some of the yield components. The mean grain yield (2.95 t ha^{-1}) in raised bed planting method was 4 % higher than conventional flat sowing planting method (2.42 t ha^{-1}), however, the variety V_1 produced the highest grain yield (2.51 t ha^{-1}) with raised bed planting method, and variety V_3 produced the lowest (1.26 t ha^{-1}) with flat planting method. All the yield components were significantly influenced by cultivars. Among the varieties, V_1 was the best performer in bed planting system owing to desired yield components. It may be concluded that bed planting method is most suitable for wheat in irrigated area when appropriate genotypes are used. Among other factors, it is believed that the raised bed technology may improve wheat yield. The experiment also revealed that the raised bed planting method may be less susceptible to adversities of climate change because it portrays better ability to plant roots anchorage on beds, ability to withstand water stress and may help to conserve genetic resources via the promising genotype of Inqilab-91. It is recommended this genotype be further assessed in future research programmes to further improve its yield performance, thereby promoting food security in Pakistan.

I.R. Noorka (✉) • S. Tabasum
Department of Plant Breeding and Genetics, University College of Agriculture,
University of Sargodha, Sargodha, Pakistan
e-mail: ijazphd@yahoo.com

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Keywords Conventional • Innovative • Population • Raised Bed • Technology

20.1 Introduction

Pakistan having an area of 7.96 Million Km^2 and burgeoning population of almost 170 Million is striving for food security. Agriculture in Pakistan contributes 21.5 % Gross Domestic Product (GDP) with an employment of 45 %. The contribution of agriculture to GDP is continuously declining from 50 % at the time of existence (1947–50) and (2009–2010) (GOP 2010). The Punjab province have an area of 205,345 Km^2 the considered as agricultural province. A diversity of agricultural crops is being grown in Punjab but most commonly is the wheat crop. Punjab produces almost 75 % of total country wheat production(Qayyum and Pervaiz 2010). Wheat is a versatile crop and an account for 38 % of the total cropped area and it contributes 13.1 % in value addition. Production wise Pakistan ranked 6th position while area wise 8th and yield wise 59th having an average yield of 2,504.58 Kg $ha^{-1.}$ FAO (2010). Wheat is a staple food crop in Pakistan. It has been grown in area of 23,864 ha in Pakistan. In Punjab province of Pakistan, wheat is grown in central Punjab as winter crop. Currently Punjab' is sharing 76.64 % in wheat production (Govt of Punjab 2010). Since the green revolution in 1960s, the wheat yield is either decreased or become stagnant. There are many reasons of low production, among them sowing methods gained much importance in Pakistan. The selection of sowing methods mainly depends on farmer resources such as availability of farm machinery, manpower, soil condition and water resources and meteorological conditions prevailed, as well as time left after previous crop (Table 20.1). The farmers get various products from wheat crop such as wheat straw which he makes hay for animals, but wheat grain yield is the ultimate goal of the farmers, therefore, in many breeding and agronomic research programs the researchers mainly focused on achieving high wheat yield using various technologies including effects of different sowing methods (Singh and Singh 1992; Singh et al. 1994). Planting technique on raised bed has attained prominence among farming community in the USA and rest of the world. The farmers recorded that wheat planted on raised bed improved mechanical weed control and water and fertilizer use efficiencies and proved as most economical (Sayre and Ramos 1997; Hobbs et al. 1998; Dhillon et al. 2000; Quanqi et al. 2008) (Table 20.2).

Availability of the sufficient quantities of water to offset crop water requirements is essential for optimum crop production. At the germination stage at least the soil must be minimum at field capacity as well soil temperature is between 4 and 37°C, Splide (1989) reported an the optimal temperature between 12 and 25°C. Innovative raised bed planting is preferred to save water and to eliminate weeds by mechanical ways. Experiments have shown that yield has been increased up to 8 % because plant receives more sunlight and energy on raised beds (Evans and Lee 1977).

In raised bed less seed rate is required compared to flat sowing method, it also enhances fertilizer use efficiency due to efficient root system. This technique is not affordable by many smallholder farmers due to economic constraints as it involves

Table 20.1 Agromet data recorded during 2009–2010 at Sargodha, Punjab, Pakistan

Latitude 32.05° N			Longitude 72.67° E		Altitude 187 m	
Sr. No	Year	Month	Minimum temp °C	Maximum temp °C	Humidity (%)	Rainfall
1	2009	November	7.0	22.00	50	0.0
2	2009	December	7.6	23.00	57	0.0
3	2010	January	5.8	17.30	66	2.6
4	2010	February	10.0	23.60	64	23.9
5	2010	March	17.5	32.00	63	14.7
6	2010	April	22.9	39.40	70	3.3

Source: Pakistan Meteorological Department, Government of Pakistan

Fig. 20.1 Pakistan map (Courtesy Pakvisit.com)

the use of expensive heavy machinery (Gupta et al. 2002). For wider adoption of this technique, the government should provide the machinery on a nominal rent basis to facilitate the farmer to improve wheat yield from their farms and improve livelihood.

To have full benefit from the raised bed it is essential to eliminate crusting on beds top, such a practice can save 30 % water from total losses (Fahong et al. 2003), the raised bed also minimizes water logging effects, provide better drainage conditions and mechanical activities. Raised bed planting system also provides opportunities for the precise application of fertilizers and irrigation and hence minimized environmental hazards. The present economic recession has seriously threatened the farmer globally by raising inputs prices like hybrid seed, fertilizers, weedicides, pesticides and diesel for machinery. In these perspectives, the raised bed planting technique is gaining momentum for saving inputs and economic cost

Fig. 20.2 Punjab map (Courtesy Visitpak.com)

Table 20.2 Area, production and yield of wheat in Pakistan

Year	Area (ha)	Production (t)	Yield (kg/ha)	Changes
2005–2006	8,448	21,277	2,519	−1.9
2006–2007	8,578	23,295	2,716	7.8
2007–2008	8,550	20,959	2,451	−9.8
2008–2009	9,046	24,033	2,657	8.4
2009–2010	9,042	23,864	2,639	2.1

Source: Ministry of Food and Agriculture, Federal Bureau of Statistics, Government of Pakistan

for wheat cultivation. Raised bed technology showed less lodging as compared to flat sowing as well as 11.2 % increase in grain yield along with 40–50 % saving in irrigation water (Ahmad and Mahmood 2005). Keeping in mind the need of the poor smallholder farmer to sustain agriculture on his farm and to improve livelihood, present study was conducted to evaluate planting methods for and their effects on water demand and wheat production.

20.2 Materials and Methods

The experiment was carried out at the experimental station of the University College of Agriculture, University of Sargodha, Pakistan, (32.05° N latitude and 72.67° E longitude and 187 m altitude) during November, 2009 to April, 2010. Soil samples were taken from the experimental site at the depth of 0–15, 15–30, 30–60 and 60–90 cm and were subjected to analysis after proper drying, grounding process and sieved through 2 mm Sieve (Gee and Bauder 1986), ECe, SAR, pH and

Table 20.3 Experimental area soil and irrigation water physio-chemical analysis

Sr. No	Parameter	Value for soil	Value for irrigation water
1	Sand	50 %	–
2	Silt	21 %	–
3	Clay	29 %	–
4	Texture of soil	Sandy clay loam	–
5	EC_e	1.72 dS m^{-1}	0.70 dS m^{-1}
6	Organic matter	0.72 %	–
7	HCO_3^-	3.02 mmol L^{-1}	6.0 mmol L^{-1}
8	Cl^-	8.2	1.5
9	SO_4^{2-}	5.30	0.21
10	$Ca^{2+} + Mg^{2+}$	3.29	–
11	Na^+	12	–
12	Available K^+	210 mg/kg	–
13	Sodium Adsorption Ratio (SAR)	–	4.5
14	Total soluble Salts (TSS)	–	7.67 mmol L^{-1}
15	Residual Sodium Carbonates (RSC)	–	3.4

extractable ions by the methods given by (Bigham 1996); organic matter detection by the methods of (Nelson and Sommers 1996), and K (Soltanpour and Worker 1979) as depicted in (Table 20.3). The objective was to study the effect of planting methods and wheat varieties on the yield and yield contributing characters of wheat. The experiment was conducted under semi-controlled environmental conditions in the field. The agro-meteorological data of the experimental site is depicted in Table 20.1 while soil and water chemical analysis is in Table 20.3.

20.2.1 Preparation of Raised Beds and Sowing of Seeds

Following were performed to make the raised beds.

- Straight lines were marked in the field by using a marker.
- A bed maker was used to prepare the beds
- Mould bold plough was used to plough the field.
- Rotavator was used to make the field free of clods and soil aggregates.
- Tractor was used to prepare the land and finally
- Single row hand drill was used to sow the seeds in lines.

As a field preparatory operation for sowing, three ploughings and two plankings were done with the help of Tractor, followed by the preparation of nine beds using Tractor and Bed Maker. The seed were sown on the raised beds with the help of single row hand drill. Contrary to the raised bed sowing, in another field lines were made with the marker and the seeds were sown as flat sowing with the help of single row hand drill.

Table 20.4 Wheat varieties used in the experiment

Variety	Name of wheat variety
V1	Inqilab-91
V2	Sehar-2006
V3	Kohistan-97
V4	Bakhar-02
V5	Pasban-90

The main image behind the raised bed planting technique is very simple, where the field is well prepared and by the help of ridger/bed shaper raised beds are made instead of conventional planting systems in which flat field were sown.

20.2.2 Experimental Plan

The experiment was consisted of two factors viz., planting method (raised bed planting, conventional planting method) and varieties. The experiment was laid out using split plot fashion assigning the planting method on the main plot and second factor varieties (Table 20.4) in the sub-plots. The diverse high yielding and best adopted varieties were selected to measure the planting behaviour as well as their genetic potential indifferent planting methods. Prior to sowing, the seeds, were treated with fungicide Vitavex-200 @ 0.25 % to prevent the attack of soil borne diseases. Seeds were sown on November 26, 2009 by help of pore drill. Thinning was done followed by 1st weeding for maintaining plant to plant distance of three inches. The fertilizers were applied equally at the rate of NPK 52:46:25(GOP 2010). Two irrigations were applied, first at 20 days after sowing, the second at 55 days after sowing followed by weeding. Ten plants were randomly selected from each plot prior to harvesting for collection of data on plant characters. An area of 1 m^2 of each plot was harvested, threshed and the grains were cleaned, dried at 12 % moisture content and weighed carefully to record the grain yield per m^2. Finally the grain yield per m^2 was converted to t ha^{-1}. The data were collected and subjected to statistics analysis. The mean differences were adjudged by Duncan's Multiple range Test as described by Gomez and Gomez (1984).

20.3 Results and Discussion

20.3.1 Effect of Planting Method

Sowing methods had a significant effect on grain yield. The sowing methods effects lodging, seed sowing, seed germination, water and labour saving (Singh and Singh 1992; Singh et al. 1994; Ahmad and Mahmood 2005). Planting method had significant positive effect on yield and contributing characters (Table 20.5). The highest grain yield (2.95 t ha^{-1}) was obtained from raised bed planting method whereas the lowest (2.42 t ha^{-1}) was obtained in conventional method. All varieties used irrigation water efficiently in water stress days of November-January as well as rainy days of February-March (Table. 20.1) in raised bed planting methods and gave best yield as compared to conventional flat sowing method. These results are in line with the findings of Talukder et al. (2004). Similarly biological yield (5.80 t ha^{-1}), total tillers $plant^{-1}$ (6.52), spikelets $spike^{-1}$ (21.60), grains $spike^{-1}$ (54.73) were highest in the raised bed planting method. Tripathi et al. (2002) reported that raised bed planting showed significantly higher grain $spike^{-1}$ than conventional method.

20.3.2 Effect of Variety

Variety had significant effects on all yield and yield contributing characters except spike length, grain yield, biological yield and harvest index (Table 20.5). The highest value for all the growth and yield parameters was obtained from the variety Inqlab-91. These results are also supported by similar work conducted at the Ayub Agricultural Research Institute (AARI) Faisalabad, Pakistan (AARI 2006). The reasons for variability in growth and yield characters is likely be due to genetic variability of the varieties principally influenced by the heredity.

20.3.3 Interaction Effect of Planting Method and Variety

Interaction between planting method and variety were not found to have significant effect on yield and yield contributing characters except Grains $spike^{-1}$, biological yield and harvest index (Table 20.6). All the yield components except plant height and spike length produced higher values under bed planting method with Inqlab-91 variety. The highest grain yield (2.51 t ha^{-1}) was observed in Inqlab-91 in bed planting method (Fig. 20.3).

20.3.4 Impact of Climate Change on Wheat Production

Climate change, agriculture and wheat production are interrelated processes and its implication, adaptation and mitigation are translated in global scale. Global warming has significant effects throughout the world on food production due to the interaction of carbon dioxide, temperature, snowfall and precipitation. There balanced proportion will be helpful towards adaptation and mitigation of induced climatic changes and maximize food production. It is true carbon dioxide have decisive role in plant growth. Rise in carbon dioxide concentration have positive effects in increasing photosynthesis rate but if its rate exceeds than 380 parts per million with respect to oxygen concentration (210,000 ppm), than most of the plants will suffer starvation

Table 20.5 Effects of planting methods and variety on the yield and yield contributing characters of wheat

Treatment	Plant height (cm)	Peduncle length (cm)	Total tillers plant^{-1} (no)	Spike length (cm)	Spikelets spike^{-1}(no)	Grains spike^{-1} (no)	1,000 grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Planting method										
M1	101.86 a	18.65 a	6.52 a	18.50	21.60 a	54.73 a	50.90	2.95 a	5.80 a	43.25
M2	96.08 b	16.28 b	4.67 b	18.48	18.58 b	46.40 b	50.32	2.42 b	4.48 b	44.38
L.S	0.01	0.01	0.01	NS	0.05	0.01	NS	0.05	0.05	NS
Variety										
V1	101.90 a	18.57 a	6.67 a	19.00	21.90 a	53.98 a	51.67 a	2.93	5.96	54.57 a
V2	99.68 b	16.23 c	4.95 c	18.58	19.28 ab	51.02 b	47.63 ab	2.48	4.04	41.47 c
V3	99.20 b	16.98 c	5.15 b	18.62	18.29 b	51.66 b	45.30 bc	2.41	4.49	41.69 c
V4	100.10 ab	17.62 b	5.08 b	17.77	19.68 ab	47.21 c	46.47 b	2.53	4.81	46.78 b
V5	97.28 c	18.01 ab	4.99 c	16.98	19.43 ab	46.20c	45.82 bc	2.61	4.90	42.08 bc
L.S	0.01	0.01	0.01	NS	0.01	0.01		NS	NS	0.01

In a column, figures having similar letter(s) or without letter(s) do not differ significantly as per DMRT

NS = Not significant, M_1 = Bed planting method, M_2 = Conventional method, V1 = Inqlab-91, V2 = Sehar-2006 V3 = Kohistan −97 V4 = Bakhar-02 V5 = Pasban-90

Table 20.6 Interaction effects of planting method and variety on the yield and yield contributing characters of wheat

Interactions	Plant height (cm)	Peduncle length (cm)	Total tillers plant^{-1} (no)	Spike length (cm)	Spikelets spike^{-1} (no)	Grains spike^{-1} (no)	1,000 grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V1 × M1	98.60 a	22.60 a	6.80	18.29	19.77	54.91 a	55.91	2.51	5.68	49.17
V1 × M2	102 a	19.80 c	6.05	19.08	17.67	48.96 b	48.73	1.56	3.60	44.97
V2 × M1	99.00 a	19.20 c	4.65	18.62	18.77	38.26 d	45.86	1.83	5.16	45.40
V2 × M2	82.60 e	17.80 d	4.50	18.20	16.87	36.02 d	44.74	1.58	3.59	44.51
V3 × M1	89.03 a–b	20.90 b	5.90	18.71	17.71	41.51 c	46.76	2.31	4.03	46.54
V3 × M2	85.06 c–e	19.30 c	4.85	18.23	16.77	34.47 e	43.77	1.42	3.55	42.51
V4 × M1	87.63 b–c	16.80 e	5.65	18.90	18.42	38.41 d	48.62	1.83	4.18	44.83
V4 × M2	78.65 f	14.20 f	4.35	18.61	16.11	35.99 e	46.73	1.28	3.24	43.54
V5 × M1	86.70 b–d	15.20 f	4.60	18.39	17.50	39.14 d	41.32	1.91	3.89	43.83
V5 × M2	83.13 e	18.60 d	3.65	17.90	16.56	35.42 e	40.93	1.26	2.19	39.56
L.S	0.05	0.01	NS	NS	NS	0.01	NS	NS	NS	NS

In a column, figures having similar letter(s) or without letter(s) do not differ significantly as per DMRT
NS = Not significant, V1 = Inqlab-91, V2 = Sehar-2006, V3 = Kohistan-97, V4 = Bakhar-02, V5 = Pasban-90

Fig. 20.3 Preparation of raised beds and sowing of seeds

due to the action of rubisco enzyme (Photorespiration). C_3 crops like wheat will suffer more due to its susceptibility to develop fewer stomata developing on plants (Woodward and Kelly 1995).

Man-made greenhouse gases arises from multi-sources revealed 72 % carbon dioxide, 18 % methane, 8 % nitrous oxide and 1 % other gases, however segments with less than 1 % fraction are considered non significant as reported by the emission database for global atmospheric research version (IPCC 2007) Fig. 20.4. Due to sever attack of greenhouse gases, the earth temperature is continuously rising which show its worrisome in declining staple food production particularly the

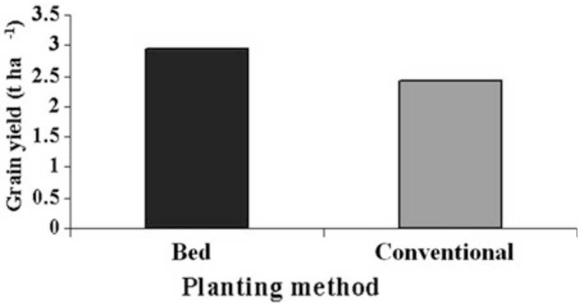

Fig. 20.4 Effect of planting method on grain yield of wheat

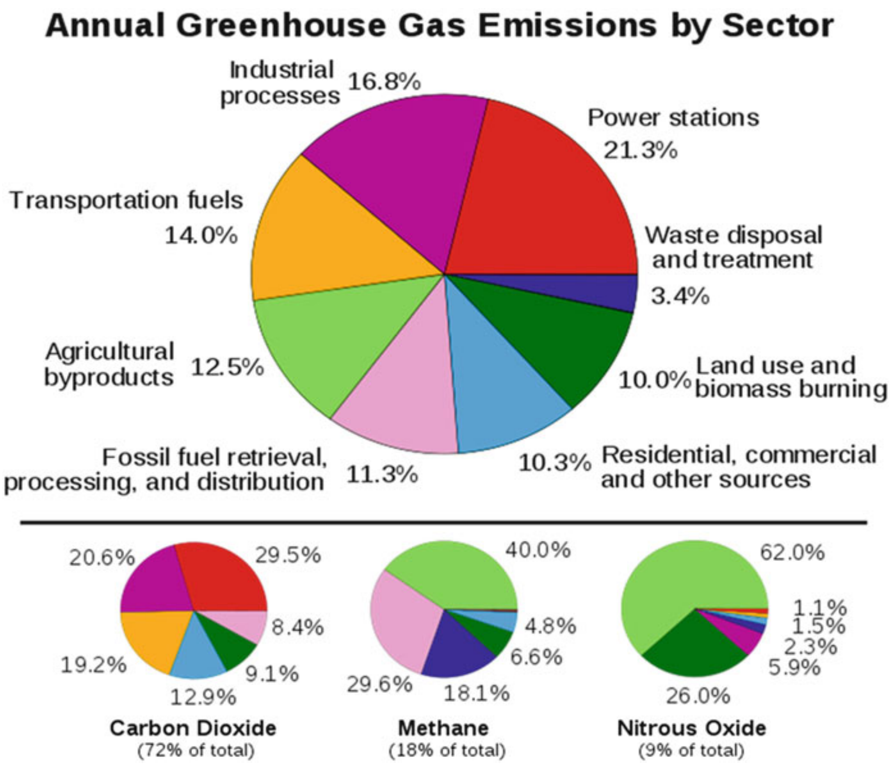

Fig. 20.5 Relative fraction of man-made green house gases (Courtesy IPCC 2007)

rainfed areas of Africa, Asia and Latin America where wheat and other cereal crops are at climax tolerance level. The yield level will drop significantly up to 30 % if small climatic changes occur (Lobell et al. 2008). Studies in sub-Saharan Africa have been revealed that wheat is a crop more vulnerable to climate change impacts than other grains such as millet, Easterling (2007) concluded that sub-Saharan Africa would likely surpass Asia as the most food-insecure region. This critical issue for assessing future food demand and supply will be insecure predominantly South Asian areas where there is strong dependence on wheat grains (Fig. 20.5).

20.3.5 Key Future Impact and Vulnerabilities

Water is the key factor in our daily life as well as for crop production. Access to safe fresh water is now considered as the basic human right (United Nations Committee on Economic, Social and Cultural Rights 2003), also guaranteed in Millennium Development Goals (UNDP 2006). Sustainable provision of freshwater resources has gained much momentum now and it will be question mark in future (European Union 2000) and (United Nations 2006; World Water Council 2006). Climate related changes and their trends observed in last decade is although not very high but not ignorable, like un even precipitation, depletion of ground water, surface water shrinkage, sudden floods and drought, which are likely to be prominent in future because the signals are evident. These vulnerabilities may be largest in arid and semi-arid zones of the globe and low-income and developing countries will be hailed in consternation (Lenton 2004). Globally the demand of water is increasing due to high population growth, high cropping intensity and occasional stresses. In addition unmanaged agricultural practices, water use efficiency, flood magnitude and frequency are adding new vagueness (Arnell et al. 2001). During the course of this study, the historical climatic action and prevailing water stress, raised bed technology proved itself a best option to ensure consumptive use of water to produce handsome quantity of wheat crop. The experiment results showed that all wheat genetic resources used in study showed quantum increase in grain yield (Table 20.5). These types of results were confirmed by Talukder (2003) who have stated that wheat genotypes produced significantly higher yield under raised bed planting system (Sayre and Moreno Ramos 1997; Dhillon et al. 2000) also reported genotype and bed planting interaction significantly. Indeed, the present results depicted by the experiment have shown and confirmed by earlier researchers like (Hobbs et al. 1998; Reeves et al. 1999) who emphasised that raised bed planting schemes can facilitate the farmer to reduce cost of production in the form of using less seeds, fertilizers, weedicide application and low fuel consumption as well low crusting and compaction and to overcome climatic hazards. The increase in grain yield in case of bed planting is also the result of reduced lodging which has prominent effects on wheat yield as depicted by (Quanqi et al. 2008). Similar results showing 11.2 % increase in grain yield along with 40–50 % saving in irrigation water, minimum impact of lodging (20.5 %) was observed on raised bed technology while (34.6 %) on flat sowing was reported by (Ahmad and Mahmood 2005). Introduction of this technique in north Mexico had improved the wheat grain yield by at least 10 % and water economy by up to 35 % in comparison with the conventional system (Aquino 1998). It is need of hours that integrated management production and action should be used as an instrument to see the adaptation sights to measure climate change. More favourable effects on yield tend to realization of the potentially beneficial effects of light, carbon dioxide, water use efficiency on crop growth and decrease in potential yields is likely to be caused by shortening of the growing period. There are large suspicions to reveal, predominantly because there is deficiency of in sequence flow of knowledge on explicit confined regions, in response to extent of climate change, so the sound effects of technological changes on wheat yield may fill global food apprehension. The societal views, management strategies integrated with reshaping planning and conservation resource technology like raised bed planting technique linked with conjunctive use of outstanding genetic resources (Inqilab-91 in present study) may explicitly address impediment to the combat forth coming needs (Moench et al. 2003).

In order to further study the effects of climate change, global warming on agricultural crop, some models such as crop development models, insect pest and disease development models, climate projections models, yield prediction model, water and fertilizer use model, may squeeze the knowledge to contest climate, soil, and various agricultural practices.

20.4 Conclusion

Present study concluded that, in raised bed planting method (M_1) all varieties have depicted best results in yield and yield contributing traits. Among the varieties, all showed prominent and explore best genetic potential in raised bed method; however the variety Inqilab-91 has produced the highest grain yield in both raised bed and conventional planting methods which may be due to its best genetic architecture as compared to other varieties under observation. This variety also showed best performance predicting to respond the adverse climatic changes. The increased grain yield under raised bed was due availability of maximum sunlight and energy as well as efficient use of inputs and non lodging and stronger plant anchorage behaviour of the wheat crop on the bed. It was further noted that raised bed depicted best use of irrigation water during normal irrigation as well as in rainy days due to its best drainage system. The experiment also revealed that raised bed planting method may be practiced to combat climate change effects, conserve the genetic resources and promising genotype Inqilab-91 and its successive generation may be used in future research programmes to for better yield performance to ensure food security in the country.

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Postface

Since 2009, the two international biannual conferences on "*The Integration of Sustainable Agriculture, Rural Development, and Ecosystems in the Context of Food Insecurity, Climate Change, and Energy Crisis*" and on "*Climate Change, Agri-Food, Fisheries and Ecosystems: Reinventing Research, Innovation and Policy Agendas for Environmentally- and Socially-Balanced Growth*" – jointly organized in Morocco by the NRCS and the GIZ – are analyzing the current global situation and actual international research related to sustainable agriculture in the context of local and global environmental change and food security. Both conferences stressed that sustainable agriculture, food security and environmental change should be studied on the basis of linked sciences and economic and resource efficiency. Climate and environmental change are major interferences on the natural balance of efficient resource use worldwide. And additionally human behaviour in exploiting land and water resources has resulted in land and vegetation degradation, overexploitation of fisheries, depletion of aquifers, and unsustainable resource use in general.

Currently, seven billion people living on earth, but almost three billion lack access to modern energy for cooking, and some 1.5 billion don't have electricity at all. The fact is directly linked to increased levels of poverty. Prognoses say that the world population is expected to reach about nine billion till 2050. To cover the global natural resource consumption of this population worldwide, a productivity of about 1.5 earths is necessary. Prognoses say that we need two earths to cover our steadily raising resource consumption in 2030. The agricultural production must increase by 70 % globally and 100 % in developing countries. Currently, about one billion people go to bed hungry each night or die of hunger (i.e. in central Africa).

To secure the current world food production, it would be no problem to feed everyone of the current world population of seven billion. Roughly half a billion people are starving worldwide, while only Europe wastes 20 Mio. t food every year. This unequal dispensation is ruining the world's balance in natural resource and also the world's peace.

To support seven billion people on our planet, we have to assure enough resources and water. As this rapid growth mostly happens in developing countries

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while the industrialized countries almost stay constant, we have to lay the focus of our research on the poorer nations. Growing cities – Megacities and Metacities – are causing serious problems as heavy industries are growing and job possibilities with these industries as well – a serious vicious circle. If current processing technologies and infrastructure systems are not suitable to deal with end-of-life materials of growing cities, other sustainable solutions are still requested.

Scientists, politicians and decision-makers are imposed to the obligation of securing resources – including food and water as basic life essentials – in respect of local and global environmental change. The linkage of the research topics climate, water and natural resources enables us to originate possible future holistic solutions for global food security/food safety, sustainable agriculture, water availability for a secured and environmentally-friendly world.

The biannual *NRCS-GIZ Conferences* have identified and reconfirmed key issues for immediate consideration regarding climate and environmental change adaptation, sustainable agriculture and food security: a need to create a paradigm shift in agricultural policies; reforming food aid policies; investment in agriculture research; development and extension; rewarding the agriculture profession by promoting beneficial price regimes; ensuring research leading to appropriate biotechnology advances and innovations; strengthening of agricultural systems; bringing abandoned lands into production whilst preserving forests; provision of affordable credits to farmers; favourable free trade agreements between developed and developing countries; reforming policies on bio-energy production; improving livestock welfare; combating desertification; and producing scientific soil information.

As a follow up to the *NRCS-GIZ Conferences* (2009, 2011) and its research outcomes, the international conference on "*Global Environmental Change and Human Security: The Need for a New vision for Science, Policy and Leadership*" (GECS-2012) has been organized on November 22–24, 2012 in Marrakesh, Morocco. This edition has engaged a broad range of audiences and provided an update of the latest understanding of environmental change caused by current development models and schemes, human security implications of this change, and options available for different societies to respond to present and future challenges. Participants have considered how conceptions of security are being transformed in the face of environmental change, and how urgent a shift – in science, policy and leadership – is required to manage efficiently and prudently the current dynamics. The event served as a space to conceive this critically needed roadmap while conceiving future policy and research agendas within the context of post-Durban (2011) and Doha (2012) era.

The Editors
Mohamed Behnassi • Olaf Pollmann • Gabrielle Kissinger