Mohamed Behnassi · Shabbir A. Shahid
Nazia Mintz-Habib *Editors*

Science, Policy and Politics of Modern Agricultural System

Global Context to Local Dynamics of Sustainable Agriculture

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Ideas for Change

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Preface

This book is the outcome of an international conference on "Climate Change, Agri-Food, Fisheries, and Ecosystems: Reinventing Research, Innovation, and Policy Agendas for an Environmentally and Socially-Balanced Growth (ICCAFFE2011)" organized on May 19–21, 2011 in Agadir (Morocco) by the North-South Center for Social Sciences (NRCS) in collaboration with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany and the Institute for Research and Development (IRD), France.

A wide range of participants had taken part in the second edition of this conference (researchers, experts, policy makers, NGO actors, businesses, professional organizations, advisory and support services, development institutions, etc.). Researchers and experts from institutions in Northern and Southern countries and from a wide variety of disciplines (including social sciences, ecology, meteorology, agronomy, biology, genetics, animal sciences, food processing, sociology, anthropology, economics, management, geography, land planning, modeling, engineering sciences, educational sciences, marine sciences, etc.) had enriched and widened the scientific exchanges, and consequently shaped the conference outcome.

ICCAFFE2011 was organized in a global context marked by: (1) the failure of the Copenhagen Summit to come up with a binding agreement to deal with climate change; (2) The fragility of the world food security, the seriousness of hunger consequences, and the inefficiency of different policies and programs devoted to achieve sustainable food security; (3) the decrease of global marine biodiversity and fish stocks because of different pressures exerted by overfishing, environmental degradation, and the impacts from human-induced climate change; (4) The growing loss of biodiversity and degradation of forest ecosystems, as a result of climate change and anthropic activities impacts, despite a global convention committing governments to halt the decline.

The conference program had covered a diversity of themes, such as, (1) climate change, food security and agriculture, (2) climate change adaptation in food and agriculture perspective, (4) innovation to address climate change, (5) sustainable agriculture and capacity building, (6) biofuel linkages with climate change, agriculture, and food security, (7) sustainable marine ecosystems and fisheries, (8) contesting the agro-food system in the context of climate change, (9) food's climate impact and the need for a green and climate-friendly consumerism, (10) climate change, ecosystem services and biodiversity conservation, and (11) the need for proactive and coordinated policy responses.

The book chapters, selected after a rigorous peer-review, represent the best part of the conference proceedings, published in three contributed volumes. The chapters are distributed into four parts. Part I deals with sustainable agriculture development within a context marked by environmental, economic and social dynamics and addresses topics such as global climate change, agriculture, and related challenges including socioeconomic factors, adaptation, poverty reduction and water management. Part II deals with impacts of soil degradation in terms of agricultural productivity and covers issues pertaining to expert systems in assessing and managing degraded lands, agricultural productivity, land suitability and rehabilitation. Part III focuses on livestock production enhancements—such as feed resources and supplemental feeds for animals—and women capacity building in dairy management. Part IV shares the outcomes of research projects in the field of agrobiodiversity, climate change and livelihoods, addressing topics such as comanagement of forests, carbon consumption models, biodiversity conservation and carbon sequestration, and scarce mangroves forests.

We hope this book will be an excellent source of scientific information to be used by a myriad of stakeholders, such as researchers and experts, professors and students, land use planners, decision makers, NGO actors, and politicians.

The Editors

Acknowledgments

I have been honored to share the editorship of this volume with my colleagues Dr Shabbir A Shahid, a Senior Scientist at the International Center for Biosaline Agriculture (ICBA) Dubai, United Arab Emirates and Dr. Nazia Mintz-Habib Social Scientist at the University of Cambridge, UK whose commitment and intellectual potential made the editing process a smooth and exciting experience. I highly acknowledge the efforts of the editors for their dedications and hard work to bring this book into its final shape.

On behalf of my coeditors, I would like to gratefully and sincerely thank the members of the Scientific Committee, from the inception of the conference theme through conference organization and completion of this book. Their involvement in the peer-review of the preselected chapters had contributed to the speeding up of the publishing process. Deepest thanks go also to all participants in ICCAFFE2011 who made this event possible even if not all could contribute to this volume. Acknowledgements are also due to many institutions for their support. In particular, we thank the sponsors of the 2011 Conference, which in addition to NRCS, include the GIZ and the IRD.

While the real value of this volume should be credited to chapters' authors, 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

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Abbreviations and Acronyms

ADPs	Agricultural Development Projects
AGRA	Alliance for Green Revolution in Africa
BARI	Bangladesh Agricultural Research Institute
BCS	Body Condition Scoring
BEST	Board on Environmental Studies and Toxicology
CBC	Community Based Conservation
CFM	Community Forest Management
CIRDAP	Center on Integrated Rural Development for Asia and Pacific
CPC	Commune Peoples' Committee
CSO	Central Statistical Office
DPC	District Peoples' Committee
DRI	Desert Research Institute
$dS\ m^{-1}$	decisiemens per meter
EIA	Economic Impact Analysis
FAO	Food and Agriculture Organization
FGD	Focused Group Discussions
FLA	Forest Land Allocation
FPU	Forest protection Unit
GCM	Global Circulation Models
GDP	Gross Domestic Product
GHG	Green House Gasses
GMP	Green Morocco Plan
GR	Gypsum requirement
HCMEXS	Heavy Clay Management Expert System
ICALRRD	International Center for Agricultural Land Resources Research and Development
ICBA	International Center for Biosaline Agriculture
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IITA	International Institute of Tropical Agriculture
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change

ISRI	Indonesian Soil Research institute
IUCN	International Union of Conservation Nature
IWMI	International Water Management Institute
KADA	Knowledge Acquisition Development System
KARI	Kenya Agriculture Research Institute
KFRI	Kenya Forestry Research Institute
KSA	Kingdom of Saudi Arabia
MDGs	Millennium Development Goals
MIA	Marginal Impact Analysis
NAEP	National Agriculture Environmental Program
NDL	Northern Delta Lakes
NGO	Non Government Organization
NRCS	North-South Center for Social Sciences
NWFPs	Non Wood Forest Products
NWRC	National Water Research Center
OECD	Organization for Economic Cooperation and Development
PARC	Pakistan Agricultural Research Council
RBDA	River Basin Development Authorities
RDP	Rural Development Program
SAR	Sodium Adsorption Ratio
SD	Standard deviation
SPII	Seed and Plant Improvement Institute
SPSS	Statistical Program for Social Sciences
SSA	Sub-Saharan Africa
TISTR	Thailand Institute of Scientific and Technological Research
UNDP	United Nations Development Program
UNSPPA	Uganda National Seed Potato Producers Association
UWA	Uganda Wildlife Authority
WB	World Bank
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development
WFP	United Nations World Food Programme
WHO	World Health Organization
WIGs	Women Interest Group
WRI	World Resource Institute

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About NRCS

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, 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, NRCS aspires to serve as a reference locally and globally through rigorous research and active engagement with the policy community and decision-making processes. NRCS is currently chaired by Mr. Mohamed Behnassi, Doctor Professor of Global Sustainability and Human Security Politics.

About the Editors

Dr. Mohamed Behnassi, Ph.D. in International Environmental Law and Politics, is Associate Professor and Head of the Department of Public Law, Faculty of Law, Economics and Social Sciences of Agadir, Morocco. He is the Founder and Director of the North-South Center for Social Sciences (NRCS) and member of the advisory board of the World Forum on Climate Change, Agriculture and Food Security. His core teaching, research and expertise areas cover the Global Environmental and Human Security Politics, Corporate Social Responsibility, and Adaptation to Environmental Change. 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; Climate Change, Energy Crisis and Food Security/Ottawa University Press 2011) and published numerous papers in accredited journals and communicated several oral presentations in relevant international conferences. In addition, Dr. Behnassi has organized many outstanding international conferences covering the above research areas. He had also completed in 2011 a U.S. 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 a key research project on behalf of the Royal Institute of Strategic Studies (IRES) in Morocco titled: “Food and Health Security Face to Climate Change in Morocco: An Adaptation Strategy within the Perspective of an Integrated Governance”

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Dr. Shabbir A Shahid a Senior Scientist at Dubai based International Center for Biosaline Agriculture (ICBA), as Sir William Roberts fellow earned Ph.D. degree from the University of Wales, Bangor UK in 1989. He joined ICBA in 2004 and has over 33 years experience (Pakistan, UK, Australia, Kuwait and United Arab Emirates) in agriculture related Research, Development and Extension activities. He has held positions, Associate Professor (University of Agriculture Faisalabad, Pakistan), Associate Research Scientist in Kuwait Institute for Scientific Research, Kuwait and Manager of Soil Resources Department, Environment Agency–Abu Dhabi, UAE. During his professional career he has been working in applied agriculture projects in many countries (Pakistan, Kuwait, UAE, Qatar, Oman, Niger, Morocco, Jordan, Spain, Syria etc). In the GCC countries he has been working for the last 18 years and very much familiar with agriculture activities, climate change challenges, and food security issues. As Technical Coordinator he completed soil survey of Kuwait and Abu Dhabi emirate. In the latter survey, by the first time in the history of soil research he has discovered Anhydrite soil in the coastal land of Abu Dhabi emirate. His innovative research on the saline soils of Pakistan highlighted the dominance of thenardite (Na_2SO_4) and mirabillite ($Na_2SO_4.10H_2O$) contrast to older hypothesis of halite (NaCl) dominance. He is a prolific author of over 150 publications in peer reviewed refereed journals, proceedings, books and manuals. He is currently—life member and Councilor of the World Association of Soil and Water Conservation, and member advisory board "World Forum on Climate Change, Agriculture and Food Security-WFCCAFS". Dr Shahid enjoyed working as members of Scientific Committees, International Advisory Boards of International Conferences, and Editors of Scientific Books, and reviewer of Scientific Journals. International Center for Biosaline Agriculture

International Center for Biosaline Agriculture

Dr. Nazia Mintz-Habib focuses on the political economics and impact assessment of public policies and institutions in developing countries. Her research interests include modern agricultural policies, technological innovation like biotechnology and market development. Nazia is a Sir Isaac Newton Trust Fellow and a Malaysian Commonwealth Studies Fellow at the University of Cambridge, UK where she is heading a cross-sectoral food security analysis project. Recently she joined as a lead research consultant with the International Food Policy Research Institute (IFPRI) to improve a novel integrated analytical framework called Institutional Feasibility Study (IFS) to better study the global value chain of genetically modified cotton and its impacts on poverty and food security in Africa. Prior to this, as a research associate at Harvard University's John F. Kennedy School of Government, she studied the green economy and sustainability science, the results of which were presented at the Rio+20 summit in Brazil. She has been invited to participate in many policy consultation projects, including for the World Bank, and the United Nations (UN). Aside from academic research, Dr. Mintz-Habib has provided policy proposals to the governments in Tanzania, Malaysia, Bangladesh and the Arab region on issues of food security, agricultural policies and climate change adaptation. Her publications can be found both as working papers for the United Nations and in academic journals. A native of Bangladesh, she is actively involved in several civil society development projects in her homeland, including a program that provides scholarships for women in science. Nazia holds a PhD from the University of Cambridge, where she was a Commonwealth Scholar

Part I
Sustainable Agricultural Development Face to Environmental, Economic and Social Dynamics

Chapter 1
Agricultural and Food System—Global Change Nexus: Dynamics and Policy Implications

Mohamed Behnassi, Shabbir A. Shahid and R. Gopichandran

Abstract Agricultural and food system can unequivocally be described as major agent of global change since it has been responsible for more environmental externalities than any other technology in a variety of ways. This system has also had a major impact on humanity, notably through the process of development with which it is intimately associated. In the meantime, the converse aspect of the relationship between agriculture, environment, and people means that the environmental, socioeconomic, and technological developments have had, and will continue to have, repercussions for agricultural and food system. Thus, the real agricultural and food challenges of the future will differ according to their geopolitical and socio-economic contexts. From a policy viewpoint, however, it is also critical to understand the degree to which agriculturally related activities may contribute to global-scale environmental change and the extent to which policies to prevent, mitigate, or adapt to environmental change may themselves affect agriculture and food security. With reference to this multidimensional approach, the present chapter analyses the interactions between agriculture and global environmental change and highlights the related dynamics pertaining to socio-economic drivers, science and technology. Policy implications are underlined within the perspective of making these interactions sustainable and human security-oriented.

Keywords Agriculture • Food • Environmental footprint • Global change • Science and technology

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1.1 Introduction

Humanity has relied solely on hunting, fishing, and gathering for food for most of its two million years of existence. Agriculture—the domestication of plants and animals—appeared only about 10,000 years ago, roughly corresponding to a period of widespread climatic and ecological fluctuations (Matthews et al. 1990) and to an acceleration of population growth. Whether the spread of agriculture was a trigger for more rapid population growth or was itself a response to increasing population or environmental pressures remains a controversial question. One explanation for this observation is that agriculture and related technological and social innovations may have emerged initially as a way to compensate for an unreliable or declining resource base arising from population pressures, environmental fluctuations, or both (Chen 1990).

Explaining the origins of agriculture are instructive because it highlights the close links that may have persisted for many millennia among environmental fluctuations, agriculture, and human welfare. In the long term, agriculture has clearly brought the potential for larger populations, expanded exploitation of climatic and other natural resources, and reduced vulnerability to many forms of environmental fluctuation and extreme climatic and natural events such as droughts and floods. At the same time, however, agriculture and the increasing globalization of food systems may have increased vulnerability to other problems, such as market failures and the unequal distribution of food (Chen 1990).

With reference to this multidimensional approach, this chapter analyses the interactions between agriculture and global environmental change and highlights the related dynamics pertaining to socio-economic drivers, science and technology. Policy implications are underlined while emitting recommendations within the perspective of making these interactions sustainable and human security-oriented.

1.2 Agriculture, Society, Technology, and Global Environmental Change

Agriculture can be seen as a technology that represents a fundamental bond between people and environment. It plays a pivotal role in the people-environment relationship and there is a reciprocal relationship among all three. Intrinsically, it comprises both the generator and recipient of stimuli for change. This relationship has existed since the pre-agricultural era; it intensified as permanent arable and pastoral farming developed between eight millennia and ten millennia ago in many centers of innovation. Essentially, agriculture manipulates biotic and abiotic resources to produce food, energy, and useful substances such as hides and fiber; specific plants and animals are selected for certain qualities and they are husbanded using the resources of soil, water, and climate (Mannion 2003; Fig. 1.1).

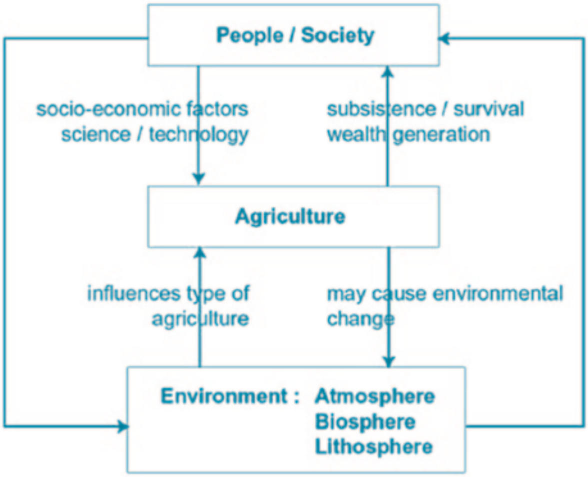

Fig. 1.1 The primary relationship between agriculture, people, and environment. (Source: Mannion 2003)

Based on these facts, agriculture can unequivocally be described as a major agent of global change[1]; since its inception 10,000 years ago, agriculture has been a direct cause of change in the biosphere. According to Mannion (2003), agriculture will continue to cause environmental change at scales from the local to the global and in the meantime global change will influence the extent and characteristics of agricultural systems. The likely roles of environmental change, notably climatic change and deteriorating soil and water quality, of socioeconomic developments—such as the spatial pattern of population growth and globalization, and the impact of new technologies, e.g., biotechnology and information technology—are matters of crucial scientific concern.

"Global change" is a term widely used to describe the effects of human activities on the Earth. Although the term sometimes refers only or primarily to global climate change, it covers also the interactions between natural changes in the Earth's physical and biological structure and the broader effects of human activity. Thus, global change includes changes in many aspects of the globe's environmental systems, including climate (BEST 2000).

Agriculture has been responsible for more environmental change than any other technology. As it has expanded and intensified, to sustain and promote population growth through the provision of food and commodities for trade in the process of wealth generation, agriculture has caused a wide range of environmental externalities. According to Chen (1990), the global food system may influence the global environment in a variety of ways. The direct impacts of agriculture on the environment include modification of land for agricultural purposes and byproducts

[1] The concept of global change is now well understood and to a large extent accepted amongst scientists, agencies and the informed public. Issues such as climatic change, desertification or the loss of biodiversity are not only major media topics, they are also regulated by international conventions aimed at finding solutions to these problems, inter alia through choices related to policy, technology, economics, and social awareness.

of production such as methane released by rice paddies and livestock. Activities such as food processing, distribution, and preparation use fossil fuels, fuel wood, refrigerants, and other inputs and generate wastes. Indirect impacts include the effects of energy, materials, and pollution entailed in constructing and maintaining equipment, transportation and storage facilities, and other infrastructure used in food production, fisheries, and related activities, and in supporting the populations involved in them.

Moreover, the loss of biodiversity is perhaps the most significant environmental problem because of its irreversibility. Deforestation and forest degradation, water depletion and degradation of irrigated land, soil degradation, global and regional climate change are all initiated or accelerated through injudicious agricultural practices (Mannion 2003). Of course, it is still difficult to quantify such problems, to attribute them consistently to particular activities, and to ascertain whether alternative uses of resources would have resulted in greater or lesser impacts (Chen 1990). These problems are highly interactive, making it difficult to predict or evaluate their combined impact. Likewise, the full extent of environmental damage from agriculture is still difficult to assess with available data and has only been attempted in a limited number of studies (Hazell and Wood 2008). The combined effects of most of these environmental problems have not threatened yet the overall capacity of the world to feed itself, despite its important local impacts on human well-being (Hazell and Wood 2008). Nevertheless, environmental problems associated with agricultural growth could, if not checked, threaten future levels of agricultural productivity at country and regional levels as well as impose future health and ecosystem service costs.

Agriculture has also had a major impact on humanity, notably through the process of development with which it is intimately associated. It is linked with population growth and wealth generation; where surpluses are produced people have been freed from food production. This, in turn, has contributed to trade, industrialization, technological endeavor, and service provision through its facilitation of division of labor (Mannion 2003).

The converse aspect of the relationship between agriculture, environment, and people means that the environmental, socioeconomic, and technological developments have had, and will continue to have, repercussions for agriculture. Soil erosion, desertification, and the impairment of water quality can, in extreme cases, result in the abandonment of agricultural land; even in cases of slight to moderate degradation, productivity and carrying capacity will decline. Thus, agriculture becomes self-defeating, a problem which is more common in poorer nations than in richer nations; the former have fewer safeguards, often little research on effective conservation measures, and limited access to technology. There is also much speculation as to the likely impact of global warming on the world's agricultural systems. Agriculture, through its part in altering the character of the biosphere and its consumption of fossil fuels, has played a significant role in global warming but how global warming will affect agricultural systems remain debatable; for some nations there will be advantages and for others there will be problems (Mannion 2003).

Included in the many socioeconomic factors that will continue to influence agriculture are population change, trade relationships (part of the globalization process), and rising standards of living. None of these factors operate uniformly on a global basis but the repercussions may be global. The pressure on agricultural systems in developing nations will increase substantially, and at the same time there will be pressures to increase the productivity of agricultural goods for export. Where standards of living are increasing, as in emerging nations, changing food demands, and especially increasing consumption of meat and dairy products, will cause agricultural systems to change in response to consumer choice, i.e. market forces. Forces that are external to a nation will also influence agricultural systems. In some cases the production of goods for export takes precedence over the production of staple foods, which are sometimes provided through food aid[2] (Mannion 2003).

At the turn of the millennium, information technology and scientific developments have had significant impacts on agriculture. Information technology can facilitate the efficient use of resources through improved land-use practices. Knowledge-based systems can be used to control irrigation systems and to determine the quantity and location for artificial fertilizer treatments and applications of crop protection chemicals, i.e. they can be used to determine best management practices. In terms of scientific advances, biotechnology is likely to have the most profound effects on agriculture. The advent of genetic engineering in particular must be considered as a major agent of both agricultural and environmental change in the early twenty-first century. Genetic engineering has applications in medicine and environmental remediation, but its main and most controversial application to date has been in agriculture. The possibilities of engineering traits such as herbicide, drought and salinity tolerance, pesticidal properties, and so on, are exciting; all could increase productivity substantially. However, there are as many potential disadvantages as there are advantages. Genetic engineering could produce just as many environmental threats as it presents opportunities for conservation. It could also have repercussions for human health and, like most technologies, it is not available equitably (Mannion 2003).

1.3 Can Today Agriculture Meet the Food Security Challenge of Tomorrow?

Food is the most basic of all resources, and food production has effectively diverted more natural landscape to human purposes than any other ecologically significant human economic activity. Massive famines punctuate the history of human civilization—ironically, since civilization was made possible by agriculture—and, until relatively recently, fear of food shortages was a concern of most human groups (Rees 2004). Along with a few technological breakthroughs to increase yields, the food needs of growing populations were historically met by expanding the cultivated area. As the most fertile and irrigable lands became scarce, further expansion meant bringing poorer and lower yielding land into cultivation (Smith 1998). By the nineteenth century, there was growing pessimism about the possibilities of

[2] The case of Sudan can be given as example.

feeding ever-growing populations, as exemplified in the writings of Malthus. The task seemed even more overwhelming as advances in medicine and public health led to longer life expectancies and higher fertility rates.

Furthermore, not only poor countries are currently net importers of food. Wealthy countries such as Spain, the Netherlands and the United Kingdom have agricultural eco-footprints up to several times larger than their domestic agricultural land bases. Unlike the poorer developing countries, these wealthy nations have, so far, financed their considerable food-based "ecological deficits" with the rest of the world. Actually, countries that are net food importers are more the rule than the exception. Most of the world's 183 nations are partially dependent on food imports. Just five countries—the United States, Canada, Australia, France and Argentina—account for 80 % of cereal exports and most of the safety net in global food markets (Pimentel and Pimentel 1996). These countries have exceptionally high crop-land-to-population ratios and relatively few soil constraints, and use intensively mechanized, fossil-energy dependent production methods (Rees 2004).

Public investments in modern scientific research for agriculture has led to dramatic yield developments in recent decades. The achieved advances were fuelled by modern plant breeding, improved agronomy and development of inorganic fertilizers and modern pesticides. Most industrial countries had achieved sustained food surpluses by the middle of the twentieth century, and some developing countries did the same in the closing decades. However, not all countries have shared the global success of agriculture, and hunger and malnutrition persist in many parts of the world[3].

In general terms, the global food situation is very favorable today. Already more food is produced than needed to feed the entire world population and at prices that have never been so low. More precisely, agricultural production has grown much faster than the population in recent decades, leading to a steady increase in per capita agricultural output (including food) and a steady decline in world prices for most agricultural commodities. As a result of this unprecedented growth in agricultural productivity, the world now produces more than enough food to feed the entire population to minimum UN standards if it were distributed more equitably. Even more remarkably, this surplus has been achieved despite the diversion of considerable land, labor and other rural resources to the production of higher-value foods to meet the changing food demands of growing, more urbanized and more affluent populations. This includes the additional cereals needed as feed grains in intensive livestock systems and oil crops for inland aquaculture (Hazell and Wood 2008).

[3] Africa is the only continent that has yet to achieve food surpluses. This continent has not been able to increase its agricultural production to keep pace with population growth, leading to periods of decline or stagnation in its food and total agricultural outputs per capita. Africa has yet to experience the kind of technological revolution enjoyed elsewhere and still uses few modern inputs in agricultural production. As a result, yields of all major crops in Africa have grown little over the past 40 years and cereal yields have stagnated for the past 20 years. Moreover, and while hunger is now largely a distributional problem in most parts of the world, Africa still faces the additional burden of a classic food shortage problem. Sub-Saharan Africa still relies on food aid, and the food gap is projected to increase significantly in the future (Hazell and Wood, 2008), especially within the perspective of climate change, water shortage and conflicts.

Despite these accomplishments, serious hunger, health and environmental concerns remain and even in countries and regions that have performed better and now have food surpluses (e.g. much of South Asia), hunger and malnutrition are still widespread[4]. The fundamental hunger problem today is one of income distribution rather than food shortages. The hungry are simply too poor to buy the food that abounds, while, at the same time, obesity and chronic illnesses associated with excessive food intake are becoming a serious problem among richer people (WHO 2002, 2003). Based on this fact, simply increasing global supplies will not solve this distribution problem. Additionally, since food production, buying power, and consumption are not distributed evenly with population, large surpluses and deficits will persist at regional, national, and subnational levels (Chen 1990).

The real agricultural challenges of the future will, as today, differ according to their geopolitical and socio-economic contexts. The current divide between those who eat well and those who go hungry will continue, defined largely by differences in per capita incomes within and between countries. Factors that distinguish the various trajectories of agricultural development also exhibit significant spatial variability, such as differences in farming systems and productive capacity, population densities and growth, evolving food demands, infrastructure and market access, as well as the capacity of countries to import food or to invest in agriculture and environmental improvement. Environmental problems associated with agriculture too vary according to their spatial context, ranging from problems associated with the management of modern inputs in intensively farmed areas to problems of deforestation and land degradation in many poor and heavily populated regions with low agricultural potential. In short, despite globalization and increasing world trade in agriculture, there remain large, persistent and, in some cases, worsening spatial differences in the ability of societies both to feed themselves and to protect the long-term productive capacity of their natural resources (Hazell and Wood 2008).

1.4 Agricultural and Food Production with a Better Environmental Footprint

The current scientific attention to the threat of global environmental change has tended to focus on the possible impacts of a changing environment on agriculture and the implications for global and regional food security. From a policy viewpoint, however, it is also critical to understand the degree to which agriculturally related activities may contribute to global-scale environmental change and the ex-

[4] Food security is essential to support the health and nutrition that are vital for sustained progress in developing nations. Up to 1/3 of child mortality in these countries is a direct consequence of malnutrition (WHO, 2009). Diseases like malaria are also spreading to new geographic areas due to climate change (IPCC, 2007), further impeding the productivity of agricultural workers and others. Tackling the impacts of climate change on malaria, malnutrition and diarrheal disease could add as much as 1 % of current gross domestic product (GDP) in sub-Saharan Africa and South-East Asia up to 2030 (Accenture et al., 2011).

tent to which policies to prevent, mitigate, or adapt to environmental change may themselves affect agriculture and hunger. These two issues are likely to become especially important for decision making processes not only about how to reduce the magnitude of human perturbations to the environment but also about how to improve both food security and environmental sustainability in the overcrowded world of the future.

The OECD and FAO's Agricultural Outlook for 2010–2019 suggests that the world is on track to meet growing demand for food (OECD and FAO 2010). But the agricultural sector will need to overcome four key hurdles as well as coping with rising production and distribution costs: changing land use and availability, growing water scarcity, climate change, and food wastage.

- Land for agriculture is becoming more scarce. It is being lost to spreading urban and industrial areas, use for growing biofuel crops, soil erosion as a result of intensive and poor farming practices, and climate change. As people migrate to cities for better education and employment, there are also fewer families in rural areas to farm the land.
- Irrigated agriculture accounts for approximately 70 % (UN-Water 2009) of global water usage, and by 2030 almost half of the world's population will be affected by water scarcity (OECD 2008). In many developing countries, irrigation makes up over 90 % of water withdrawals (WBCSD 2009).
- Climate change impacts farming practices and is influenced by them. Extreme weather events, such as droughts and flooding, as well as longer-term changes in climate, damage crop yields and change growing cycles. The agricultural industry is currently responsible for around 30 % (IAASTD 2008) of the world's carbon emissions. This could increase as a result of poor farming practices, deforestation and growing demand for animal protein in people's diets.
- While improved agricultural productivity is essential, reducing waste will also increase availability. Around one third of the food in the supply chain is either lost or wasted at the farm, during storage and distribution, or in households (FAO 2011).

In addition to the above orientations, investments should be focused on other related areas with similar importance:

- Engage in trust-based free trade: The world's farmers are producing an all-time record level of calories which remain unevenly distributed and irregularly available. The world can go on providing food in economical fashion—with a better environmental footprint—if every farmer plants the right crop for his soil and climate and then freely trades with others based on the principle of comparative advantage. Although food security is a complex issue, this fundamental economic principle is simple. It recognizes that fertile soil, abundant rain and plentiful sunshine are not equally available across our planet. If every country on Earth tried to pursue self-sufficiency, there would be less food. The role of trust-based free trade becomes increasingly important if we are going to exploit the law of comparative advantage.

- Ecological agriculture, which works with nature rather than against it, can drastically reduce environmental externalities such as greenhouse gas emissions. Moreover, compared with today's destructive chemical and fossil energy intensive agriculture, ecological agriculture better adapts to and survives the effects of environmental change.
- Climate change has prompted a wide array of policy responses ranging from the creation of carbon markets to adaptation programs for vulnerable communities. Few of these policies have invited the degree of controversy that surrounds biofuels, as emerging evidence of the adverse environmental and social impacts of biofuel production indicates that biofuels may not be the climate change panacea that policy-makers had made them out to be. The promotion of biofuels as a fossil fuel alternative has been a significant aspect of the global quest for solutions to mitigate climate change. However, the quick-fix has proven to be problematic as food security and environmental concerns emerge. There are growing concerns about how increased biofuel production can assert upward pressure on food prices, increase GHG emissions, and exacerbate degradation of land, forest, and water sources[5]. Championed as a panacea to climate change, an agent for rural economic regeneration, and a means to securing energy independence, biofuels have not turned out to be the perfect solution. Questions surrounding the environmental and social costs of biofuels have overshadowed earlier optimism as evidence of the role of biofuels in rising food prices, accelerating deforestation and doubts about the climate benefits continue to emerge (Lin 2011). Clearly, we urgently need to engage in an honest discussion about balancing food and fuel and make biofuels more responsive to shifts in supply and demand.
- Africa should be made as a part of the solution. Africa represents about 60 % of the potentially available cropland in the world, and it is well suited to harvest the fruits of photosynthesis. Africa can contribute critically in feeding the planet's growing population but its agricultural productivity is still the lowest in the world. The challenges seem overwhelming: unclear property rights; limited access to fertilizer, quality seed and mechanized equipment; inadequate roads and storage facilities; lack of market institutions and prices that encourage farmers to invest in their operations year after year. For Africa to feed itself—and help feed the world—the issue of price adequacy is crucial. Today, there is more momentum than ever to tackle these issues. Under the Group of 8's New Alliance for Food and Nutrition Security, and the Grow Africa partnership, companies, nongovernmental organizations and African governments are working to develop sustainable markets for food grown on the continent. Global food security cannot be achieved without closing the agricultural productivity gap between Africa and the rest of the world.

[5] Concerns about the food security dangers of current biofuels development have prompted the United Nations Special Rapporteur on the Right to Food Jean Ziegler to call biofuels a "crime against humanity." In 2008, when food prices were soaring, he demanded an international five-year ban on biofuels production (Ziegler, 2008).

Orienting policy interventions, scientific research and private investment within the above perspective while reversing the current undesirable trends has the potential to ensure sustainability and less environmental footprint for agricultural and food production systems.

1.5 Concluding Remarks

We have reviewed a number of the key issues and drivers of significance to agriculture globally. We have seen that immense progress has been made from a humanitarian perspective in feeding a world population that has doubled in the past 40 years, become more wealthy, and increased its per capita demand for low-cost food in terms of quantity, quality and diversity. However, much still remains to be done both to further strengthen food security for the majority, and to attack the persistent, large and, in some places, still-growing pockets of hunger. Furthermore, all this needs to be done in ways that improve (or at least damage less) our long-term capacity to sustain food production. This means conserving biodiversity, soils, water and other resources that will provide the level and quality of ecosystem services necessary to support agriculture in the future.

However, while some drivers may be common, it is unlikely that appropriate responses to change—either positive or negative impacts—will likewise be similar. The geopolitical and agro-ecological contexts under which agriculture is conducted globally are very heterogeneous and consequently a specific approach is needed to tackle the relevant challenges.

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Chapter 2
Challenges Facing the Macroeconomic Policy for Sustainable Development in Agriculture—Based on the Model of Organic Agriculture in Bulgaria

Vania Ivanova and Ekaterina Sotirova

Abstract The ecological significance of sustainable development has increased dramatically since the so called 'green economy' and organic production have been turning into sources of competitive advantage for the country in the international markets. For its part this undoubtedly leads to stronger economic competitiveness. All government's measures to overcome the consequences of the world economic crisis should aim at directing the economy toward sustainable development and low carbon-emission intensity. The opposite would mean unstable and insecure future, growing production costs as a result of dynamic energy prices and problems in terms of climate changes. Bulgarian economy is strongly dependent on tourism and agriculture. These two sectors show enormous potential for developing 'green economy'. Adequate macro-economic policy aiming at developing these sectors would serve as an additional incentive for creating competitive advantage. Organic agriculture as a sector provides various opportunities due to the well-established traditions. The production of oil-yielding crops, fruit, vegetables, wine and meat has always had excellent world markets. What would really stimulate and intensify the development of this branch is the establishment of a national fund with the aim to finance the development of new environmental technology and innovation? Eco fees (including the newly introduced carbon dioxide tax) can contribute significantly to this fund. Stimulating the development of 'green' production should involve different fiscal and other economic instruments. Long-term tax reliefs and favored development of eco-innovations and biotechnologies facilitate the integration of the environmental aspect in the system of economic, industrial and social policies.

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2.1 Introduction

The globalization of relations and contacts in world agriculture has raised a lot of new issues that the individual countries and the international community as a whole have to address. They are related to the specific nature of national production, the active import-export flows, the activity of transnational companies and the international credit and financial institutions and markets, and the setting up of strong integration units. In the context of these processes, issues related to achieving sustainable development are becoming more topical. This necessitates combining equilibrium in the economic and ecological system with reducing or overcoming the negative effects of increased human activity which damages the environment.

The main point of the chapter is researching and exposing the problems related to the progressing and affirmation of the bio farming and production of organic products in Bulgaria, considering the transforming of this sector into a leading one in the development of sustainable and ecologic economy. Also, it would accelerate its level of competitiveness in the world market.

The methodology of the research is based on empirical data from the National Statistic Institute and the Ministry of Agriculture in Bulgaria. They are presented in the form of tables and take place after the 2000. The last year, which gives us the official data, quoted in the chapter, is 2010. Along with the analysis of the data, comparisons are made, considering some points with other, mainly European countries.

Agriculture is a traditional sector for the Bulgarian economy. Bulgaria is a country with extremely suitable conditions for developing plant breeding and animal husbandry—fertile soil, pastures, experience and traditions in this area. The sector is of great importance to Bulgarian economy. It ranks second in the structure of the national economy, after manufacturing. In comparison with the developed countries and some countries in transition Bulgarian agriculture contributes significantly to calculating the gross value added (4.3 %) and to providing employment (19.9 % of those employed in the national economy)[1].

The reforms toward the transition to market economy have exerted significant impact on the development of agriculture over the past decade of the twentieth and the beginning of the twenty-first century. The complex and multifaceted changes in Bulgarian agriculture are related to the need for transition to development within market environment, to the process of its transformation and to the process of European integration, which we have witnessed over the past years. In comparison with other countries in transition the changes in Bulgarian agriculture are more profound and along with the expected positive results we observe some difficulties which hinder its development.

[1] Source: National Statistical Institute.

Table 2.1 Main economic indicators in agriculture. (Source: National Statistical Institute, BNB)

Indicator-year	2000	2005	2006	2007	2008	2009	2010
Share in GDP (%)	12.8	7.7	6.8	5.1	6.0	5.1	4.8
Share in GVA (%)	14.5	9.4	8.5	6.2	7.3	5.6	4.3
Employment (thousands)	89.5	69.9	66.4	60.8	60.0	63.1	64.3
Average yearly salary							
For the country (Euro)	1,428	1,943	2,128	2,584	3,144	3,655	3,885
In the sector (Euro)	1,234	1,213	1,310	1,835	2,352	2,638	2,950
Usable land (thousand hectares)	4,424	3,128	3,090	3,058	3,051	3,123	3,103
Production (million Euro)							
Plant growing	1,274	1,592	1,719	1,531	2,384	2,045	2,074
Stock-breeding	1,414	1,135	1,219	1,219	1,323	1,806	1,831
Share in export (%)	5.0	6.8	5.7	5.6	8.2	10.4	10.7
Share in import (%)	4.1	3.9	3.9	4.5	5.4	7.9	7.6

2.2 Significance of Organic Farming

Over the past half a century Bulgarian agriculture has gone through a period of complex transition from petty agriculture (at the end of the first half of the twentieth century) to big collective farming (Cooperative farming until the end of the 80s of the twentieth century) and back again to strongly fragmented land and the formation of a great number of petty farms along with an insignificant number of large-scale farms.

Agriculture is the sector of the Bulgarian economy where market changes started in the beginning of the 90s. Of greatest importance are the changes in the form of ownership and the utilization of land, in the nature and size of the organizational forms, the structure, specialization and intensification of production, in the employment etc. The major parameters in the development of Bulgarian agriculture are given in Table 2.1.

There are a lot of problems facing agriculture in Bulgaria. In the first place, every year it sustains losses amounting to hundreds of millions of levs from unsold produce. The reason for that is the fact that people abandon their arable land or the land is used for other purposes. Nearly 30,000 ha farm land is destroyed and is transferred for utilization in other sectors—industrial, protected or resort areas or it is used for the construction of infrastructural projects.

Another significant problem impairing the efficiency of agriculture in Bulgaria results from the lack of motivated, initiative and innovation-oriented people. This is due to constant process of young, well-educated, highly qualified workforce, capable of accepting technological innovation and implementing good practices in agriculture, leaving the country. There is a strong trend toward aging farmers. Between 2004 and 2010 the average age of farm managers was 61 years, and 41 % of them were older than 65 years. Barely 3 % of the managers were up to 35 years of age.[2]

[2] Ministry of Agriculture (2010).

The unfavorable age profile combines with a continuous drop in incomes of farm workers after 1990. In 1997 the average income of an employed in the sector was three times higher than the average annual payment in the country. Ten years on the situation is reversed—the average income of people working in agriculture is twice as low as the average annual payment. The farmland market analysis shows that the prices of land in Bulgaria are a lot lower than the prices in the other EU member states.

The situation on the market of farmland bought in order to use it for other purposes—for example, construction, is entirely different. The prices of this type of land exceed by between a few tens to a few hundreds the price of land purchased for farming purposes. For example, in Southeast Bulgaria in 2008 0.1 ha farmland fetched € 80,000[3]. Changing the purpose of the purchased farmland is not solely related to construction projects. Some of these purchases are made in order to produce crops used in the production of biofuels and for building wind and solar farms—primarily in North and Northeast Bulgaria, along the Danube river and the Black sea coast. Land bought for such purposes costs from € 350 to 600 per 0.1 ha.

Along with this change of the purpose of farmland another important problem facing agricultural efficiency in our country is the fragmentation of the farms. In 2007, under the EU criteria there were nearly 500,000 farms in our country. The larger part—88.9 % were small farms with usable land of up to 1.9 ha. Large-scale farms with 5 ha made up barely 3.2 %. This structure determines low employment and ineffective utilization of farmland.

Agriculture can develop in three major areas—conventional, organic (bio) or based on genetically modified food (GMO). The worldwide trend is toward increasing the importance of organic crop production and animal husbandry and related production. Unlike traditional farming, organic farming follows harmony in nature, respects biological cycles and does not pollute environment. The use of natural and organic products is closely related to the latest international trends for healthier and more ecological way of life. Nearly 170,000 farmers and nearly 149,000 companies in the 25 European Union (EU) countries are involved in organic farming. The biological products produced in Europe comprise mainly cereals, fruit and vegetables, vines, dairy and meat products. The first European countries which started producing organic products in the beginning of the 90s were Austria, Germany and Switzerland. Ever since, however, areas with organic crops in Europe have increased from 100,000 ha to over 8 million ha (mha) in total. A large part of organic production is concentrated in Australia (11.3 mha), Argentina (3 mha) and Italy (1.2 mha)[4]. The world market of organic products is estimated to exceed $ 26 billion.

The domestic Bulgarian market of organic products reaches around € 4 million annually. Organic products are considerably more expensive than their counterparts since no insect pesticides or stimulants are used in their production. There is also organic animal husbandry—when animals are fed with organically produced forage

[3] Ministry of Agriculture (2010).

[4] Eurostat.

Table 2.2 Organic product's prices, euro per kilogram. (Source: NSI)

Product	Organic	Non-organic
Milk	0.89–0.99	0.55
Bananas	2.49	0.99–1.99
Carrots	2.09	0.59–0.89
Mushrooms/500 grams	3.95	1.29
Lettuce	2.09	0.99–1.45
Potatoes	0.99	0.25
Minced meat	15.1	3–7
Eggs	1.49 (6 pieces)	0.59 (10 pieces)
Sunflower oil	3.99	0.89

and are not given any antibiotics or hormones. This, however, makes production more expensive—simply because a tomato plantation is not treated with pesticides the yield drops by 20 %.

Prices of organic products are high both worldwide and in Bulgaria. Despite the increase in supply, this high level is determined by the increased demand motivated by economic, social and ecological concerns. These high prices present a favorable prerequisite for specialization in a particular field of organic crop production or animal husbandry, both for the domestic market and for export. This represents a market niche with vast opportunities for achieving and maintaining sustainable competitive advantage. No price policy research in this market share has been conducted in Bulgaria. The data in Table 2.2 is indicative—it shows a comparison of prices of some traditionally manufactured goods and some organic ones, produced in organic farms in Germany.

Natural resources, traditional landscape and biodiversity are part of the national wealth. Preservation, restoration and appropriate management comprise the main goal of the sustainable development of rural regions in Bulgaria. Like in many other regions in Europe, one of the great challenges facing the restructuring and revival of the economy in rural areas in Bulgaria is to achieve the appropriate balance between securing food, the need for environment preservation in rural areas and the need for promoting economic development, creating new job opportunities included. One of the most reliable means to achieve the necessary integration of these political goals is organic farming. Supporting it as an eco-efficient method for agricultural production, which is also economically efficient, should take priority in the agricultural policy.

Determining this type of production as strategic ensues from its importance:

- To environment preservation, biodiversity and ecologic norms;
- To establishing a new type of behavior among producers and mostly among consumers;
- To creating alternative employment in rural areas with predominantly unfavorable conditions for conventional agriculture;
- To promoting 'green economy'—an alternative to sustainable development, promoted by the EU after the 2007 crisis and in accordance with the UN policy.[5]

[5] European Commission, La PAC à l'horizon (2020).

The focus is on 'green economy' since the ecological field gains priority and the fact that production 'gets green' serves as a source for competitive advantages on the world market. The development of organic manufacture of products and food might prove to be a successful instrument to improve competitiveness of agricultural produce.

The ecologic goals pursued through stimulating the development of organic farming and the production of organic goods are as follows:

- Increasing the land where the methods of organic production are used, as well as the number of organic farms;
- Promoting the creation and development of different systems for organic production;
- Promoting more 'balanced' systems of organic production based on crop-rotation and mixed farms (plant- and animal-oriented);
- Maintaining balanced ecosystems and preserving the soil, water and energy resources;
- Improving the landscape in rural areas by sustaining the biological diversity and preserving the natural habitat, which also contributes to making rural areas attractive for people;
- Enhancing the reliability of seed and seedlings involving methods for organic production.

As a result of the prohibition for utilizing mineral fertilizers and synthetic products for plant protection, organic farming has a favorable impact on biodiversity, contributes to the preservation of water and soil quality, and facilitates the equilibrium in the soil-plants-animals system. Organic crop production stimulates the use, therefore the preservation, of old local plant varieties due to their better resistance to illnesses and pests and to their better adjustment to local conditions, i.e. they have a positive impact on preserving the genetic diversity of crops. Organic bee-keeping improves pollination in the wild and contributes to preserving biodiversity. Orchard pollination increases yield with no further use of nitrogen fertilizers, which facilitates soil preservation.

The considerable potential organic farming has in Bulgaria is determined by a multitude of factors:

- Favorable natural and climatic conditions;
- High share of land meeting the requirements for organic farming. The transition to market economy brought about the collapse of heavy, polluting industry, as well as intensive agriculture using a lot of fertilizers. Vast areas of idle land appeared and remained such for a long time. Thus, it became possible for soils to get clean from old pollution and to 'rest', accumulating fertility. As a result, around 80 % of the land in Bulgaria is considered 'clean', while 38 % of the arable land are suitable for organic farming;
- Growing demand on the world and the domestic market;
- Good legislative framework and regulation;
- Existing control and product certification systems;

- Progressively growing understanding of the benefits from this type of production;
- Well qualified specialists in this field;
- Potential for development of innovative and scientific and research projects resulting in greater efficiency; effective mechanism meeting the requirements of the European standards as defined in the Common Agriculture Policy (CAP) for granting subsidies.

There are considerable opportunities for developing such production in the country due to the natural and climatic conditions and soil diversity. This provides for growing a wide range of organic products. This type of farming will benefit the development of rural regions and prevention of land backwardness. The additional common benefits are related to creating new 'green' jobs, low-carbon production and sustainable rural development.

2.3 Results from the Development of Organic Farming in Bulgaria

In Bulgaria, like in any other EU country organic agriculture is subject to certain rules. The crops are grown on land which has not been treated with fertilizers at least 3 years. This has to be certified by a company authorized by the state. After that, organic and certified seeds should be used. The end produce should be approved by an authorized company, too. There are ten authorized companies and about 300 organic farms in Bulgaria.

Organic food does not have the good commercial presentation the modern consumer is used to, and quite often tit are not durable since it is grown in entirely natural environment. But the food is characterized with something else which is of much greater importance—the loyal consumers whose number has increased over the past years exponentially. There is an upward trend for the product range for this type of buyers and organic food, which until recently was sold solely in specialized stores, become regular stock in local supermarkets. The times when only honey, herbs and nuts were sold at these stands are gone even in Bulgaria. Vegetables, fruit, food and drinks, pastry and confectionery, even lamb and veal are sold there. About 300 types of organic food are produced in the country. We can compare this number with the numbers in the remaining East European countries where there are between 1,000 and 2,500 organic goods, while in West Europe they exceed 10,000 where there are also non-food products—mainly cosmetics. All this means that there is a tendency toward a growing market and larger product range. The 2010 data show that the budget for organic food has been considerably increased.

Since 2001 there is a law in Bulgaria under which farmers are entitled to financial aid. It regulates the production and processing of organically produced goods, grown in natural environment (without chemicals, genetically modified ingredients, different artificial additives etc.). Organic farming in Bulgaria occupies 166,741 ha, which is 3.1 % of the municipal land and its production is constantly increasing. It is mainly pastures (155.793 ha) that are certified as ecologically clean. The same certificate has been granted to 242,677 ha of forest where herbs, mushrooms and wild berries are collected.

Currently, the structure of the organic produce sold in the country is as follows: food is offered by 66 % of all traders, herbs—48 %, organic cosmetics—41 %, essential oils—29 %.[6]

The problems traders and manufacturers of organic products face can be grouped as follows:

- Financial problems, including insufficient funds, expensive production, considerable expenses, expensive animal feed etc.. Production becomes more expensive when the quantities sold are very small. What is more, certification itself costs around € 350,000 per year. The produced goods are much more expensive than conventional goods which predetermine the fact that it is almost impossible to operate organic farming without initial investment. The European subsidies aim to offset the additional costs but in order to qualify for those subsidies farmers have to meet high requirements.
- Difficulties related to the production process—undeveloped processing establishments, difficult access to plant protection products for organic products, difficulties related to watering or providing the necessary machines, resources, treatment etc.. Small, fragmented plots run by several enthusiasts dealing with organic farming, cannot provide access of this type of production to the EU markets.
- Labor-intensive production requiring qualified workforce that cannot be easily found.
- Low purchase prices and problems related to selling production in the country and abroad, sluggish market for organic goods in Bulgaria. Only 1–1.5 % of the milk is sold as organic. The prices of organic goods are by 30–50 % higher than those produced in conventional agriculture, but this is not a big problem on the Bulgarian market since there is a coherent group of consumers of this production.[7] The bigger problem lies in the insufficient supply, lack of manufacturers, distributors and retailers of such products. It will take time and coherent government policy to stimulate and control the quality of goods in order to complete the chain. A serious problem arises from the fact that there is no clear differentiation between the notions natural, ecological and organic, of which only organic by law has the brand guarantee for producer and consumer.
- Difficulties which ensue from legislation, control and bureaucratic procedures. Due to administrative and volitional reasons a little more than 1 % of the € 455 million earmarked for the period 2007–2013 for Bulgaria have been absorbed. There are two certifying bodies in Bulgaria and the certificates it issues are recognized on the European market. The services of foreign certifying firms may be used, but the certificate costs additional around € 20,000 per year. The legal framework in the field of organic farming is not homogeneous, the laws are not exhaustive, there are no national minimal requirements for the production of

[6] Ministry of Agriculture, Sofia (2009).

[7] Ministry of Agriculture (2010).

typically national organic goods, and there is no data about the state of organic farming in the country. Organic farmers should have at least 10-year rent contracts if they are to develop this type of agriculture, but over the last years mayors have started to terminate long-term contracts for municipal land on a large scale, which has additionally hindered the process.

So, it becomes obvious that the excellent opportunities for organic farming in our country cannot be utilized for the time being due to the mentioned practical obstacles. The Bulgarian market is insolvent in this field, whereas the world market remains inaccessible because the Bulgarian organic farming is fragmented, which determines the limited production.

Bulgarian agriculture and the related industries are the leading sectors in foreign trade. They have become of particular importance after the country joined the EU in 2007. This can be explained both with the historical development of the sector and with the modern prospects and tendencies in the sector.

Over 95 % of the currently certified organic production manufactured in Bulgaria is exported mainly to western European countries (the Netherlands, Germany, Switzerland, Austria), the USA and Canada. These are mostly herbs—dried and as tea, fresh, frozen or tinned fruit, vegetables, honey, nuts, essential rose, lavender and peppermint oils.

Bulgarian firms fulfill orders of foreign contractors who process or repackage the production and sell it with their brand. Bulgarian organic products are sold with foreign brands which are recognizable by the European consumer. This, for the time being, is the only successful way of breaking into the world market.

2.4 The Necessity of Efficient Macroeconomic Policy in the Field

The fact that Bulgaria is focused on recovering from the recession should not divert our attention from the pressing issues related to what kind of economy we want to develop. If we do not do everything necessary to direct the economic recovery of the country toward sustainable low carbon future, we will be faced with a long-lasting uncertainty and considerable expenses due to the energy price dynamics and a destabilizing environment.

Along with that we have an incredible opportunity—to stimulate our own recovery, disclosing new sources of jobs and export. Bulgaria stands a good chance to find its place in this field. Our economy is strongly dependent on tourism and agriculture. Both branches have potential for ‘green economy’.

If the government and the business take too long, Bulgaria will not only lag behind in its competitiveness, but there will be serious consequences for the labor market, prices, wages and incomes. Actually, this is the next big challenge the country has to address after the crisis. Stimulating such production creates prerequisites for competitiveness and new comparative advantages for the Bulgarian economy.

Overcoming the consequences of the current economic crisis through the use of resources to stimulate ‘green’ manufacturing is not simply an opportunity, but an indispensable prerequisite for the modernization of the European economies. The future competitiveness will depend on energy efficiency and resource management. Although Bulgarian firms are strongly threatened by cost rise and loss of competitiveness in comparison with the rest of the world by making firm ecological commitments, this is a serious investment in the future.

One of the greatest challenges facing Bulgaria in the process of economic restructuring is securing balance between the sufficient production of food and increase in employment and the preventive environment protection.

Currently, organic farmers can receive financial aid under the first pillar of the Common Agricultural Policy through direct payments and measures for supporting prices. Stimulating measures are envisaged under the second pillar of CAP for rural development by means of agri-environmental payments. These are axis-2, measure 214 and axis-1, when purchasing the necessary equipment for organic agriculture.

Financing agricultural producers involved in ecological farming, including organic farming is based on Measure 214 “Agri-environmental payments” from the Rural Development Programme (RDP) (Ministry of Agriculture Sofia 2007) for the period 2007–2013. The implementation of Measure 214 is regulated by Regulation 11 of 06.04.2009 stipulating the terms and order for implementing measure 214 “Agri-environmental payments” from the Rural Development Programme for the period 2007–2013. In terms of organic production Regulation 11 specifies the financial aid for organic plant breeding and organic bee keeping.

Agri-environmental activities are financed for a period of 5 years. The financial help is in the form of annual payments with 82 % of the funds provided by the EU, and 18 %—by the national budget. The people receiving aid under sub-measure “Organic farming” are obliged to observe the requirements laid down by Regulation of the Council 834/2007 and Regulation of the Commission 889/2008 and should get at least once over the five-year support period a certificate or written proof for compliance of the manufactured goods with the rules for organic production.

There is a National agri-environmental programme (NAEP) too. Its main goal is stimulating the eco-friendly agricultural production methods. NAEP will provide agri-environmental payments for farmers who willingly cultivate their land in an environment friendly way and in this way provide benefits for the entire society.

Farmers involved in organic agriculture are entitled to the following amount of money under RDP:

- Arable crops: in transition—€ 181/ha, undergone transitional period—155 €/ha;
- Permanent crops, vines, oil rose; in transition—505 €/ha, undergone transitional period—418 €/ha;
- Vegetable crops, including mushrooms: in transition—483 €/ha, undergone transitional period—357 €/ha;
- Bee hives: in transition or undergone transitional period—11.5 €/ha.

In 2008 BGN 4.232 million were paid out to 106 applicants who have submitted applications. To applications submitted in 2009 for the period 01.12.2009–06.07.2010 BGN 4.569 million were paid out under the measure.[8]

The qualitative analysis of the approved applications shows that the number of the approved applicants for aid under the measure is merely 2.6 % of the goal set in the RDP, but the plots approved for aid are 25.5 % of the set goal. In terms of genetic resources the number of the approved projects amount to 9.8 % of the target.

Another area in providing financial aid to farmers (including those dealing with organic agriculture) is investment lending. In 2009 investment lending was directed toward stimulating the investment process in agriculture and is carried out within the framework of three programs—"Plant breeding", "Animal husbandry" and "Agricultural machinery". The three investment programs and the subsidies granted refer to the so called "existing government aid" with maturity date 31.12.2009. The activities and objects to be financially supported are:

- Purchasing pedigree and fertile animals;
- Creating and restoring bee hives;
- Purchasing machines for animal husbandry;
- New construction, purchasing, restoring and restructuring of agricultural buildings and milk-collecting stations;
- Creating and restoring permanent crops;
- Establishing nurseries;
- New construction, purchasing, restoring and reconstruction of greenhouses;
- Restoring rice fields;
- Purchasing agricultural machinery and tools, including spare parts.

Twenty-nine projects have been financed, respectively refinanced under the three investment programs. Credit funds amounting to BGN 31,919,036 have been granted, which is by 162.5 % more than the funds extended in 2008 (BGN 12,578,299). The investment projects are financed directly from the Fund with an annual interest rate of 6 % and through refinancing by the Commercial banks at 9 % interest rate.[9]

By 2013, when the Rural Development Programme ends, Bulgarian producers will have at their disposal approximately BGN 1.6 billion reserve budget for agri-environment, organic production and compensatory activities in the mountainous regions and these funds cannot be transferred to any other activities. Producers and experts believe that a very big part of these subsidies will not be absorbed because the requirements toward environment-friendly plant breeding and animal husbandry are very demanding.

The European regulations require that 8 % of the agricultural land in Bulgaria be planted with organic fruit, vegetables and cereals by 2013. Currently there are merely 3.1 % organic plants. The aim of the programme is to have 3 % organic production of the whole agricultural production.

[8] Ministry of Agriculture www.mzh.government.bg/.

[9] Ministry of Agriculture (2010).

Strategic goals and earmarked budget:

- Development of the market of organic products—BGN 29,975,000;
- 8 % of the used agricultural land should be cultivated in an organic manner by 2013—BGN 84,017,000;
- Practice-oriented scientific research, education, training and consultancy in the field of organic agriculture—BGN 48,359,000;
- Introducing an efficient system of control and certification—BGN 2,173,000.

For each of the strategic goals the budget is presented in detail for each year. The total budget granted for the fulfillment of the National Plan for Development of Organic Farming (NPDOF) goals is BGN 164,544,000.

The achievement of these goals requires much more active policy on the part of the state to stimulate and encourage organic producers.

2.5 Recommendations for Improving the Macroeconomic Efficiency

- We should not rely entirely on European subsidies. They should be accompanied with government support to stimulate organic production. In 2009, in the conditions of economic crisis, farmers faced difficulties in acquiring the financial resources necessary for the sowing campaign from the commercial banks. Given the situation State Fund Agriculture initiated two schemes for short-term credits at 3 % interest rate. This practice can be implemented with priority for organic farmers.
- Bulgarian organic farming today can provide neither permanent nor sufficient deliveries for the European market and for the domestic one alike. This is a reason why big chains of stores do not show any interest (or just slight interest) toward these products. It is possible to carry out trade in smaller but specialized and easily recognizable shops with constantly growing network of stores.
- Financing scientific research related to new technology for organic production and processing of organic products should take priority. Creating an entire chain: science—production—processing—placement of organic food would spur the development of the sector. Ecological technology is the road to the future development of "green economy". The measures which would stimulate and accelerate a behavior like that are mainly the following:
  - Creating a national fund supporting the development of new ecological technologies. Its resources should be the result of "green taxes" (for example, carbon tax should be collected in a separate fund).
  - Encouraging the creation of funds for developing ecological production (through lower taxes for a long period of time, other reliefs and preferences) and in particular the innovative and scientific activity directed at developing ecological technology.
  - Encouraging the creation of municipal and regional funds financing similar activities.

  - Creating new jobs in sectors with high ecological potential.
  - The provision of subsidies and payments in agriculture should depend on and correspond with the equipment meeting the ecological norms and standards.
  - Partnership between the national government and the European structural funds in financing ecological projects.
- The state can define ecologically clean regions in the country where organic farming can be developed. If the process is regulated, the farmers will not waste money and time to get certification. This activity can well be combined with ecotourism and/or historic tourism for which Bulgaria provides excellent conditions. This type of putting together various activities brings to the fore a different, entirely new product, directed at our health and the wellbeing of the entire planet. This product matches the needs of the new tourist, i.e. the one who cherishes the clean and beautiful nature, the meals cooked from ecologically clean products, the tourist who finds all that not only a tourist attraction, but a lifestyle.
- An acceptable idea is the one about "green VAT"—lowering VAT for products which meet the ecological norms and for companies which change their behavior in the direction of ecologically-oriented model of production. So far the choice of productions which can take advantage of lower VAT was based on social considerations rather than ecological. The introduction of such reliefs for sectors with energy saving production and with low carbon intensity would be a step forward in the "greening" process of the economy. A measure like this would affect favorably the end price of organic products, therefore their competitiveness. A number of additional fiscal reliefs are possible both for producers of organic products and for the processing establishments, such as partial remission of the corporate tax for registered farmers who are legal entities, remission of corporate tax for tax liable individuals, remission of tax on incomes from farming for registered farmers and tobacco producers who are physical bodies, tax exemption for buildings used for farming, imposing preferential excise duty rates on motor vehicles used for agricultural land cultivation.
- Additional financial aid encouraging farmers to use and manage environmentally-friendly resources. An approach like that is part of the new tendencies to reform the EU Common Agricultural Policy after 2013 and corresponds with the process of 'greening' of agriculture.
- Maximum simplification of the certifying procedures of organic products and the administration of payments. With regard to encouraging more farmers to switch to organic production it is necessary to gradually enlarge the scope of the activities under measure 214 "Agri-environment". Closely connecting the policy for encouraging organic agriculture with the other measures for sustainable development of rural areas. For example, giving priority to financing infrastructural projects in the municipalities with predominantly developed organic farming and ecological tourism.

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Chapter 3
Environmentally Sound and Commercially Sustainable Agricultural Development in Nigeria

Usman Haruna and Mohammed Bashir Umar

Abstract The chapter highlights the environmentally sound and commercially sustainable agriculture development in Nigeria. It provides basic information about Nigeria and addresses the present status of agriculture, use of agricultural inputs, environmental degradation, commercial farming and its pre-requisites, paradigm shift and sustainability. Nigeria has the capacity to produce crops ranging from cereals to trees and fruit crops, therefore, it has good potential for sustainable development of commercial agriculture. This can be achieved through the expansion of cultivable areas and use of external inputs to achieve maximum yields per hectare in commercial farming.

Keywords Commercial agriculture • Environmental degradation • Input use • Small-holder farmers • Sustainable development

3.1 Introduction

The environment to most people is no more than a word in the dictionary used by the society. When it is viewed as an ecosystem, it has broader meanings, such as; it is a relatively stable community of organisms with established interlocking relationships, exchanges and their natural habitat (Abdul 2001). About 80% of Nigerian population lives in rural areas (Fomoriyo 1985), and engaged in agricultural production such as forest and trees for essential products, such as fuel wood, fodder, fruits, nuts, dyes, medicines, building material, ropes, nets, fungi, honey etc. (Abdul 2001). The fuel wood and fodder alone are, in many rural communities two of the

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most essential ingredients for survival. Their short supply leads to quick rural life degeneration and the communities have to struggle for survival.

However, on one hand, perhaps even more important is the fact, that many rural families depend on the tree products for income. Collecting, processing and selling the fuel wood and other products are often the only ways by which most rural communities can earn cash income. On the other hand, Abdul (2001) concurred that the forests also, are great but cheap source of industrial raw materials used in the manufacturing of pulp for paper, saw-wood, plywood, gum, oil, resin, pharmaceuticals and many other highly needed industrial raw materials.

The gradual disappearance of forests and replacement with human misery in the form of food and social insecurity victimized the rural people. Hunger and unemployment forced the equally uneducated ruralites to seek solace elsewhere through the cheapest means—migration either by economic, social, political or the least discussed ecological migration.

Today the environment is however, no longer a concern about a locality or wildlife or deforestation or pollution. It is the crisis about the developmental pattern which we have followed so far: a global issue which forces us to think as to where we are going. What shall happen if we do not stop, reconsider and make necessary modifications in our means, methods and objectives?

Also, the teaming and ever rising population and the need to increase export capacities so as to expand and strengthen the country's horizon in international trade provide yet another challenge to raise agricultural production perhaps, sustainable commercial agriculture in Nigeria.

This chapter is premised on the need for a closer look at the environment, commercial agriculture and sustainable development. In order to achieve this objective, the chapter seeks to discuss the following two questions:

- What is the status of agricultural production, food import and export?
- What are the common features of agricultural input use and factors that may be related to them?

It is expected that by providing answers to these posers the objective of this chapter may be achieved.

3.2 An Overview of Nigeria

The Federal Republic of Nigeria is in West Africa located between Latitudes 4° to 14°N and between Longitudes 2°2′ and 14°30′E (Fig. 3.1). To the north the country is bounded by the Niger Republic and Chad; in the west by the Benin Republic, in the East by the Cameroon Republic and to the south by the Atlantic Ocean. The country takes its name from its most prominent river, the Niger. Nigeria has a land area of about 923,769 km^2 (FOS 1989); a north-south length of about 1,450 km and

Fig. 3.1 Map of Nigeria showing major cities/towns and rivers

a west-east breadth of about 800 km. Its total land boundary is 4,047 km while the coastline is 853 km. The Federal Ministry of Environment of Nigeria (FMEN 2001) in 1993 estimated irrigated land to be 9,570 km^2 and arable land about 35 %; 15 % pasture; 10 % forest reserve; 10 % for settlements and the remaining 30 % considered uncultivable for one reason or the other.

Nigeria is a country of marked ecological diversity and climatic contrasts. The lowest point is the Atlantic Ocean at sea level while the highest point is the Chappal Waddi at 2,419 m. Nigeria has diverse biophysical characteristics, ethnic nationalities, agro-ecological zones and socio-economic conditions.

3.2.1 Geomorphological and Physiographic Information

The landscape of Nigeria displays an enormous variety of scenery. The diversity of rock types, the influence of geological structure and the impact of successive changes in climate in molding the uplands and redistributing material provides a wide assortment of landforms. Tectonic processes are almost negligible, with volcanic activity last experienced in the tertiary. The impact of natural hazards is mercifully low, if not entirely absent.

The geology of Nigeria is dominated by igneous structures that form most of the highlands and hills. The rocks of the basement complex, mainly of igneous origin, are encountered in over 60 % of the surface area. The landforms can simply be classified into highlands, plateaux, hills, plains and river valley systems. The landforms are more deeply dissected in the south than in the northern parts.

The topography of the country shows that Nigeria is highest along the eastern border and rises to a maximum of 2,040 m above sea level (asl) at Vogel Peak, south of the Benue river. The Jos plateau, that is located close to the centre of the country rises to 1,780 m at Sphere hill and 1,698 m at Wadi Hill. The Plateau is also the watershed, from which streams flow to Lake Chad and the rivers Niger and Benue. The land declines steadily northward from the plateau and this area, known as the High Plains of Hausaland, is characterized by a broad expanse of level sandy plains, interspersed by rocky dome outcrops. To the south-west, across the Niger River similar relief is represented in the Yoruba highlands, where the rocky outcrops are surrounded by forest or tall grass and form the major watershed for rivers flowing northward to the Niger and southward to the sea.

Elsewhere in the country, lowlands of less than 300 m stretch inland from the coast for over 250 km and continue in the trough-like basins of the Niger and Benue rivers. Lowland areas also exist in the Rima and Chad basins at the extreme north-west and north-east of the country respectively. These lowlands are dissected by innumerable streams and rivers flowing in broad sandy valleys. The low-lying areas are generally below 300 m and these are found in the centre and the south (Iloeje 2001). The Udi Plateau for instance attains a height of over 300 m, and this seems to break the monotony of the surface in the low lands.

Thus, according to Iloeje (2001) Nigeria is divided into the high plateaux and the lowlands. The High Plateaux consists of the Northern Central plateau. The Eastern and North-eastern highlands, and the Western uplands, while the Lowland comprises of the Sokoto plains, the Niger/Benue trough, the Chad Basin, the interior coastal lowlands of Western Nigeria, the lowlands and scarplands of South-eastern Nigeria as well as the Coastal Margins and swamps.

3.2.2 The Soil Types

Soil types in Nigeria are influenced by and follow very broadly, the climatic and vegetational zones of the country. This is expected because the degree of available moisture in the soil is an important factor in soil reactions, fertility and productivity. The soils of the humid tropical forests are quite different from those of the drier forests and the savanna zone, which in turn are different from the savanna zone. The major soil types in Nigeria, according to FAO soil taxonomy legends are fluvisols, regosols, gleysols, acrisols, ferrasols, alisols, lixisols, cambisols, luvisols, nitosols, arenosols and vertisols. These soil types vary in their potential for agricultural use.

Nigerian soils can be classified into groups made up of four (climatic) zones that are soil associations. The groups are: (1) Northern zone of sandy soils, (2) Interior zone of laterite soils, (3) Southern belt of forest soils, and (4) zone of alluvial soils (Iloeje 2001) and the soil types (classification) are well distributed among the groups (Adegbola 1979).

3.2.3 Climate

Nigeria, by virtue of its location, enjoys a warm tropical climate with relatively high temperatures throughout the year and two seasons—the rainy or wet season that lasts from mid-March–November in the South and from May to October in the north; and the dry season that occupies the rest of the year (Oyenuga 1967). However, in a country like Nigeria, where the temperatures do not fluctuates regularly, constant elements such as relative humidity and rainfall are heavily relied on to differentiate between the season and climatic zones. The climate of the country is influenced by the interaction of two air masses: (1) the relatively warm and moist tropical marine mass which originates over the Atlantic Ocean and is associated with Southwest winds in Nigeria, and (2) the relatively cool, dry and relatively stable tropical continental air mass that originates from the Sahara Desert and is associated with the dry, cool and dusty North-East Trades (*harmattan*).

Rainfall varies from place to place and from season to season. In the wet season, the full effect of the tropical maritime air mass is the main reason that brings rainfall, while in the dry season the rainfall is less. The total annual rainfall decreases from the south to the north. The southern two-thirds of the country have double peak rainfall while the northern third has a single peak.

Temperature also varies from place to place and from season to season. It has been observed that there are considerable contrasts between the coastal areas and the interior, as well as between the high plateau and the lowlands. On the plateau, the mean annual temperature varies between 21 °C and 27 °C. In the Jos area, temperatures are between 20 °C and 25 °C. On the lowlands such as the Sokoto Plains, the Chad Basin and the Niger-Benue lowlands, the mean annual temperature is 27 °C. The coastal fringes have lower means than the interior. It appears therefore that altitude and proximity to the seas determine to a large extent the distribution of temperature in Nigeria. Generally, temperatures are high throughout the year because Nigeria lies within the tropics and the mean monthly figure could go above

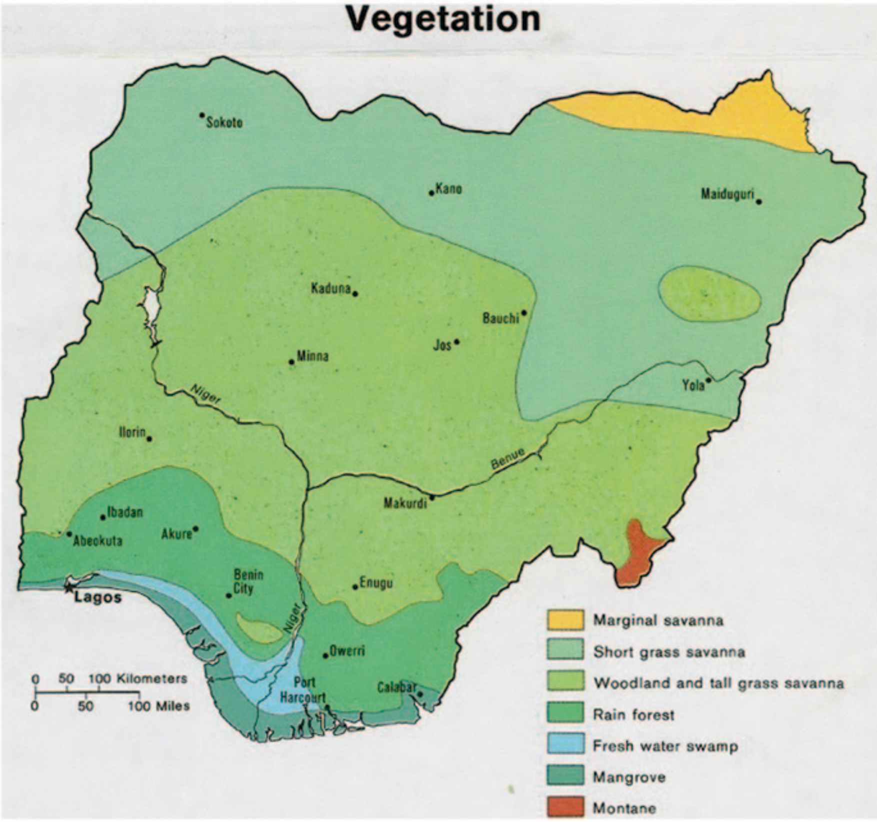

Fig. 3.2 Map of Nigeria showing the vegetation zones

27 °C, while daily maximum temperatures can go between beyond 35 °C–38 °C depending on the location (Iloeje 2001).

In general, while there is hardly any dry season in the extreme southern tip of the country, the wet season hardly lasts for more than three months in the north-eastern part. Similarly annual rainfall totals range from 2,500 mm in the south to less than 400 mm in parts of the extreme north (FMEN 2001).

3.2.4 Agro-Ecological Zones

A number of classifications of Nigerian vegetation have been published since the 1950s (Fig. 3.2). The development of categories reflects changing perceptions of the significance and value of such classifications**.** Combined effects of temperature, humidity and rainfall, and particularly, the variations that occur in the rainfall that govern the natural vegetation zones exerts a major influence on the types of indigenous plants that grow or the exotic types that can be introduced successfully into the country. Oyenuga (1967) reported that the humid, tropical forest zone of the south that has longer rains is capable of supporting a number of plantation crops such as cocoa, oil palm, rubber, coffee, cotton and staple crops like, yam, cassava, cocoyam, sweet potatoes, melon, groundnut, rice maize and cowpeas. However, in some parts of the east and many areas near the coast, the high rainfall has led to badly leached soils and severe erosion in some places.

The North with its lower rainfall and shorter rainy season consists of savanna land, and this represents 80 % of the vegetation zones of the country. The savanna land forms an excellent natural habitat for a large number of grazing livestock such as cattle, goats, sheep, horses, camels, and donkeys.

The natural vegetation zones are resulted from the interaction of the climate, humidity, rainfall and soils (Oyenuga 1967; Iloeje 2001). These factors have been modified by human activities and man's pattern of land use (Oyenuga 1967; Iloeje 2001). Based on the above, Oyenuga (1967) classified Nigeria into nine (9) agro-ecological zones viz.: (1) The mangrove forest and coastal vegetation, (2) the freshwater swamp communities, (3) the tropical high forest zone, (4) the derived Guinea savanna with relict forest, (5) the Southern Guinea savanna zone, (6) the northern Guinea savanna zone, (7) The Jos plateau, (8) The Sudan savanna, and (9) The Sahel savanna. However, Iloeje (2001) grouped the country into (A) forests and (B) savanna zones. These two major zones were further sub-divided into three zones each such as (A) Forests that consist of (i) salt-water swamp, (ii) fresh-water swamp, (iii) high forest; and (B) Savanna zone that consist of (i) Guinea savanna (ii) Sudan savanna, and (iii) Sahel savanna.

3.2.5 Water Resources Endowment

The Nigerian freshwater environment consists of a number of rivers and their flood plains, streams, lakes and wetlands, with the rivers and streams relatively evenly distributed all over the country. Annual rainfall is however highly variable across the different regions, varying from about 250 mm in the extreme north of the country, to about 2,500 mm in the south.

Rainfall constitutes a significant source of water, with the annual renewable total estimated at about 319 billion m^3 during the mid-1980s (Aminu 2000; CBN 2000). The Niger river is of great significance in the management of water resources, not only in Nigeria, but also in other countries in the West African sub-region. It is one of Africa's 55 international rivers, traversing such countries as the Republic of Benin, Burkina Faso, Chad, Cote d' Ivoire, Guinea, Mali, Niger, Nigeria, and Sierra Leone. Within the context of co-operative management of water resources, it is important for us to note, that shared rivers have implications for the perception of water rights, as well as on the issue of national security and sovereignty.

The Benue is another major river in Nigeria. Other than the Niger and the Benue, the country has well over 40 rivers and streams (Orubu 1995; Majasan and Young 1997). There are also the large lakes, including the Chad and Kaiji. The Nigerian sector of the Lake Chad has a total surface area of about 550,000 ha, whiles the Kainji Lake, has a total surface area of about 127,000 ha. These water bodies support a multiplicity of economic activities, including fishing, transportation and recreation. The Niger delta occupies the largest proportion of the total land area of the geographic southeastern part of Nigeria. It supports a wide variety of fish and other aquatic resources.

Earlier in 1976, the development of water resources had received a boost, by the creation of the River Basin Development Authorities (RBDAs) to provide water for irrigation purposes, as well for human consumption, particularly in rural communities. The RBDAs were relatively more active during the mid-1980s. In 1985, the RBDAs had about 32,600 hectares (ha) under irrigation, sank 108 borehole and 8 earth dams. The respective achievements for 1989 were 67,900 ha; 462 boreholes and 16 earth dams. During the period 1991–1996, the total area of land brought under irrigation by the RBDAs was 46,600 ha, representing only 16.9 % of the cumulative total of 275,400 ha achieved for the period 1985–1996.

Under the Agricultural Development Projects (ADPs), the cumulative number of boreholes drilled country-wide over the period 1985–1996 was 53,499, with the total area of land brought under irrigation estimated at 85.6 million ha, mainly through the Fadama Irrigation Programme (Sharma et al. 1996).

3.2.6 Forest Resources

A careful study of the vegetation of Nigeria shows that true and protected forest is mainly found in the southern part of the country and it occupied 93,345 km^2 in 1993 that is 9.6 % of the total land area of the country. This area increased to 11.4 % in 1994 but dropped to 10 % in 1995 (CBN 2001).

Exploitation of forest resources often causes deforestation, which has been a big problem in this Nation. Nigeria destroys 600,000 ha of forest annually whereas only 25,000 ha are replenished. This is often done to service wood based industries apart from fuel. However, a huge sum of N 180 billion is lost annually to deforestation. Deforestation has increased real fuel wood prices in the last two decades and this result in an estimated loss of between N 45 to 60 billion annually (Eboh 2005). This economic cost of fuel wood losses per year was estimated by the increase in the cost of fuel wood supply taking into account, the increase in the cost of collecting the wood and the transportation costs.

The lost of forest has also reduced access to and supplies of non-timber food products for export by as much as 40–50 % in the last 5 years. This implies that in due course, forestry for sustainable development in Nigeria will depend on importation of wood and wood products, plunging the country into imbalance trade depleting the nation’s foreign reserve.

3.2.7 Status of Agriculture in Nigeria

Food and Agriculture Organisation of the United Nations (FAO 2004) reported that in Nigeria, per capita Gross Domestic Products (GDP) was $ 1,841.81 with a share of agriculture of $ 370.71. However, on regional basis Nigeria produces above average production, and is one of the leading countries in the production of root and tuber crops (Raphael and Longinus 2007).

On a general note, Raphael and Longinus (2007) observed that Nigeria appears to have good capacity for producing most crops. Nigeria's comparative advantage in cassava production has been boosted by series of policy efforts undertaken by government including far reaching research and extension programs embarked upon by the International Institute for Tropical Agriculture (IITA).

Indeed, if the full potential of cassava production in Nigeria is achieved, it can provide a substantial proportion to the sub-Saharan Africa's need for carbohydrates and industrial starch. Several studies have shown that shared growth in agricultural sector and overall economy would be triggered on a sustainable basis through the expansion of cultivated areas, where possible and in particular through emphasis on the use of external inputs such as fertilizers, agrochemicals, irrigation and mechanization, and improved varieties (Kelly et al. 1999; Naseem and Kelly 1999; Camara and Heinemann 2006). Nigeria has the greatest area allocated to arable crops production across the entire region, but indications are that frontier expansion and fallows are no longer achievable in some parts of the country. This is due mainly to population increase and the resulting land scarcity. Areas such as south eastern Nigeria will therefore present a classical example (Raphael and Longinus 2007).

This high potentials stand against the reality of land under irrigation and the total potential area exploitable relative to the total cropped area is not large enough to generate revolutionary increase in crop production (Rosegrant and Perez 1997).

Agricultural products grown in Nigeria can be divided into two main groups: food crops, produced for home consumption, and export products. The most important food crops are yams and manioc (cassava) in the south and sorghum (Guinea corn) and millet in the north. In 1999, production of yams was 25.1 million t (67 % of world production); cassava (manioc), 33.1 million t (highest in the world and 20 % of global production); cocoyams (taro), 3.3 million t; and sweet potatoes, 1,560,000 t. The 1999 production estimates for major crops were as follows (in thousands of tons): sorghum 8,443; millet 5,457; corn 5,777; rice 3,399; peanuts 2,783; palm oil 842; sugar cane 675; palm kernel 565; soybeans 405; and cotton lint 57. Many fruits and vegetables are also grown by Nigerian farmers. Cocoa was the leading non-oil foreign exchange earner; however, growth in the sector has been slow since the abolition of the Nigerian Cocoa Board. The dominance of small-holders in the cocoa sector and the lack of farm labor due to urbanization have led to a drastic decline in cocoa production. Nigeria has the potential to produce over 300,000 t of cocoa beans per year, but production only amounted to 145,000 t in 1999. Rubber is the second-largest non-oil foreign exchange earner. Thus, there are high potentials for increased crop production in the country to meet the ever-increasing demand of the population.

3.2.8 Agricultural Inputs Use in Nigeria

As reported by Raphael and Longinus (2007), two major factors influence land access and use in sub-Saharan Africa. The first has to do with variations in population density while the second relates to land tenure practices. Population density varies from as low as five persons per hectare in semi-arid areas of East Africa to as high as 150 persons per hectare in some semi-arid areas of West Africa.

In the absence of adequate external inputs at prices affordable to small holder farmers, the result of land scarcity is soil nutrient mining, which gives rise to over exploitation of agricultural land. The propensity for nutrient mining of agricultural land and severity of its consequences are said to be the highest in Africa (Raphael and Longinus 2007).

With a fixed amount of continually increasing population, per capita water availability is on steady decline. At present, many countries including some of the sub-Saharan Africa are facing serious water stress. The affected population is over 300 million people with a projection of about 3 billion by 2025 (Rosegrant and Perez 1997).

The projections of water demand by 2020 indicate consistent withdrawals would increase by 35 % between 1995 and 2020 to reach 5,060 billion m^3. The share of domestic and industrial uses of water in relation to total water demand is projected to double from 13 % in 1995 to 27 % in 2020, reducing the share for agricultural uses (Pinstrop–Anderson et al. 1997).

Moreover, Haruna et al. (2003) reported that land under irrigation in Nigeria was 243.6 million ha, per share of water use for agriculture was 68.8 %, industrial 10.1 %, domestic use 21.1 %, rainfall index of 1,320.13 mm and percent of irrigation land under arable and permanent crops at 0.706 %.

Disaggregated data for various years also shows, that sub-Saharan Africans have witnessed a decline in fertilizer growth since 1990 (Camara and Heinemann 2006). Bumb and Baafante (1996), for instance noted that growth rates for 1970–1990 was 7.9 %, but for the period 1991–1995 growth had slowed down to 2.6 % per year. This is below the 3.3 % projected annual growth for 1990 through 2020 and far below the 8–10 % growth rate needed to increase cereal production to a level that would ensure food security. To raise the level of fertilizer in sub-Saharan Africa, a number of factors have been isolated to include agro-ecological and geographical, historical and structural, demographic, national income, infrastructure and crop choice factors (Camara and Heinemann 2006).

Another good measure of the level of mechanization of agriculture is the use of tractor. Food and Agriculture Organisation (FAO 2004) observed a 0.83 % number per hectare of tractor use and almost zero percent per hectare use of threshers and harvesters for 1979–2004 period for Nigeria, in the sub-Saharan Africa sub-region. To date the situation is not any better and pathetic, and must urgently be redressed for country with a very high population growth rate and whose agriculture must be commercialized to feed such a high population.

3.2.9 Environmental Degradation in Nigeria

During the colonial period and thereafter, traditional human activities which had earlier been environmentally sound were disturbed; fencing of pastures, prescribed nomadism that resulted in overgrazing, fallowing in agricultural practices were abandoned due to reduction of land holdings, large dams and irrigation schemes increased the incidence of water-borne diseases such as *schistosomasis.* However, over the past decades, some major environmental problems that have commanded the attention of environmental scientists, many national governments and donor agencies are the widespread of land degradation and the phenomenon of desertification. In the absence of taking wide ranging appropriate intervention strategies, Nasir (2002) observed that desertification is not only capable of hindering social and economic development of the affected region or country, but more importantly, it is as well capable of causing irreversible damage to its land resource base and environmental quality as a whole.

These events and many others such as geometric population growth, rapid urbanization and accelerated industrial development have combined to produce serious environment stresses including poor health, sanitation and nutrition, soil erosion, deforestation, wildlife depletion and accumulation of solid wastes. In southern Nigeria, where thick forest exists, deforestation leads to landslides, and coastal and inland erosion. In the savannah belt; it leads to the problems of desertification advancing southward at an average rate of 8 km per annum. Nigeria is currently losing about 351,000 ha of land through desertification. Economically, desertification accounts for 73 % of the estimated total cost of about $ 5.11 million the country is losing to environmental degradation annually.

The Nigerian population was expected to rise to 244.5 million by 2010, and the fire wood demand (principal cause of desertification in the north) to rise to 83.5 million cubic meters (Abdul 2001). In a study it is estimated that 82 million t of trees are reduced in Nigeria annually, depleting forest resources by 3.5 % per annum. At this rate, by 2020, the total Nigerian forest reserves will be disappeared, with additional losses of agricultural soils, biodiversity, genetic materials, industrial raw materials, and habitat for billion of creatures and subsistence for 70 % of 144.5 million Nigerians (Abdul 2001).

3.2.10 Modern Commercial Farming

Commercial farming is the most advanced stage from subsistence through mixed and diversified farming of individual holding in a mixed market economy. On specialized farms, Todaro (1977) opined that the provision of food for the family with some marketable surplus, no longer provides the basic motivational objective. Pure commercial profit becomes the criterion of success and maximum per-acre yields derived from man-made (irrigation, fertilizers, hybrid seeds, pesticides, etc.) and natural resources become object of farm activity, production is entirely for the market and economic concepts such as fixed and variable costs, savings, investment and rates of return, optimal factor combinations, maximum production possibilities, market prices and price support takes on quantitative and qualitative significance. Also, capital formation, technological progress, and scientific research and development play a major role in stimulating higher levels of output and productivity.

Nonetheless, specialized farms may vary in size and function from intensively cultivated fruit and vegetable farms to vast rice, wheat and corn fields, etc.. In most cases, sophisticated labor-saving mechanical equipment ranging from large tractors and combine harvesters to airborne spraying techniques pursuit a single family to cultivate many thousands of hectares of land therefore, the future of all specialized (commercial) farms, is the emphasis of the cultivation of one particular crop. The use of capital intensive and in many cases labor-saving techniques of production and the reliance on economies of scale to reduce unit costs to maximize profit should be followed.

It should be noted that before the advent of mechanization technologies for the processing and storage of agricultural crops, most commercial farmers export their farm produce like cocoa, rubber, coffee, cassava, fruits and vegetables, etc., to other countries at very low prices and in raw form. But with improved processing technologies, available, commercial farmers can now add value to their produce and process them locally to generate more income.

Investments of commercial arable farmers in Nigeria into improved storage structures for grains, cold storages for livestock, fruits and vegetables, etc., as well as the improved marketing strategies, during periods of surplus harvest has helped to stabilize and guarantee good prices for the farmers and agro-processing industries. For instance, about 55 % of Nigeria's roots and tubers are consumed locally (especially potatoes, cocoyam, yam and cassava), while the balance of 45 % is exported. The only way that prices of the exported products can be guaranteed is through better storage and transport facilities with corresponding value additions. Oil crops like groundnut, soyabean, oil palm, etc., are processed into vegetable oil using appropriate mechanization technologies. As vegetable oil, they can be stored for longer period and sold at a guaranteed market price at a later date.

With the introduction of technologies to commercial arable farming in Nigeria, the commercial farmers have been able to diversity their investment. Most commercial farms have various investments in fisheries, livestock, agro-processing, machine and spare parts production, marketing, research and development, etc.. These diversified investments have yielded more income, generated employment and also sustained the commercial farming business in Nigeria.

However, Todaro (1977) further concurred that for all practical purposes commercial farming is no different in concept or operations in both developed and especially the less developed nations, owned and managed by large "agric business" multinational corporations. This brings us to the question: What are the pre-requisites for commercial farming?

3.3 Pre-requisites for the Transition from Subsistence to Commercial Agriculture

About 80 % Nigerian population lives in the rural areas and about 70 % are directly engaged in agricultural production (Ega 1988). Fomoriyo (1985) also, asserted that majority of farmers are subsistence producers, consuming most of their produce. Farm lands are fragmented due to population explosion and inheritance. Farm productivity is very low resulting in low average income for all farmers. As such, poverty is therefore, greater in the rural than urban areas; this suggests that to improve existing situations, production in Nigeria must be increased.

The key to promote dynamic growth in agricultural sector is to develop viable small and medium scale rural enterprises. Todaro (1977) observed that the conditions for developing the sector include the following.

3.3.1 Land Reform

Farm structure and land tenure pattern need to be adapted to the dual objectives of increasing food production and promoting a wider distribution of the benefits of agrarian progress. It may be added that since, human development is about creating an environment in which people can develop their full potentials and lead productive, creative lives in accord with their needs and interests. Oroka (2009) suggested that, urban agriculture (horticulture and ornamental gardening) should be considered as a livelihood source of urban employment.

3.3.2 Supportive Policies:

The full benefit of small-scale agricultural development cannot be reached unless government support systems are created which provide the necessary access to needed inputs to enable small cultivators to expand outputs and raise their productivity.

3.3.3 Integrated Development Objectives

Improvement in levels of living including income, employment, education, health and nutrition, housing and a variety of social services, decreasing inequality in the distribution of rural incomes and rural-urban imbalances in incomes and economic opportunities, the capacity of the rural sector to sustain and accelerate the pace of those improvements.

3.4 Development Paradigm and the Concept of Sustainability

The environment today is no longer a concern about a locality or wild-life, deforestation or pollution. It is rather, a crisis situation about the development pattern which we have followed so far. It is indeed a global issue which forces us to think as to where we are going? What shall happen if we do not stop, reconsider and make proper adjustments in our means, methods and objectives in life? It is high time that we should rethink and make appropriate steps to build up a world of permanence—in short a sustainable society which lasts forever.

However, the present edifice of the new world order is erected on a tripod of centralized control involving political supremacy resources—intensive technologies and globalized economy. Homogenization of global variables of a natural consequence of such centralized control, whereas diversities are the first casualty- that include not only economic but even the social, institutional, cultural and ecological diversities (Rajeswar 2010).

More so, the applications of thermodynamics concerning with conservation of energy and the maintenance of 'higher order' against disorder (entropy) are well illustrated in biological and ecological sciences, and in turn they constitute the bedrock of the science of sustainability. Even the present knowledged society of the New Age has been built on the same old premise of enlightenment that "knowledge is power" oblivious to the true nature of knowledge that requires an electric approach involving diverse perspectives, knowledged societies as envisaged by the European Commission for Knowledge Society, does not refer to any cultural renaissance, socio-political empowerment, intellectual pursuit or spiritual awakening, but it refers to the techno-economic order with a knowledge-based economy (Martin 2005).

Moreover, social engineering in a top down pattern has been established wherein capital investments in technology payback huge economic returns and the role of societies is limited to instrumental activism only. Hence, it would be prudent to call it economy-based knowledge, rather than a knowledge based economy.

Therefore, in a knowledged society of sustainable development, there has to be a paradigm shift in the conceptual framework, emphasizing an all inclusive knowledge economy alone. In other words, there has to be an attitudinal change replacing the conventional belief that "knowledge is power" by a system perspective that "knowledge is for empowerment". For instance, most of the developing countries in tropical regions have a comparative advantage when it comes to renewable energy—whether it is solar or biomass. Compared to Europe for example, energy costs from biomass are almost one third in Brazil. Likewise, the so called 'Sun Belt' around the earth with high intensity solar radiation traverses many developing and less developing countries making them potentially capable of meeting the whole global energy demand with solar energy. Attainment of energy autonomy by poor countries and societies by means of benign technology and the science of sustainability would herald a new era of decentralized bottom up development.

As Rajeswar (2010) pointed out sustainability is not a goal, but only a means and it is a science by itself, but unlike conventional sciences which are supposedly value-free, and immoral, the science of sustainability is inclusive not only of values and responsibilities, but also of the institutions and instruments that stand for sustainability. In the present "post-structured" or "post-modern era", it is "knowledge ecology"—which goes beyond "knowledge economy"- that is a prerequisite in striking a right balance between development and sustainability.

Also, as aptly observed, to build a sustainable world, the following practices should be put in place:

- Protecting and augmenting re-generability of the live-support systems by:
  - Rationalized husbanding of all renewable resources,
  - Conserving all non-renewable resources and prolonging their life by recycling and revision.
  - Avoiding wasteful use of natural resources.
- Fair sharing of resources, means and products of development between and within the nations of the world.
- Educating people regarding the conceited economic and environmental costs of over-consumption of resources with particular reference to its impact on developing countries of the world.
- Adopting willingly, sustainability as a way of life by encouraging frugality and fraternity.
- Meeting all the genuine social needs and legitimate aspirations of people by blending economic development with environmental imperators to remove poverty.

3.5 Conclusions

The environment viewed an ecosystem as the habitat for about 80 % of 144.5 million Nigerians engaged in agricultural production, depending upon forest and trees for a long list of essential products. As pointed out, Nigeria has a good capacity for producing most crops from cereals to trees and, as such will have a positive growth in agricultural sector and the overall economy would be triggered up on a sustainable basis, through expansion in cultivated areas, where possible and in particular through emphasis in the use of external inputs such as agrochemicals, irrigation, fertilizers, pesticides and mechanization which are part of the criterion of success and maximum per hectare yield in commercial farming.

Unfortunately, records have shown that the status of Nigerian agriculture is not that impressive, input-use in terms of land access and use, water supply for irrigation, fertilizer, tractor and harvester use is pathetic. There is therefore, a need for the country to embark on strategies to make it self-sufficient and marches toward mechanization and commercialization of the sector. This will enable it to feed itself and have exportable surplus for income generation.

Therefore, measures should be taken to provide the pre-requisites for commercialization within the context of the framework of sustainability which is all inclusive not only of values and responsibilities but also, of the institutions and instruments that stand for sustainability. In short, a fundamental shift from the concept of the current development paradigm to the systems perspective of cooperation and interdependence of all the systems is recommended.

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Chapter 4
Some Socio-Economic Factors Affecting Farmers' Participation of Agricultural Extension Education Efforts: A Case Study in Northeastern Thailand

Seksak Chouichom

Abstract The participation and contribution of agricultural extension can be the most useful approaches to ensure greater dissemination and sustainability of gains for the Thai farmers. The objectives of this study therefore were to ascertain farmers' participation and involvement of agricultural extension programs, to identify some factors affecting farmers' participation of extension program, and also to clarify constrains toward the prevention farmers' involvement and association toward agricultural extension programs and services. The data were collected from 190 farmers household in Surin province, northeast Thailand. The semi-questionnaire structures were used as tools for data collection. One way ANOVA is used for analysis the statistic. The results coming from this study showed that the farmers had the neutral pagination level of the participation. Moreover, some socio-economic data of farmers merely educational level is significantly influenced reasons toward their participation. The main obstacles among farmers observed in this survey include lack of leaders/representatives for farming group activities of the participation. This study also suggested that agricultural mobility service should meet farmers often in order to motivate more famer's participation in extension activities and get more information and knowledge.

Keywords Agricultural extension • Extension services • Involvement • Extension tasks • Thailand

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4.1 Introduction

The application of scientific research and knowledge toward improving agricultural practices has evolved from a purely unidirectional input of such information by farm extension workers into one that is characterized by more active participation of target beneficiaries. Since a few decades ago, the Thai government has adopted many forms of participatory methods in its agricultural extension services and programs with the idea that active participation and contribution can be the most useful approaches to ensure greater dissemination and sustainability of gains for the farmers (Chit-Anan 1998 and Ruekrai 1981).

In fact, participation can actually provide more useful feedback information necessary for planning useful extension work. Van den Ban and Hawkins (1996) elaborated on the meaning of participation to encompass farmers or their representatives participating in the organization of the extension service, in the decision-making on goals, target group, messages and methods and in the evaluation of activities. Additionally, participation also entails the cooperation of farmers in the implementation of the extension curriculum by attending extension meetings, demonstrating new methods on their farms, etc. (Farrington 1997).

Numerous reasons have been cited as to why it is advantageous for farmers to participate in decision making within the extension scheme. By participating, the farmers will have vital information for planning a successful extension program, including their purposes, knowledge, technologies experience, and social structure. Furthermore, they will be more motivated to cooperate in extension programs if they share some responsibility and accountability for it (Van den Ban and Hawkins 1996; Farrington 1997; Lahai et al. 1999).

The Department of Agricultural Extension (DOAE) in Thailand plays an important role in implementing agricultural strategies to increase agricultural yield and eventually reduce rural poverty (Van den Ban and Hawkins 1998). Effective extension practices as well as rural infrastructure have played important roles in poverty reduction and promotion of consumption (Dercon et al. 2009). Agricultural extension has been defined by Moris (1991) as 'promotion of agricultural technology to meet farmer's needs'. Agricultural extension development in various countries particularly in Thailand is being reoriented to prepare for more fundamental demand and service sustainability, awareness, knowledge, and resources' users (Chit-Anan 1998). By creating a redefined agricultural extension that is more demand driven and more responsive to farmers, participatory methods can assist to ensure that services are applicable and responsive to community conditions and beneficial to the actual needs of farmers (Ruekrai 1981 and Anderson et al. 2006).

Thai agricultural authorities have recently tested the participatory and cooperative methods in order to reduce the barriers of agricultural knowledge and technology transfer between farmers and the extension workers (DOAE 2012). The transferring technology and knowledge methods to farmers in precedent had forced farmer rather than motivated farmers' needs to join and gain agricultural activities or knowledge (Vanclay 2004). Then again, ultimate goal is to achieve greater empowerment toward agricultural development (Picciotto and Anderson 1997). However, the level of participation in extension work among rural Thai farmers is still negligible with many inherent problems of socio-economic and technical nature (Birkhaeuser et al. 1991 and Vanclay 2004).

Therefore, the objectives of this study were, to find out the farmers' participation level in agricultural extension education programs, to examine the correlation between their socio-economic data and their participation in agricultural extension, and to identify some farmers' obstacles toward the participation of agricultural extension education efforts in northeastern Thailand.

4.2 Methodology

4.2.1 Study Area

The survey of this study was conducted in Muang district of Surin province which has a land area of 8,124.056 km^2 in northeastern Thailand. The area allocated to rice farming amounted to 3,172,132 Rai (1 Rai = 1,600 m^2) or around 71.52 % of the entire provincial agricultural land (3,631,421 Rai) in 2008. Surin has the 10th largest population among 76 Thai provinces, being 1,404,252 persons. This province is divided into 17 districts (Amphoe) with 158 subdistricts (Tambol) consisting of 2,119 villages (Moobaan). The number of farming households was 189,139. About 92.8 % of the total population lives in the rural area, most of whom were doing rice farming.

4.2.2 Data Collection

The research was carried out in September 2008 following the pretest conducted one month earlier. The sample size in this research was 190 farmers who were engaged in rice cultivation and selected by random sampling. The study employed a semi-structured and structured questionnaire. In order to complement both quantitative and qualitative data, more information was collected through focus group discussion. This analysis used population-based survey to determine the participation of farmers about extension education programs. The interviews were conducted on the farm site or in the farmers' households. The interview schedules were composed of open-ended and closed questions but some questions elicited quantitative data as well. The modified interview schedule includes 28 statements of participation regarding agricultural extension programs. The received responses were scored on a five-point Likert's scale ranging from "strongly agree (5)" to "strongly disagree (1)" (Likert 1932).

4.2.3 Data Analysis

The data were analyzed with the Statistical Package for the Social Sciences for Windows. Descriptive statistics was applied to analyze percentage, arithmetic mean, and standard deviation (SD). One way ANOVA (F-test) statistics were computed to explore farmers' participation toward agricultural extension education programs. A significance of $p < 0.05$ was set for statistical analyses.

4.3 Results and Discussions

4.3.1 Demographic Characteristic of Interviewed Farmers in Surin Province

As shown in Table 4.1 the average age of farmers was 46.84 years; most of the farmers in the area were old farmers, were able to read and write, and also sign their names. The majority of the farmers finished higher levels (4.79 years) than the Thai standard compulsory school years at that time (primary school grade 4). The number of hired labor annually was 3.02 man crops. Most of the rice farmers usually find extraordinary jobs during the off-season such as construction labor, cutting sugarcane, rice harvesting, and silk weaving in Surin and neighbor areas. The average farm area of farmers was 28.21 Rai (1 Rai = 1,600 m^2), they used two wheel tractors and small water pumps as convenient agricultural devices for their agricultural activities. Their average total income was 128,389 ThB/year (US$ 1 = 36 ThB). Farmers' income was still low, resulting in rural farmers moving to big cities to seek alternative jobs and earn more income to support their families. Besides, the farmers had experience with rice farming for 23.05 years. They contracted agricultural extension workers 4.25 times a month, while radio and television were communications media from which they usually receive all information. The budget for their farming was 27,498.48 ThB a crop, the big portion of which was spent for agricultural activities. They attended agricultural organizations like Bank for Agriculture and Agricultural Cooperatives (BAAC), organic rice farming groups, One Million One Village Fund, agricultural cooperatives at an average of 1–2 times/month. Likewise, various studies of Chouichom and Yamao (2010, 2011); Chareonsiri (2005) has also discussed the same average of some socio-economic information of farmer in northeastern Thailand particularly in Surin area.

4.3.2 Farmers' Participations Toward Agricultural Extension Efforts

In this section we explored the farmers' participation and involvement to extension programs in order to measure their actual participation toward four stages of the extension programs as showed in Table 4.2. Roughly, consistently and somewhat of

Table 4.1 Socio-economic data of farmers in Surin province

Variable	Frequency	%	SD	Mean
Sex			0.52	–
Female	108	56.84		
Male	82	43.16		
Age (years)				
≤30	4	2.11	7.89	46.84
31–40	27	14.21		
41–50	74	38.95		
51–60	58	30.53		
≥60	27	14.20		
Education			3.12	4.79
Primary school (4 years)	131	68.95		
Junior high school	31	16.32		
High school	26	13.68		
Bachelor degree	2	1.05		
Household farm labor (persons)			2.01	3.02
2	91	47.89		
3–4	76	40.00		
≥4	23	12.11		
Farm size (Rai)			12.46	28.21
Small (≤15)	17	8.95		
Medium (15–25)	93	48.95		
Large (>25)	80	42.10		
Family member (persons)			1.98	4.56
2	13	6.84		
3–4	70	36.84		
5–6	82	43.16		
>6	25	13.16		
Total income (Baht/year)			94,383	128,389
≤50,000	20	10.53		
50,001–100,000	109	57.37		
100,001–150,000	27	14.21		
150,001–200,000	15	7.89		
≥200,000	19	10.00		
Extension contact (time/month)			2.05	4.25
≤3	51	26.84		
4–5	103	54.21		
>5	36	18.95		
Farming experience (years)			17.21	23.05
≤10	28	14.74		
11–20	106	55.79		
>20	56	29.47		

participation levels (mean score = 2.61–3.40) showed in almost every factors measured of their participation. For instance, the participants involved and participated in the discussion together with extension workers about the needs of extension and development for agricultural progress in their community at only strong level of the participation (mean = 3.84), and involved in identifying for needs of involvement

Table 4.2 Farmers' participations toward agricultural extension efforts

Detailed duty/function	Level of participations					Mean	SD
	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)		
Participation in the initial stages							
1. You discuss about the needs of extension and development for agricultural progress in your community	22 (11.58)	79 (41.58)	22 (11.58)	3 (1.58)	3 (1.58)	3.84	0.93
2. You participate in identifying for needs of involvement in agricultural extension and development	20 (1.05)	68 (35.79)	74 (38.95)	24 (12.63)	4 (2.11)	3.39	0.92
3. You participate in considering trends and prospects for agricultural projects of your community	2 (1.05)	52 (27.37)	86 (45.26)	42 (22.11)	8 (4.21)	3.22	0.77
4. You participate in initial planning of the agricultural extension project	2 (1.05)	36 (18.95)	98 (51.58)	44 (23.16)	10 (5.26)	3.06	2.78
5. You participate in priority-setting process of the agricultural extension and development project	2 (1.05)	35 (18.42)	76 (40.00)	63 (33.16)	4 (2.11)	2.99	0.84
6. You participate in expressing ideas regarding the role of agricultural extension and development for your village	7 (3.68)	47 (24.74)	85 (44.74)	42 (22.11)	9 (4.74)	2.97	0.85
7. You participate in proposing improvements for agricultural extension involvement in the village	3 (1.58)	53 (27.89)	81 (42.63)	48 (25.26)	5 (2.63)	2.97	0.91
8. You have present the problems, requirements, and recommendations regarding agricultural extension to extension agents through oral discussion	6 (3.16)	59 (31.05)	103 (54.21)	17 (8.95)	5 (2.63)	2.86	0.82

Table 4.2 (continued)

Detailed duty/function	Level of participations					Mean	SD
	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)		
9. You propose requirements and recommendations regarding agricultural extension to extension workers through writing	3 (1.58)	49 (25.79)	104 (54.74)	28 (14.74)	6 (3.16)	2.70	0.88
Participation in the planning stages							
10. You participate in priority-setting during the planning stage	3 (1.58)	23 (12.11)	76 (40.00)	70 (36.84)	8 (4.21)	2.58	0.87
11. You participate in data handling to define involvement in agricultural extension and development	2 (1.05)	24 (12.63)	76 (40.00)	67 (35.26)	21 (11.05)	2.56	0.89
12. You participate in outlining the methods and plans of the agricultural extension and development project	2 (1.05)	27 (14.21)	74 (38.95)	56 (29.47)	31 (16.32)	2.53	0.95
13. You participate in formulating the objectives of agricultural extension and development	1 (0.53)	25 (13.16)	81 (42.63)	55 (28.95)	28 (14.74)	2.58	0.91
14. You participate in defining the duty of participants in the agricultural extension and development project	3 (1.58)	29 (15.26)	72 (37.89)	59 (31.05)	27 (14.21)	2.57	0.96
Participation in the implementation stages							
15. You participate in information dissemination about the role of agricultural extension and development in cooperation with local community	19 (10.00)	67 (35.26)	55 (28.95)	36 (18.95)	13 (6.84)	3.28	1.04
16. You participate directly and actively in implementing agricultural extension and development as a front-line personnel	22 (11.58)	65 (34.21)	55 (28.95)	40 (21.05)	8 (4.21)	3.24	1.07

Table 4.2 (continued)

Detailed duty/function	Level of participations					Mean	SD
	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)		
17. You sponsor materials and labor as your share in agricultural extension and development project	7 (3.68)	39 (20.53)	80 (42.11)	57 (30.00)	7 (3.68)	3.04	0.78
18. You participate in implementing agricultural extension and development project in a leadership position	5 (2.63)	34 (17.89)	76 (40.00)	61 (32.11)	14 (7.37)	2.95	0.75
19. You participate in agricultural extension and development in minimal capacity	4 (2.11)	44 (23.16)	107 (56.32)	27 (14.21)	8 (4.21)	2.89	0.90
20. You participate in soliciting for help and assistance from others for participation in agricultural extension and development	3 (1.59)	36 (18.95)	109 (57.37)	36 (18.95)	6 (3.16)	2.76	0.70
Total						3.03	0.70
Participation in the assessment stages	2 (1.05)	42 (22.11)	78 (41.05)	58 (30.53)	10 (5.26)	2.83	0.82
21. You participate in the assessment of implementing stages of agricultural extension and development duty							
22. You participate in the assessment of actual implementation of agricultural extension and development project	4 (2.11)	27 (17.21)	72 (37.89)	69 (36.32)	18 (9.47)	2.63	0.91
23. You participate in searching for data collecting tools for agricultural extension and development	3 (1.58)	33 (17.37)	77 (8.95)	60 (31.59)	17 (8.95)	2.70	0.90
24. You participate in constructing the data collecting tools for agricultural extension and development	2 (1.05)	36 (20.53)	90 (47.37)	51 (26.84)	11 (5.79)	2.82	0.84

Table 4.2 (continued)

Detailed duty/function	Level of participations					Mean	SD
	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)		
24. You participate in data collection in agricultural extension	4 (2.11)	31 (16.32)	98 (51.58)	48 (25.26)	9 (4.74)	2.82	0.86
25. You participate in reporting and monitoring in agricultural extension and development	3 (1.58)	30 (15.79)	92 (48.21)	52 (27.37)	13 (6.84)	2.80	0.81
26. You participate in assessing the reports in agricultural extension and development	1 (0.53)	36 (20.53)	91 (47.89)	51 (26.84)	11 (5.79)	2.76	0.84
27. You participate in assessing the performance progress in agricultural extension and development periodically	2 (1.05)	37 (19.47)	78 (41.05)	59 (31.05)	14 (7.37)	2.79	0.87
28. You participate in assessing the impact or achievement of farmer involvement in agricultural extension	4 (2.10)	31 (16.31)	89 (46.84)	53 26.89	13 (6.84)	2.75	0.88

The mean scores, 4.21–5.00 = strongly participation, 3.41–4.20 = strong participation, 2.61–3.40 = Neutral, 1.81–2.60 = no participation, 1.00–1.80 = strongly no participation

in agricultural extension, and took part in considering trends and prospects for agricultural projects of their community at somewhat of participation level (3.39 and 3.22). The reason most farmers participated in the initial stage of the participation was because they would like to contribute actively and interact with the extension workers. Farmers interviewed indicated that the dealings together with extension workers and the programs are way in which they may benefit from them. Besides, in this initial stage, farms also discussed and considered their actual needs of the further extension programs which can possible increase rice productivity of the community in the future. Phokakulkanon (2000) mentioned in her results studied in Ubonratchatani province that rice farmers had participated in seeking-problem and indentified their needs among their group in neutral level (mean = 2.61) of the participation. The considering for initial need of agricultural extension programs will be accomplished successful when farmers and extension workers had brain storming together.

Additionally, in term of the planning stages, farmers had neutral felt entire participation (mean = 2.62) toward agricultural extension education programs.

They expressed they participated in priority-setting during the planning stage, and took part in formulating the objectives of agricultural extension education programs at the same neutral level of the participation (mean = 2.58). The main reason of low scores by farmers' participation almost in every issue due to sometime the local Agricultural Extension Office had provided some progressive programs previously. Farmers therefore could not formulate objectives and do decision-making in some agricultural programs. The farmers' participation in decision-making must be actively pursued by rural extension service, though the use of approaches and methods that really increase the influence farmers may exert upon extension programs (Engel 2010). The designing and assigning objective of programs together with extension workers played significant reason for decision-making of the planting in next crop (Tawai 2008).

Furthermore, in the implementation stage, farmers showed their total participation in somewhat level of the participation (mean = 3.03) toward agricultural education program in almost every items. The majority of participants showed their participation in information dissemination about the role of agricultural extension in cooperation with local community or group at neutral level of involvement (mean = 3.28). They gave the vital reasons that they can improve opportunities for their decision-making of the programs because they gained truly information from extension staff. As well as farmers will obtain information which is crucial for planning a successful extension programs, including their knowledge and also they will be motivated to cooperate in extension programs if they share responsibility for it. Chouichom et al. (2010) mentioned in their previous research about participation that most respondents engaged in discussions with technical agencies and freely shared farm experiences and knowledge with other farmers as opposed to having communications problems created from misunderstandings. Engel (2010) mentioned in case of rural society, it underscores the role of farmers' group in articulating extension efforts to the needs of rural farming community. A more active participation by the farmers in rural area could possibly have resulted in a more relevant choice of extension activities.

From field surveyed, moreover, in the assessment stage, farmers illustrated the total score in fair level of the participation (mean = 2.79) toward extension education programs. They also uttered in each statements in neural level. The most activity that they done were the participation in the assessment of implementing stages of agricultural extension (mean = 2.83). That means farmers had little chance to assess and evaluate extension program even minor programs. They mentioned that such kind of tasks is extension staffs' mission. Farmers can do only collecting the data and occasionally merely interview. Farmers said that progress of program have to monitor closely, not only the farmers member of the group, but also by the extension men also. Van den Ban and Hawkins (1996) point out that with the trend toward more participation farmers are also involved increasingly with extension evaluation, not only from data collection, but also for deciding on criteria for successful extension programs.

Table 4.3 The correlation between some personal traits of farmers toward the participation in agricultural extension works

Factors	Correlation (F-test)
Age	0.298
Education	0.043*
Family members	0.359
Farm laborers	0.514
Farm size	0.537
Total family income	0.415
Extension worker contact	0.384
Farming experience	0.372

* $p<0.05$

4.3.3 Correlation Between Some Personal Traits of Farmers Toward the Participation in Agricultural Extension Works

According to Table 4.3 the statistic showed that the educational level of farmers is significantly correlated to their participation at the 5 % level, indicating that farmers who have higher education tend to have a positive participation and possess more joining the various kinds of agricultural extension programs to develop and improve their knowledge. Cao et al. (2009) mentioned that the program was considered successful and a significantly higher level of support for the project was expressed by the better-educated respondents ($p<0.05$). Furthermore, as important as formal education; useful education in the form of utilizing specialist consulting and training services also increase the agricultural productivity and income of farmers (Serin et al. 2009). The results of Chizari et al. (1997) found farmers' educational level affected their participation in rice production activities as well. Opportunities for the extension service to better meet the unique educational and technological need for rural rice farmers.

4.3.4 The Constraints Toward the Farmers' Join in Extension Activities

According to the statistic results showed in Table 4.4, approximately 74.74 % of farmers surveyed complained that they lack leaders/representatives for group activities that would play extremely crucial roles and had great motivation to join extension programs in order to learn and improve new agricultural knowledge and information. Among the farmers surveyed, 67.37 % did not have time to participate the extension programs. This is due to the fact that extension workers always set the agricultural programs conflicted together with farm works tight schedule. Farmers who are working on small size farms are more likely to have heavy workloads and tight schedule in their farms (Parry et al. 2005). Another obstacle is lack of collaboration from members (57.37 %). Interviewed participants needed more members'

Table 4.4 The constraints toward the farmers' participation in extension programs

Constrains	Number	%
1. Organizational aspect		
1.1 lack of collaboration from members	109	57.37
1.2 lack of leaders/representatives for group activities	142	74.74
2. Individual farmer aspect		
2.1 lack of understanding of the agricultural extension programs	82	43.16
2.2 do not have time to participate the extension program	128	67.37
2.3 weak well-being	69	36.32
3. Extension agent aspect		
3.1 do not continuously follow up the extension works/program	89	46.84
3.2 do not pay important attention to implementation of curriculum	46	24.21
3.3 lack of specialization and expertise for knowledge distribution	64	33.68

participation in order to design and make decision-making for new agricultural information and extension programs. The other constraints cited that agricultural extension program did not continuously follow up the extension works/programs (46.84 %), lack of understanding of some agricultural extension programs (43.16 %), lack of specialization and expertise for knowledge distribution (33.68 %), and little pay important attention to implementation of curriculum of extension programs (24.21 %). Chouichom et al. (2010) mentioned in previous participation research that the main obstacles cited by farmers include lack of technical knowledge and training in organic rice farming, specifically farm management know-how.

4.4 Conclusions

This study examined the level of the participation and involvement of farmers toward extension programs among farmers in Surin province, northeast Thailand. Farmers expressed neutral and positive participation toward extension education programs to develop the militancy of agricultural farming activities. The results of this study showed that most of the farmers had participated in initial and implementation stage of the participation. Statistical results showed that merely farmers' education had significantly influenced farmers' participation toward in extension programs. The main obstacles among farmers observed in this survey include lack of leaders/representatives for farming group activities of the participation.

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Chapter 5
Factors Influencing the Choice of Inorganic contrasting to Organic Practices in Irish Potato Production and Viable Actions to Reverse the Trend: A Case Study of Kisoro District, South-Western Uganda

Joy Samantha Bongyereire

Abstract The study hinged on the socio-economic analysis of inorganic versus organic practices in Irish potato production in Kisoro District, Uganda. The study comprised of field surveys and desk reviews using materials gathered from various departments at Kisoro District Local Government (KDLG), NGOs, agro inputs dealers, Key Informants (KI) and farming communities. Production per hectare was looked into since it gives a clue to the types of farming systems employed, which determines the use of inorganic amendments. The findings showed that the use of inorganic practices in Kisoro District is associated with immigrant farmers from Rwanda, NGOs and agricultural extension personnel. Actual adoption is determined by farmer income and type of farming—commercial farmers and farmer associations remained active because of financial capability. The high population pressure, the need for more output, intensive cultivation and reduced soil productivity per ha have led to the use of inorganic practices in Irish potato production. The practices face different challenges such as inability to continuous purchase and judicious use of inorganic fertilizers, threats to human and ecosystem (environmental) health that are paving way for traditional organic farming. The latter contains several benefits including good quality potatoes, low health risks to humans and ecosystems and sustained soil fertility.

Keywords Socio-economic analysis • Farming systems • Organized seed production • Inorganic versus organic practices • Human and ecosystem health

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5.1 Introduction

The white potato *(Solanum tuberosum)* also known as the Irish potato, rivals the maize in volume and value production worldwide (Heiser 1990; Mann 2006). In Uganda, available data indicates that potatoes were probably introduced to the country by colonial administrators just after 1900, as a garden vegetable (Ministry of Agriculture and Forestry 1981). Other probable sources were from Kenyan, Rwandan and Zairian farmers and traders located along the borders. The crop diffused among Ugandan farmers living in the cool highlands of the country. By 1945, potatoes were widely grown in the highlands of Kigezi and Bugisu and were even described as a weed as well as a crop (Akimanzi 1975). Production was severely damaged in the late 1940s by infestations of late blight (*Phytophthora infestans*) and to a lesser extent early blight (*Alternaria solani*) (Kasimbazi 1982).

The growing demand for the crop eventually led to rising imports, prompting the formation of the Kigezi Potato Development Scheme in 1966 by the Department of Agriculture. In 1968, a breeding programme was established at Makerere University in collaboration with the International Potato Centre (CIP). Throughout most of the 1970s and 1980s, Uganda experienced a series of civil conflicts that made it difficult to obtain reliable data on crop production (Akimanzi 1975). The main potato production in Uganda is concentrated in areas with elevations of 1,500–3,000 m above sea level (Rufumbaguza 1984). Highlands form a relatively small portion of Uganda's arable land and are densely populated. Potato production in these areas has not increased relative to demand (Rufumbaguza 1984). The highland areas generally receive 900–1,400 mm of rain annually. The main rainy season is from February to May, with a secondary peak between September and January. Temperatures range from 10–30 °C depending on altitude. Soils are considerably, ranging from leached soil, acidic oxisols and ultisols, to fertile volcanic soils in the South (Rufumbaguza 1984; Turyamureeba 1983; Akimanzi 1975).

The Irish potato sub-sector in Uganda greatly contributes to nutrition, household income and national economic development through exports, a source of employment to many people in the country, henceforth contributing to Uganda's Gross Domestic Product (GDP). Kisoro and Kabale Districts are the largest producers of Irish potatoes. The highland climatic conditions and cheap labour earn a comparative advantage over the other Districts in Uganda (De Point Development Consultants 2009). According to a report for the Government of Uganda, the future demand for ware potatoes is expected to rise as can be seen in Table 5.1 (IITA-FOODNET et al. 2001). Other reports indicate that potato is a relatively minor food in Uganda compared with cassava, banana, maize, sorghum, beans, sweet potato and other food crops. However, in some areas, particularly the southwest, they are a major staple. Estimates for 1984 show an average annual consumption of 10 kg per capita (http://www.lanra.uga.edu/potato/africa/uganda.htm). Consumption is probably much higher in major production areas and urban centers (Rufumbaguza 1984; Turyamureeba 1983).

Table 5.1 Projected urban and rural potato demand for Uganda (2000–2015). (Source: IITA-FOODNET et al. 2001)

Year	Estimated urban population (×000)	Estimated rural population (×000)	Estimated urban population growth (in 2000 = 100 %)	Estimated rural population growth (2000 = 100 %)	Estimated urban potato consumption (Mt)	Estimated rural potato consumption (Mt)	Total estimated potato demand
2000	3,565	18,646	1	1	206,674	271,326	478,000
2005	4,785	20,255	1.34	1.09	277,401	294,739	572,140
2010	6,328	22,037	1.78	1.18	366,853	320,670	687,523
2015	8,648	23,869	2.43	1.28	501,351	347,328	848,679

Assuming other socio-economic and cultural factors such as price, income, and urbanization are held constant, this would mean that any impact achieved through the adoption of new technology, improved marketing, or accelerated urbanization would increase demand levels. Accordingly, the demand for Irish potatoes would be approximately 850,000–1,000,000 metric tons (Mt) per year (IITA-FOODNET et al. 2001). According to this projection, by the year 2010, urban demand would outstrip rural demand. In 2015 urban potato demand of 500,000,000 Mt will double the rural demand of 347,000 Mt (IITA-FOODNET et al. 2001). It is important to understand that in these estimates, population was considered to be the only growth factor.

The report jointly compiled by IITA (International Institute of Tropical Agriculture), FOODNET International,CIP, CGIAR (Consultative Group on International Agricultural Research) and ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa) (IITA-FOODNET et al. 2001) for the Government of Uganda identifies the need for sustainable potato seeds. While only a few farmers use saved seed, majority rely on seed acquired from relations, neighbors, or local market, which leads to spread of pests and diseases. Organized seed production is critical to improving productivity in the Irish potato sub-sector. In Rwanda, especially in Ruhengeri and Gysenyi provinces, potato production is still facing serious problems such as insufficient production, poor quality seed and other management inefficiencies that compel farmers to use inorganic amendments (Fane et al. 2006) (Table 5.2).

The issue of seed sustainability is critical in Kisoro District, which is one of the centers of focus of this chapter. Majority of farmers depend on local seed supply. There are also other noticeable challenges. Firstly, this system of potato seed production can lead to spread of diseases and low yields. Secondly, much of the potato production in Kisoro District depends on inorganic fertilizers and chemical sprays, even in sub-counties with grayish fertile volcanic soils. Dependence on inorganic inputs would have serious implications on human and ecosystem health. The runoff of nitrogen and phosphorus into water systems causes serious problems for fisheries. Indeed, leached and eroded fertilizers are the single largest cause of water

Table 5.2 Potato production statistics in ten selected districts of Uganda in 2000 and 2001. (Source: IITA-FOODNET et al. 2001, Government of Uganda)

Year	2000		2001	
Districts	Hectates	Metric tons (Mt)	Hectares	Metric tons (Mt)
Kapchorwa	0	0	2,500	27,500
Mbale	840	10,080	1,050	12,600
Sironko	755	8,305	700	5,250
Mubende	0	0	4,800	28,800
Masaka	192	1,344	200	1,300
Mbarara	0	0	10,710	77,112
Bushenyi	0	0	800	5,600
Kisoro	24,930	448,740	25,160	452,750
Kabale	32,500	603,355	33,750	615,375
Nebbi	660	7,720	725	7,910
Total	*59,877*	*1,079,544*	*80,395*	*1,234,197*

pollution in the United States. The fertilizer nutrient feed alga that in turn causes eutrophication where fish are deprived of oxygen (The Economics and Politics of Ecology 2006).

The organic farming website (www.acresusa.com) indicates that the use of supplemental nutrients to increase crop yields started as trial and error in the form of wood ashes, ground bones, salt paper, and gypsum. Justus von Liebig (1803–1873), a German chemist laid the foundation for the use of chemical fertilizers as a source of plant nutrients in 1840. He recognized the importance of various mineral elements derived from the soil in plant nutrition and the necessity of replacing those elements in order to maintain soil fertility. Two British scientists, J.B. Lawes and J.H. Gilbert, in turn established the agricultural experiment station at Rothamsted in the United Kingdom. They built on the work of Liebig and experimentally demonstrated the importance of chemical fertilizers in improving and maintaining soil fertility. In fact, the application of synthetic fertilizers was the basis of global increase in agricultural production after World War II (www.acresusa.com).

Further, the organic farming website (www.acresusa.com) adduces that global fertilizer use was merely 27 million tons (Mt) in 1959 and 1960; it increased five times to 141 million Mt over the forty-year period ending in 2000. The projected fertilizer demand for the year 2020 is 220 million Mt. Intensive fertilizer use on input responsive cultivars grown on prime irrigated land was the basis of the Green Revolution in South Asia and elsewhere that saved millions from hunger and malnutrition. Similar to fertilizer use, there has also been a rapid increase in global pesticide use. Much of the Green Revolution depended on the use of pesticides (www.acresusa.com). Global pesticide use was four million Mt in 1970, 5 million Mt in 1985, and 5 million Mt in 2001. As much as 85 % of all pesticides are used in agriculture and the misuse can cause severe environmental problems. It is estimated that chemical pollution in agriculture costs about $ 100 billion in diverse public health and environmental damage each year worldwide. The health risks are due to lack of or inadequate occupational and other safety standards, insufficient enforcement, poor labeling, illiteracy, and insufficient knowledge about the hazards of pesticides and fertilizers (www.acresusa.com).

In the developing world, Uganda inclusive, organic farming of Irish potatoes has not penetrated in most of rural areas, despite national and international emphasis to promote it. The situation has been complex amongst farmers who traditionally are used to inorganic amendments, but are willing to switch to innovative solutions. Use of inorganic chemicals in Kisoro District can be traced back to the twentieth century, after WWII (World War II). It was first promoted by the Food and Agricultural Organization (FAO) of the United Nations in post colonial era and later by immigrant farmers from Rwanda, government extension staff and laborers in Mubuku Irrigation Scheme as well as the Uganda Wildlife Authority (UWA) that advised farmers to go inorganic after farmers lost their big chunks of fertile cultivable land as a result of creation of Bwindi and Mgahinga Gorilla National Parks in the early 1990s. The research was therefore set to review the use of inorganic fertilizers and chemical sprays in Irish potato production in the face of increasing emphasis for organic production by smallholders not only in Kisoro District but countrywide. Focus was on four sub-counties namely Nyarusiza, Muramba, Kirundo and Kisoro Town Council. While communities in the sub-counties are not identical, they provided the researchers a chance to compare the different physical and socio-economic contexts for examining the choice of agricultural systems employed in Irish potato production.

5.2 Conceptual Framework

Worldwide, there was a boom in productivity when "improved" crops and inorganic (mineral) fertilizers were first adopted. Yet, in many places, the increased productivity has not been sustainable and may have degraded land, thus needing more and more fertilizer in order to maintain yields. More pesticides are used in potato production than for any other crop worldwide (Meyer 2002). The Organic Farming Association of India (www.ofai.org) observes that the increase in productivity made possible by chemical use has been viewed as a positive outcome for economic reasons, yet the increased use of agricultural chemicals poses a threat to the stability of the environment. Using deadly sprays of chemical poisons not only suppresses the defense mechanisms of crops but also ruins the product because pesticide residues are bound to remain after the harvest since most pesticides are non-biodegradable. In developing countries, extended effects of the agro-chemicals in the ecosystem affect life differently—including their accumulation in birds, loss of pollinators and production of wild plant species, the loss of heritage landscapes and biodiversity, which are supported by traditional farming systems, use of agro-chemicals has implications on cultural aspects (Dabbert et al. 2004). Loss of wetland plants due to accumulation of pollutants in water has been associated with disappearance of traditional ritual sites and rites in different communities in Uganda.

Meyer (2002) documented that production of Irish potatoes can be adversely affected by excess fertilizer applications due to physical and chemical changes in the soil. Although most crops can use either form of nitrogen, from organic or inorganic fertilizers for growth, plant composition; microbial activity in the rhizosphere, availability of minor elements, and the interactions of factors that influence disease severity are affected by the form of nitrogen utilized. Plant nutrition is a major component of disease management and is known to influence stages in the disease cycle of multiple host-pathogen systems. The dynamic interactions of the environment with the plant and pathogen remain areas of active research. All essential mineral elements are known to influence disease incidence or severity. "*The Industrial Revolution was a disaster for the human race—The Unabomber, 1996*" (The Economics and Politics of Ecology 2006)

The Economics and Politics of Ecology (2006) advises that adequate food could be grown using organic methods if the world adds about 50 % more farmland, but this, critics contend, would diminish their "environmental and biodiversity advantages". However, in countries such as China, there is no possibility of adding more land to cultivation. Uganda can factually increase cultivable land by more than 50 % through policy change and strict enactment—allocating vast idle land owned by rich city dwellers to poor smallholders that comprise majority producers.

Critics of organic farming fail to note that while use of synthetic fertilizers have doubled agricultural yields over the past 30 years, "conventional farming has degraded soils irreversibly in large areas of the world, and consequently the remaining land will be farmed as well, rather than used for ecological compensation" (Economics and Politics of Ecology). In short, due to its destructive impact on soil fertility, the current level of production from conventional agriculture is unsustainable. Organic farming would use 35–51 % less fertilizers, 20–41 % less energy, and 96 % less pesticide thus avoiding the deleterious effects of the latter on soil fertility and biodiversity (The Economics and Politics of Ecology 2006). While the organic system may require some 25 % more land, it enhances soil fertility and is, thus, sustainable. In the Economics and Politics of Ecology, it is stated thus: "*A nation that destroys its soil destroys itself.*"

In developing countries, mechanisms for detecting and controlling excessive use of inorganic chemicals do not exist and if they do, they hardly function due to weaker institutional structures (Meyer (2002). Recent creation of national environment management authorities (NEMAs) is also along way to making reasonable impact. Excessive use of inorganic fertilizers and chemical sprays is neither discouraged, nor regulated. In liberal Uganda, there isn't a law regulating the importation of synthetic materials. Moreover, this is done at the expense of human and ecosystems health.

From 1992 to-date, significant changes have occurred in Irish potato production in Kisoro District due to inorganic fertilizers and chemical sprays. They would appear to be part of larger trend for other developed and developing countries, while total area planted with potatoes has decreased due to limited cultivable land and high population density, higher productivity per unit area has resulted in a steady increase in annual production in Kisoro and Kabale Districts (IITA-FOODNET et al.

2001). The observed increase in potato production can be attributed to “modern” agricultural practices that produce high yields.

Irish potatoes are grown in Kisoro District inorganically as food and cash crop even in fertile volcanic soils, especially the areas bordering Gorilla National Parks and the Virunga mountain ranges. Production of potatoes, therefore, does not only meet the demand but rapidly contributes to land degradation. Low incomes coupled with illiteracy have led to a vicious cycle of poverty following environmental degradation that leads to reduced productivity. Dependence on inorganic amendments is perhaps affecting human and ecosystem health, and could overly be pushing poor smallholders to a situation worse off contrary to the 2007 Uganda’s Poverty Eradication Action Plan projections. It is important and urgent that this situation is understood to guide the choice of remedial measures. By carefully studying the socio-economic characteristics of those farmers practicing organic systems in Irish potato production and those that practice inorganic farming of the potatoes, the researcher was convinced that it would provide pointers to understanding the basis of either choice. With increased understanding of the rationale of either choice, a compromising strategy to revert the trend of ever greater dependence on inorganic inputs will henceforth be proposed. In the long run, the practice of shifting to dependence on organic practices, negative impact of potato production on the environment and other sub sectors especially beekeeping will be minimized, land productivity boosted and the health of farmers and consumers in Uganda and outside improved. In addition, the profitability of the potatoes to local farmers in Kisoro will be enhanced. In Uganda, as in most parts of the world, organically produced foods are highly priced and highly demanded for. Such practices would also increase the market of Kisoro potatoes to key destinations such as the European Union markets and the wide market in the East African Community and other neighboring countries especially South Sudan. The current vicious cycle of poverty among Kisoro smallholder farmers could be greatly done away with.

5.3 Study Area

Kisoro District is located in the southwest Uganda, lying between longitude 29° 35″ and 29° 50 East and latitude 1° 44″ and 1° 23″ South (Fig. 5.1). It is bordered by the Republic of Rwanda to the South, the Democratic Republic of Congo to the West, Kanungu District to the North and Kabale District to the East. The total land area of the District is approximately 729.2 km^2, of which 67.2 km^2 is open water and swamps and 662 km^2 is open land. The District is remote and has its headquarters in Kisoro Town Council, approximately 510 km from Kampala, Uganda’s capital city. Administratively, Kisoro District is divided into 13 sub-counties, one Town Council, 36 parishes and 389 villages. In spite of its geographic isolation, Kisoro District is the most densely populated rural district and the second most densely populated District in Uganda. The projected 2009 mid-year population of the district was 236,600 (105,300 males and 131, 300 females). The population has been

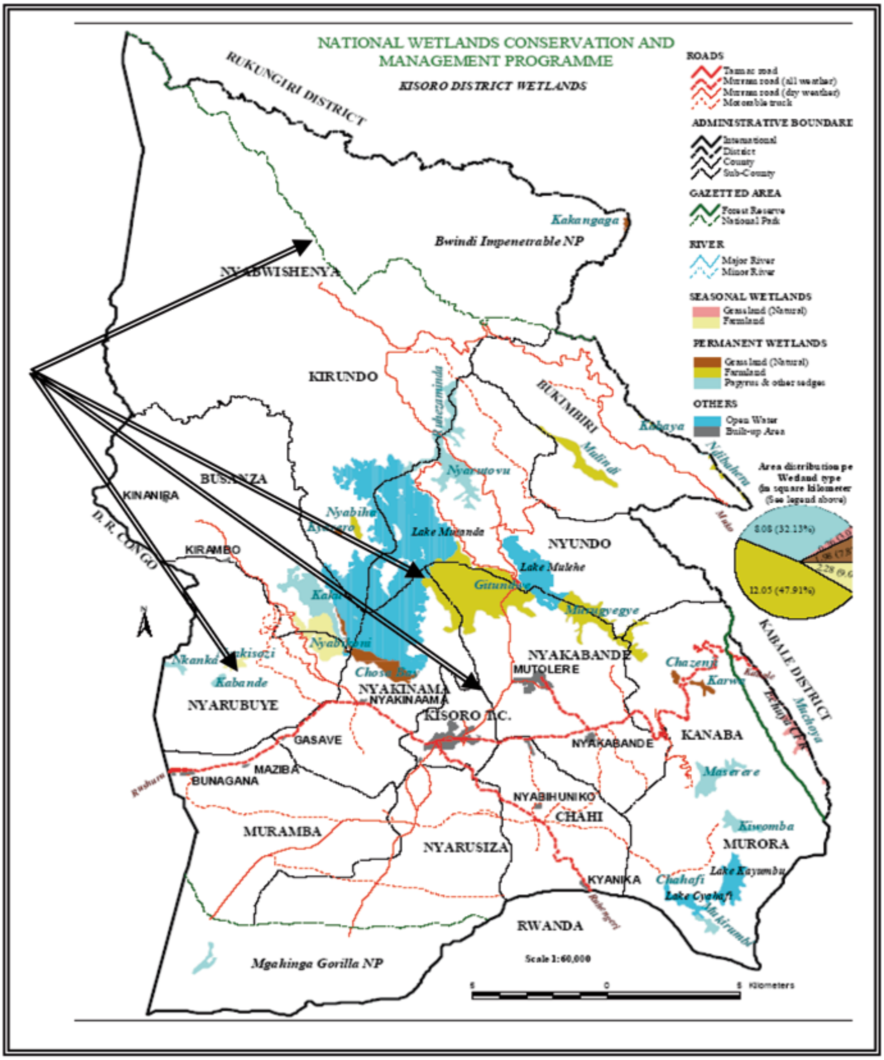

Fig. 5.1 Map of Kisoro District showing sub-counties where the study was carried out. (Source: National Wetlands Conservation and Management Programme Draft Report on Mapping Wetlands in the Districts of Bushenyi, Ntungamo, Rukungiri, Kabale and Kisoro, 1999. The *arrows* point to the surveyed sub-counties where the study was carried out.)

growing steadily since 1969 (114,798) through 1980 (126,664), 1991 (186,681) to 2002 (220,312). The annual population growth rate is 1.5% (Uganda Population and Housing Census 2002). The population density of the district is 353.9 persons per km^2 (Kisoro District Development Plan 2010/2011–2012/2013). About 95.2% of the population lives in rural areas and the rest in towns. Over 60% of the population is less than 19 years and 4% are above 65 years of age. This indicates a high dependency burden often manifested in large numbers of unemployed youth. Due to population pressure, a number of people have migrated to other districts in search of land. The hilly terrain, soil fertility and accessibility mainly influence the settlement pattern. Consequently, the sub-counties of Nyarusiza, Muramba and Nyakabande, which have the above factors, are more densely populated than the rest of the sub-counties. The study was carried out in four sub-counties: Kisoro Town Council, Kirundo, Muramba and Nyarusiza (Kisoro District Development Plan 2010/2011–2012/2013).

5.4 Study Methodology

Different research instruments such as questionnaires and focused group discussion (FGD) were used. The study was carried out in Muramba and Nyarusiza sub-counties that are the most densely populated and intensively produce Irish potatoes largely by inorganic system. Previously sensitized farmers on organic farming were also sampled with the assistance of respective NGOs (e.g. Gorilla Organization, Kisoro District Farmers association, Mgahinga Community Development Organization). The local experience of Rubuguri Parish in Kirundo Sub-county with the Rubuguri Irish Potato Growers Association was handy in selecting areas that grew the Irish potatoes without the application of inorganic fertilizers. Kisoro Town Council was included purposely targeting peri-urban farmers. Different methods of literature review were used. The Internet was used to locate published literature on the socio-economics of the Irish potato sub-sector by subject or keyword or author or using all. Different organizations (e.g. Gorilla Organization, FAO Kisoro offices) were contacted for published/unpublished reports and data.

Two questionnaires were developed, tested, modified accordingly and thereafter administered to the respondents. One unit questionnaire was administered to farmers and fertilizer salespersons; and another to technocrats who included Kisoro District Local Government (KDLG) staff, NGO and CBO representatives. Focused Group Discussions (FGD) involving two groups of farmers in Nyarusiza and Muramba sub-counties were conducted. A Key Informant (KI), a retired agricultural officer who once worked with Mubuku Irrigation Scheme and has since 1980 lived in Kisoro District, was interviewed in detail on the evolution of inorganic farming practices in Kisoro. From each category, the farmers were randomly sampled. Questionnaires were administered to both men and women met in trading centers, households, agricultural fields, NAADS (National Agricultural Advisory Services) meetings (for FGD) and SACCO (Savings and Credit Cooperative Societies) meetings. A data entry and analysis tool was designed in Microsoft Excel Worksheet. Data obtained was pre-arranged in MS Excel and analyzed using the Statistical Package for Social Sciences (SPSS) by a trained data analyst. Data from the FGD and KI interviews were analyzed manually and summarized into a report.

5.5 Results and Discussion

This section presents major highlights of results from the study. Respondents included:

- Farmers and fertilizer salespersons: 107 (51Females (F), 56 Males (M)). The reason for including fertilizer salespersons is the fact that they are at the same time Irish potato farmers
- Technocrats—CBO, NGO, and government personnel: 21 (03F, 18M)
- Key informant: 1 Male
- FGD with Rukongi organic farmers' group—all males (24) and with Kisoro District Farmers' Association in Nyarusiza Sub-county: 20 (04F, 16M).

5.5.1 Awareness on Organic Irish Potato Production and its Sustainability

Hundred percent of the respondents were aware of organic Irish potato production and considered it sustainable. Various reasons were cited. Materials for making organic manure are cheap and locally available. Organic systems involve crop rotation which minimizes pest incidents. Continuous use of organic fertilizers such as compost manure, farm yard manure allows natural soil formation processes and fertility regeneration. Soil organisms that assist in aeration and soil structure formation are enhanced. Soils are maintained in good shape for generations. Farmers use inorganic fertilizers as a last resort. Organic food is better for human consumption as it is not contaminated with chemicals. Many informed people are not interested in food that is contaminated with chemicals. Organic farming practice does not require external (technical) knowledge. Most farmers own domestic animals such as goats, sheep, and cows and can use manure. The agriculture department and other NGOs have trained farmers in organic farming. It is ecologically sound as it helps to maintain the quality of natural resources. It is adaptable as rural communities are capable of adjusting to the changing conditions of farming. However, some respondents especially the Kisoro District NAADS Coordinator and the Senior District Agricultural Officer indicated that organic potato production is not sustainable. They argued thus, (1) under organic systems, the output doesn't meet the demand, hence cannot be for commercial, and (2) most diseases of Irish potatoes cannot be treated by organic measures. Sustainable organic potato production will require minimum and controlled use of inorganic chemicals until disease-free or resistant crop species are available.

5.5.2 Common Irish Potato Varieties Grown in Kisoro

According to the technocrats, the common varieties include Kinigi (28 %), Victoria (18 %), Rwangumi (5 %), Sutama (13 %), Rwashaki (15 %), Kuruza (10), Rutuku (10 %), and Sankima (5 %). Thus, Kinigi is most popular followed by Victoria and

Rwashaki. Respondents reported that Kinigi is widely grown in the district and farmers like it because of its color and higher yields than other varieties. The variety was adopted from Kinigi Research Station in north-western Rwanda, and it is reported that the variety was adopted by farmers before it was even approved by the research station. In Kisoro District, Kinigi and Victoria are mainly for commercial purposes while, Sutama and other varieties are for home consumption. Other than Victoria that was approved by the Karengyere Zonal Agricultural Research and Development Institute (KAZARDI) in Kabale District, southwestern Uganda, the rest of the varieties has never been approved. The farmers came to adopt them from the former employees of KAZARDI and most of these varieties reflect the names of individuals that were employed at KAZARDI.

5.5.3 Farming Systems in Kisoro District

Seventy five percent of the farmers interviewed confirmed that they grow Irish potatoes under mono-cropping systems. This figure included commercial farmers who produce potatoes in bulk. Twenty five percent grew potatoes under a mixed (beans, maize, peas) farming system. A few farmers specialized in Irish potato production year in year out, a practice potential in degrading soil fertility. Under this system, the use of inorganic fertilizers and spraying are high. Close examination revealed farmer preference as a crucial factor in adoption of potato variety. The technocrats listed various farming practices in the study area, including: (i) mixed farming: Irish potatoes with maize, Irish potatoes with beans, Irish potatoes with cow peas, Irish potatoes with sorghum; (ii) mono-cropping especially small scale due to land fragmentation; (iii) subsistence farming; (iv) rotational farming; (v) non fallow cultivation; and (vi) large scale commercial farming systems. The categories of people actively engaged in Irish potato growing include commercial farmers from within and outside of Kisoro District who are fairly rich, who sell potatoes to Kampala, Uganda's capital city and other external markets; peasant rural farmers especially smallholder farmers—illiterate and semi literate; smallholder subsistence and profit-oriented farmers; middle class for both home consumption and for business; a few youth; females and males that dropped out of school.

Virtually almost everyone in Kisoro District grows Irish potatoes, which is the main food and cash crop. Pressure on land is enormous. Irish potatoes and beans comprise the main course meal. Forty three percent of the respondents reported that organic farming of Irish potatoes is sustainable. They argued that traditionally, Kisoro people have practiced organic farming for centuries.

5.5.4 Employment in the Irish Potato Sub-sector

The district extension coordination office estimated that 2/3 of Kisoro population is employed in the Irish potato enterprise as follows:

- Smallholder farmers—120,000 people (17,000 households)
- Large scale commercial farmers—40,000 people (5,700 household)
- Middlemen—5 % of the commercial farmers are middlemen
- Agro input suppliers/dealers—Four (4)
- Seed Potato Suppliers—Certified seed supplied by Uganda National Seed Potato Producers Association (UNSPPA) and KAZARDI)
- It is important to note that the Irish potato sub-sector is not specialized. Most people are engaged in more than one activity.

5.5.5 Agricultural Extension Services in Kisoro District

On the adequacy of agricultural extension services in Kisoro District, 67 % of the respondents were positive while 33 % were negative. The latter cited: Limited skills among extension staff—only about 20 % of the extension workers had adequate skills and experience in Irish potato production; inadequate number of staff—there was one extension staff per sub-county. This is a ratio of approximately 1 extension staff: 25,000 farmers; most farmers get skills from fellow farmers who have also acquired skills informally; remoteness, rugged terrain, and lack of modern social services discourage qualified staff; lack of commitment—extension workers are reluctant to go to the field to advise farmers; disconnection in demonstrations—sometimes extension meetings are held in trading centers; misinformation—participating farmers are more interested in earning allowances (money) than acquiring knowledge; limited funding and facilitation—the few extension staffs do not have the resources to reach out to the farmers and offer on-farm advice; and staff apathy—the few extension staff are engaged in personal enterprises to supplement the meager government salary and make ends meet.

5.5.6 Challenges Facing Irish Potato Production and Marketing

Various issues were raised, these include land fragmentation and small land holding capacity, high costs of agricultural inputs and pesticides, lack of storage facilities, over dependency on unreliable weather—no irrigation, which leads to irregular supply, poor infrastructure—Irish potato farmers are located in areas with poor road network, lack of organized markets, especially farmers' networks, farmers are ill-equipped and are not backstopped when addressing production challenges, lack of value addition innovation. Potatoes are sold at a giveaway price making farmers unable to invest in organic farming, poor timing of planting and harvesting seasons, lack of by-laws and policies for Irish potato production, market instability (price determination by the middlemen), cost benefit analysis not done by the farmers, lack of collective marketing association to empower farmers, low yields—due to degraded and exhausted soils, high demand for Irish potatoes amidst pests and diseases, inadequate facilitation to the few staff available in terms of transport and upkeep, lack of marketing information, no linkage between suppliers and consumers or dealers, inadequate clean certified seed. Other challenges mentioned include: low level of technical knowledge and skills amongst the majority smallholder farmers; lack of manuals—no Irish potato production guidelines in place. The few available ones are written in English, which cannot be read and understood by the farmers. Level of agriculture—being mainly subsistence, farmers don't access improved seed, demand extension and follow agronomic practices, lack of quality control. Buyers take unweighed potato bags from the farmers; poor methods of farming that deplete soil fertility; loss of traditional knowledge in farming; and that a lot of capital is injected in the activity, leading farmers to get loans from MFIs (micro finance institutions) and village banks, which has deepened the debt burden.

5.5.7 External Inputs Used by the Farmers in Irish Potato Production and Their Impact

On the ecosystem and soil productivity, respondents associated use of chemicals with:

- Endangerment of beekeeping sub-sector due to accumulation of chemicals (and loss of bees) up the food chain, which are plant pollinators, occurs
- Because of the poor chemical handling and farming methods, excess nutrients find their way to ecosystems such as wetlands. Many referred this as environmental pollution
- Soil structure is destroyed and hence low productivity
- Pesticides kill not only organisms that cause damage to crops but also organisms such as the natural enemies of pests
- Agrochemicals and fertilizers kill microorganisms in the food chain and loss of important microorganisms that fix nitrogen in plants, hence low soil productivity

On the adverse effects of inorganic farming practices to humans, a considerable number of technocrats mentioned that agro-chemicals cause genetic disorders. Similar findings have been reported. For example, the high incidence of certain kinds of birth defects in areas where chemical sprays are highly relied on to spray the crop to control potato blight was reported (Hazer 1990). Table 5.3 gives a summary of the findings from the socio-economic study.

5.6 Discussion and Recommendations

Careful analysis of farmers who have been producing Irish potatoes inorganically and those that produce organically helps us understand the reasons that compel their choice and plausible measures to address the gaps identified. Integrated Environment Management (IEM) is urgently needed (Fig. 5.2) in Kisoro District to address the environmental degradation challenges, including dealing with inorganic farming.

Table 5.3 Findings summary in line with the research question and underlying theory of change

Research questions	Answers to the questions
Why do smallholder farmers choose to use inorganic amendments as opposed to organic practices?	Reduced cultivable land due to creation of protected areas—Mgahinga Gorilla National Park (MGNP), Bwindi Impenetrable National Park (BINP)
	High population density
	Peer influence: farmers learned from colleagues within and in Rwanda
	Commercialization of potatoes in and out of the district
	Irish potato is a cash and food crop
	High demand for Kisoro potatoes in fast food restaurants; they are the best for chips
	Lack of disease resistant varieties
	Susceptibility of Kinigi variety to pests and disease hence requires spraying
	Soil texture—Kisoro soils are porous—easy loss of fertility by volcanic soils, low moisture holding capacity
	Lack of disease resistant varieties
How has the culture of using inorganic soil amendments evolved among Kisoro farmers?	*Technocrats' viewpoints on when and how inorganic Irish potato production started*
	1980–1985, introduced by agriculture extension workers
	After independence (1962) when Europeans who emphasized organic farming went back home and intensified in the 1980's when soils became less fertile
	1978: Farmers copied the practice from counterparts in Rwanda where fertilizer prices were subsidized
	Kisoro District Local Government Policies and bylaws in 1998
	Farmers and KI Views
	Farmers learned from a retired agricultural officer and other casual laborers that had worked with Mubuku Irrigation Scheme between 1980–85
	MGNP adjacent communities were advised by the Uganda Wildlife Authority (UWA) to go inorganic to increase output on small pieces of land after Mgahinga was gazetted as a protected area
	Farmers continue to use inorganic practices for many reasons: (i) spraying still effective in controlling fungal infections, pests and diseases e.g. late blight; (ii) NPK fertilizers necessary for improving soil fertility and increasing the production of the potatoes; (iii) farmers are not aware of the best alternatives to maintain soil fertility, and prevent pests and diseases; (iv) farmers want to get high output from small plots

Table 5.3 (continued)

Research questions	Answers to the questions
What are the different types of inorganic fertilizers and chemical sprays used by the farmers?	Technocrats points on fertilizers: NPK, Diammonium Phosphate, Urea, rapid grow, super grow
	Chemical pesticides and fungicides—Dithane M45, Mancozeb; Fenitrothion; Ambush; Malathion; Cypermethion; Dudethoate; Ridomil; Copper hychloride; Summithion; Thermasion; Dimethoate insecticide
	Farmers mentioned: Ambush, Diathane, Agrizeb, Mancozeb, Duda cyber, NPK fertilizer, Candbush, Malitafa, Rapid grow (fertilizer), Super grow (fertilizer), M45, Marathon, Indofel, and Green zeb
What are the existing organic manures and herbicides in Kisoro?	Farm yard manure, eco sun toilets (human dung), and compost manure
	Types of organic pesticides known by farmers: animal urine; human urine; ash; soap; red pepper; Mexican Marigold (Mugabonuuka) stinging nettle; and tobacco
What are the perceived benefits and barriers to adopting organic production of Irish potatoes by the farmers in Kisoro District?	*Perceived benefits: farmers*
	Low or no expenditure on materials for making organic manure
	Proper soil fertility management, it is environmentally friendly and stable
	No expertise needed
	Boost in other sub-sectors e.g. beekeeping
	High level of sustainability, maintenance of soil structure
	Avoids chemical contamination and pollution of the ecosystem
	Good products that have better market and better prices locally and internationally
	Food produced is uncontaminated and tastier than inorganic food
	Perceived barriers (all respondents)
	Reduced household incomes
	Food insecurity
	Labor intensive
	Few domestic animals to provide organic matter
	Limited land holding capacity due to high population density
	Small sized potatoes that are not attractive to the buyers and consumers are produced

Table 5.3 (continued)

Research questions	Answers to the questions
	Low production levels are realized. In Kisoro District, the projections indicate that the ratio of seed to ware potatoes is 1:10 when inorganic practices are used and when they are not used, it is 1:5. If well processed organic manure is applied, the ratio may be more than 10 bags, and there is sustainability.
	Negative attitude of farmers. They are against the use of human waste for manure and pesticide
What measures could be put in place to promote organic Irish potato production amongst smallholder farmers in Kisoro District and elsewhere in Uganda?	Zero grazing promotion by the government as it is done in Rwanda
	Awareness raising on adverse effects of inorganic farming
	Government policy on soil protection, cross border trade and inorganic inputs
	Capacity building of farmers in organic production
	Cohesive and high level farmers' groups/associations for collective action
	Food standardization, organic certification and market access
	Scientific research on organic pesticides and insecticides and producing them on large scale

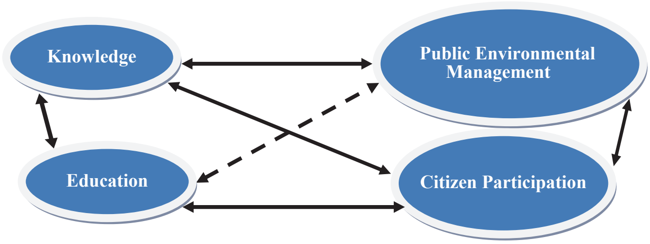

Fig. 5.2 Integrated environment management. (Source: IIEED 2002)

In Rubuguri Irish Potato Growers Association, Kirundo Sub-county, farmers have responded differently, including limiting to use only chemical sprays to prevent wilting and a host of pests and disease to realize a good harvest. This is an area that needs investigation on effectiveness of sprays alone. Unfortunately this move is localized and leadership-driven. It is important that sustainable frameworks are developed. The association members use fresh Mexican Marigold leaves to repel pest and disease from the stored potatoes. Therefore, it is highly recommended that the existing organic pesticides and insecticides such as animal urine, ash, soap, red pepper, Mexican Marigold, stinging nettle, and tobacco be subjected to laboratory experiments, studied carefully especially in the Ugandan context by the scientists to verify their effectiveness, so that they can be produced in large quantities. If successful it would motivate not only the smallholders but also the large scale Irish potato growers to go organic.

This study established that individuals and farmers' associations are responding differently to challenges of potato production. Over the past 6–10 years, there has been an increase in the use of inorganic fertilizers and chemical sprays, as a way of increasing output from decreasing cultivable land size. But investment in fertilizers and sprays is also posing challenges as such expenses translate into reduction in household income, which keeps farmers in a vicious cycle of poverty as there is little or nothing for long-term investment such as paying fees for tertiary/university sons and daughters. This negative trend further weakens farmers from investing in alternative and environmentally sound practices like zero grazing and associated use of OM (organic matter/manure).

During the FGD in Nyarusiza Sub-county, one of the perceived barriers of organic farming was the fear of reduced household income and food insecurity resulting from low production levels: In Kisoro District, projections indicate that the ratio of seed to ware potatoes is 1:10 when inorganic practices are used and when farmers produce organically, it is 1:5. If well processed OM is applied, the ratio may even be more than ten, and there is sustainability. The problem is aggravated by limited land holding capacity due to high population density. It is important to note that the successful adoption of any technology is greatly determined by the farmers. Farmers must decide on its appropriateness and applicability. Farmers mentioned that organic farming is labor intensive. Therefore, any initiative for enhancing organic farming should consider the farmers' viewpoint.

In Kisoro District, young people are less involved in agriculture because of their preference for jobs that generate quick returns, such as sorting, grading and loading Irish potato bags as well as migration to urban areas for casual and white collar jobs. This leaves agriculture to the middle aged and very old persons whose energy keeps reducing gradually due to advancement in age, poor feeding, a multitude of diseases culminating from climate change and associated with the use of inorganic practices, and a number of other preventable diseases existing in the underdeveloped world. Incurable diseases especially the HIV/AIDS pandemic worsen the situation. Labor-intensive farming systems with low levels of mechanization and composting for soil fertility improvement/management are particularly vulnerable to the impact of HIV/AIDS as the economic return to labor tends to be low. With many people falling sick and in need of health care, resources that could have been used to develop the agricultural sector are diverted to procuring drugs and caring for the sick. This slows down the development process. In such circumstances therefore, it would be feasible to raise awareness about proper usage and management of inorganic fertilizers and chemical sprays as stipulated in the Integrated Soil Fertility Management in Africa textbook as well as spearheaded by programs like AGRA (Alliance for a Green Revolution in Africa) that combine the use of existing OM with modern farming practices of using inorganic amendments.

Land fragmentation is a big issue and actually one of the main reasons attributed to farmers' inclination to inorganic amendments. Organic farming systems thrive better on non-fragmented land where farmers can grow crops, have domestic animals on part of the land for a sustainable supply of OM, as well as have a forested area that contributes nutrients to the farming system. The problem of land fragmentation coupled with lack of OM makes organic farming very labor intensive for Muramba and Nyarusiza farmers. In such a scenario, it is imperative to promote organic farming alongside less toxic inorganic fertilizers and chemical sprays such as those promoted by organizations like GNLD (Golden Neo Life Dynamite) International, a South Africa based company that now has branches in many sub-Saharan Africa countries, including Uganda. The GNLD promotes fertilizers like super glow and chemical sprays that have been tested for over 30 years and empirically proved not to have any effect neither on humans nor on soil pH. In addition, an effective government policy can result in farmers having just the right inorganic fertilizers and chemical sprays.

Illiteracy levels among farming communities are high, hence the need to sensitize the parents to utilize the Universal Primary Education (UPE) and Universal Secondary Education (USE) to send their children to school and encourage the children to study up to university level. Further more, the adults that have never been to school need to be considered for Functional Adult Literacy (FAL) courses and basic financial management skills training, since they are directly involved in the Irish Potato sub-sector. Farmers do not read the precautionary measures of using the inorganic fertilizers and chemical sprays because of illiteracy. Once they are enabled to get basic education, they will be enlightened to take keen interest to read and follow instructions.

Some of the farmers that practice inorganic production consider themselves superior. This practice is perceived as less labour demanding with higher yields. Though increased food production through inorganic means is true, some farmers have already began to see serious future implications as production drops once they stop inorganic fertilizers. During the discussion with one individual Irish potato commercial farmer and FGD, it was revealed that inorganic fertilizers must be applied to the gardens every season if a farmer is to realize any meaningful harvests. If they are not applied, the farmers will not harvest anything because the soil adapts very quickly to the inorganic fertilizers. The farmers further said that in the field with organic manure, potatoes can be planted and better yields realized and the soil maintains OM sustainably.

Organic farming in Kisoro District is hampered by lack of adequate OM. There are very few domestic animals in the district. It is imperative that efforts geared towards promoting organic farming need to integrate crop and animal husbandry. In the March Farming Matters magazine issue (Farming Matters 2010) about livestock, there is a convincing argument in the theme overview that an integrated perspective is crucial to overcome simplistic assumptions about the opportunities and threats that livestock present to family farmers. Strengthening ecologically and economically sound and socially justified livestock systems is possible; it starts with understanding the multiple functions of livestock in rural livelihoods. It is imperative to recognize that animals are a part of farming systems everywhere. Examples of animals that smallholders of Kisoro District can afford to look after to provide a wide range of needs, including household income, good nutrition and manure/sprays include chickens, ducks, rabbits, goats, sheep, pigs, and zero grazing cows.

More seriously, the people who advocate for, and promote organic farming are not practicing it. Most of the extension staffs are of the view that they retire from public service; they will practice organic farming on their farm. There should be forums for sharing best practices and boasting ‘talking the walk’. Much as there is interest among rural farmers to practice organic farming, support mechanisms are not in place. Farmers lack advice; that’s why they rely on whatever happens in their neighborhood, including cross-border practices and oral information with fellow illiterate farmers.

A few farmers who try to protect themselves while spraying use simple polythene bags. Very few farmers wear gumboots. In reality, nobody uses proper protective clothing. In general, the farmers do not consider any precautionary measures of handling chemicals. This is mainly because agro input suppliers are equally illiterate and do not advise the farmers in any way. Even though some chemicals contain precautions, the illiterates of third world countries do not bother to take time and read what is there. They are used to word of mouth mechanism of communication. They would rather consult the illiterate suppliers instead of reading from the information leaflets in the packs and information written on the packaged chemical. Despite the massive illiteracy in the target communities, the FGD revealed that some farmers are transitioning from inorganic to organic farming after realizing firsthand the negative effects the inorganic practices have caused to their health, soil productivity and agricultural production. Experience is the best teacher and hence farmers can play a vital role in action research for development.

As a matter of urgency, Uganda needs to take immediate steps to limit the size of its population and introduce land use systems that emphasize natural resource utilization in a more sustainable manner. The fertility and birthrates are very high, and the conservative family planning attitudes worsen the situation. Old traditions, whether cultural or religious need not to be strictly adhered to if they are inappropriate in addressing contemporary problems. There is need for government intervention in this case.

5.7 Conclusion

Uganda is relatively poor in minerals and its primary natural resource is land, yielding crops and trees which, unlike minerals, are potentially renewable. With careful management and long term planning, agricultural and forestry productivity can be maintained or even increased. However, the land may also be exploited destructively, possibly in ways which appear to be initially successful and which yield high profits in the short term, but which eventually result into environmental degradation seriously undermining future potential (Hamilton 1987).

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Chapter 6
Moroccan Agriculture Facing Climate Change: Adaptation and Local Distribution of the Value Added

Salma Daoud, Abdelkader Lyagoubi and M. Cherif Harrouni

Abstract Agriculture is the principal lever of economic and social development in Morocco. Since 1998, drought has become structural in the country and climatic conditions, especially rainfall, were marked by an imbalance among different regions and a heterogeneous distribution between seasons. This generates problems of agricultural production in rural areas especially in Southern Morocco which is characterized by arid climate. The rural world in general is confronted to major challenges due to natural risks (drought); low economic growth; high poverty rate and jeopardized natural resources sustainability due to overexploitation. Some production systems so-called “traditional” have shown their adaptation to environmental constraints. It would be necessary to identify them and evaluate their capacity to cope with climate change. Rural areas of Southern Morocco are underprivileged in terms of infrastructure and water resources availability. Nevertheless they present an important bio-geographic diversity of natural resources namely, Argan tree, prickly pear, honey, olives, dates, capers, almonds, carobs, saffron, roses, medicinal and aromatic plants, etc. This local richness, combined with a culture of local know-how, offers a variety of regional products adapted to the arid climate. From the economic point of view, Southern Morocco and its products constitute an important source of income or at least of essential nutrition for the local population and are by themselves a pillar of a traditional agricultural system, which needs to be preserved and valued with the aim of promoting the economic development of these regions. The National Initiative for Human Development and the Green Morocco Plan launched in Morocco in 2005 and 2008 respectively, are policies to encourage rural and social development projects with the objective of improving the income of small farmers by infrastructure development, rural youth training and technical

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assistance. These initiatives contribute in an effective way to the stabilization of the populations in rural zones while improving their living conditions.

Keywords Morocco • Drought • Natural resources • Local know-how • Traditional agriculture • Development

6.1 Introduction

Global warming and regional climatic change impose an additional threat to scarce fresh water resources in arid areas. Water scarcity, land degradation and desertification are factors which have direct negative consequences on the general status of ecosystems affected by these phenomena and on populations living in these ecosystems (Anonymous 2009a). Being in the Mediterranean region Morocco is characterized by Mediterranean climate in the north and mostly by arid climate in the south and is subject to seasonable droughts and rainfalls. Drought has become recurrent in the country since 1998 and 93 % of lands are degraded to various levels (Anonymous 2009b). This generates problems of agricultural production in rural areas especially in Southern Morocco where agriculture and economic growth of rural areas are confronted to major challenges such as natural risks (drought), poverty and sustainability of natural resources because of overexploitation. This situation is aggravated by the critical population requirements which exceed production possibilities of natural resources and by climatic variability threats which jeopardize "environmental security" (Anonymous 2009b).

6.2 The Climate of Morocco

The geographical position of Morocco in the extreme Northwest of the African continent, between 21° and 37° Northern latitude and 1° and 17° Western longitude, exposes the country to the Mediterranean climatic influence in the North (512 km coastline), oceanic influence in the West (2,943 km coastline), continental influence in the centre, and Saharan influence in the South and Southeast (Oubalkace 2007). The climate of Moroccan is mainly characterized by a warm and dry summer, when rainfall is almost absent and evaporation is particularly high. On the other hand winter is mild close to the coasts, and cold inside the country, in the Atlas and Rif mountains and in the high Eastern plateaus (Anonymous 2008a). The topography creates strongly differentiated climatic zones: the Atlas mountains (3,000 m average height) constitute an obstacle to prevailing wind creating a desert zone in the Southeast; and the Rif mountain (2,000 m average height) constitute a barrier to the Mediterranean influence. These influences mark strongly the climate of Morocco: irregular rainfall, spells of cold and heat with frequent and unpredictable droughts;

Table 6.1 Agro-climatic zones of Morocco (Anonymous 2000)

Zones	Rainfall (mm)	Percentage of useful agricultural surface (UAS)
Favorable	>400	30
Intermediary	300–400	24
Unfavorable		
South and east	200–300	12
Mountain	400–1,000	15
Saharan	<200	7

so many elements which have repercussions on the economic and social life of the country (Anonymous 2008a). Indeed, rainfall rates vary from a region to another while remaining dominated by a strong irregularity in space and time, seasonally and annually. The alternation of sequences of years with high rainfall and drought which can last several years is a character marking the climatic and hydrological conditions of Morocco (Anonymous 2006a; Oubalkace 2007). Average annual precipitations vary from over 1,200 mm in the north (Western Rif mountains), with two seasonal peaks in winter and in spring, to below 100 mm in the south. The country presents vast dry regions (south side of the Atlas) and semi-arid areas (continental plains) characterized by frequent climatic crises revealing a fragile ecosystem (Anonymous 2008a). According to Anonymous (2006b), the annual rainfall is distributed in the following way:

- More than 800 mm in the most watered area in the Northwest (western and central Rif), on the summits of the Middle and High Atlas;
- From 600 to 800 mm, in the extreme northwest, the rest of western and central Rif and of
- Middle Atlas, and on the high reliefs of the High Atlas;
- From 400 to 600 mm in the zones of Sebou, Bou Regreg, and on the summits of oriental Rif;
- From 200 to 400 mm, in the plains of Chaouia, Doukkala, Tadla, Central Haouz, Souss and low Moulouya, the High plateaus and on the reliefs of the Anti-Atlas;
- From 100 to 200 mm in the plains of Mejjate, Tensift, Moulouya, the plain of Tiznit, the southeast hillsides of the Anti-Atlas and the High Atlas, and in the South of the High plateaus.
- Lower than 100 mm further southeast, South and in the Sahara

For agricultural purposes six agro-climatic zones were distinguished based on rainfall importance (Table 6.1) (Anonymous 2000):

Water resources and agriculture are two of the most important sectors for Morocco and at the same time the most affected by varying and sometimes extreme climatic conditions and could be aggravated by climate change.

Table 6.2 Distribution of water resources in different regions of Morocco (Anonymous 2006b)

Hydraulic basins	Surface resources (million m^3)	(%)	Underground resources (million m^3)	(%)	Exploitable resources (million m^3)
Loukkos, Tangiers region and Coastal Mediterranean (North)	3,605	20	57	2	3,662
Moulouya, Figuig, Kert, Isly and Kiss (North-east)	1,611	9	421	15	2,032
Sebou (Northwest)	5,561	31	1,000	36	6,561
Bouregreg and Chaouia	848	5	114.05	4	962.05
Oum Er Rbia and El Jadida-Safi	3,412	19	405	15	3,817
Tensift and Ksob-Igouzoulen	816	5	153	6	969
Souss-Massa and Tiznit-Ifni	626	4	315.6	11	941.6
Guir, Ziz, Rheris, Draa, Sahara (South)	1,402	8	306	11	1,708
Total	*17,881*	*100*	*2,771.65*	*100*	*20,652.65*

6.3 Water Resources Potential in Morocco

Conventional and renewable Moroccan water resources are estimated to 20,653 million m^3 from which surface water resources represent 17,881 million m^3 (Mm^3) and underground natural renewable water resources 2,772 Mm^3 (the returns of irrigation and drainage by spring and river water are not included, already counted in surface water) (Oubalkace 2007). Table 6.2 presents water distribution in different regions of Morocco (Anonymous 2006b).

The disparity of the distribution of exploitable water at the national level is well marked for surface water. Indeed, 79 % of these resources are agglomerated in four basins namely: Loukkos, Sebou, Moulouya and Oum Er Rabia. However, groundwater, with the exception of Sebou, seems to be more or less better distributed Anonymous (2006b). Table 6.3 shows that 497 Mm^3 of groundwater resources present different degrees of salinity (Anonymous 2008b). The salinization of aquifers occurs mainly in zones of irrigated agriculture due to the intensive utilization of water reserves associated with high evaporation rates. In the south of Casablanca, the intensive pumping of water induced the intrusion of seawater into the aquifer (Choukr-Allah and Harrouni 1996). In the south (south of the Atlas Mountains), most of the water is brackish if not very saline. As a matter of fact, aquifers become more and more salty as one gets further away from the Atlas Mountains. In the Draa valley salinity increases from up to downstream and can reach 16 g L^{-1} before the river gets to the ocean. Aquifers exist at relatively small depths (10–15 m) in the Sahara (particularly in the coastal plateau between River Draa and Tarfaya) with rather good rates of flow but water contains 3.5–16 g L^{-1}. In the south of Morocco water is saline because of the geological substratum, and because of lack of rain

Table 6.3 Saline ground water in Morocco (Anonymous 2008b)

Aquifer	Groundwater (Mm^3)	Salinity ($g\ L^{-1}$)
Kert 14	14	0.6–10
Gareb and Bou Areg	52	6–8
Rhis—Neckor	17	2–5
Triffa 50	50	Can reach 8
Guercif 40	40	2–5
Coastal Chaouia	44	2–10
Gharb	75	2–10
Sahel 60	60	2.9 (Eloualidia)
Errachidia cretaceous	29	2–13
Aïn El Ati	7	4–14
Tafilalet	22	0.6–10
Tarfaya 10	10	In average 3.5
Foum El Oued	4	3–8
Sahara cretaceous (lower and upper)	13	2–3
Middle Draa valley	60	0.5–16
Total	497	

salinity is not reduced except in some valleys where alluvial deposits are developed and are regularly refilled by river floods. This allows the existence of small brackish aquifers suspended above saline water contained in deeper Cretaceous formations (Anonymous 2008b). Regarding non conventional water resources, the potential of wastewater is estimated at present to about 600 Mm^3 and should reach 900 Mm^3 by 2020. Re-use of wastewater in Morocco, in particular for the irrigation of farmlands and especially green spaces, is at an experimental stage. Bzioui (2004) reported that some 7,000 ha around urban areas are watered with wastewater without sanitary precaution with a volume of 70 Mm^3.

In Morocco water extraction was estimated to 12.6 km^3 in 2000. Agriculture is the main user of renewable water resources (89 %) while drinking water uses 9 % only and the industry 2 %. Nevertheless, the mobilization and valuation of water resources remain dependent on the problem of poor spatial and temporal distribution; which considerably influences river flow and the recharge of aquifers, as well as the surface of land to be irrigated (Anonymous 2006a, 2008a).

An ever-increasing demand for water combined with decreasing water resources due to frequent droughts and overexploitation have made the situation even more critical. This situation is now more worrying since the country has already mobilized all available water resources. The resources that are currently available are one level below the 1,000 m^3/capita/year scarcity threshold set by the United Nations Development Program (UNDP) indicating the appearance of shortages and latent water crisis. The potential in water varies at present from 180 m^3/capita/year, for the Moroccan southern zones considered very poor in water resources, to about 1,850 m^3/capita/year for Northern basins. The predictable demographic evolution for the next 25 years also shows that the human pressure on water resources will increase. Natural water resources per capita, at the level of the country, would be situated around 720 m^3/capita/year toward the horizon 2020. By then, 14 million inhabitants (35 % of total population of the country) would have less than 500 m^3/capita/year (Table 6.4) (Bzioui 2004).

These indicators show that the chronic shortage of water is a structural datum which should be taken into consideration in the future for the policies and strategies of water resources management.

6.4 Impact of Drought on Agriculture and Rural Population

Agriculture is a key sector in the economy of Morocco: it is the main sector of employment and income. However, it remains very handicapped by unpredictable and unreliable climatic conditions.

6.4.1 Contribution of Agriculture in the Economy of Morocco

Morocco relies on agriculture as the main lever for economic and social development of the country. It is the main activity of 45 % of the population and provides the employment to 40 % of the national active assets among them 80 % of the active population in rural areas. In spite of all these considerations, it contributes weakly to the average income per capita. Indeed, the agricultural GDP (Gross Domestic Product) contributes directly with 15–20 % of the national GDP (2000–2006) and remains very dependent on climatic variations (Anonymous 2004; Anonymous 2006c; Akesbi 2006; Anonymous 2008c). Figure 6.1 clearly shows the close relationship between the oscillations of the national GDP and the variation of agricultural activity (Akesbi 2006).

6.4.2 Agriculture in Morocco

Morocco has 71 million hectares distributed in a rather wide variety of bioclimatic zones. With 39.2 million ha, lands with agricultural vocation constitute 56 % of the whole Moroccan territory. The useful agricultural surface or arable lands represent 13 % of the national territory (9.2 million ha, Fig. 6.2).

Agricultural activity is the main factor impacting the environment in the country. It is therefore the major cause of environmental degradation and its principal victim. Agriculture activities are mainly responsible for soil erosion and loss of fertility, salinization of irrigated lands, waste of water and overexploitation of groundwater, overgrazing, degradation of biodiversity, as well as pollution of rivers and groundwater (Aït Kadi and Benoit 2010). Desertification, due to human activity is particularly important. It becomes structural, affects 92 % of the national territory, reduces yield and production, and amplifies rural poverty and loss of biodiversity. With

Table 6.4 Potential of water per basin in Morocco (Bzioui (2004))

	1971		1994		2000		2020	
	Number of basins	Population (million inhabitants)	Number of basins	Population (million inhabitants)	Number of basins	Population (million inhabitants)	Number of basins	Population (million inhabitants)
> 1,700 m^3/capita/year	5	8.4	1	2.1	1	2.4	–	–
Between 1,700 and 1,000 m^3/capita/year	1	0.9	4	14.4	4	15.6	3	8.6
Between 500 and 1,000 m^3/capita/year	1	2.4	2	4.0	2	4.5	3	17
< 500 m^3/capita/year	2	3.3	2	5.1	2	5.9	3	12

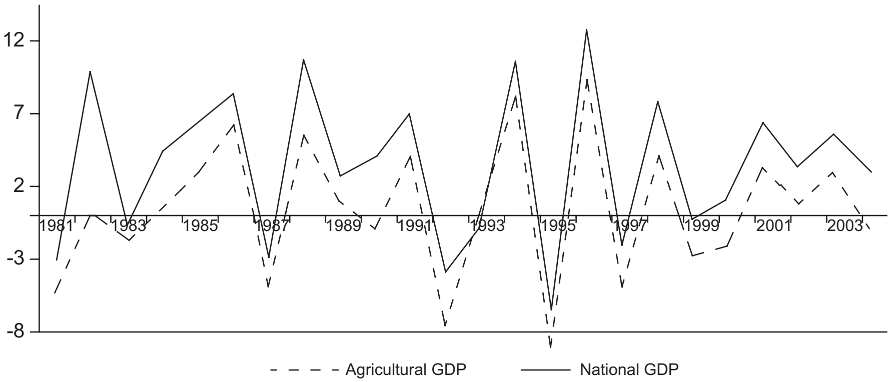

Fig. 6.1 Strong dependence of national GDP on agricultural production fluctuations

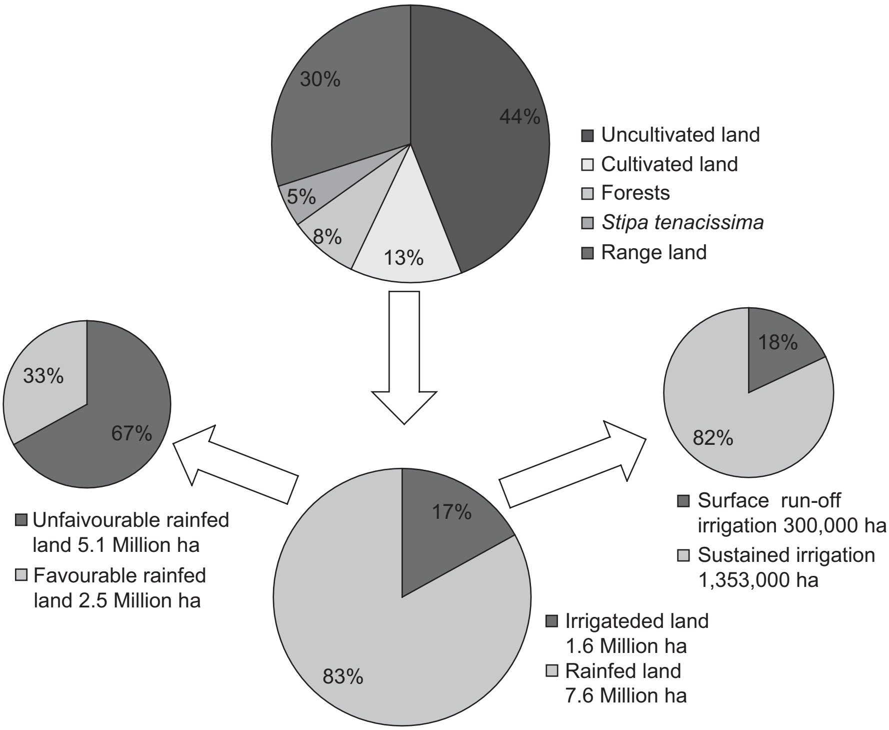

Fig. 6.2 Breakdown of the total area of Morocco. (Anonymous 2006c)

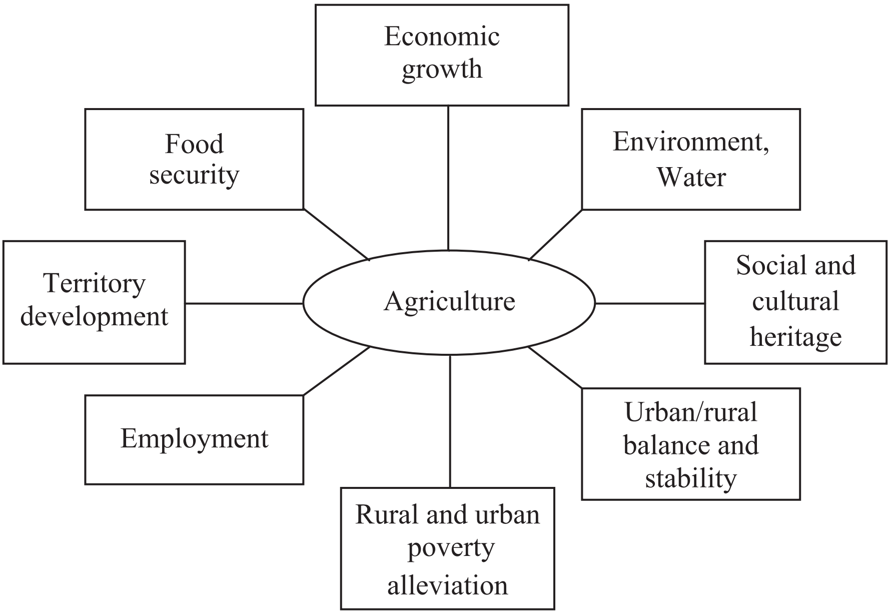

Fig. 6.3 Multifunctional importance of agriculture in Morocco (Anonymous 2006b)

climate change, vulnerability to drought and desertification increase. Moreover, by its consequences on water resources and desertification, climate change has a significant impact on national agriculture and rural world. Indeed, rural population is confronted to many challenges and risks: the main challenge comes from natural risks which have become structural risks (drought, salinity and soil erosion), since agriculture is the main user and directly in charge of the management of renewable natural resources (Anonymous 2006d); challenge of economic growth which does not redistribute enough income since the potential is not fully exploited; challenge of poverty which affects a great part of rural population, challenge of access to education and social infrastructures which are still insufficient; challenge of sustainability since natural resources are overexploited and their existence is threatened (water scarcity, loss of soil fertility, overgrazing and extension of cultivated lands). These problems are even more serious taking into consideration that the population in Morocco will double by 2030 leading to rising demands on agricultural production and the consequent great pressure on water resources (Anonymous 2008d).

For Morocco, agriculture is placed in the crossroads of problems and essential stakes (economic, social, environmental and cultural) of development of territories, food security, business and regional and international cooperation and stability of the country. These multiple problems cross, interact and have incidences on all the economic dynamics of the country (Fig. 6.3) (Anonymous 2006d).

However, in spite of the strong environmental constraints (unsuitable climate conditions, low plains), Moroccan agriculture has important assets and margins for progress (Anonymous 2006d).

1. The annual mobilizable renewable water resources on an average year (20 km^3) are three times higher than in Algeria (6.5 km^3) and six times more than in Tunisia (3.6 km^3). Climate diversity, agro-ecological situations, biodiversity, specific local productions and know-how represent a rather unique richness which can allow strategies, management options and diversified productivity.
2. The capital of production and services accumulated during the last five decades is high. The increasing accessibility to the Moroccan rural areas (equipment with metalled roads, supply of water and electricity) creates a new context which is going to change the relationship between urban and rural contexts. A rural urbanization is possible and it would allow the creation of jobs and services.
3. Modern agriculture in irrigated zones and favorable 'bour' (rainfed agricultural land) represent 20 % of cultivated surfaces with good productivity thanks to the use of modern techniques, qualified workers and the presence at the national level of several successful models of agricultural and agro-industrial companies which managed to conform to international quality standards and to reposition in more remunerative markets.
4. The traditional know-how and skills of the Moroccan farmers (management of water and soils, traditional agriculture, construction etc.) are numerous, diverse and valuable. Morocco is a young country (36.3 % of population are between 15 and 34 years age), its rural youth constitutes a high potential of skills and creativeness if it is trained and mobilized.
5. The geographical position of Morocco and its cultural closeness to Europe is an advantage. The European market is the first client of Morocco. Trade with Europe has become easier and faster, thanks to the improvement of the infrastructures of transport. The country, while asserting its Euro-Mediterranean anchoring, is opened on the world.
6. The presence of a potential and dynamic national market can constitute an important outlet. So far this market is neglected but the population growth and the improvement of the standard of living will make it more attractive.
7. A number of non commercial services (urban/rural balance of the population, social ties in rural areas, production of attractive cultural landscapes for tourism, "production" of water, finding a role for biodiversity, etc.) are insufficiently estimated but represent a high value.

Moroccan agriculture has therefore the potential to become one of the fundamental driving forces of the national economy and to contribute decisively to the economic growth. The potential for progress is very high. The strategic importance of agriculture in terms of job creation would ensure economic security to the rural population (mainly poor and socially less developed compared to the urban one), may contribute to the reduction of rural exodus and hence reduce the risk of urban instability (Anonymous 2006d).

Taking into account the constraints and the aforesaid assets, Morocco adopted new policies in the sector of agriculture with the aim of supporting the rural population and reducing social and territorial imbalance. Among these policies the Green Morocco Plan was launched in 2008.

6.5 A New Policy on Agriculture Adaptation to Climate Change

The new agriculture policy in Morocco is based on optimal valorization of soil particularities in each region, in order to increase agricultural productivity and to promote an agro-industry adapted to natural potential and assets of each region taking in consideration environmental constraints, water scarcity and desertification (Aït Kadi and Benoit 2010). The Green Morocco Plan is among the political measures adopted by the Moroccan government to improve agricultural production and alleviate poverty.

6.5.1 The Green Morocco Plan (GMP)

The GMP launched in May 2008 is a policy to promote agriculture which is considered the main lever of national economy for the next decade. Investment and organization is the strategy of the GMP adopted as factors for success. GMP has economic and social objectives. The economic objective is to develop an intensive and modern agriculture, with strong productivity in irrigated zones and favorable 'bour'. The social objective is to modernize traditional agriculture in unfavorable 'bour', mountains and oases which add up to 80% of the Useful Agriculture Surface (UAS). In these areas 70% of farms are under 5 ha (Anonymous 2008d). Tools such as infrastructure development, training and technical assistance are being used to better adapt the production to land capability and to increase productivity (Aït Kadi and Benoit 2010). GMP has adopted two approaches: Pillar I and Pillar II. The principles of Pillar I are:

- Private investment aiming to the development of a modern agriculture with high productivity and/or high value added (milk, red and white meat and cereals in favorable 'bour');
- Implementation of projects in zones with great agricultural potential (favorable bour or irrigated zones);
- Projects undertaken individually or within the framework of aggregation projects. An aggregation project allows the grouping of farmers (mainly small farmers) around an aggregator (physical or moral person or any professional organization) with the main objective of organizing agricultural networks. Several Moroccan governmental bodies have been created to facilitate the implementation of the projects essentially through investment support.

Pillar II of GMP is conceived to adapt dynamics of small farming to climate change by developing responsible agriculture which aims to supervise farmers in underprivileged regions (arid zones, mountains and oases). The supervision would allow the use of up-to-date techniques and help to considerably improve productivity and increase the income. Another aim of this pillar is to create additional agricultural income by reconversion of some lands from traditional crops to others with a better marketable value. This is especially the case of lands traditionally intended for the cultivation of cereals. Cereals whose development stages are very sensitive to drought will be replaced by other crops better adapted to arid climate and with high value added, in particular olive tree, argan tree, prickly pear, almond tree, date-palms, saffron, carob tree, medicinal plants, melliferous plants, capers etc.

A high priority should be given to the eradication of rural illiteracy and to the training of young rural leaders. Attention should also be given to integrated rural development projects locally decided with new forms of community mobilization, new opportunities for job creation and income generation. These local projects will contribute to the creation of social organizations (cooperatives, associations,…) and the consolidation of local development initiated by rural populations achieving high returns for their hard work. This can facilitate sustainable management of natural resources, valuation of human capacities and stabilization of the populations in rural zones while improving their income and living conditions (Anonymous 2006d).

6.6 Conclusion

Climate change represents a global challenge to sustainable development. With climate change already perceptible, the observed trends of aridification will only increase. Many territories will be affected by substantial mutations of production systems. With population growth and water needs for agriculture, local imbalances between resources and water demands will seriously increase. New advances in development strategies are needed to anticipate changes and limit irreversible impacts. These may include more efficient management in restoration and sustainable management of biodiversity and water. Integration into the new climatic situation is a guarantee for the success of future plans of development. Therefore, good governance and management of scarce resources are key factors to ensure sustainability. Policies at the national level such as Green Morocco Plan are contributing to counter environmental degradation and desertification. They imply collaboration between politicians, stakeholders and the local population.

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Chapter 7
Economic Impact of Climate Change on Wheat Productivity in Bangladesh: A Ricardian Approach

M. A. Monayem Miah, A. K. Enamul Haque and Sahadat Hossain

Abstract The study measured the economic impacts of climate change on wheat production in Bangladesh using Ricardian approach. Panel data on wheat yield and climate variables were used to estimate the model. Results indicated that most climate variables had a significant impact on the income of wheat production. The marginal increase of temperature during January and February reduced the net revenue by Bangladeshi Taka (BTk) 18,885 ha^{-1} (USD 239.05) and BTk 9,603 ha^{-1} (USD 121.56) respectively, whereas, marginal increase of temperature during December increased it by BTk 7,045 ha^{-1} (USD 89.18). Increasing rainfall during December and January increases the net return by BTk 128 ha^{-1} (USD 1.62) and BTk 543 ha^{-1} (USD 6.87) respectively. The study used predictions from five different Global Circulation Models (GCM) for two IPCC emission scenarios and found that impacts on net revenues for these two scenarios are mixed depending on model predictions. Net revenue will decrease for both A2 and B2 emission scenarios using precipitation and temperature predictions for 2030 for three of the models, while it will increase for two models. At the same time, for 2050, net revenue will fall when temperature and precipitation of one of the models are used for the rest net revenue will rise. This means that while our study provided marginal effects for temperature and precipitation changes on farm's net revenue, understanding about the climate change impact requires better climate modeling for the local situation. This is important to accurately predict the impact of climate change for future years.

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Keywords Climate change • Impacts • Wheat • Bangladesh • Ricardian model

7.1 Introduction

Climate change is now widely recognized as a phenomenon which is threatening the current way of our life on earth. Because the world is warming and will continue to warm as the concentration of greenhouse gases (GHG) rises in the future (IPCC 2007). One of the manifestations of climate change is fluctuations in the long term temperature in different seasons. According to a UNDP report, in 2005, Bangladesh, India and Pakistan faced temperatures 5–6°C above the regional average (UNDP 2008). The average warming in annual temperature in the Himalaya and its vicinity between 1977 and 1994 was 0.06 °C per year (Shrestha et al. 1999). Climate related changes are observed in the long term data on precipitation patterns, temperature, intensity of severe floods, cyclones, landslides, erosion, and sedimentation. Climate change is a major concern for developing countries like Bangladesh because of its tremendous social, environmental, and economic consequences. These events affect and threaten livelihoods of millions of people in the developing countries through changes in agro-ecosystem and direct threats such as loss of land, crop productivity, livestock, and household assets.

Growing body of literature suggests that climate change will significantly affect agriculture sector in developing countries and this may have serious consequences on the level of food production and food security, and would adversely affect huge population, with larger impacts on poor and smallholder farmers, especially in developing countries like Bangladesh and sub-Sahara Africa (SSA). It is important to state here that climate change may enhance in C_3 plants by increasing CO_2, but this beneficial impact will be much lower than that of harmful impact of climate change in Bangladesh. Analysis of climate data of Bangladesh depicts that there is temporal and spatial variability in the rate of change and nature of resulting impacts affecting all spheres of life (Islam 2009). Maddison et al. (2006) estimated effects of climate change on African agriculture using 11 countries data and found that there is wide variation in impacts. It varies from 1.3 % loss of agricultural output in Ethiopia to 30.5 % in Niger. Helmy et al. (2007) assessed the impact of climate change on Egyptian agriculture using Ricardian approach and found farm output and net revenue being affected by temperature and precipitation changes. In the Bangladesh context, the vulnerability is particularly high because of its large population and economic dependence on primary natural resources, being an agrarian economy. Having recognized the potential impacts of climate change as a long-term threat to agriculture sector, bulk of impacts studies are available for developed countries, while little is known about potential impacts in Bangladesh.

7.2 Rationale of the Study

In the era of 1970s wheat was a minor cereal crop in Bangladesh but today it is the second most important cereal crop in terms of both production and consumption (BBS 2010; HIES 2010). It is produced all over the country during the winter season. Wheat farmers are also vulnerable to climate change since the production of wheat is highly sensitive to temperature. Ahmed and Meisner (1996) showed that late seeding reduced the yield at the rate of 1.3 % per day of delay after November 30. Agronomic studies in India suggest that a temperature rise of 4^0C would reduce grain yields by 25–40 % (Rosenzweig and Parry 1994) and wheat yields by 30–35 % in the absence of adaptation and carbon fertilization (Kumar and Parikh 1998). IPCC fourth assessment report mentions climate change could decrease agricultural productivity in South Asia up to 30 % by mid-twenty-first century. Therefore, the country has to import a huge amount of wheat every year from different countries. It is also reported that the possibility of food imports by developing countries will be increased manifolds due to climate change (IPCC 2007).

Mendelsohn et al. (2009) measured the impact of climate change on overall crops, livestock, and fish farms in Bangladesh using a Ricardian analysis combined with a hydrological model, but no empirical study regarding the estimation of climate impacts on wheat production is available in Bangladesh. This study will contribute toward existing knowledge gap, and help researchers and policy makers to respond to climate change by adjusting agricultural and environmental policies and practices as needed. In particular, we have the following two hypotheses to be tested in this research.

7.2.1 Hypotheses

1. Temperature and rainfall would affect the wheat production in Bangladesh.
2. Forecasted climate change scenarios will have significant impacts on wheat production in Bangladesh.

7.3 Study Approach and Methods

The Ricardian log linear model used in this study is an empirical approach developed by Mendelsohn et al. (1994) to measure the economic impact of climate change on wheat production in Bangladesh. The method was named after Ricardo[1] because of his original observation that the value of land would reflect its net productivity at a

[1] In a competitive market, rents would be equal to the net revenue from the land.

site under perfect competition. This approach estimates the impact of climate and other variables on land values and farm revenues, and has been widely used in different studies (Mendelsohn et al. 1994, 1999; Cline 1996; Sanghi and Mendelsohn 1999; Darwin 1999; Gbetibouo and Hassan 2005; Kabubo-Mariara and Karanja 2007; Mendelsohn and Reinsborough 2007; Kurukulasuriya and Ajwad 2007).

The estimated changes in net productivity caused by changes in environmental variables are aggregated to the overall national impact (Olsen et al. 2000) or incorporated into an economic model to simulate the welfare impacts of productivity changes under various climate change scenarios (Adams 1989; Kumar and Parikh 1998). This model makes it possible to account for the direct impact of climate change on crop yields and the indirect substitution among different inputs including the introduction of various activities, and other potential adaptations to a variety of climates by directly measuring farm prices or revenues (Derssa and Hassan 2009). The weaknesses of the Ricardian approach are: it is not based on controlled experiments across farms; and it does not include price effects and carbon fertilization effect (Mendelsohn et al. 2009; Cline 1996).

Using Ricardian technique, net revenue from per hectare of wheat production was regressed on climate variables to identify the role of climate in explaining net revenues. The contribution of each factor to the farm performance (net revenue) was measured by regressing it on a set of climatic variables. Using net revenue per hectare of cropland as dependent variable is more robust measure since it measures what the farmer currently receives without any concerns for future returns, discounting, capital or labor market. The Ricardian approach involves specifying a net productivity function of the following form:

$$V = \sum_i P_i Q_i(X, C, Z) - \sum P_x X \tag{7.1}$$

Where, V is net revenue per hectare, P_i is the market price of crops, Q_i is the quantity of crops produced, X is a vector of purchased inputs (other than land), C is a vector of climate variables, Z is a vector of other control variables tied to the farm such as soils, and economic variables such as market access, and P_x is a vector of input prices. The farmer is assumed to choose X to maximize net revenues[2] given the characteristics of the farm and market prices. Solving Equation 7.1 leads to a reduced form model where net revenue becomes a function of all the exogenous variables, P_i, P_x, C, and Z;

$$V = R(P_i, P_x, C, Z) \tag{7.2}$$

The empirical model used in this study was a log-linear specification of the Recardian model as shown below.

[2] In Recardian analysis for climate change, farmers are assumed to be rational economic agents and maximize their profits by using land in declining order of fertility because of change in climate and soil quality (Polsky 2003).

$$\ln V = \beta_0 + \beta_1 C + \beta_2 C^2 + \beta_3 P + \beta_4 P^2 + \varepsilon \tag{7.3}$$

Where, C is a vector of seasonal temperatures, P is a vector of seasonal precipitation, and ε is an error term. Both linear and quadratic term for temperature and precipitation were introduced. In the log-linear functional form the linear coefficients provide estimates of the proportional change in V for a change in the climate variable and the quadratic terms for temperature and precipitation reflects the non-linear shape of the response function between net revenues and climate (Equation 7.3). As there is a known temperature where a particular crop grows best across the seasons, crops often exhibit a hill-shaped relationship with annual temperature.

The expected marginal impact of a single climate variable on farm net revenue evaluated at the mean of variable is:

$$(dV / dC_j) = (\beta_{1j} + 2\beta_{2j} \times C) \times V \tag{7.4}$$

The change in annual welfare, ΔW, resulting from a climate change from C_0 to C_1 can be measured as follows. If the change increases net income, it is beneficial and if it decreases net return it is harmful.

$$\Delta W = V|_{T1} - V|_{T0} \tag{7.5}$$

Where, V is the predicted net revenue per hectare from the estimated net revenue model under the future climate scenario, and $T1$ is the predicted level of climate variable (temperature or rainfall, in this case) and $T0$ is the normal average temperature under the current climate scenario, ΔW is the difference between the predicted value of the net revenue per hectare under the future climate scenario and the current climate scenario.

7.3.1 Data

Panel data[3] regarding wheat yield and climate variables (i.e., temperature and rainfall) were used in this study to estimate the model. In order to calculate net revenue from wheat production per hectare, the last 10 years' (1999–2008) wheat area, total wheat production, input quantity, input prices, and output prices for 15 districts were taken into account in this study. The selected districts were Dinajpur, Rangpur, Pabna, Rajshahi, Bogra, Jessore, Khulna, Mymensingh, Dhaka, Faridpur, Sylhet, Comilla, Chittagong, Rangamati, and Barisal. Data on production inputs, crop output, and farm revenues were compiled from different sources—BBS, Department of Agricultural Extension (DAE), Department of Agricultural Marketing (DAM), WRC, etc.

[3] The same cross-sectional unit (say, a firm, state) is surveyed over time. In other words, pooling of time series and cross-sectional observations over time.

Weather data corresponding to 15 meteorological stations spread across Bangladesh were interpolated for the purpose of developing the district specific climate data (see Kumar and Parikh 2001; Dinar et al. 1998, for more details on the surface interpolation employed to generate district level climate data). Climatic variables for the past 49 years (1950–1998) from all the 15 districts were used to capture the climate change effects over time and space. Monthly climate data (i.e., temperature and rainfall) were divided into a number of variables according to wheat season. Since temperature and rainfall are critical to wheat production and there are certain critical periods, the average temperature and rainfall for December, January, and February over the period 1950–1998 for each of the 15 districts represent the climate variables used in this study. This is done based on the discussion with the agronomists. Thus, these data points do not vary over time but instead vary across districts.

7.4 Results of the Economic Impact Analyzes

Net revenue for wheat was calculated by deducting total cost of cultivation from gross revenue of wheat (value of grain and straw). Table 7.1 presents the summary statistics of variables included in the Ricardian model. The average observed net revenue of wheat cultivation was estimated at BDT 9989.98 (USD 126.46) per hectare. The net revenues ranged from BDT 1015 (USD 12.85) to BDT 36334 (USD 459.92) in the observations. The mean temperatures for December, January, and February were 19.75°C, 18.52°C, and 21.04°C respectively. The corresponding figures for rainfall were 9.10 mm, 8.18 mm, and 18.43 mm respectively. In these periods temperature and rainfall varied from 17.05°C to 22.60°C and 2.70 mm to 35.00 mm respectively. Detailed climatic scenarios have been shown in Table 7.1.

The independent variables used in the model were linear and quadratic terms for climatic variables temperature and rainfall. Rise in temperature played a crucial role in the growth as well as yield of wheat. It revealed that late seeding reduces the yield at the rate of 1.3 % per day of delay after November 30 (Ahmed and Meisner 1996). On the other hand, three irrigations are recommended for better yield since wheat is a winter crop. Based on the growing season and irrigation requirement, temperature and rainfall periods were divided into three variables (December, January, and February). In the regression, temperature and rainfall were expected to have a negative and positive impact on net revenue of wheat respectively.

The regression results presented in Table 7.2 indicate that rise in temperature in December and February reduced net revenue from wheat production and converse is also true. On the other hand, the coefficient for January temperature is positive and significant. It indicates that January temperature had positive impact on net revenue.

The coefficients for December and January rainfall are positive, whereas it is negative for February rainfall implying that December and January rainfall have positive and February has negative impact on net return per hectare (Table 7.2).

Table 7.1 Summary statistics of climate variables used in Ricardian model

Variables	Mean	SD	Minimum	Maximum
A. Net revenue (BDT ha−^{1})	9,989.98 (USD 126.45)	5,150.67 (USD 65.20)	1,015.00 (USD 12.85)	36,334.00 (USD 459.92)
B. Temperature (in°C)				
December temperature	19.7476	0.7326	18.58	21.42
December temperature squared	390.4708	29.1303	345.38	458.60
January temperature	18.5156	0.8304	17.05	20.31
January temperature squared	343.4841	30.8099	290.70	412.29
February temperature	21.0353	0.8753	19.35	22.60
February temperature squared	443.2229	36.7464	374.25	510.70
C. Rainfall (in mm)				
December rainfall	9.1013	2.5611	3.83	16.41
December rainfall squared	89.3361	46.3389	14.63	269.35
January rainfall	8.1795	2.5549	2.70	13.70
January rainfall squared	73.3672	43.5101	7.29	187.69
February rainfall	18.4307	6.9578	3.53	35.00
February rainfall squared	387.9961	263.6461	12.43	1225.00

1 USD = BDT 79.00 (Bangladeshi Taka)

Table 7.2 Regression coefficients of climate variables over net revenue

Climate variable	Coefficients	Std. Error	*t*-value	$P > t$
Constant	109.909[b]	43.84747	2.50	0.013
December temperature	−15.8907[b]	7.10096	−2.24	0.027
December temperature squared	0.4202[b]	0.17962	2.34	0.021
January temperature	20.2024[b]	7.91906	2.55	0.012
January temperature squared	−0.5966[c]	0.21357	−2.79	0.006
February temperature	−12.5097[b]	5.35939	−2.33	0.021
February temperature squared	0.3202[b]	0.12587	2.54	0.012
December rainfall	0.1748[a]	0.10433	1.68	0.096
December rainfall squared	−0.0089	0.00556	−1.60	0.111
January rainfall	0.1214	0.14578	0.83	0.406
January rainfall squared	−0.0041	0.00802	−0.51	0.613
February rainfall	−0.0539[a]	0.03238	−1.66	0.098
February rainfall squared	0.0016[b]	0.00078	2.07	0.040
N	150			
R^2	0.5272			
F (12, 137)	12.73[c]			

Log of net revenue (BDT ha^{-1}) is dependent variable [a, b, c] Indicate significance at 10, 5, and 1% level respectively

However, the total impact of climate variables shall be interpreted as a whole considering both linear and quadratic terms and so the actual interpretations of the sign and magnitudes of impacts are further explained below under the marginal analysis.

Table 7.3 Marginal impact of climate change on net revenue per hectare

Period	Climate variable	
	Temperature	Rainfall
December	7,045[b]	128[a]
January	−18,885[b]	543
February	−9,603[b]	−51[a]

[a, b] Indicate significance at 10 and 5 % level respectively

7.4.1 Marginal Impact Analysis

The marginal impact analysis was undertaken to observe the effect of marginal change in temperature and rainfall on wheat farming in Bangladesh. The marginal impacts of temperature and rainfall have been shown in Table 7.3.

7.4.2 The Impact of Forecasted Climate Scenarios

The impact of climate change on the net revenue per hectare was analyzed using the climate scenarios from the Special Report on Emission Scenarios (SRES). The SRES is a report prepared on future emission scenarios to be used for driving climate change models in developing climate change scenarios (IPCC 2001). Two different SRES emission scenarios: A2 and B1 (Nakićenović and Swart 2000) were used for this analysis (Table 7.4). The B1 scenario (most conservative) predicts only a small increase in greenhouse gas emissions and A2 scenario (business as usual) predicts a very large increase. Predicted values of temperature and rainfall from five climate models such as CCSM (Boville and Gent 1998), ECHAM (Cubasch et al. 1997), GFDL (Manabe et al. 1991), MIROC (Tokioka et al. 1996), and HADCM3 (Gordon et al. 2000) were applied to predict the changes in climate in the decades around 2030 and the decades around 2050.

Mendelsohn et al. (2009) also used these climate scenarios to estimate the impact of climate change on overall crops, livestock, and fish farms in Bangladesh. In their study net revenues were regressed on flooding, climate, and control variables. Several climate models with hydrological model were then used to predict temperature, precipitation, and flooding changes in Bangladesh. The analysis reveals that Bangladeshi farms are sensitive to flooding but the effects are small. The biggest effects are from changes in temperature and rainfall and these effects depend greatly on the climate scenario and what were the results of Mendelsohn et al. (2009)

By using parameters from the fitted net revenue model as shown in Table 7.2, the impact of changing climate variables on the net revenue per hectare was analyzed using the equation 7.5. The results of the predicted impacts from SRES models are presented in Table 7.4. The Table 7.4 shows that majority of the predicted values on net revenue changes indicate positive impact of climate change variables on net revenue per hectare by both B1 and A2 emission scenarios. The predicted values

Table 7.4 Forecasted climate changes and emission scenario for winter season.

Model	A2 emission scenario		B1 emission scenario	
	Temperature (°C)	Rainfall (%)	Temperature (°C)	Rainfall (%)
Year: 2030				
CCSM	1.63	−12.4	1.45	11.3
ECHAM	0.43	50.1	0.19	43.6
HADCM3	1.87	27.4	1.42	15.0
MIROC	0.99	−20.6	0.99	14.1
GFDL	2.06	−19.7	1.82	29.1
Year: 2050				
CCSM	2.32	9.4	1.54	31.1
ECHAM	1.29	109.8	0.85	76.6
HADCM3	2.97	46.7	2.10	33.5
MIROC	1.63	0.4	1.43	9.1
GFDL	2.99	−18.2	2.60	−39.1

(Source: Nakićenović and Swart 2000; Mendelsohn et al. 2009)

estimated from the models CCSM, MIROC, and GFDL under A2 emission scenario during 2030, and model MIROC during 2050 predict reduction of net revenue from wheat production. On the other hand, two of the B1 2030 climate scenarios predict net reduction in net revenue from wheat production, but the other three scenarios predict gain in net revenue from wheat. Similarly, only one of the B1 2050 climate scenarios predicts damages and the other four scenarios predict benefits.

The decreased net revenues ranged from 2.91 to 24.77 % and increased net revenues ranged from 5.71 to 113.34 % were estimated under A2 emission scenarios during 2030 and 2050 respectively. Under B1 emission scenarios, the decreased net revenues ranged from 0.36 to 4.59 % and increased net revenues ranged from 1.05 to 18.58 % during 2030, whereas the net revenue decreased 32.5 % during 2050 (Table 7.5).

However, estimates depicted above are susceptible to changes based on predictions given by the global climate models. As of now, these models are predicting climate variables on a 300 × 300 grid scale and in this case, Bangladesh falls into one/two grids. Our field data on temperature shows significant variation of temperature and rainfall throughout Bangladesh. The impact as shown in Table 7.4, therefore, is unable to illustrate the real impact of climate change. It is only indicative.

7.5 Conclusions and Policy Implications

The study clearly provided evidence of climate sensitivity of wheat production in Bangladesh. According to the study, it is evident that profitability of wheat production will be affected due to changes in climate variables and it will affect the total production of wheat in Bangladesh. The regression results indicate that rainfall effect is much less than temperature effect on wheat production. Furthermore, it has

Table 7.5 Impact of climate change on net revenue under forecasted climate scenarios

Model	A2 emission scenario		B1 emission scenario	
	Net return change (BDT ha^{-1})	% change	Net return change (BDT ha^{-1})	% change
Year: 2030				
CCSM	−1133	−11.35	−36	−0.36
ECHAM	957	9.58	1159	11.61
HADCM3	1958	19.61	105	1.05
MIROC	−2473	−24.77	−458	−4.59
GFDL	−462	−4.62	1854	18.58
Year: 2050				
CCSM	2999	30.04	1108	11.1
ECHAM	570	5.71	952	9.53
HADCM3	11315	113.34	3245	32.5
MIROC	−290	−2.91	−195	−1.97
GFDL	5398	54.07	133	1.33

shown that monthly variations of climate variables are more important than an annual average changes in the climate variable. More importantly, December, January, and February temperature do not have same effect. The marginal analysis shows that a marginal change in temperature during January and February reduces the net revenue and a marginal change in temperature during December increases the net revenue. Increasing rainfall during December and January also increases the net revenue of wheat per hectare. Marginal impact of February rainfall is found to be very negligible. Under this situation, it is important to use a downscaled global circulation model to find more robust estimates of future climate variables by districts of Bangladesh and this will provide a better picture of impact of climate change. Given these limitations, the impacts of climate change on net revenue on per hectare of wheat production under forecasted climate scenarios reveal that warming generally would reduce wheat production in Bangladesh but the effect depends on the seasonal distribution and magnitude of the warming.

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Chapter 8
Farmers' Attitude Toward the Traditional and Modern Irrigation

Methods in Tabuk Region—Kingdom of Saudi Arabia

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Abstract The Kingdom of Saudi Arabia is one of the most water deficit countries. The country is not suitable to support sustainable agriculture. Even though to achieve food security, the agriculture sector receives prime importance in the national developmental plans. Water remains an essential input for crop production, and hence it has to be used wisely and economically. Farmers in the Kingdom are still using old traditional methods to irrigate their farmlands. However, to conserve and maintain the precious water resources, it is important that farmers use modern irrigation methods. The present research primarily aims at studying the farmers' attitude towards the use of different irrigation methods, in the region of Tabuk. Data were collected through the structured questionnaire and administered personally after checking its validity and reliability. Simple random sample technique was used to take a sample of 320 farmers which represents 7.9 % of the total population of farmers employing irrigations in order to meet the study objectives. The questionnaire phrased in simple language consists of sixteen questions to measure the attitudes of farmers towards irrigation methods. The correlation between some personal characteristics and socio-economic conditions of the farmers and their attitudes towards the use of both traditional and modern methods of irrigation were studied. Data were subjected to statistical analysis by using SPSS (2009). Findings of the study indicate that farmers have the positive attitudes towards the use of modern irrigation methods. Therefore, sufficient quantity of water can be saved by the farmers by replacing the old traditional irrigation methods with the modern ones. The study suggests the need for awareness campaigns among the farmers. Launching of agricultural extension education programs on efficient and water saving irrigation methods could be very suitable and viable option for conserving and maintaining water resources of the kingdom.

Keywords Irrigation methods • Farmers' attitudes • Water conservation • Awareness campaigns • Extension education

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8.1 Introduction

Water is an essential component of every living being on earth, and its significant and vital role in agricultural development has been fully realized in the various developmental plans of the Kingdom of Saudi Arabia (KSA). The water resources of the Kingdom are viewed as the most important cornerstones for their potential role to realize developments in agriculture sector and ensure food security for the future. The sector consumes almost 88 % of the total water extracted from all the sources (FAO 2008; Darfaoui and Al-Assiri 2010). Water consumption for agricultural purposes in the Kingdom has been estimated more than 8,000 million m^3 per year of groundwater storage (Al-Salamah et al. 2011; JCC 2012).

However, the volume of available water resources remains the most essential determinants of agricultural expansion both in terms of horizontal and vertical expansion. Different irrigation methods result in different levels of productions and are known to play an important role in water conservation to further agricultural expansion. The water sources in the Saudi Arabia include surface water, groundwater, seawater desalination, and sewers. Surface water comes from rainfall, and its storage is low due to low and irregular rainfall, especially in the northern and central regions (Ministry of Planning 1990; Al-zahrani et al. 2011).

In the KSA groundwater is available at various depths (Al-Omran 2002). The KSA enjoys the wealth of ground water due to the geology of the water bearing rocks. The water production capacity of these rocks varies depending on the type of layer and the thickness of the configuration and their inherent characteristics (Al-zahrani et al. 2011). Wastewater treatment plants also supplies water to irrigate some crops. Presently it is used on a limited scale, but still reduces the consumption of groundwater in some areas. Agriculture sector consumes maximum water compared to other sectors. Estimates show that consumption of water in the KSA has been increased by 5.50 % by household use, 11.5 % by industrial activities, and 83 % for agricultural operations (Abdel-Aziz 1986; Al-zahrani and Baig 2011).

The agriculture use of water in the KSA depends primarily on the availability of groundwater resources for irrigation purposes. The agriculture sector uses more than 8,000 million m^3 per year of groundwater storage (Column 1991; JCC 2012). According to Al-Salamah et al. (2011) over 90 % water extracted for various uses is groundwater.

Irrigated agriculture is considered high water consuming sector in the world. Water scarcity is more pronounced in the arid and semi arid areas, where low average rainfalls and limited water supplies are the most affecting factors in crop production (Atta et al. 2011). The KSA is an arid country and hence agricultural sector remains the largest consumer of water (Development Plans 1980–1985, 1985–1990, 1990–1995, 1995–2000, 2000–2005, 2005–2010; Al-zahrani and Baig 2011).

It is essential to reconsider economical ways of water consumption by agricultural sector. In this regards, the Kingdom has developed national plan for water, especially after the emergence of evidence indicating the total consumption of water has reached to the critical levels. The Sixth and Seventh Development plans, launched in the years of (1995–2000; 2005–2010) stress on the collection of comprehensive and accurate data to overcome the issues related to water in order to make effective planning for water resources management. The most important measures enlisted in water resources policy focus on maintaining non-renewable groundwater reserves. National Water Plan is in place to achieve the optimum utilization of water and agricultural policies that would lead to reducing water consumption in the agricultural sector and application of modern irrigation methods, and the rational use of water for domestic, recreational and industrial sectors. The plan also focused on the reconsideration of the tariff of water consumption. The plan calls for the re-evaluation of the regulatory framework for managing its water resources and making it in line with the emerging needs of the community (Ministry of Planning 1990).

In addition, the Kingdom has also directed all the efforts and possibilities for rational use of water for agriculture to reduce the exhaustible groundwater depletion. Ministry of Agriculture has worked to reduce the production of high delta water crops such as wheat, barley and forage. The Kingdom is not exporting wheat any more. Despite the measures have been taken to promote the cultivation of crops consuming less water, yet the water consumption rates in the agricultural sector are still quite high (Al-Zahrani and Elhag 2003).

The Kingdom is determined to practice agriculture by employing its water resources sustainably and it remains the basic and key element to future agricultural development plans. Many researchers (Atta et al. 2011) believe that sound and appropriate agricultural technologies can help improving agricultural production both in quality and volume, and limit the depletion of water resources. Similarly Nwachukwu and Egwuonwu (2012) also believe that development and application of modern and appropriate irrigation technologies can certainly improve water use efficiency, ensure sustainability of water resources and their utilization, elevate crop yields and empower farming communities. Realizing the importance of water situation, the MEP (2010) stresses to bridge the gap between the rates groundwater extraction and their natural replenishment rates. Keeping in view the situation of water resources, the Kingdom Saudi Arabia has also launched a program to employ new sources of water, efficient utilization of irrigation systems, and modern irrigation methods to save water and lessen the stress on groundwater resources (MEP 2010; Atta et al. 2011; KACST 2012). About 66% irrigators adopt modern irrigation methods like irrigation in the Kingdom whereas only 34% farmers apply irrigations by employing surface irrigation systems (MEP 2010). The situation calls for finding all the alternatives and techniques to rationalize water consumption. All those involved in scientific research are required to maintain the presently available water resources in good conditions and at the same time make efforts to explore the new water saving irrigation technologies. To combat the situation, Kingdom has started employing new modern irrigation methods to reduce the extraction pressures on groundwater resources as reported by Atta et al. (2011). Al-Zahrani et al. (2012) maintain that if improved irrigation methods used effectively, they would enhance yields, quality of crops and the water-use-efficiency as well. The researchers reported encouraging response on the adoption of new irrigation technologies that are proved to be cheap, reliable and simple to use. Therefore, it is imperative and seems justified to create awareness on the water saving modern irrigation methods among the farmers. However, before diffusing innovation in the farming community and taking any new technology to the farmers, it is extremely important to study the attitudes of the farmers.

Present study is an endeavor to gather information on the attitudes of the farmers toward both traditional and modern irrigation methods. Agricultural extension can certainly contribute in the dissemination of modern agricultural methods, particularly in the areas where modern irrigation methods have been adopted by the farmers (Agricultural Extension Centre 1996). Therefore, at this juncture, it seems appropriate to take into account the role of agriculture extension in the present initiative.

8.2 Research Problem

8.2.1 The Study Area

Study sites are located in the irrigated parts of the province of Tabouk. The sites are situated in the north-western part of Saudi Arabia. The sites are located above the sea level (670 m), spreading over an area of 104,000 km^2, and the town of Tabouk enjoys an equitable climate. With the mild climate area, the summer temperatures range between 80–114 °F (27–46 °C) whereas the average temperature reaches 29 °C. During winter, temperatures are in the range of 39–64 °F (4–18 °C), occasionally reaching as low as 20 °F (−6 °C) with an average of 17 °C. On occasions temperatures fall below zero, therefore, wide-spread frosts are also common in the winter. Insignificant rain is received in the area from November to March and precipitation ranges between 50 and 150 mm with an annual average of only 50 mm. Some snow is not uncommon every 3–4 years. Western, northwestern, and southwestern winds blow all year round. The growing season is relatively short, sowing starts in early December and the harvest occurs in May. Wheat, maize, alfalfa and sorghum are the major cereal crops grown in the area.

Tabuk region is viewed as one the most important agricultural areas in the Kingdom. The region is blessed with abundant water supplies, soils are fertile and favorable climate, resulting higher crop yields as compared to other parts of the Kingdom (Department of Agriculture 2006). Due to these positive features, the Saudi Government has set up a General Department for Agriculture, followed by seven branches in Tabuk, Taima, Duba, Trowel, Fads, and Coaq, to control crop diseases control insects/pests, provide other agricultural services and carry outagricultural extension activities.

In Tabuk region agriculture is developed both horizontally and vertically. In 2008, the cultivated area for all fodders, cereals, vegetables and fruits reached 9,365; 28,793; 3,602; 10,444 ha with the production of 195,499; 188,145; 111,154; and 92,338 t respectively (MOA 2009). Tabuk Region is famous for realizing higher yields per unit area. Tabuk region ranks the 2nd highest in cereal production and ranks 7th in terms of area under cereal production among all the regions of KSA. It happens to be 5.57% of total area under cereal production in the Kingdom. Similarly, wheat production reached about 8 t ha^{-1} and Barley about 9 t ha^{-1}. These figures indicate the potential of these areas for producing cereals and establish the importance of enhancing water use efficiency by employing modern irrigation methods (Al-Zahrani et al. 2012). The traditional irrigation methods are employed on an area of 1,135,683 ha whereas the modern irrigation methods are practiced on 1,164,085 ha (Department of Agriculture 2006).

The expansion in cultivated area calls for the need to increase irrigated areas by modern methods that in return would reduce area to be irrigated by traditional methods. Since the farmers' attitudes of Tabuk region toward methods of different irrigation methods has not been previously studied, therefore it seems imperative to identify the farmers' attitude toward different irrigation systems. The study would be helpful in selecting the most appropriate methods for irrigation.

8.2.2 Research Objectives

The main objective of the study is to analyze the farmers' attitudes toward the use of traditional and modern irrigation methods in the region of Tabuk. The specific objectives are to:

- determine the correlation between some personal characteristics and social and economic developmentof farmers and their attitudes toward the use of both traditional and modern irrigation methods;
- determine factors influencingfarmers' attitudes toward the use of modern irrigation methods.

8.3 The Methodology

8.3.1 Data Collection

A questionnaire was developed with the help of the Departments of Agricultural Extension and Rural Society; Agricultural Engineering; and Plant Production at the King Saud University, Saudi Arabia. The questionnaire contains all the essential questions that could be helpful in gathering required information toward meeting the objectives of the research.

Before collecting the data from the respondents, pre-testing of questionnaire for the validity and reliability was made by the five faculty members of the Department of Agricultural Extension and Rural Society to measure its stability. A group of

23 farmers from the research area was exposed to the questionnaire at two different occasions, separated by a time period of 21 days. The stability coefficient was calculated for all parts of the questionnaire by using the Simple Pearson Correlation Coefficient. The study revealed significant correlation at the level of 0.01 which means that all parts of the questionnaire carried the high consistency.

8.3.2 The Overall Sample

The sample included all the farmers (4,038) in the region of Tabuk (Department of Agriculture 2006). A simple random sample of 320 farmers representing 7.9% was taken. The targeted farmers were identified by employing the size equation (Kregcie and Morgan 1970). About 166 farmers did not respond, representing 4.1% of the sample.

8.3.3 Data Analysis

The data were analyzed by using percentages, arithmetic means, average, and standard deviation. Simple Pearson Correlation Coefficient was used to find correlation between some personal characteristics and social and economical development of farmers. Farmers were taken as independent variables and their attitudes toward traditional and modern irrigation methods were treated as dependent variables. Multiple regression analysis was used to analyze factors affecting farmers' attitudes toward the use of modern irrigation methods. The data were analyzed by using Statistical Program for the Social Sciences (SPSS 2009).

8.4 Results and Discussion

Likert scale with five-divisions was used to classify the respondents. This was based on their use of traditional and modern irrigation methods. Data against the 16 statements were collected by using the questionnaire, consisting of eight positive and eight negative statements. The attitude of each farmer is measured against the level of his agreement to each of the statement in one of the following categories: 1 = completely agree, 2 = agree, 3 = I do not know, 4 = disagree, 5 = completely disagree for the positive statements and the order for the negative statements remained like 5, 4, 3, 2, 1. Information regarding the attitudes of the farmers toward the use of traditional and modern irrigation methods is presented in Table 8.1.

Table 8.1 Farmer's attitudes toward the use of traditional an modern irrigation methods

Statements	Traditional irrigation methods			Modern irrigation methods		
	Mean	Standard deviation	Rank order	Mean	Standard deviation	Rank order
1. Does not require trained labor?	4.41	0.78	1	2.11	0.96	14
2. Easy to implement and in-expansive	4.08	0.77	2	2.28	0.93	13
3. Can involve high initial cost?	3.90	1.28	3	1.42	0.71	16
4. An economical method to employ	3.69	1.07	4	1.74	1.04	15
5. Can cause relatively high salinity that may lead to the burning of leaves?	3.06	0.91	5	2.58	0.97	12
6. Can cause difficulty in the application of fertilizers and pesticides?	2.81	1.26	6	3.59	1.06	11
7. Easy to use farm machinery	2.30	0.93	7	3.96	0.75	8
8. By applying the irrigation method, light and frequent irrigations can be made efficiently	2.24	0.85	8	4.46	0.72	3
9. Can deliver water to all parts of the field uniformly and efficiently?	2.16	0.88	9	4.63	0.66	2
10. When applied, salts get accumulated on the soil surface	2.13	0.92	10	3.67	0.87	10
11. Can manage the irrigation system automatically?	2.09	0.62	11	4.34	0.87	4
12. Can reduce the infestation of weeds and the risks of pests and plant diseases?	2.04	1.25	12	4.32	0.94	5
13. When used for irrigation, it will wash away the surface layer of the soil	2.04	0.75	13	3.83	0.92	9
14. Can save time, effort and energy?	2.02	0.75	14	4.64	0.57	1
15. Can cause significant wastage of irrigation water, and is less efficient for the application of water to all parts of the field uniformly?	1.61	0.84	15	4.31	0.79	6
16. Can cause wastage of water as the farmer has no control over the amount of water to be applied to the crops?	1.60	0.93	16	4.02	0.89	7

8.4.1 Attitudes of the Farmers Toward the Application of Irrigation Methods

8.4.1.1 Attitudes Toward Traditional Irrigation Methods

The statement “does not require trained labor” with the highest mean 4.41 and SD 0.78 got the highest rank from the perspective of farmers toward the traditional irrigation methods. The statement “easy to implement and inexpensive achieved the 2nd highest mean 4.08 and SD 0.77. The statement “high initial cost” with the mean 3.90 and SD 1.28 remained with the 3rd highest rank, and the statement “cost-wise economical” attains the fourth position with the mean of 3.69 and SD 1.07. With an average account more than 3.67 for each statement, indicates the positive attitude of the respondents toward traditional irrigation methods on the Likert scale.

With the mean 1.60 and SD 0.93, the lowest rank was observed for the statement “Traditional irrigation method can lead to waste of water as the farmer has no control over the volume of water to be applied to the crops. Whereas the 2nd lowest mean 1.61 and SD 0.84 was attached to the statement “can result the significant wastage of irrigation water, being less efficient for the irregular distribution and application of water”. The respondents indicate traditional irrigation cannot save time, and takes more efforts and energy. The statement received the 3rd lowest rank with mean 2.0 and SD 075. These statements were ranked at the bottom, being with the lowest means, indicating the farmers’ attitude toward traditional irrigation methods with an arithmetic mean less than 2.33.

8.4.1.2 Attitudes of Farmers Toward Modern Irrigation Methods

The positive statements such as: Modern irrigation methods can apply water to all parts of the field uniformly and efficiently (Mean 4.63; SD 0.66); can result light and frequent irrigations with high efficiency (Mean 4.46; SD 0.72); can manage the irrigation system automatically (Mean 4.34; SD 0.87); and can reduce the spreading of grasses and weeds and can check the risk of pests and plant diseases (Mean 4.32; SD 0.94); were ranked from the second to the fifth order to indicate the farmers’ attitude toward modern irrigation methods with a mean more than 4.3 for each statement.

With the mean 1.42; SD 0.71, the statement “modern irrigation methods have high initial cost” received the lowest rank. The 2nd lowest mean 1.74; SD 0.71 was observed for the statement “Economical”. The statement “Modern irrigation methods do not require trained labor” received the 3rd lowest mean 2.11; SD 0.96.

Table 8.2 Distribution of farmers according to the numeric value for their attitudes toward traditional and modern irrigation methods

Numeric value for the conventional and modern irrigation methods	Conventional irrigation methods		Modern irrigation methods	
	No.	%	No.	%
Less than 38 degrees (negative trend)	27	16.3	–	–
38 degrees to less than 59 degrees (neutral trend)	139	83.7	119	71.7
59 degrees or more (positive trend)	–	–	47	28.3
Total	166	100.0	166	100.0

The overall average of traditional irrigation methods (42.19); Standard Deviation (4.59) The overall average modern irrigation methods (55.91); Standard Deviation (4.88)

8.4.1.3 Distribution of Farmers Regarding Their Attitudes Based on the Numeric Values

The distribution of farmers on the basis of the numeric values that represent the attitudes toward traditional and modern irrigation methods is presented in Table 8.2. Some 16 statements have been used to determine the attitudes of farmers by employing 5 point Likert scale, whereas 16 indicates the minimum and $16\times5=80$ is the maximum score to indicate the attitude. Similarly $80-16=64$ is the range we do have to express attitude. To indicate the level of acceptance for a particular irrigation system we used three categories like negative, neutral, and positive. After having a range of 64 for attitudes divided by three levels of acceptance, we come up point 21.3. Adding up of 21.3 to $16=37.3$, the resultant figure indicates negative trend. Similarly $80-21.3=58.7$ indicates the positive attitude. That's how the numeric values for the traditional irrigation methods were calculated, that ranged from 37.3 degrees (as a minimum) to 58.7 degrees (as a maximum) with an average of 42.19 and the standard deviation of 4.59. The numeric values for the modern irrigation methods ranged from 42 degrees (as a minimum) and 68 degrees (as a maximum) with a mean of 55.91 degree with the standard deviation of 4.88. The numeric values have been divided in three categories as shown in Table 8.2.

Farmers with negative attitudes toward traditional methods of irrigation, with the numeric values less than 38 degrees, account for 16.3%, while no farmer had a negative attitude toward modern irrigation methods. The second category includes the farmers with their neutral attitudes, accounting for 83.7% of the conventional irrigation versus 71.7% for modern irrigation methods. Al- Ghobari (2007) also maintains that drip irrigation method is an established mean to offer significant and tangible benefits, and proved very beneficial for high-value crops particularly on the areas experiencing water shortage. Similarly according to Al-Amoud (2010) modern irrigation methods have greater acceptance among the farmers as they exhibit greater efficiency and in turn also result higher yields. His field experiments showed that drip irrigation systems could save water up to 60% and result 25% higher yields. Drip irrigation systems demonstrated three-fold higher water-use-efficiency than the conventional systems. He is of the opinion that a considerable amount of water could be saved due to the reduced evaporation water by employing modern irrigation methods compared to other traditional irrigation systems.

The numeric values to indicate their neutral attitudes toward both the irrigation methods range between 38 degrees and less than 59 degrees. The third category includes the farmers with positive trends. Not a single farmer (0%) showed the positive attitudes toward traditional irrigation methods whereas 28.3% farmers were found with positive attitudes toward modern irrigation methods. The study identifies a significant portion of the experimental population (respondents) with neutral attitudes toward irrigation methods. These facts and figures call for the launching of agricultural extension and training programs to modify the neutral attitudes into the positive attitudes toward the modern irrigation methods. According to Casewell and Zilberman (2001) the diffusion of the modern irrigation technologies is perceived as one way to restrict and reduce the harmful effects of water shortage particularly areas vulnerable to shortages of water supplies. Positive attitudes were expressed with the numeric value 59 degrees or more as revealed in the Table 8.2.

8.4.1.4 Correlation Between Some Personal, Socio-economic Characteristics and Attitudes of Farmers Toward Irrigation Methods

Table 8.3 illustrates that using the simple correlation Pearson coefficient, a positive correlation, significant (at the level of 0.01) was noticed between the characteristics like age, the acreage of land receiving traditional irrigations (independent variables) and attitudes of farmers toward the use of traditional irrigation (dependent variable). The correlation coefficients (simple) for age and area of land irrigated by traditional methods are reported as 0.216 and 0.188, respectively. The study reveals that farmers with more age and an increased acreage of irrigated lands use the traditional irrigation methods and are less inclined toward modern irrigation methods. However, an inverse relationship was found for the factors age and land receiving irrigation and the trend toward modern irrigation methods, and the simple correlation coefficients were −0.220 and −0.177 in this case.

A negative correlation (significant at the level of 0.05) between the number of family members working in agriculture, the annual income (independent variables) and attitudes of farmers toward the use of traditional methods of irrigation (dependent variable) was noticed in the study. Simple correlation coefficients for both the factors were 0.173 and 0.156 respectively. However, the proportional and significant (at 0.01) correlation exits for the farmers' attitude toward modern irrigation methods. The study indicates that greater the number of family members involved in the farm business and higher the annual incomes levels are, it would be more likely they adopt the modern irrigation methods and less likely they practice traditional irrigation methods.

Table 8.3 Correlations between some personal characteristics, socio-economic factors and the attitudes of farmers toward the irrigation methods

Independent factors	Attitudes of farmers toward conventional irrigation methods	Attitudes of farmers toward modern irrigation methods
Age	0.216**	−0.220**
Number of family members working in agriculture	−0.173*	0.261**
Area irrigated bytraditional method	0.188**	−0.177*
Annual income	−0.156*	0.255**
Level of education		0.502**
Length of stay at the farm		0.269**
Total area of the farm		0.296**
Area irrigated by modern irrigation methods		0.326**

*Significant at the level of 0.05; **significant at 0.01

As reflected in Table 8.3, a positive and significant correlation was found (at the level of 0.01) between the independent variables like: educational status; length of stay on the farm; the total area of the farm; Area of the land irrigated with modern irrigation methods; and trends of farmers toward the use of modern irrigation methods (as the dependent variables) with the correlation coefficients (simple) 0.502, 0.269, 0.296, 0.294, 0.326, respectively.

These results indicate that farmers with higher educational levels, big farms, total area of the farm, area irrigated by employing modern irrigation methods exercise a positive attitude toward the modern irrigation methods. Progressive farmers embrace the innovations readily and the findings of the study are in consistent with reported by Rogers (1995). According to Rogers (1995) farmers with high educational and income levels could have the important implications on their behavioral change and are more likely to adopt modern agricultural practices. The positive correlations realized for these factors indicate farmers with these characteristics would readily accept the extension messages and such farmers be used to influence the farmers having neutral and negative attitudes for the modern irrigation methods.

8.4.1.5 Correlation between Socio-economic Factors and Attitudes of the Farmers toward the Modern Irrigation Methods

In an attempt to explore the most important determinants and factors affecting the attitude of the farmers toward the use of modern irrigation methods, the use of regression analysis of step-wise was also administered. Farmers' attitude toward the use of modern irrigation methods was treated as the dependent variable whereas the personal characteristics, socio-economic features of farmers were considered as the independent variables. Factors like: the total area of the farm; educational status;

Table 8.4 Correlation between socio-economic factors and attitudes the farmers toward the modern irrigation methods

Variable	Partial regression coefficient	Cumulative value (P) regression coefficient of determination R^2	F-value
Total area of the farm	0.089	0.089	14.20**
Educational status	0.069	0.158	13.55**
Length of stay at the farm	0.063	0.221	12.88**
Annual income	0.025	0.246	11.59**

*Significant at the level of 0.05; **significant at 0.01

length of stay at the farm; and the annual income contributed significantly in changing the trends of farmers toward the use of modern irrigation methods and similarly the partial regression coefficients for all the four variables (Table 8.4) were positive and significant (at a level of 0.01) indicating the positive attitudes of farmers toward modern irrigation methods.

8.5 Conclusions and Recommendations

The study revealed that some 16.3 % of the farmers had the positive attitude toward the traditional irrigation methods whereas 83.7 % of them had a negative attitude. With regards to trends toward modern irrigation methods, about 28.3 % of the total respondents/farmers were found with positive attitudes and some 71.7 % with neutral trend. The results reflected the presence of significant and positive correlation for the factors like: age and the cultivated area irrigated by traditional methods, land area, and farmers attitude toward the use of traditional irrigation methods. The inverse relationship significant at the level of 0.05 between the number of family workers in agriculture, annual income and farmers attitude toward the use of irrigation methods, and show that both the total area of the farm, educational status, length of stay at the farm and annual income is responsible for the interpretation of 24 % of the variance overall trends of the farmers toward the use of modern irrigation methods.

Based on the results obtained, the study establishes the importance of the agriculture extension and training programs for the farmers of the area of research to mitigate the negative attitudes and modify the neutral attitudes toward the modern irrigation methods. Based on the findings of the study, following are the recommendations.

There is need to design the agricultural extension and training programs for the farmers in the research area to modify neutral attitudes of the majority of respondents toward the modern irrigation methods. It is imperative to organize and implement the campaigns to disseminate information among the various farmer groups through demonstration of the various irrigation methods. An extensive awareness campaigns for the farmers using various modern methods of irrigation are needed to conserve and maintain the long term sustainability of water resources. They must completely need to abandon the flood irrigation methods to minimize the wastage of precious water.

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Part II
Impacts of Soil Degradation in Terms of Agricultural Productivity

Chapter 9
Using Expert System for Sustainable Agriculture and Capacity Building in Degraded Soils

Gehan Abdel Hakeem Ibrahim Sallam

Abstract In Egypt to keep pace with the increasing food requirements for the rapidly growing population, there is an imperative need to reclaim and cultivate more agricultural areas. More attention should be given to increase the productivity of the degraded salt affected soils since they are potentially productive and require less investment, effort and time for restoring their productivity in comparison with other marginal arid lands. At present salt affected areas are either of poor or of low quality mainly due to the occurrence and development of salinity and sodicity problems, which hinder realization of the beneficial results of any agricultural inputs. The management of degraded salt affected areas is a multi-disciplinary strategy and joint efforts between key persons who involved in this process. The transfer of the knowledge from consultants and scientists to landowners and farmers to support their capacity represents the bottleneck for the development of degraded soils at the national level. Therefore, there is a need for an unconventional method to collect and transfer the knowledge and expertise in the degraded problematic soils domain to the general responsible persons who involved in this process. It promises great prospects for application and great economic value to adopt Expert System (ES) as an artificial intelligence and a management tool in accordance with the research results achieved by the degraded problematic soils ameliorating experts and their successful experiences. Therefore, a user-friendly expert system computer program was developed for the management of degraded problematic soils. The developed Management Expert System (HCMEXS) can help users to make appropriate decisions on the management of degraded soils to achieve the goal of soil improvement, it also helps farmer to make correct decisions on agricultural practice.

Keywords Expert system • Artificial intelligence • Degraded soils • Expertise • HCMEXS

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9.1 Introduction

The Nile Delta and the Nile valley of Egypt, is one of the oldest agricultural areas in the world. These have been under continuous cultivation for at least 5,000 years. The Delta of the Nile is one of the most fertile and intensively cultivated regions in the world (Abu El Azz 1971). The total Egyptian agricultural land is about 7.8 million feddans (1 feddan = 0.42 ha) that is almost entirely depended on irrigation. The majority of the delta is occupied by heavy clay soils, representing approximately 260,000 feddans.

Saline and sodic problems are mainly associated with heavy clay soils (FAO 1970). To offset the increasing demands for food production, attention has been given to solve the problems of saline and sodic heavy clay soils to increase their productivity since they are potentially productive and require less investment, effort and time for restoring their productivity in comparison with other types of marginal lands as well as new land reclamation. The risks of soil salinization are particularly acute in clay soils, this is due to the absence of an economically viable drainage method to control salinity (Rycroft and Amer 1995). Therefore, there is an urgent need to establish the limits for sustainable farming on heavy clay soils and to devise economical types of drainage systems. It was obvious that the drainage management for problematic heavy clay soils is a multi-disciplinary process concerning crop variety, water management, soil improvement, drainage management and socio-economic aspects. Hence, the management of problematic heavy clay areas requires a multi-disciplinary strategy and joint efforts between key persons who involved in this process.

Since the mid eighties advances have been made with draining and reclaiming most of the problematic heavy clay areas to maximize the food production (DRI 2001). After these years of comprehensive progress, there has been a lot of data on the research and practical experiences and formation of a comprehensive management system for heavy clay soils. The transfer of this knowledge from consultants and scientists to the responsible persons in the field scale, landowners and farmers represents the bottleneck for the development of heavy clay soil on the national level.

Therefore, it was necessary to develop a comprehensive multidisciplinary strategy for management of problematic heavy clay soils and develop a tool to transfer it to the general public of farms and the responsible persons in the field scale.

Under such conditions, a Heavy Clay Management Expert System (HCMEXS) has been developed to help users to make appropriate decisions on heavy clay management so that the goal of improvement of heavy clay soil can be achieved, it also helps farmer to make correct decisions on agricultural practice.

9.2 Expert System

Management of water resources is becoming increasingly complex. Emerging computer based decision support systems, and technologies such as expert systems, geographical information system, and decision analysis methodologies are being used to enhance decision-making in this complex environment (Fontane 1992).

Expert systems are computer programs that manipulate knowledge to solve a specific problem in the same manner as the human experts using common sense, logic and experience. However, an expert system must achieve the same levels of performance in the domain of interest that human experts can achieve. Once an expert system is developed, we can see the advantages of this "Artificial Expertise"; it is permanent, easy to transfer and document, consistent and inexpensive to use (Jones et al. 1992).

Expert System application to drainage and irrigation management is a new subject. Unfortunately little has been published on expert systems for water management that are being used routinely and therefore most of the applications of artificial intelligence concepts would be most appropriately classified as still in the prototype development phase (Fontane 1992).

During the past years, there were some related expert systems applications that have been developed. In China an expert system for the comprehensive amelioration of the saline-sodic soil of Huang-Huai-Hai plain was developed (Wang 1992). An expert system for Border Irrigation Management (ESBIM) model was developed. The system is a knowledge-based expert system for improved irrigation management of freely draining graded borders (Muhammed et al. 1994). An Expert Geographical Information System (EXGIS), was developed for the evaluation of natural resources (Yialouris 1995). Crop Information Management System (CIMS) was developed in 1997 (Brennan et al. 1998). The Work Efficiency Institute in Finland had developed two knowledge-based computer programs for planning plant production (Palonen 1994).

In Egypt, an Expert System Model for Generating Water Policies (ESMGWP) has been developed in the Ministry of Water Resources and Irrigation to guide the decision maker (DM) to generate realistic water policies (Mohamed 2001). In 1989, the Egyptian Ministry for Agriculture (MOA) initiated the Expert Systems for Improved Crop Management (ESICM) project with main objectives of building an expert system laboratory within MOA that has the capacity to identify, develop, and maintain expert systems. Since that time several expert systems were developed. The first expert system has been developed for cucumber seedling production under plastic tunnels (El Dessouki et al. 1992). Another expert system for the technical feasibility of Citrus cultivation (CITEX/feasibility) was developed (Salah et al. 1992). In 1995, an expert system was developed for tomato disorders (El-Shishtawy et al. 1995). In 1995, an integrated system for irrigated wheat crop management in Egypt (NEPER WHEAT) was also developed (Schroeder et al. 1995). In 2000, Grapes Production Management Expert System (GRAPEX) was developed to give advice to the grapes growers in Egypt to improve grape productivity quality and quantity (Edrees et al. 2000).

Rafea and Shaalan (2001) indicated that, the task of building an expert system involves: information gathering, domain familiarization, analysis, design, and implementation efforts. The adapted methodology of knowledge engineering includes three main activities to produce successive versions of expert system. These activities are:

- Knowledge acquisition,
- Knowledge analysis and modeling, and
- Knowledge verification and validation

9.2.1 Knowledge Acquisition

Knowledge Acquisition is considered the bottleneck of the expert system building process. In fact, it has been said that knowledge acquisition is probably the most important task in the development of an expert system. Traditionally, human experts have been the source of knowledge for expert systems. Before developing the system, qualified experts must be located. Those experts must have the expertise and also have time to work with knowledge engineers.

The term 'expertise' is used to mean all of the expert system's knowledge before it is reduced to the formal rule sets of a knowledge base. Three different activities were planned to acquire expertise and knowledge base required to develop the Heavy Clay Management Expert System (HCMEXS). Each of these activities has a role in acquiring knowledge about heavy clay management domain. The first activity was reviewing literature in several related fields to study and analyze previous experiences in the field of drainage of problematic heavy clay soils and gather the available knowledge from textbooks and research publications.

The second activity was acquiring knowledge through the measurements program in the case studies areas to obtain and evaluate the existent experiences in these areas and through interviewing leading experts. The third activity was a questionnaire comprising Drainage and Reclamation and Improvement experts. The questionnaire was the final and the main source of knowledge acquisition. The objectives of the questionnaire were to bring together local expertise of the experts in the field of land reclamation and improvement and drainage and arrive at a final assessment of the state of drainage and crop production in the heavy clay areas. This questionnaire aims at bringing all information together and defines how to proceed with work in the reclaimed heavy clay areas.

Drainage and Reclamation and Improvement experts in Egypt were contributed in this study. The expertise of the experts were collected through the questionnaire that provides knowledge for the different factors that affect the drainage management of problematic heavy clay soils such as the; irrigation system performance, crop data, soil improvement including leveling, leaching, plowing, sub-soiling and gypsum application and drainage system. Two sets of questionnaires were sent out to 20 different experts.

Questionnaire I was designed to provide knowledge of the experts of drainage of problematic heavy clay soils such as their approach, and their decision process regarding different alternatives in management and planning of drainage. Questionnaire II is specific to the experts of reclamation and improvement of heavy clay soils. Of 20 experts to whom the questionnaires were sent, 13 Drainage experts replied to questionnaire I, and 7 reclamation and improvement experts replied to questionnaire II. Finally, the collected expertise of the experts who contributed in this study was combined in one copy.

On the other hand, the main persons who involved in the process of the management of problematic heavy clay soils in Egypt include The Egyptian Public Authority for Drainage Projects (EPADP) members who are responsible for the designs, implementation, operation, maintenance and development of drainage systems, the Executive Authority for Land Improvement Projects (EALIP) members who have the overall responsibility of all types of land improvement in Egypt and play a central role to implement the strategy of the government for better utilization, conservation and restoration of land productivity and the farmers who are the key persons of all processing in these areas.

Based on above, three sets of questionnaires were prepared and sent to EPADP, EALIP and farmers in the predefined areas of heavy clay soils in Egypt to be filled. In total 20 copies of the EPADP questionnaire were filled and returned. In case of EALIP, 6 copies of the questionnaire were filled. Seven copies of the farmer questionnaire were also filled through special interviews with them in their fields in our case studies areas. The collected knowledge from these 33 copies of questionnaire combined with the collected expertise of the experts who contributed in this study was used to form the database of the expert system.

9.2.2 Conceptual Model and Knowledge Base

The acquired data was analyzed according to Knowledge Acquisition Development System (KADS) approach to get the required database for the expert system and define the main concepts and properties of the system. The documented knowledge was analyzed aiming at identifying concepts, properties of these concepts, and relations. The relations are either between concepts or between expressions. Concepts and relations found to be used by more than one subsystem were identified and grouped in a common knowledge base. The Heavy Clay Management Expert System (HCMEXS) is divided into eight subsystems: irrigation system performance; crop management; soil improvement; leveling; sub-soiling; gypsum application; drainage and economic.

For every subsystem the main concepts and properties were defined, as below:

- If it is nominal or numerical,
- If it has single value or multiple value (S/M),

- If the source of value would be the user or it would be derived from the model,
- The expected value for each property, and
- The prompt that would to be used to define the value of the property in case of the source of the value is the user.

Consequently the system rules were generated from the acquired concepts properties for each subsystem in the base that the "Right Hand Side" is the rule conclusions part and the "Left Hand Side" is the conditions part. HCMEXS Expert System comprises 461 rules. The flow chart of HCMEXS is shown in Fig. 9.1. This flow chart shows the main inputs and outputs for every subsystem and the interrelation between the different subsystems.

9.2.3 Expert System Implementation

The Expert System HCMEXS was implemented using SICStus Objects and KROL programming language. The user interface was implemented using Tcl/Tk/Tix packages. The main screen of the developed expert system is shown in Fig. 9.2. It consists of eleven buttons, the about button gives a brief description for the system, the new session button is used to run the system for new case without needing to restart the system, the Exit button is used to end the system and each one of the others eight buttons is considered with a different subsystem of the expert system.

9.2.4 Irrigation System Performance Subsystem

The first input data screen in the irrigation system performance subsystem is inquiring about the availability of the irrigation water in the area and the second one about the use of drainage water in irrigation. If the answer for the availability is no, then another screens would appear to ask the user about the existing conditions of the irrigation system. Finally the result screen will appear including suggested operations to improve the system and the different improvement rate in relation to the different solutions and the area location as shown in Fig. 9.3.

9.2.5 Crop Management Subsystem

The input data for this subsystem are soil salinity, irrigation water quality and salinity and volumetric water content of the soil. The output screen will appear including suggested crop names (Fig. 9.4). For every crop there will be details including cultivation season; irrigation water quantity; average crop yield; fertilizations and leaching water quantity, method and precautions.

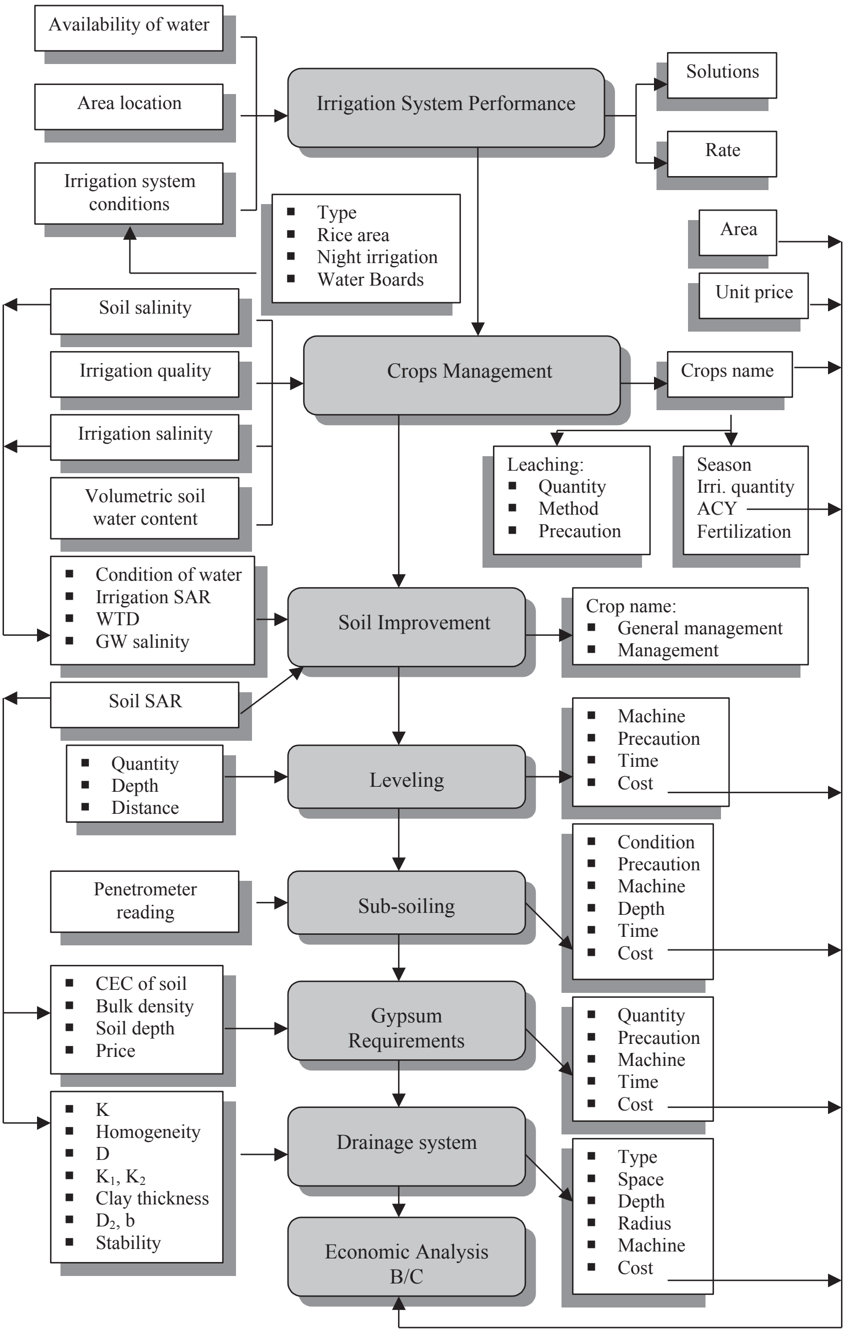


Fig. 9.1 HCMEXS flow chart

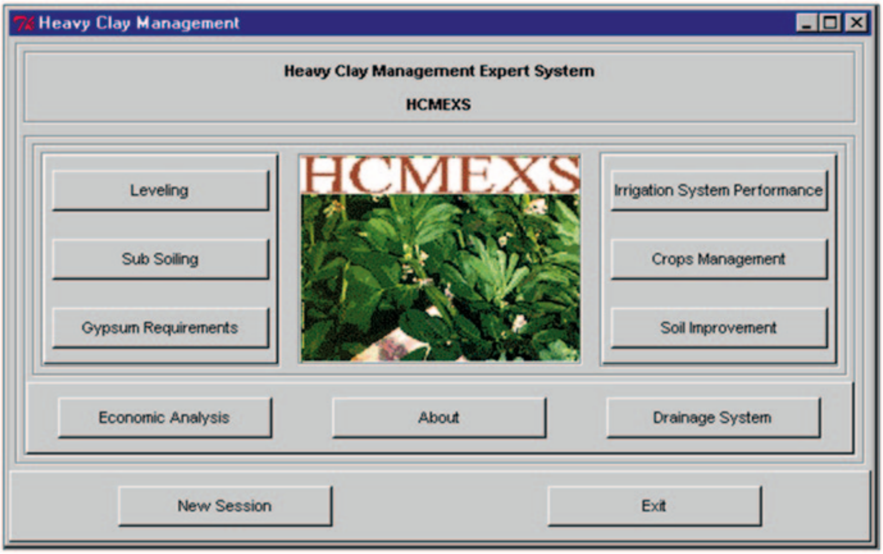


Fig. 9.2 HCMEXS main screen

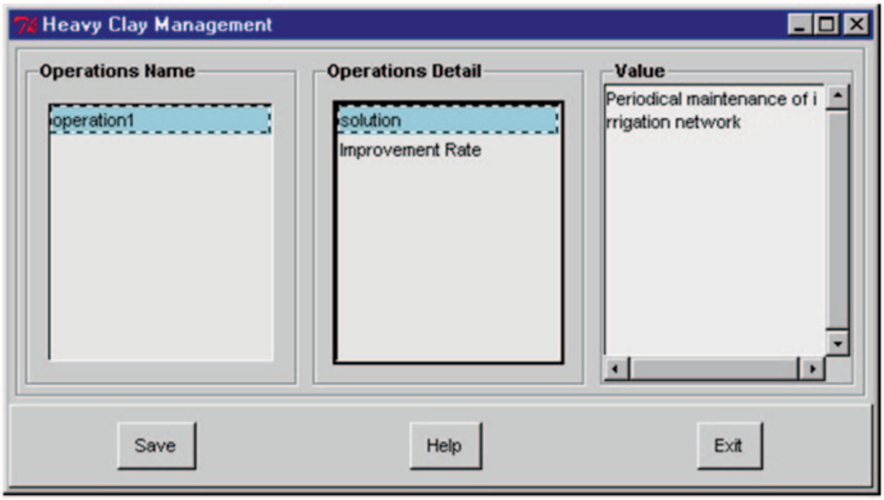


Fig. 9.3 Output screen of irrigation system performance subsystem

9.2.6 Soil Improvement Subsystem

The input data for this subsystem are the condition of irrigation water availability and the sodium adsorption ratio and salinity of the soil, the sodium adsorption ratio

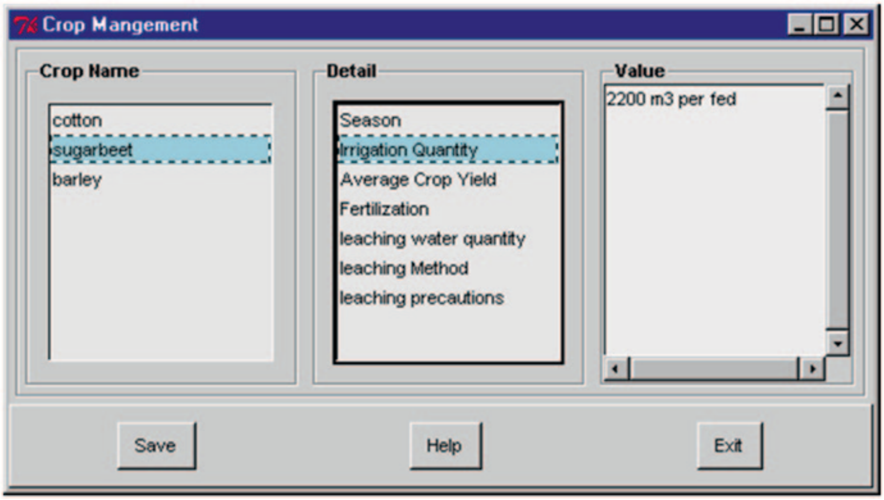


Fig. 9.4 Output screen of crop management subsystem

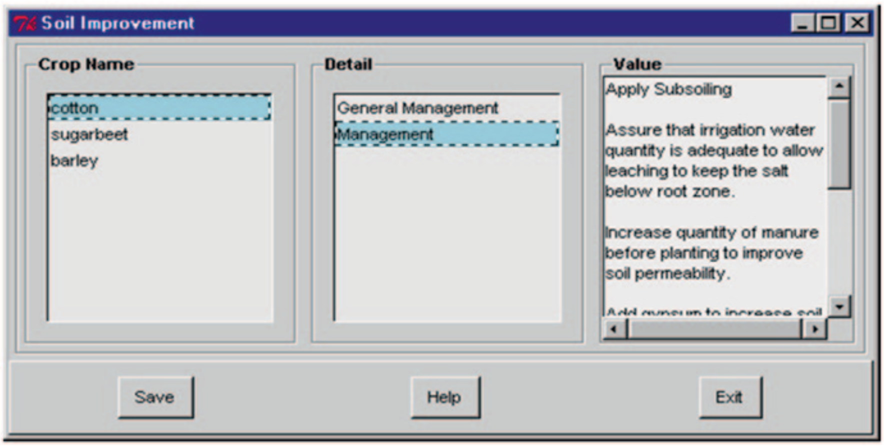


Fig. 9.5 Output screen of soil improvement subsystem

and salinity of the irrigation water and the depth and salinity of the ground water table. The output screen will appear including the suggested crops that resulted from the subsystem of crop data. There will be details including general management and specified management for each crop (Fig. 9.5).

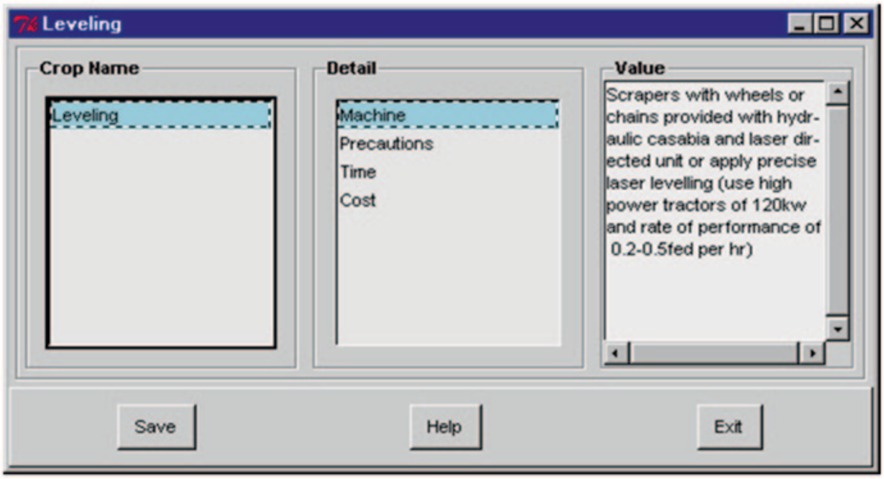


Fig. 9.6 Output screen of leveling subsystem

9.2.7 Leveling Subsystem

The input data for this subsystem are the quantity of removed soil, depth of cutting and the distance of removing soil. The output screen will appear including the used machine, leveling precautions, leveling time and cost as shown in Fig. 9.6.

9.2.8 Sub-soiling Subsystem

The input data for this subsystem is the measurement of soil compaction measured with penetrometer at 25–50 cm depth. The output screen will include the recommended condition, precautions, machine, depth, time and cost of sub-soiling as shown in Fig. 9.7.

9.2.9 Gypsum Requirements Subsystem

The input data for this subsystem are Sodium Adsorption Ratio (SAR) of the soil, the bulk density of the soil (g cm $^{-3}$), cation exchange capacity (meq/100 g of soil), the depth over which the soil structure has to be improved (cm) and finally the price of one ton of gypsum. The output screen will include the required quantity of gypsum, precautions, machine, time and cost of gypsum application as shown in Fig. 9.8.

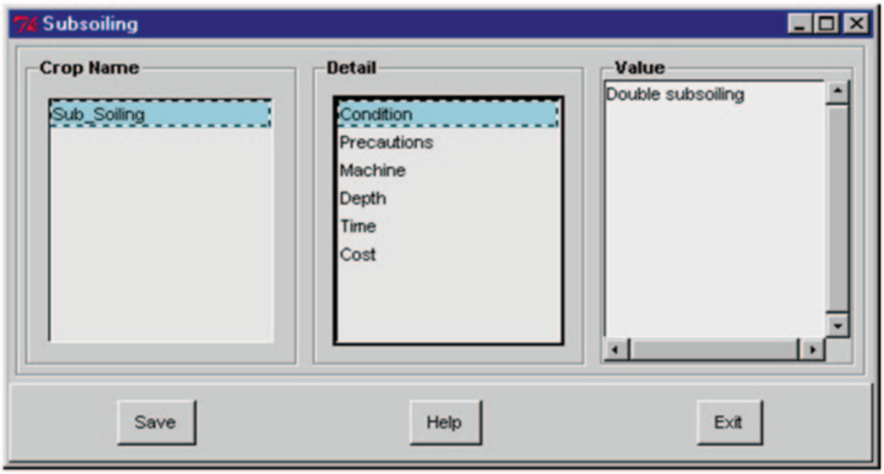
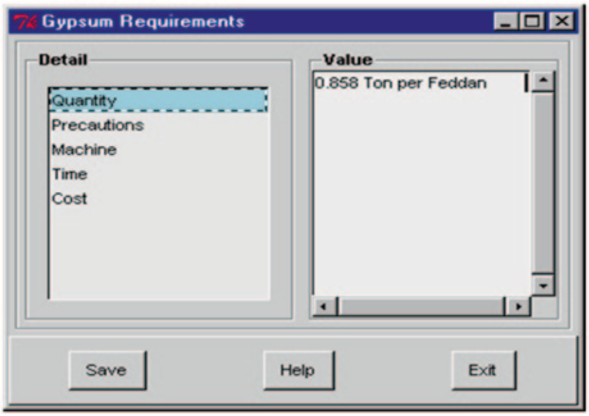


Fig. 9.7 Output screen of sub-soiling subsystem

Fig. 9.8 Output screen of gypsum requirements subsystem



9.2.10 Drainage System Design Subsystem

The main input data for this subsystem are the hydraulic conductivity and the Sodium Adsorption Ratio (SAR) of the soil. If the suggested drainage system would be subsurface drainage system, according to the acquired knowledge, and the hydraulic conductivity is more than 0.1 m per day, then the system will ask the user to enter the value of the depth to the impermeable layer from the drain level. If the suggested drainage system would be subsurface and the hydraulic conductivity is less than 0.1 m per day, then the system will ask the user about the homogeneity of the soil profile. If the soil profile is homogeneous then the user must enter the

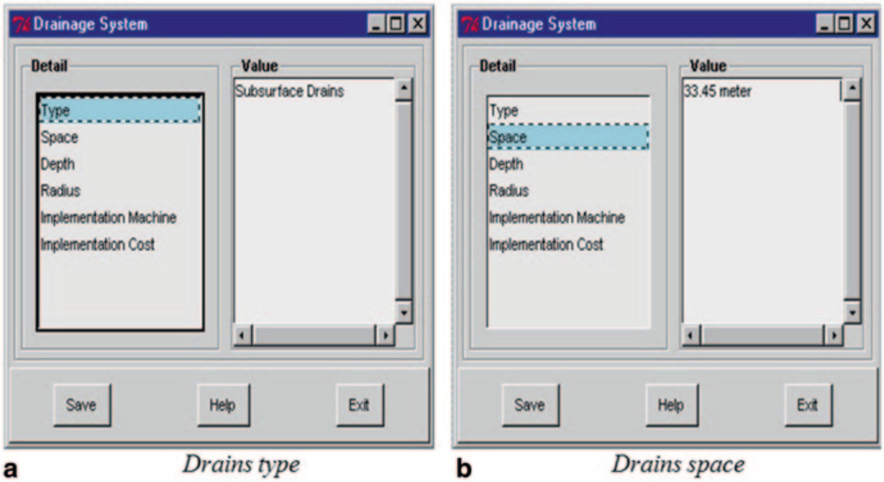


Fig. 9.9 Output screen of drainage system design subsystem

depth to the impermeable layer. However, if the soil profile is not homogeneous, the user will enter the values of the thickness of the clay layer (Dc), hydraulic conductivity of the more permeable layer (K2), vertical hydraulic conductivity of the clay layer (K1), thickness of the bottom layer (D2), and the width of the trench (b) in which the pipe is installed. The output screen will include the type, space, depth and radius of the field drains in the both type of drainage (surface or subsurface) and the machine and cost of implementation in the case of subsurface drainage system (see Fig. 9.9).

9.2.11 Economic Analysis Subsystem

In this subsystem the first screen will appear asking the user to enter the proposed crops to be cultivated in every season as shown in Fig. 9.10. Consequently, a second screen will appear to enter the cultivated area and the unit price of each crop as shown in Fig. 9.11. The data in this screen must be saved. If the other subsystems, or some of them, were not be run before applying the economic subsystem then the system will ask the user to enter the required data to run these subsystems to get the final economic evaluation. The output screen will include the benefit cost ratio (B/C) of the whole process of the heavy clay management as shown in Fig. 9.12.

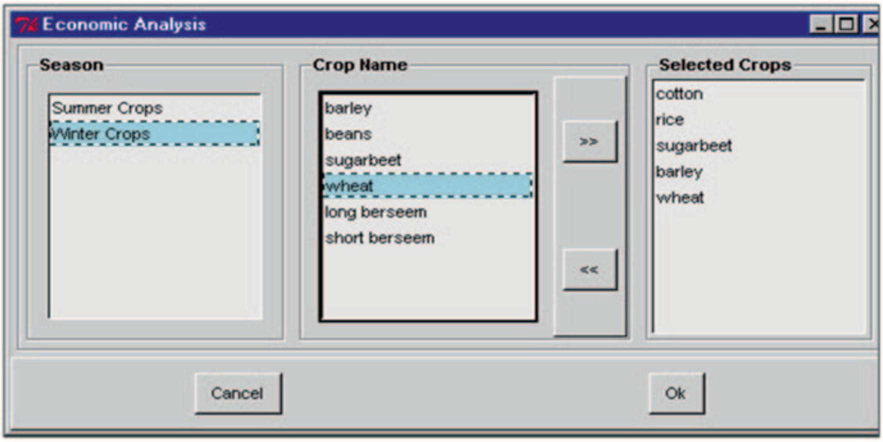


Fig. 9.10 First screen of economic analysis subsystem

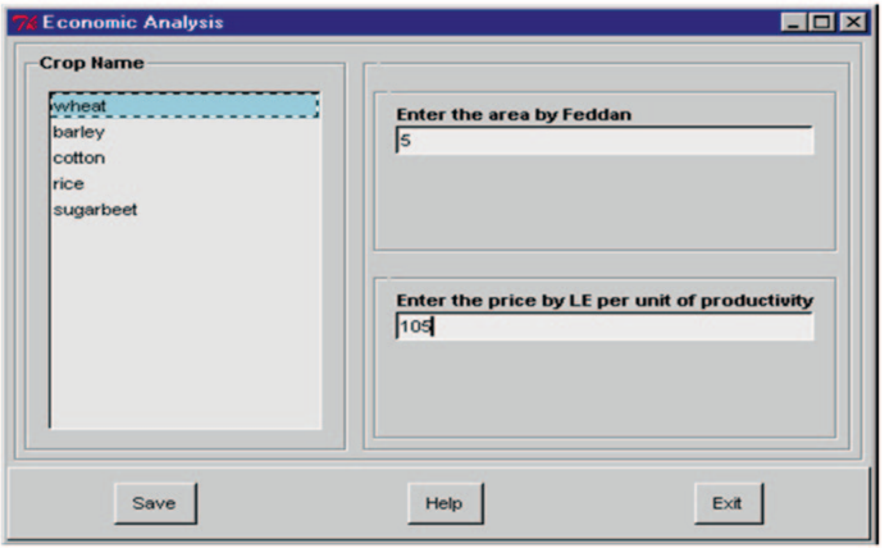


Fig. 9.11 Second screen of economic analysis subsystem

9.2.11.1 Expert System Verification and Validation

Verification and Validation is the demonstration of the consistency, completeness and correctness of the software. An incorrect system can make costly errors or may not perform up to expectations. In either case the decisions generated may be wrong or inappropriate.

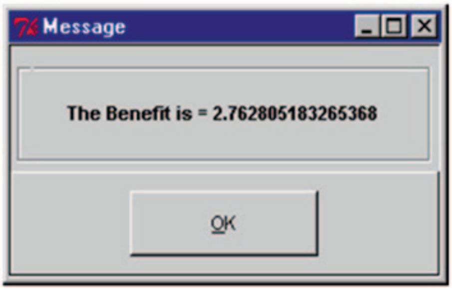


Fig. 9.12 Output screen of economic analysis subsystem

Verification can and should be done at the end of each of phase of the life cycle. Simply, it is building the system right. The verification techniques include two phases, the first one during the development stage and the second one after the development stage. During the development stage of the expert system HCMEXS, the non case-based techniques include tracing, spying and other traditional debugging techniques were applied. Tracing and debugging techniques were applied using dummy data, to test the correctness of the developed rules, and the expected behavior of the inference engine.

The 'after development stage' which is called 'testing' or 'examination' stage was aimed to find the discrepancies between the design and requirements specifications against implementation and finding the discrepancies between expected behavior of the system against the actual behavior. Any encountered differences were documented so that system maintenance was accomplished by walking through both of the designs and the requirement specification documents and making the required correctness to clear any discrepancies.

After the development of the expert system HCMEXS, the case testing Validation technique was applied by preparing "Typical Cases". The developed expert system was tested with two typical cases. These cases were selected to serve requirements satisfaction as spelled out in the requirements specification document. This Validation technique aims at testing the developed expert system and finding the discrepancies between expected behaviors of the system according to the knowledge of the experts against the actual behavior.

9.3 Conclusions and Recommendations

It was clear that, the problems in the heavy clay soils are not a single factor. Problems concern crop variety, water management, soil improvement, drainage management and socio-economic aspects. Hence, the management of problematic heavy clay areas should be a multi-disciplinary strategy and joint efforts between key persons who involved in this process. Therefore, it was of great prospects for application and great economic value to adopt Expert System (ES) as a management tool in accordance with the research results and experience of consultants and scientists.

The developed user-friendly expert system computer program HCMEXS can help users to make appropriate decisions on heavy clay management, it also helps farmer to make correct decisions on agricultural practice. It is also recommended to involve the Geographical Information System (GIS) technology within the developed expert system (HCMEXS) as GIS provide new tools to collect, store retrieve, analyze, and display spatial data in a timely manner and at low cost.

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Chapter 10
Managing Degraded Lands for Realizing Sustainable Agriculture Through Environmental Friendly Technologies

Mirza B. Baig and Shabir A. Shahid

Abstract Ever increasing population and shrinking fertile and productive agricultural land resources are viewed as the biggest threats to sustainability of world's resources. To feed more mouths, and reverse land degradation, many biological, engineering, and chemical strategies have been tried; unfortunately these have met partial success. Land and environmental degradation is on the increase, declining the productive capacities of the fertile soils. The land issues like soil erosion (water and wind), salinity and waterlogging; and desertification are hammering crop yields and have severely disturbed the ecosystems in Pakistan. In this chapter attempts have been made to enlist factors and causes responsible for land degradation and resultant lower crop-yields. The prime causes of land degradation and low crops yields in Pakistan are: poor irrigation and drainage practices, deforestation, over-grazing, loss of biodiversity, water scarcity, frequent droughts, migration and unending new residential areas, mass-scale agriculture, flash floods, rising populations, prevailing poverty, and weak link between research-extension-farmers. Degraded lands can be rehabilitated by employing an integrated approach comprising physical, chemical, hydrological, and biological methods. However, it would require scientific diagnostics of the degradation level and to be able to make informed decisions to combat the issues in a holistic way. It is imperative that technical programs must be intervened/interwoven with the extension education components aiming at creating awareness, capacity building, and the active participation of farming community including civil society, NGOs, women groups and youth folks.

Keywords Salinity • Waterlogging • Erosion • Saline agriculture • Community involvement • Women groups

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10.1 Introduction

Pakistan is spreading over an area of 79.61 million hectare (mha). The arable lands in Pakistan are 23 million ha (PCST 2005a). Roughly quarter of the total area available for cultivation is suitable for intensive agriculture. Desertification and degradation processes have affected about 68 million ha of fragile lands across the country (Sheikh and Soomro 2006; Khan et al. 2012). Currently Pakistan sustains about 180.7 million inhabitants (Economic Survey 2011–2012), and the population is increasing at the rate of 2.1 % per annum (Anjum et al 2010), and hence the country has no option other than over-exploitation of its fragile natural resources including soil to produce more food to meet the ever increasing demands of growing population. As a result of these urgencies, the sustainability of natural resources and environmental protection and conservation issues have arisen in the country. On the other hand, land-holdings are getting further sub-divided and fragmenting due to prevailing law of family inheritance, swallowing good agricultural-lands, primarily meant for crop production (Zia et al. 2004; Baig and Straquadine 2011). Resultantly, today per capita cultivated land is decreased to only 0.16 ha (FAO 2000; Sheikh and Soomro 2006). In addition, significant areas of current agricultural lands are being taken over by urbanization and industries. The climate change will add further constraints to achieve and ensure food security in Pakistan. Thus, the future requirements of food and fiber are to be met through agricultural enhancements on finite land resources.

Keeping in view the current land degrading status and the future threats plus emerging food and fiber requirements for the ever-increasing population, concerted efforts have to be made to enhance agricultural productivity from the available resources. Such an agricultural enhancement is possible through, adopting innovative technologies, such as conservation agriculture (no or low-tillage, rainwater harvesting, use of alternate water sources (treated wastewater) for agriculture, using salt and drought tolerant crop varieties, climate smart irrigation practices, and enhanced fertilizer use efficiency. Despite, agriculture in Pakistan has realized an impressive growth during the past many decades, yet the average yields of all crops realized by the farmers still happen to be lower than their potential and yields realized by the progressive farmers and research organizations (PCST 2005a). Wide yield-gaps exist between the average and potential crops yield (Table 10.1). Unfortunately, crop yields of wheat, rice, and maize crops are stagnant regardless of efforts being made by research and extension services in the country, the yield stagnation is thought to be due to deteriorating soil-resources (Zia and Rashid 1995; Zia et al. 2004; PCST 2005b) and impact of climate change that yet has to be quantified.

At this juncture and critical scenario, several environmental threats have put the sustainable economic future of the country at stake. Among all these, land degradation perhaps appears to be the most prominent threat impacting the environment and the production systems (Shah and Arshad 2006). Among the other issues faced by the national agriculture, quality improvement and complete rehabilitation of degraded land resources should be kept on high national agenda to realize

Table 10.1 Potential yield and yield gaps of various crops (tonnes per ha). (Source: Pakistan Statistical Pocket Book (PSPB 2005). Government of Pakistan. Statistics Division, Federal Bureau of Statistics. Islamabad, Pakistan)

Crops	Potential yield	National average	Yield gaps
Wheat	6.4	2.2	4.2
Rice	9.5	2.0	7.5
Maize	6.9	1.5	5.4
Sugarcane	160.0	46.0	114.0

sustainable agriculture. Therefore, the situation requires identifying the causes and factors degrading our soil-resources and devise socially acceptable, economically viable and practicable and feasible technologies. The objective of this chapter is to realize sustained crop yields; outline improvement strategies to recover soil health and productivity. In this chapter, efforts have been made to discuss land issues, improvement measures to devise suitable farming systems focusing on producing more food, conservation of natural resources while ensuring clean and pollution-free environment.

10.2 Threats and Root Causes of Land Degradation in Pakistan

Land has been recognized as a very precious natural resource, sustaining human and plant life (Bhatti and Khan 2012). The soils of Pakistan used to be very fertile and were producing enough to feed every single individual of the country. Today the country's healthy lands have low fertility status plus show symptoms of various ailments. Many researchers (Zia and Rashid 1995; Zia et al. 2004; Ahmed and Qamar 2004; Shah and Arshad 2006; Sheikh and Soomro 2006; Anjum et al. 2010; Khan et al. 2012) have enlisted different types of land degradation in Pakistan and have tried to identify the possible reasons and causes, however, important ones are: poor irrigation systems, insufficient drainage, deforestation, water erosion, over-grazing, water shortage, frequent droughts, farmer's migration to urban areas, intensification of agriculture, flash floods, population pressures, high poverty levels and soil salinization and sodication. Poverty and lack of farmers' education remain the prime reasons causing land degradation. Land degradation acts as a strong barrier to sustainable land management and prevents the intensification of agriculture.

Agriculture sector will remain the leading driving force for national growth and the major contributor to the economy of Pakistan. Having the direct or indirect involvement of about 62 % of the country's population, agriculture sector contributes 21 % to the GDP and employs 45 % of the total workforce. The sector furnishes the raw materials to the industries and provides about 60 % of foreign exchange earnings. Today an increase in agricultural growth has become unavoidable and in the near future Pakistan will have to double its cereal production, especially wheat, to meet food requirements of its ever-growing population. Ahmad and Zia (2003) reported that the introduction of high yielding crop varieties, application of high rates of farm inputs and over-exploitation of natural resources have caused a number of environmental problems. On the other hand, due to the economic pressures, monoculture oriented commercial agriculture (cash crops) and short fallows accelerated the land degradation. To achieve agricultural enhancements, farmers are using high rates of fertilizers and apply heavy and frequent irrigations. These practices could build-up of high chemicals that may reflect in the agricultural commodities. In addition, non sustainable agricultural practices lead to waterlogging and salinization of prime agricultural lands. After working 8 years in Pakistan, the SLMP (2011) discovered that unsustainable land management practices is another cause of land degradation that comes in the form of soil erosion, loss of soil fertility and associated crop productivity, flash floods, sedimentation of water courses, and deforestation and the associated loss of carbon and biodiversity assets. The report further ascertains that this land degradation will continue at an accelerated pace, causing severe damages to the structural and functional reliability of the already stressed ecosystems of the country. In addition, some workers believe that introduction of generous subsidies offered by the government to realize intensification in agriculture is likely to enhance the problem such as degradation of the agro-ecosystems, pollution of streams and rivers (pesticides, fertilizers remains), nutrient mining, and reduction or elimination of beneficial micro-organisms. Commercial investments in monoculture oriented agriculture may ultimately lead to the loss of traditional local agriculture production systems and valuable crop varieties.

10.2.1 Declining Water Resources

Best local agriculture production can be achieved only if best soils and sufficient water resources are made available. Looking at the world map of physical and economical water scarcity produced by IWMI, it reflects that most of Pakistani lands fall in the highly water scarce areas. In country, either development of water resources is approaching or has exceeded sustainable limits, more than 75 % river water flows have been diverted to agriculture, industry or domestic purposes.

Few decades ago Pakistan used to be a water surplus country. However, presently water availability has been extremely declined and hence water scarcity has emerged as an extremely sensitive issue. Farmers are competing for water with other sectors in the sowing seasons. If the water continues to be used at the current rate, it is projected, that within the next five decades, some 90 % of all available sources of water will be completely consumed. According to Khaliq (2007), current surface water resources are meeting only 40 % of total water requirements of the country. Similarly estimates made by the International Water Management Institute (IWMI) reveal that Pakistan would be among the top 17 water scarce countries that may face severe water shortage by 2025. According to PCST (2005a), the countries having less that 1,000 m^3 per capita per year will start facing persistent but an acute shortage of water. At present, in Pakistan about 1,250 m^3 per capita water is available annually, indicating the threatening water stress situation, the country is going to face. While discussing the reasons negatively impacting the water resources, Ahmed (2007) reports that over-using of water and application of heavy irrigations to the crops more than their requirements would certainly and seriously harms the water resources. Being an agricultural based economy, the availability of water for irrigating the crops in the growing seasons is critically important. Qureshi et al. (2010) ascertains groundwater has an essential role in agriculture. However, when efficient irrigation application methods are employed significant water losses can be minimized and checked. However the prime factors responsible for low water use efficiencies include: water losses in the poor water conveyance systems (from source to fields) in the open and poorly maintained and structured water-courses and channels, unleveled agricultural fields; over-watering (including over-pumping of groundwater) in the absence of modern irrigation systems (drip, sprinkler, subsurface etc.). In order to address the demand of growing population, and an effort for climate change adaptation, the needs to focus on enhancing agricultural productivity through better protection and management of the limited water resources. Use of alternate water sources such as treated wastewater (rich in nutrients-NPK), will reduce farmers dependency on costly fertilizers, and can also help improving water and nutrient use-efficiencies. To realize the inherent and potential benefits of such technologies, it is imperative to make them available to the farmer, (the ultimate stakeholder) by developing a strong link between research-extension-farmer.

10.2.2 Issues Related to Irrigation and Drainage Practices

The scientists have agreed on the consensus that efficient irrigation systems are must to intensify agricultural production and to optimize water uses. Commonly used flood irrigation leads to significant wastage due to seepage and evaporation. Despite the world's largest contiguous canal irrigation network in Pakistan, its working efficiency is 40–45 % (Economic Survey 2010–2011) and 30 % as national average (Bhutta and Smedema 2007). About 80 % of cultivated area receives irrigation water from these canals and appreciable agricultural productions (90 % of agricultural output) are realized in the country (PCST 2005a). At the same times, the overall poor water management at the system and farm levels is causing waterlogging and salinization in the cultivated areas.

Despite the presence of magnificent canal irrigation system, realization of stagnant and lower crop yields than their potential has always been a concern after the era of green revolution. The situation prompted Shah et al. (2011) to identify the reasons for lower and poor crop yields and factors responsible include: inadequate and poor drainage, excessive water losses, outdated land and water management practices, split, patchy and fragmented land-holdings, and waterlogging and salinity. In the country the waterlogging issues arise due to the human activities like: the hindrances caused in natural drainage due to construction of roads; improper alignment and poor maintenance of irrigation channels; and insufficient drainage of excessive rainwater. Once the agricultural areas are affected by waterlogging and salinization, it also threatens the ecosystem in the nearby vicinity.

10.2.3 Droughts and Flash Floods

Pakistan suffered from severe drought during 1997–2003, consequently water shortages for humans, livestock, and agriculture were experienced, and in addition the agricultural fields and infrastructures were badly affected. Continuing water shortages and droughts have negatively affected the Pakistan's economy, and increased vulnerability and hardships particularly for the rural communities. Frequent droughts in Pakistan and elsewhere cause widespread damages even to the biological potential of the fertile lands. Some 3 million inhabitants and 7.2 million livestock heads have been adversely affected by the droughts experienced in many parts of the provinces of Balochistan, Sindh, and southern Punjab. A sizeable portion of human population lost their lives and thousands of livestock and wild ungulates also got perished due to the drought conditions. The droughts also rigorously influenced livelihoods of locals and in cases forced them to migrate toward the places where they could find jobs, feed themselves, and provide feed, fodder and forage to their livestock. Consequently, such mass-scale migrations disrupted traditional land use patterns, resulting in the disappearance of permanent loss of traditional management practices and enhanced the land degradation and desertification processes.

Similarly, flooding has been a regular feature occurring due to the heavy downpour received during the monsoon season in arid and semiarid regions of the country, causing losses of millions of dollars and thousands of human lives. The country experienced the worst flood of the history of mankind in 2010 that washed away the thousands of human beings, livestock, and tonnes of standing and stored agricultural produce causing damages of millions of dollars. Excessive flooding washes away the top soil, buries it under the infertile sediments and obstructs cultivation; such phenomenon results in the land degradation and loss of biodiversity.

10.2.4 Deteriorating Range Resources Due to Overgrazing

Spreading over an area of 28.5 million ha (32.4 %), the rangelands are in the highly deteriorated conditions. Today, rangelands are highly vulnerable to degradation due to climate change and anthropogenic activities. Despite, rangelands are still sustaining some 163 million of livestock heads (PCST 2005b; Economic Survey 2010–2011) making Pakistan the fifth largest producer of milk in the world (PCST 2005b; Economic Survey 2010–2011; Baig and Straquadine 2011). Livestock rearing is an important component of Pakistan's agriculture sector and an income generating activity for small farmers contributing to livelihood improvement. As such 35–40 million rural masses depend upon livestock and 30–40 % of their incomes are generated from this sector (Economic Survey 2010–2011). Approximately, the sector accounts for 55.1 % to the agriculture value added and 11.5 % to GDP. High demand of livestock products (milk, butter, meat) of ever increasing population and the present situation of the farmers, perhaps this pressure doubled livestock number since 1967, leading to overgrazing and exceeding the carrying capacity of rangelands and the result is rangelands degradation. Overgrazing degrade the rangelands in many ways, such as but not limited to, soil compaction, loss of vegetation, and subsequent denudation leading to soil erosion, loss of productive surface soil (rich in organic matter), and ecosystem fragmentation. Recent estimates (Ahmad and Zia 2003) reveal 48.3 % rangelands are completely degraded, declining 15–40 % of their capacity to support livestock needs. Providing another estimate Farooq et al. (2007) report that rangelands of Pakistan, covering an area of 50.9 mha (63.9 %) are a very precious resource base for livestock, however it is diminishing, leading to low livestock production and loss of productivity.

On the other hand Anjum et al. (2010) report the degradation of more than 60 % rangelands producing even less than one-third of their potential due to overstocking beyond their carrying capacity. They further noted that over-grazing of rangelands had brought their productivity levels as low as 15–40 % of their potential. In addition, aridity and prolonged droughts have further adverse impacts on their vegetation (Farooq et al. 2007). Such deteriorated rangelands are difficult to rehabilitate. In this situation, it would be wise to devise and launch an integrated rangeland management approach to keep its rangelands protected and productive (sustainable) while maintaining a healthy balance between vegetation and livestock (Intercooperation Pakistan 2006). There is a need to develop grazing systems in the rainfed areas like: closing and re-opening at the appropriate times. To enhance vegetation on rangelands and ensure the year-around availability of feed for the livestock, re-seeding with the palatable grasses, and leguminous species remains imperative.

10.2.5 Diminishing Forest Resources

Forests play pivotal role in the national economies through sustaining the supply of wood and wood products. In addition forests also improve environmental quality through carbon sequestration. Worldwide, land use change (forests to agriculture) has contributed to 33 % anthropogenic CO_2 emission (IPCC 2007), and within the last 50 years, some 30–50 % mangroves forests are reduced through deforestation, and urbanization of coastal lands. Mangroves store more than five times carbon than other forests on per unit area basis; this could be attributed to their special rooting structure, capable of retaining high amount of organic matter (Shahid 2012).

Though Pakistan presents the wide diversity of landscapes and vegetation, yet ranks among the countries with the highly low forest cover. Forests spread over a small area of 4.0 million ha, which is 5.0 % of the total area in the country (PCST 2005b; Siddiqui 2007). The area under forests includes state-owned forests, communal forests, and privately owned forests as well. By using another criterion to estimate the extent of forests Shah and Arshad (2006) report that forests spread over an area of about 12 million ha. Of this total forest area, different forests types cover different hectarage like: scrub and planted trees (4.2 million ha), natural and modified coniferous scrub, riverain and mangrove forests (3.5 million ha), tall tree forests (2.4 million ha), scrub forest (1.1 million ha), and plantations (0.7 million ha).

Pakistan suffers from the highest deforestation rate in the world (Economic Survey 2009–2010), where forests are disappearing at an alarming rate, that is three times higher than other South Asian countries. Irshad et al. (2007) reported an indiscriminate removal of vegetation/forest due to ruthless removal of timber, woodfuel, and other non-timber forest products, at the rate higher than the natural forest regeneration. Pakistan loses about 3.1 % of forest cover annually. Since most of the households still continue to use woody biomass as firewood for cooking and heating, therefore, making the forests disappear (higher rate) at an annual rate of 5 % (Anjum et al. 2010). FAO (1996) noted the national forests disappear on some 77,000 ha annually because of illegal felling and ruthless cutting. FAO is of the view that the continuation of an absolute annual loss such an alarming rate, the forests in Pakistan would completely disappear by 2015.

Although, a desirable range of a country's land under forest is 20–25 % whereas only 5.0 % of Pakistan's total area is under forests (Siddiqui 2007). According to Khan et al. (2012) all the major forest types and vegetation cover have been affected severely in the recent years due to the factors like: ruthless and indiscriminate removal of forests; their poor, unplanned and unscientific management; overgrazing; and ecological changes, resulting the anthropogenic activities. Whereas according to Ahmed and Zia (2003) key factors responsible for the degradation of forest resources in Pakistan include: shallow soils on steep slopes, unsuitable soil structure, degradation in soil productivity, inadequate irrigation, poor quality planting stock, low survival rate of new seedlings, poor regeneration and low stocking in coniferous forests, low intensity of cultural practices and defective and inappropriate logging practices.

Deforestation in the country results severe environmental issues like: soil erosion, floods, droughts and increasing desertification, and non-protection of coastal lands. The indiscriminate removal of forests leaves the soil exposed and absorbs less rainwater falling on the bare-ground. The situation can cause water runoff and soil erosion, and ultimately may lead to desertification. The removal of productive surface soils exposes low quality subsurface soil leading ultimately to low agricultural production and, in turn results an enhanced poverty.

10.2.6 Increasing Population Pressures

Pakistan with an estimated population of 180.7 million in 2011 remains the 6th most populous nation in the world (Economic Survey 2010–2011); its population is growing at 2.03 % per annum (Anjum et al. 2010). Rising of the population continues at the current rate, the projected population of the country may touch the figure of 217 million by 2020, 234 million by 2025 and could be doubled by 2050. This situation will put more pressure on the available resources which are also shrinking due to natural and anthropogenic factors, leading to fragmentation of agriculture and ecosystem degradation (Sheikh and Soomro 2006).

10.2.7 Migration and Permanent Settlements

Pakistan is predominantly an arid country with 80 % falling in the arid and semi-arid regions (Shah et al. 2011). Today Pakistan stands among the most arid countries with an annual rainfall of below 240 mm (Farooq et al. 2007). Due to prolonged droughts especially the dry areas, Sindh, and Balochistan provinces are unable to produce enough food production to feed its populations, making them suffer from malnutrition and migration. Resultantly, the more productive and irrigated neighboring areas experience a high influx of migrants. Forced migrated population often competes with the sitting populations for land resources especially they want their share for water and grazing resources for their livestock, placing greater pressures on the natural resources.

This sort of migration often puts greater social and economic pressures on the locals forcing them to bring basic changes in their lifestyles. For example, with the electrification of the villages and increased road network in previously remote areas of Balochistan, transhumance practices are weakening. Many graziers and pastoral communities have now started permanently residing in the areas located near the roads. In order to develop new agriculture lands, they are digging deep wells for meeting irrigation requirements of their lands. Such developments can make the traditional use of rangelands degraded and in cases may lead the vegetation cover to completely disappear.

10.2.8 Rising Poverty Levels

In the recent economic crises, poverty levels have increased in rural areas and declined in the urban areas. About one-third of the total households in the country were below the poverty line, whereas, poverty levels in rural areas reached about 39 %. In absolute numbers, about 36.45 million poor persons were living in the country in 2004–2005. The population living below the poverty line in rural areas was about 28.10 % and 14.9 % in urban areas in 2004–2005 (Economic Survey 2006–2007). In the year 2006, about 27.0 % in rural areas, and about 13.1 % people in the urban areas were operating below the poverty line in the year 2005–2006. In this situation, poor and small farmers were forced to make use of their limited land resources more intensively to meet their urgent and pressing needs by over-exploiting and compromising the long term sustainability of their lands and other natural resources. Also, the prevailing weak safety nets can further make the rural poor vulnerable. In the event, when their livelihoods are at stake, they feel threatened due to little or absence of safety nets, they are forced to increase pressures on natural resources. In Pakistan, currently available social safety nets for the poor, marginalized and vulnerable are not strong enough, neither meeting their needs and nor within reach.

For the livelihood of the rural poor, opportunities and support through the safety are quite meager, predominantly for those depending upon the natural resources (Baig and Straquadine 2011).

10.3 Soil Issues and the Processes of Land Degradation

Marginal soil and land-resources have the potential to result the low agricultural yields. Anthropogenic activities, in addition to the natural processes and rising population-pressures cause the problems like: wind and water-erosion; water-logging; salinity/sodicity; loss of organic matter and decreasing biodiversity. Persistent salinization and sodicity issues are constantly declining the productive capacities of the healthy and fertile soils (Ahmed and Qamar 2004; Shah and Arshad 2006). It is estimated that almost 38 % of Pakistan's irrigated land is waterlogged, and about 14 % is saline. Use of agricultural chemicals has also gone up by a factor of about 10 since 1980. Soil erosion and water-logging are known to be the most significant and major constraints causing serious damages to our land resources and the environment.

10.4 Waterlogging in Pakistan

Pakistan has the largest canal network in the world supporting its agriculture primarily in the Indus Basin covering an area about 16.6 million ha. Water remains the most critical input to realize crop-production but canals systems are viewed as a blessing and a problem. On the one hand, irrigation projects require huge financial allocations and on the other hand, just after a few decades, the irrigated areas require heavy expenditure for lowering the water-table (resulting from seepage from the canal-system and mismanaged irrigation). It is believed (Shah et al. 2011) that excessive water percolation from the canal system causes the issue of waterlogging. The other reasons leading to waterlogged conditions possibly could include: growing of high delta crops like sugarcane on permeable lands, construction of roads and buildings can obstruct the natural drainage channels. Among the other factors responsible for waterlogging, improper alignment and poor maintenance of open drainage systems, inefficient disposal of rain water are worth to mention.

Khaliq (2007) reported an area of 1.55 million ha to be affected by waterlogging in the country. On the other hand, the Soil Survey of Pakistan reported the total waterlogged area reaches 4.11 million ha during the summer rains in the country and the waterlogged area is thought to be doubled during the post-monsoon season. Depth of water during post-monsoon is three times higher than observed in premonsoon season. High water-table could considerably lower the agriculture and crop yields. Factors like restricted aeration in the root zone under waterlogged and salinized soil conditions, reduced bearing-capacity of soil, weak foothold of the crop plants and an increased attack of crop-diseases seriously reduce the crop yields (Zia and Rashid 1995; Zia et al. 2004).

10.4.1 Suggested Innovative Remedies to Control Waterlogging

The following technologies, if properly adopted, can help lower the water-table, combat and manage the water-logging issue to a great extent:

- Immediate initiatives are needed to shift its irrigation resources perennial to non-perennial.
- Measures for the construction of surface-drains and tile-drains must be undertaken.
- Installation of tube-wells for the purpose of irrigation and vertical drainage should be done.
- Lining of canals, water-channels, and lowering of water-levels of canals deserving sufficient measures are required to be undertaken.
- Seepage through canals results the issue of waterlogging. Canals system can be improved by employing scientific planning and designing and research based management principles of irrigation.
- Waterlogging issue can also be addressed if canals are managed on proper scientific lines.
- In order to optimize the water-use, cultivation of high-delta crops on moderately to rapidly permeable soils must be avoided, high values crops requiring less water need to be encouraging.
- In the waterlogged areas, water-tables can be lowered down by planting trees (bio-drainage).

10.5 Soil Salinity Problem in Pakistan

An estimate given by Ghafoor et al. (2004) indicates that salt-affected soils both in the irrigated and nonirrigated areas spread over 6 million ha. Similarly scientists (Zia et al. 2004; Ahmed and Qamar 2004) have reported roughly 5.7–5.8 million ha of irrigated areas affected by varying degrees of salinization. Of this, 44.1 % is saline, 55.4 % is saline-sodic and 0.5 % sodic soils. Most of salt-affected soils are located in the province of Punjab (2.6 million ha), followed by Sindh (2.3 million ha).

Shah and Arshad (2006) reported slightly a higher figure, with an area of 6.28 million ha affected with salinity and sodicity at the national level. The majority of salt-affected soils are saline-sodic in nature. On the contrary, WAPDA (2007) reported a decline in salt-affected lands from 6.0 to 4.5 million ha in 1980s. The soil sodicity has significantly reduced the drainage capacity of the soils that in turn results lower crops yields, declined fertility and loss of biodiversity (Shah et al. 2011). An account of extent of salt-affected soils of Pakistan is presented in Table 10.2.

Table 10.2 Soils affected by various types of salinity and sodicity (000 ha). (Source: S & R Directorate, SCARP Monitoring Organization, WAPDA, Lahore, 2001–2003)

Type of soil	Punjab	Sindh	KPK/FATA	Balochistan	Pakistan
Soils with surface/patchy salinity and sodicity					
Irrigated	472.4	118.1	5.2	3.0	598.7
Unirrigated	–	–	–	–	–
Gypsiferous saline/saline-sodic soils					
Irrigated	152.1	743.4	–	76.6	972.1
Unirrigated	124.5	536.3	–	160.1	820.9
Porous saline-sodic soils					
Irrigated	790.8	257.0	25.7	29.4	1102.9
Unirrigated	501.0	150.1	7.8	364.0	1022.9
Dense saline sodic soils					
Irrigated	96.7	32.5	0.9	–	130.1
Unirrigated	530.0	379.7	8.9	714.8	1633.4
Total	2667.5	2217.1	48.5	1347.9	6281.0

10.5.1 Suggested Innovative Remedies to Control Salinity

Reclamation of saline soils can be easily achieved if sufficient good quality water is available. In dense soils, salts are leached down into the deep horizons by employing intermittent deep-plowing and heavy irrigation. Further, removal of salts can be achieved by adopting rice-berseem rotation, leading to improved soil-productivity. Under such rotation, if the last harvest of berseem (*Trifolium alexandrium*) is incorporated into the soil, this practice helps building the organic matter and improves the soil physical health. Afterwards, rice-wheat cropping, with Sesbania as green manuring crop should be planted and chopped into the soil. If green manuring is not practiced, then farmyard manure (FYM) should be applied instead. By employing such initiatives, the saline-sodic soils can be made productive for realizing improved yield (Zia and Rashid 1995; Zia et al. 2004; Baig et al. 2005).

10.6 Integrated Approach of Soil Management and Reclamation

In order to increase yield per unit area on the marginal soils (saline, saline-sodic, sodic) through improving soil and water use efficiencies, effective, efficient and long-term soil quality improvement requires the use of an integrated approach including physical, chemical, hydrological, and biological methods specific to the site's conditions (Shahid 2002; Shahid et al. 2013). However the combination of innovative strategies needs to be adopted on the basis of the site characteristics to make such lands productive and realize sustainable production systems, presented as under:

10.6.1 Chemical Amelioration Approach

Small scale interventions aiming at improving the soils conditions are founding blocks of any reclamation approach (Shah et al. 2011). Chemical methods are used to rectify soil sodicity. The objective is to reduce the exchangeable sodium percentage (ESP) below threshold value (ESP 15). The prime purpose is to enhance the concentration of calcium in soil. This process involves the application of chemical amendments like gypsum ($CaSO_4.2H_2O$), sulfur (S) and acids (HCl, H_2SO_4). However, the acids are only used in case soils are sodic and calcareous. The acids decompose $CaCO_3$ and its equivalents and Ca is induced to replace exchangeable sodium from soil exchange complex. To be effective, gypsum amendment required for reclamation has to be based on gypsum requirement determined in the laboratory. Calcium replaces excessive Na^{+1} from the clay particles/complex while forming sodium-sulfate. Since sodium-sulfate happens to be a soluble salt, therefore, it can be leached out of the root-zone with the heavy irrigations. Sulfur through biological oxidation by *Thiobacillus thiooxidans* transformed to sulfuric-acid, which helps in reclamation of sodic soils.

10.6.2 Biological Approach

In this approach, soil is made productive and reclaimed by growing *Sesbania bispinosa, Leptochola fusca,* and other green-manures crops like Berseem (*Trifolium alexandrium*). Growing of salt-tolerant plants, crops, grasses, shrubs, and trees has been a very successful mode of utilizing and improving the salt-affected soils effectively. The tree species like *Atriplex and Eucalyptus, Chenopodium, Suaeda, Salicornia, Kochia, Sesbania, Salsola Juncus,* and many other species have been successfully tried in reclaiming the salt-affected soils. Deep rooted plants and trees with high evapo-transpiration demand are capable of presenting biological drainage, in turn providing favorable environment for the succeeding crop species (Irshad et al. 2007). Deep roots of the tree are known to improve the physico–chemical conditions of the soils by improving soil structure, increasing pore space, enhancing water and nutrient holding capacity (Baig et al. 2005). However, there is a need to explore for suitable leguminous and crops like alfalfa, berseem, sesbania, and other promising species that could improve the organic contents of soils and create enabling environment for the biological life (Khan et al. 2012).

10.6.3 Physical Approach

Numerous physical methods have also been employed to reclaim the salted lands. Among these, the appropriate methods are: land leveling, salts scraping, deep plowing and tillage, subsoiling and sanding. Laser leveling seems essential for uniform water distribution. These practices do help in reclaiming salt-affected soils through improving physical conditions of soil (Zia et al. 1986; Zia et al. 2004; Shah et al. 2011). By employing the appropriate tillage practices that change the soil surface conditions resulting into low salinity in the root-zone (bed shaping and irrigation management). Experiments on managing salted soils indicate that salts tend to accumulate on the ridges away from the wet zone particularly upon the application of water in furrows (Shahid et al. 2011). They further reported that harmful effects of salinity can be minimized by placing the seeds on the off-center slopes of a single row. Such practices would expose the seed to the minimum salinity zone and provide the best possible moisture conditions. In addition by disrupting the dense layers, reclamation process can be enhanced by improving permeability through the operation of subsoiling.

10.6.4 Hydrological Approach

Hydrological approach is concerned with water use and drainage. By adopting an engineering approach, it is assumed that salinity issue in the irrigated areas can be reversed by adopting drainage schemes, aiming at lowering the water tables (Qureshi and Barret-Lennard 1998). For realizing successful reclamation of saline-sodic soils, leaching and drainage are two known and established basic requirements. In case, soils are permeable, artificial drainage is not required, but such a condition seldom happens in saline-sodic soils. Various types of drainage-systems (vertical drainage by installing tube-wells; horizontal drainage; tile drainage; surface drainage) are employed in order to achieve soil-reclamation.

Conventionally, saline soils have been reclaimed by employing techniques like flooding or by ponding water. In order to move the salts down into the deeper soil horizons, the leaching requirement (LR) is very important parameter to calculate. Rhoades (1995) has described procedures to calculate LR and to predict the yields losses causing by salinity. Putting the modern irrigation systems (sprinkler, drips, sprayers, and subsurface system) into the practices can certainly improve water use efficiency; however, each irrigation system has the potential to develop salinity at the specific soil zone and this issue needs to be examined and monitored carefully.

10.6.5 Saline-Agriculture Approach

Saline agriculture or biosaline approach refers to economic utilization of salt-affected soils for realizing economic agricultural yields by fitting plant life without having their reclamation. This particular approach involves the cultivation of salt-tolerant species of agricultural importance and significance and adaptation of special agronomic practices to improve the yields of these crops (Irshad et al. 2007). In Pakistan, the most prominent salt-tolerant plant-species tried and tested in the reclamation programs include: Kallar grass (*Leptochola fusca*), *Artiplex spp., Acacia spp. and Eucalyptus spp.* (Zia et al. 1986; Zia and Rashid 1995; Qureshi and Barret-Lennard 1998; Zia et al. 2004; PCST 2005a).

Table 10.3 Salt-tolerant plants potentially suitable for planting under saline conditions. (Source: Kahlown and Majeed 2002)

Type of crops	Salt tolerant crops shrubs and trees
Forage crops	Sorghum (*Sorghum bicolor*); millet (*Pennisetum americanum*); barley (*Hordeum vulgare*); alfalfa (*Medicago sativa*); clover (*Trifolium alexandrinum*); cluster bean, rape (*Brassica napus*); oats (*Gvena sativa*)
Grasses	Sindicus; Panicum; Gayana kallar grass (*Leptochloa fusca*); Bermuda grass (*Cynodon dactylon*)
Bushes	Atriplex; Blue bush; Asparagus
Fruit trees	Zizyphus; date (*Phoenix dactylifera*); falsa (*Grewia asiatica*); ber (*Ziziphus mauritiana*); pomegranate (*Punica granatum*); guava (*Psidium guajava*)
Forest tree	Jand (*Prosopis cineraria*); tamarix; swanjna (*Moringa Olifera*); neam (*Azadirachta indica*); desi acacia ampliceps jungle kikar (*Prosopis juliflora*); Safayda (*Eucylptus*); vilaiti kikar (*Parkinsonia*); Iple-Iple (*Leucana leucocephala*)
Shrubs	Kikar (*Prosopis juliflora*); jojoba (*Ziziphus mauritiana*)

Recently Shah et al. (2011) have reported very encouraging results of biosaline agriculture approach. The researchers have successfully demonstrated restoring the productivity of thousands of hectares of salt-affected soils by growing trees like *E. Camaldulensis* and salt-bushes like *Atriplex amnicola and Atriplex lentiformis*. An account of suitable grasses, crops plants, trees, shrubs is presented in Table 10.3.

In another project, focusing on reclamation and rehabilitation of salt-affected soils, Shah et al. (2011), tried to develop and promote sustainable biological farming systems for the degraded lands. They were quite successful in demonstrating technical and social interventions for the rehabilitation of degraded lands. As the outcome of their research, they also developed a package of saline agriculture technologies, consisting of salinity/waterlogging tolerant trees, crops, grasses and fodders; fish farming and installation of tube-wells. By employing these technologies, farming communities were able to elevate their incomes, poverty levels went down, livelihoods and environments were improved and above all women of the area felt empowered. In addition to making the degraded lands productive, researchers also focused on capacity building and the participation of local communities. The benefits realized as the result of these efforts were three times more than the cost of the projects and the researchers believe that the tangible benefits realized by the farmers clearly indicate the rate of acceptance and adoption of the reclamation technology package, evolved by them.

10.7 Soil-Erosion in Pakistan

Almost 76 % of the country's total area has been severely affected by the wind (40 %) and water (36 %) erosion. Approximately, 1 billion tonnes of soils are being washed away annually, depositing in the dams and ultimately falling into the Arabian Sea (Irshad et al. 2007). Soil loss caused by water erosion is quite high in

Khyber Pakhtoonkhawa (KPK) province and is followed by Northern Areas (NA), Baluchistan and Punjab provinces (Irshad et al. 2007). About 50–60 % of the annual rainwater is lost through runoff, causing moisture shortage and erosion on the rainfed areas receiving medium to high rainfall. The susceptibility to erosion or the extent of erosion hazard depends upon the soil types. Soil orders primarily affected by soil erosion include: Alfisols, Entisols, Inceptisols, and Mollisols. However, water-erosion mostly occurs either in active flood-plains or on sloping hills (affected severely by water-erosion). In the country, low rainfall areas like: Thar, Thal sand desert of Cholistan, and vast areas of Province of Balochistan have been affected by the wind-erosion (NAP 2002; SLMP 2011)

10.7.1 Water-Erosion

Water erosion has affected an area of about 11 million ha (Khan et al. 2012).Water erosion is mostly prevalent in high rainfall steep slopes, particularly in the Potohar region (Shah and Arshad 2006). In these rainfed areas, almost 50 % rain water is being lost as runoff (Anjum et al. 2010). Water erosion is a major hazard on areas, receiving poorly managed for logging operations; indiscriminate land clearance; overgrazing, and removal of vegetation for feed, forage and fuel and inadequate management of runoff. All these factors make the soil bare and lead to erosion. In addition widespread use of annual crops on the farms further aggravate erosion problem.

The soils in the Indus basin are considered to be relatively young, recent and undeveloped. The surrounding mountains have some of the world's steepest and largest slopes. Strong and forceful summer rainfalls, along with melting of snow in high mountains, contribute to the hazards of soil-erosion. In addition, the other key factors responsible for soil erosion include: land-use practices, vegetation cover, type and structure of the soil. For example, an active water-erosion, a continuing process could be witnessed on the loose soils of Pothowar Plateau, also experiencing great potential for gully-formation and taking away the highly productive topsoil. In the northern mountainous region of the country, the water-erosion on the steep slopes is low in the areas covered with the permanently closed canopy-forests whereas the erosion hazard is greater on the steep slopes when cultivated with arable crops.

At the upstream, due to deteriorated riverside infrastructure, fertile top-soil is washed away, considerably decreasing the productivity of the erosion subjected lands. On the other hand, at the downstream, the deposition of the tonnes of sediments significantly lowers the efficiency of hydropower-generation and irrigation-systems (Khaliq 2007; Khan et al. 2012).

10.7.1.1 Innovative Remedies for Water Erosion

Water erosion is a very common phenomenon noticed on the rainfed lands, subjected to heavy loss, primarily occurring due to water flows due to rains, the improper land use under inappropriate cropping systems, grazing by the free roaming livestock and illegal ruthless removal of vegetation cover (Irshad et al. 2007). Water-erosion primarily could be attributed to the hammering action of raindrops and uncontrolled water flow. To control soil erosion and to conserve soil moisture, various types of structures can be constructed at appropriate locations to dispose off the excess runoff including retaining walls, water disposal outlets, spillways etc (Rashid et al. 2008). Many researchers (Zia et al. 2004; Sheikh and Soomro 2006; Irshad et al. 2007; Anjum et al. 2010) have presented remedial measures to combat the issue which are enlisted as under:

- Adoption of the practices like cover and strip cropping are important in controlling water erosion.
- Measures are needed making the water flow to the areas where it is desired to be taken at a controlled velocity.
- Construction of drop-structure and use of flood-retarding structure are useful measures
- Establishing the surface-cover (mulches) would reduce the force of the hammering action of rain. Such surface-covers are capable of intercepting the rain before hitting the soil.
- Maintaining a good cover of grass on the areas having the potential of erosion hazard. Strong cover provided by the grasses and grassy waterways proved a good option to check water erosion.
- Maintenance of borders ("Watbandi" land-leveling and terracing) in the field would reduce the amount of runoff by promoting infiltration and check erosion.
- Minimize clean cultivation and keep the lands always covered with vegetation
- Adequate, strong administrative and policy measures deserve strict implementation to halt, reverse the deforestation, and stop the illegal cutting of forest vegetation.
- Rangelands of the country are severely deteriorated for having been exposed to unplanned and un-scientific grazing of free roaming livestock. Rangelands must be managed by employing appropriate grazing plans like: rotational grazing.
- Initiatives like adoption of practices like low or zero tillage and the concepts of conservation agriculture are to be introduced to the areas facing the issue.

The lands with *Gully erosion* are not easy and economical to reclaim. However, control of runoff and erosion is extremely important on such lands to halt further deterioration. In addition, the affected areas can be improved by bringing vegetation covers back by employing the controlled grazing systems. Small and medium sized gullies, with suitable outlet, could be managed effectively by diverting of run-off water at the gully heads. Large gullies can be converted into the leveled lands by constructing the drop-structure. Such measures would help slowing down the water flow; reduce sediments loads by checking runoff. Impounding of runoff water at gully-heads would check gully formation, besides making drinking water available (Zia and Rashid 1995).

Pakistan Agricultural Research Council (PARC) has developed a model by employing an integrated land and water-conservation approach and has successfully been practiced in the Pothowar Plateau. The crops, pastures, orchards, fruit and forest trees, are raised on the land keeping in view to its suitability and capability. Approximately, 4 % of total area was used for making grassed water-ways and ponds. The lands of the area were developed requiring minimum operations, without disturbing or removing the soil. Today, gullies have been completely reclaimed and erosion problem has been fully eliminated from the area. Forest-trees have yielded appreciable wood, fruit trees are bearing fruits and crops are resulting reasonable yields, converting the problem area and wastelands into continuous sources of income. However, by adopting this model, farmers of the similar areas can make their degraded lands productive to realize sustainable productions (Zia and Rashid 1995; Zia et al. 2004).

The *Steep sloping lands* occur mostly in the northern and western mountains of the country. Steep sloping lands can be used for agricultural production; however, they should be dealt with great care. Some of the innovative but remedial strategies presented by (Baig et al. 1999; Zia et al. 2004) to check erosion and realize sustainable agriculture include:

- Making of stone bench-terraces would protect steep slopes and prevent erosion and run-off; promote water infiltration and support the growing vegetation.
- Lands with more than 15 % slope should not be put under plow for further expansion of the area to practice agriculture.
- Development of terraces would check runoff; utilize water efficiently to realize better hill farming.
- Scientific but research-based range-management site-specific strategies suitable to local environmental features must be adopted to improve rangelands.
- Soils should be used for forage-production by introducing a mixture of legume and grasses instead of growing monoculture oriented crops, such as only maize crop in hilly areas.
- Measures for the improvement of existing bench-terraces are needed as they also act as water-disposal systems, including grassy waterways and drop-structures.

10.7.2 Wind Erosion

Sandy areas along Makran Coast are also severely affected by the wind erosion. Land degradation by wind-erosion causes about 28 % of total loss of soil experienced in country (Khaliq 2007). The arid environment and the aridity phenomenon prevailing in the areas remain the prime and immediate physical cause of erosion. However, erosion is common to witness in the areas around habitations and watering-points trampled by livestock. The most damaging and degrading factor responsible for the wind erosion hazard could be the over exploitation of rangelands for fuel-wood and nomadic livestock grazing, without taking into account their carrying capacity. Winds are responsible for the movement of sand dunes, depositing thick layers of sand on roads, railway tracks and croplands, and threatening rural dwellers. Fine soil-particles, organic matter constituents and other soil-nutrients are lost during strong winds blowing (Muhammad 1994; Zia et al. 2004; SLMP 2011).

The province of Punjab experiences the highest magnitude of soil loss due to the strong winds than Sindh, Baluchistan and Khyber Pakhtoon Khawa (KPK) provinces of Pakistan (NAP 2002; SLMP 2011).

10.7.2.1 Innovative Remedies for Wind Erosion

Wind-erosion can be checked by employing less aggressive cultivation techniques. The measures that could maximize the residue-conservation and reduce soil-pulverization are to be put into practice. Many researchers (Alim and Javed 1993; Baig et al. 1999; Zia et al. 2004) presented various remedial measures to combat the wind erosion, salient points of their suggestions and the suitable options includes the following:

Cultivation Techniques

- It would be beneficial to use tined implements, rather than cultivating the soil with the disc implements, as the latter buries the surface-residues.
- Blade and chisel plow, with steep points should be used. Such implements will result the formation of clods and check erosion.
- Bare and naked soils should not be cultivated frequently. Therefore, the number of cultivations should be reduced to avoid breaking of clods and minimize the soil disturbance.
- Implements, such as chisel plow, which go deep into the soil produce the bigger size of clods and this practice would prevents and checks erosion. Soil-clods greater than 2 cm in size should comprise and cover at least 50 % of the soil-surfaces. Such initiative could be a productive and preventive measure toward erosion control.

Vegetation Cover

At least half of the ground should be covered with the vegetation to protect the productive lands; otherwise, erosion hazard may deteriorate these lands capable of sustaining plant and human life. The use of vegetation will help controlling erosion by:

- Holding, arresting and trapping the eroded soil-particles and vegetation can decrease and diminish the erosive power.
- Providing resistance against the wind force and reducing the wind-speed at ground level.
- Acting as a cover against the wind-forces, thus preventing wind from removing soil.
- Adopting controlled grazing plan and by placing check on the uprooting, cutting and burning of natural vegetation.
- Growing of hedges around cultivated fields located near the active sandy ridges and areas exposed to the winds has been proved very efficient and effective practice to control erosion and keep the lands intact.

- Planting the wind-breaks around the erosion-vulnerable areas. Such plantations help slowing down the wind velocity and in turn check erosion.
- Practicing strip-cropping on vulnerable areas has been recognized as an economical way of combating erosion.

10.8 Implications for Agricultural Extension Education and Awareness Programs

The scientists and the researchers of the country have been able to devise suitable technologies for the rehabilitation of degraded lands to realize sustainable economic yields. However, any technology, no matter how efficient, useful and productive it is, would be of no use unless it is adopted and put into the practice by the end-users i.e., farmers.

While working with the rural communities on the lands degraded with salinity, researchers like Shah et al. (2011) established the importance of such community participation in the salted land rehabilitation programs. They organized training programs for the community including Women's Interest Groups (WIGs) on the community management skills for participatory planning and implementation of development programs. The successful demonstration plots and reclamation technologies became popular among the farmers. Resultantly, farming community participated in such programs while sharing the costs.

Therefore, at this juncture, agricultural extension has a pivotal and prime role in reversing the land degradation processes and making them productive. To realize this objective, it is imperative to create awareness among the rural masses on the prevailing issues, potential technologies available to mitigate these issues for improving the situation.

There is a need to educate the rurals, policy-makers, planners, government officials, members of the civil society and NGOs etc. Initiatives on capacity building, organizing of workshops, training courses for the communities including farmers, youth women groups; support from electronic and print media are important. Bright chances and rich opportunities do exist to make the problem soils productive, realize sustainable crop yields if all the stakeholders equip themselves with necessary technical skills on the subject and play their roles in the rehabilitation programs with dedication and devotion.

10.9 Conclusions and Recommendations

Pakistan is known for its agrarian based economy. Some 90 % of its land has been classified as arid or semiarid, facing the issues like drought and soil degradation leading to desertification. Almost 68 million ha of land area falls in the fragile regions. Only one fourth of the country's land mass is irrigated, supporting high input and intensive agriculture. However, the land degradation threats faced by both the low and potential areas include: wind and water erosion, salinity, sodicity, waterlogging, flooding, and loss of organic matter result lower agricultural yields. Among the major limitations determining agricultural potential are: flooding and ponding; presence of surface/subsurface clays making tillage operations difficult, excessive sands, subsoil compaction or plow pan formation; surface crusting; nutrient depletion and structure deterioration.

To feed the rapidly multiplying population and to keep the land resources healthy and productive for the future generation, and to mitigate the environmental issues damaging natural resources, it is imperative to closely look into reasons of land degradation and adopt innovative measures to reverse these processes. Putting innovative technologies into the practice depending upon the nature of the issue could be highly helpful. For example, by adopting engineering and biological approaches and strategies described in the chapter can surely tackle the problem of water-logging in Pakistan. Similarly, white-alkali (saline soils) containing sufficient soluble salts can be managed and reclaimed through intermittent deep plowing and heavy irrigations.

The rapidly vanishing vegetation resources are accelerating land degradation processes. Therefore, it is very important to maintain the existing natural vegetation and protect it from excessive browsing, ruthless and illegal cutting and uprooting, and burning. Also, there is need to focus on bringing vegetation back and re-greening of bare slopes; reseeding with suitable grasses and plant species; proper care of growing plants until they are fully established, and protecting vegetation from grazing livestock. The introduction of rotational grazing on such areas can facilitate the rehabilitation process.

However, steep slopes should not be cultivated and in case land has already been cleared for cultivation such slopes should either be replanted or reseeded with suitable tree/bush species, or proper bench terraces should be constructed and maintained. Alternate sources of fuel, food, fodder and other requirements should be provided to the locals living in the hilly areas to retain the vegetation cover in place.

Saline agriculture is a promising solution to utilize saline soils and saline water where other solutions of reclamation do not work or seem impractical, however lands are made productive by growing salt-tolerant crop plants, grasses, bushes, shrubs, and tress. Many plants grown on salt-affected soils have economic value, high nutritional value for use as forage or fodder crops and many have high contents of proteins and oils in their seeds.

By employing sea/brackish water for irrigation, it is quite possible to realize sustained high yields of biomass and seed by growing halophytes/salt tolerant plants. Besides the role of halophytes in drainage and reclamation processes, they also make agriculture more sustainable. That is why saline agriculture has emerged as a first rate alternative measure to improve environment and combat pollution.

Black alkali (saline-sodic/sodic-black soils) can be made productive by adopting an integrated land reclamation approach. The particular strategy consists of the use of chemical amendments (like gypsum, calcium chloride, sulfuric acid, hydrochloric acid, sulfur and ferrous sulfate), by-product of sugar industry (press mud);

biological means, such as use of FYM, green manures; composts; and physical methods, namely deep plowing, chiseling and sanding.

The judicious and wise use of brackish and unfit underground water for crop-production on salt-affected soils is an economical and suitable remedy to adopt. The strategies reported in the chapter if adopted with spirit would certainly combat issues like water and wind-erosion and halt the loss of soil fertility. Integrated approaches to maintain and enhance soil-fertility and health and the judicious fertilizer-management for improving crop yields should be put into practice.

However, rejuvenating the health of salt-affected soils and their chemical reclamation is a time consuming and costly business, in most cases out of reach of ordinary farmers, therefore, bio-saline approach is another option for growing salt-tolerant crops, shrubs, fruit, and forest trees.

The country experiences the issues like waterlogging and salinity do arise due to the seepage from the canals however; they can be addressed by the lining of water conveyance system including canals and water courses. Such initiative not only improves the conveyance efficiency but also checks the over efficiency of the irrigation system. The pressurized irrigation systems (like drip and sprinkler) involve the highly efficient technology capable of saving water without its wastage and damaging land resources.

Finally, beyond any doubt, human induced pressures are deteriorating the precious land and other natural resources while causing serious and irreparable damages to our environment. It is, therefore, essential to cope with land degradation problem on the basis of war-footing. In the situation to manage the land resources on sustainable basis, it is imperative to devise and introduce frameworks and instruments, capable of matching, accommodating and addressing the local needs in the best possible manners.

In addition to the remedial measures suggested in this chapter, awareness and capacity building programs through extension and education are of paramount importance. Enabling policies, creation of suitable conducive environment and more importantly their implementation with real spirit to complement the existing efforts are the essential ingredients of any rehabilitation program.

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Chapter 11
Land Suitability Evaluation for Jatropha (*Jatropha Curcas* L.) Plantation in Indonesia

Anny Mulyani, Adi Priyono and Fahmuddin Agus

Abstract In recent years, there is a growing interest in biofuels as substitute for fossil oils to counter greenhouse gas emission and global climate change. The *Jatropha curcas*, a tropical shrub is attracting the interests of policy makers and the energy industry as one of the promising sources of high quality biofuel, extracted from the seeds. Although Jatropha has been publicized as a wonder biofuel with unlimited potential, the key issue is the productivity under different environments and land types. In this regards it is essential to assure that the lands where Jatropha is to be grown has the potential to support such plantation. In Indonesia, we characterized the main producing areas of Jatropha in 2007–2008. The evaluation was made through studying soil morphologies, chemical properties and their relationship with plant growth and Jatropha oil content.The results showed that *Jatropha* can grow and develop over a wide range of soil textures (3–88 % clay), soil pH (4–8.2), soil available P and exchangeable K, cation exchange capacity, elevation of up to 900 m above sea level, and precipitation from 527 to 4,154 mm per annum. However, Jatropha does not develop satisfactorily at altitude > 1,000 m above sea level and in poorly drained soils. The variations in soil characteristics and climate lead the variation of the oil content (46–61 %), oil viscosity (72–86 centipoise), and the weight of 100 seeds (48.2–72.8 g). It has been generally observed that in areas with higher rainfall, the plant height leaf area, leaf weight and stem diameter were less than those in the low rainfall areas. The longer the dry months (> 8 months), the lower is the oil content. This land suitability criteria can be applied to develop land suitability maps and, in turn, *Jatropha* development in Indonesia.

Keywords Land Suitability • Soil Properties • Climate • *Jatropha Curcas* L. • Indonesia

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11.1 Introduction

Currently, there are debates on biofuels and the interest is growing as substitute for fossil oils to counter greenhouse gas (GHG) emission and global climate change (GCC). Some views growing Jatropha (tropical shrub) on prime lands a threat to local food production as it competes with other crops, others view it has the potential if grown in marginal lands and prime lands are secured for food crops. The Jatropha is a perennial plant that can grow on a wide range of soils, including marginal lands which are of poor quality in terms of agricultural use. Currently biodiesel feedstock is dominated by rapeseed and other food crops, posing challenges to future food security. Thus, using marginal land for *J. curcas* cultivation is therefore attractive since it would not displace food-producing crops. Even though Jatropha is a wonder biofuel with unlimited potential, the key issue is the viable productivity under Indonesian conditions.

The Jatropha is a multipurpose plant, which can be used as firewood, erosion control on sloping land and as a living fence, in addition to oil production (Puslitbangbun 2006; Henning 2007). It is also suitable for small scale business and thus promises wider interest among smallholder farmers. It is a drought resistant and a fast growing plant, although the plant grows better under a non extreme dry and moderate to more fertile soils (David et al. 2006). Jathropha planting for oil production preferably use seedlings developed at nursery because of long living span and higher production compared to those using cutting. For the purpose of fencing and as erosion control direct seeding or cutting can be used (Mahmud et al. 2006).

Owing to the many benefits of Jatropha plants, and the increasing demand for producing renewable fuels in Indonesia lead the government of Indonesia to seek the potential of Jatropha (*Jatropha curcas* L.) as a biofuel crop, a crop that is traditionally planted at home garden in the drier areas of Indonesia. Also the limitation of Jatropha farming on large scales lies in the fact that well developed high yielding Jatropha varieties currently not available and therefore potential lands have not been exhaustively explored.

The Indonesian National Team of Biofuel Development (2005) has promoted the development of biofuel commodity areas of 6.4 million ha (mha) for palm oil, sugarcane, cassava, and Jatropha during 2005–2015. Amongst these crops the target area for Jatropha is 2 mha.

The objectives of the present study are to evaluate the existing areas where Jatropha is being cultivated to see their potential for such cultivation.

11.2 Conceptual Framework

First step for the successful Jatropha plantation is to determine the suitability of soil and climatic characteristics. Present study has shown that the area suitable for Jatropha cultivation in Indonesia is much higher than the currently cultivated area.

Perhaps the reasons being the lack of incentives by the Government to farmers and poor skills for Jatropha plantation. Other factors like extension services, post-harvest handling (processing and marketing) are also important, however, the present study focuses on the land suitability aspects.

11.3 Study Area and Land Suitability

Present study is completed in two phases; (1) preparartion of land suitability map for Jatropha at scale 1:1,000,000 and; (2) detail land suitability map at scale 1:50,000. The land suitability map of Jatropha in Indonesia at exploration scale (1:1,000,000) has been developed in 2006 and this was intended for the national level planning. The criteria of land suitability for Jatropha at this level (Table 11.1), are based on climate (rainfall), elevation, relief, and physiography. The data have been obtained from the available databases with the scale 1:1,000,000 (CSAR 2000, 2001; IAHRI 2003).

For detailed land suitability map (1:50,000), characterization and identification of land and climate in the main Jatropha producing areas in Indonesia was conducted in 2007–2008. Soil morphology, chemical properties and their relationship with plant growth and Jatropha oil content were evaluated. This study has been conducted in several Demonstration Farms of Jatropha under the auspices of Indonesian Ministry of Agriculture in the provinces of Lampung, West Java, Central Java, East Java, West Nusa Tenggara (NTB), East Nusa Tenggara (NTT), and Central Sulawesi (Fig. 11.1). The study is consisted of field observations, laboratory analysis, and data processing for developing land suitability criteria.

11.4 Study Methodology

Morphology of soil profiles (depth, colour, texture, structure, consistency, drainage, pH, the concentration of coarse material or rock fragments, and existence of plant roots from each soil horizon) was described using the standards of FAO (1990) and Soil Survey Division Staff (1993). Soil samples were collected from profiles and analysed for soil texture, organic carbon (Walkley and Black 1934), total N (Kjeldahl method), soil pH, potential P and K (25 % HCl extractable), exchangeable Ca, Mg, K and Na, cation exchange capacity (CEC), base saturation, and Aluminium saturation using the standard methods (Eviati and Sulaeman 2009; Burt 2004) where appropriate.

The Jatropha seed production was evaluated from 100 seed weight, oil content of fruit flesh (Soklet method) and viscosity (Rheometer). Field observation data and the results of soil and plant analyses were used for the preparation of land suitability class criteria for Jatropha, the flow chart for land suitability mapping is presented in Fig. 11.2.

Table 11.1 Criteria of land and climate suitability class for *Jatropha curcas* (for the scale 1:1,000,000). (Source: Mulyani et al. (2006))

Land Suitability		Elevation (masl)	Annual rainfall (mm)	Dry month, ≤100 mm	Wet month≥200 mm	Limiting factor	Land unit of agriculture Planning[b])	Climate unit (Rainfall pattern)[a])
Symbol	Suitability							
S1	Very suitable	<400	1,000–2,000	4≤DM≤5	≤4;≤5	–	1B2, 1B3, 1K2, 1K3	II-B; II-C
–	–	–	2,000–3,000	5≤DM≤6	≤6	–	–	III-A
S2	Suitable	<400	1,000<AR<2,000	6≤DM≤8	≤4	Water available	1B2, 1B3, 1K2, 1K3	II-A
–	–	–	2,000<AR<3,000	–	5–6	Slightly low radiation	–	III-B,
S3	Marginally suitable	<700	<1,000	DM>8	≤2; 0;≤2	Water available	1B2, 1B3, 1K2, 1K3	I-A, I-B, I-C
–	–	–	2,000<AR<3,000	3≤DM≤4	6–8	Low radiation	–	III-C
–	–	–	3,000<AR<4,000	DM=3	7–9	Very low radiation	–	IV-C
–	–	–	–	–	–	–	–	–
N	Not suitable	>700	3,000≤AR≤4,000	≤2	7–11	Very low radiation	–	IV-A, B, D
–	–	–	>4,000	≤2	7–12	Very low radiation	–	VA-D; VIA-D

[a]**ClimateMapping Unit**: *I* (rainfall<1,000 mm/year), *II* (rainfall 1,000–2,000 mm/year), *III* (rainfall 2,000–3,000 mm/year), *IV* (rainfall 3,000–4,000 mm/year), *V* (rainfall 4,000–5,000 mm/year), *VI* (rainfall>5,000 mm/year)

Rainfall pattern: *A* (simple wave pattern, minimum rainfall on July-August), *B* (multiple wave pattern), *C* (double wave pattern), *D* (simple wave pattern, maximum rainfall in July-August)

[b]**AgriculturePlanning Mapping Unit:***1B2* (suitable for annual crops on upland with, <15% slope, wet climate, and lowland<700 masl), *1B3* (suitable for perennial/estate crops on upland, 15–30% slope, wet climate, and lowland<700 masl), *1K2* (suitable for crops on upland with, <15% slope, dry climate, and lowland<700 masl), *1K3* suitable for perennial/estate crop on upland, 15–30% slope, dry climate, and lowland<700 masl)

Fig. 11.1 Observation points for soil characteristics and crop performance

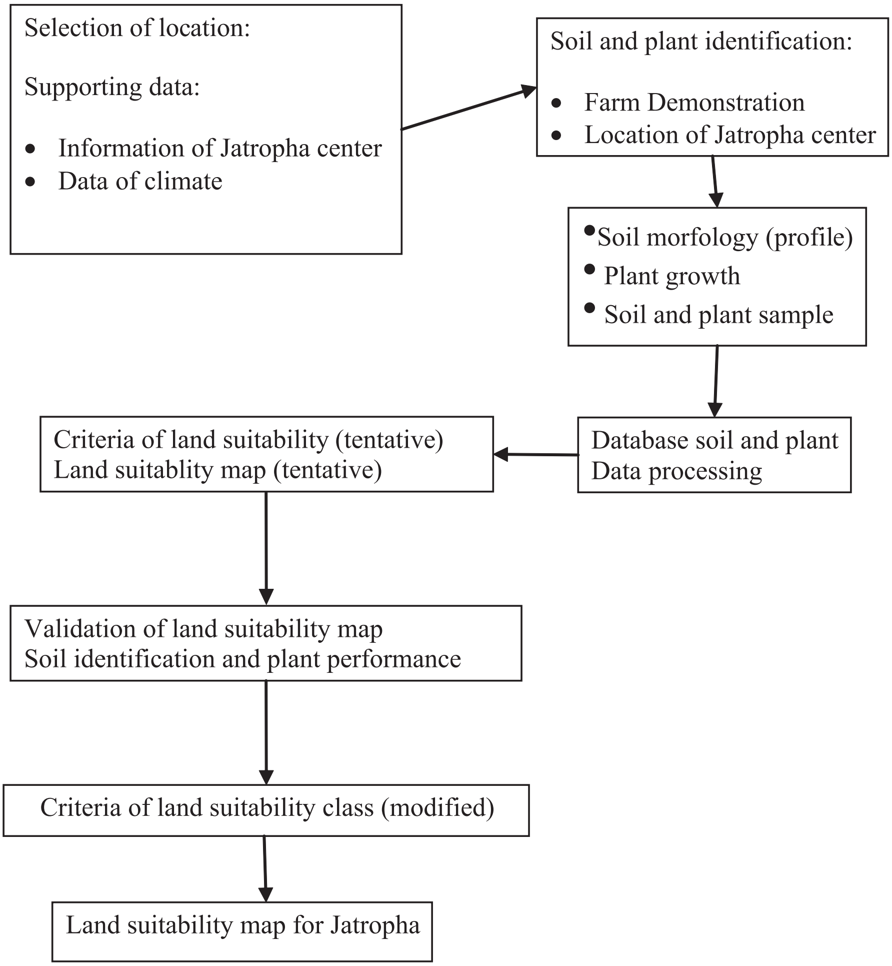


Fig. 11.2 Flow chart for developing land suitability map for Jatropha

Table 11.2 Distribution of land suitability classes for Jatropha and land availability for extensification of all agricultural commodities in Indonesia

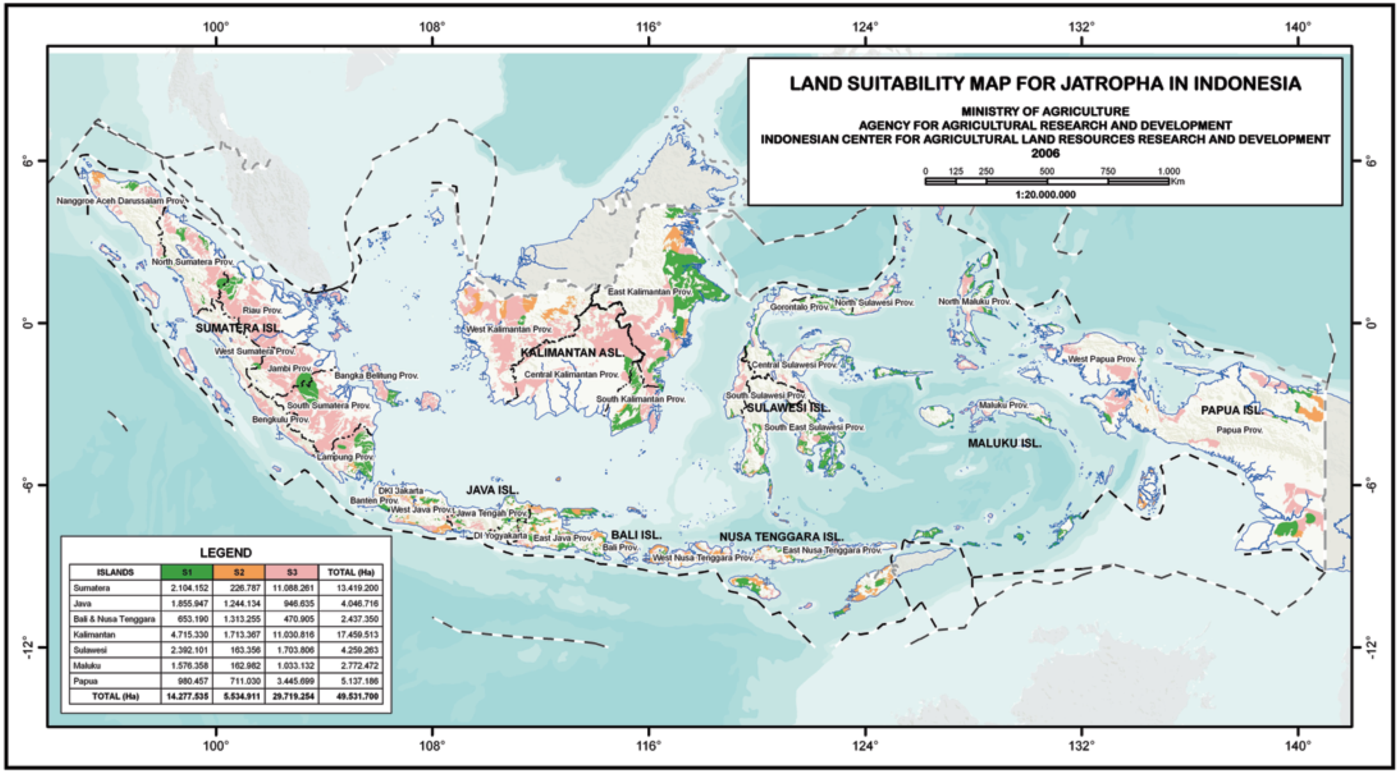
Islands	Land suitability class (ha)[a]				Land availability for extensification[b]
	High	Medium	Low	Total	
Sumatra	2,104,152	226,787	11,088,261	13,419,200	4,538,561
Java	1,855,947	1,244,134	946,635	4,046,716	199,497
Bali + Nusa Tenggara	653,190	1,313,255	470,905	2,437,350	747,824
Kalimantan	4,715,330	1,713,367	11,030,816	17,459,513	10,911,452
Sulawesi	2,392,101	163,356	1,703.806	4,259,263	816,632
Maluku + Papua	2,556,815	874,012	4,478.831	7,909,658	5,179,951
Indonesia	14,277,535	5,534,911	29,719,254	49,531,700	22,393,917

[a] Mulyani et al. (2006)
[b] ICALRRD (2008)

11.5 Results and Discussion

11.5.1 Land Suitability at the National Level

Based on the national land suitability criteria (Table 11.1) and by overlaying the agriculture planning and agroclimate maps, we were able to identify an area of 49.5 mha or about 26 % of the total areas of Indonesia (188.2 mha) suitable for Jatropha cultivation. Most of these lands were distributed at elevation of < 700 m above sea level (masl). Table 11.2 shows that most of land suitability classes were in the category of low suitability with limiting factor of high (> 3,000 mm) or low annual rainfall (< 1,000 mm) and steep slope (15–30 % slope), distributed in all islands mainly in Sumatra and Kalimantan Islands. Generally, land of high suitability class have been used for food crops (maize, cassava, soybean, geenbean, nuts) and estate crops (such as palm oil, rubber, coconut, cacao, coffee). About 22.4 mha land is available for future agricultural intensification, distributed mainly in Kalimantan, Papua, and Sumatra Islands (Table 11.2). These potential lands have to be shared between Jatropha and other commodities. It is believed that in future there will be a competition of land for these commodities and the most profitable will grow quickly. During 1996–2011 oil palm plantation development was very rapid in Sumatra, Kalimantan, and Papua (Central Bureau of Statistics 1996, 2011). Therefore, most of the available and suitable land for Jatropha development are in small parts of Java, Bali, West Nusa Tenggara and East Nusa Tenggara provinces. The suitable land for Jatropha, that likely does not compete with other food crops is around 3.5 mha and currently covered by grasses, shrubs and bushes. These lands have shallow soil depth, steep slopes (> 15 %) and low per annum rainfall (< 2,000 mm). Distribution of land suitability classes for Jatropha in Indonesia is presented in Fig. 11.3.



ISLANDS	S1	S2	S3	TOTAL (Ha)
Sumatera	2.104.152	226.787	11.088.261	13.419.200
Java	1.855.947	1.244.134	946.635	4.046.716
Bali & Nusa Tenggara	653.190	1.313.255	470.905	2.437.350
Kalimantan	4.715.330	1.713.367	11.030.816	17.459.513
Sulawesi	2.392.101	163.356	1.703.806	4.259.263
Maluku	1.576.358	162.982	1.033.132	2.772.472
Papua	980.457	711.030	3.445.699	5.137.186
TOTAL (Ha)	14.277.535	5.534.911	29.719.254	49.531.700

Fig. 11.3 Distribution of land suitability class for Jatropha in Indonesia

11.5.2 Detailed Land Suitability

The criteria for detailed land suitability assessment for Jatropha cultivation at 1:50,000 are not yet available. To develop these criteria, we conducted characterization and identification of land and climate in the main producing areas in several Demonstration Farms of Jatropha in the provinces of Lampung, West Java, Central Java, East Java, West Nusa Tenggara (NTB), East Nusa Tenggara (NTT), and Central Sulawesi. Soil morphologies, chemical characteristics and their relationship with plant growth and Jatropha oil content were evaluated. Then, the selected parameters were used to set up the criteria of land suitability for Jatropha in detail levels.

11.5.2.1 Performance of Jatropha

Jatropha can grow and develop at different soil order types namely Entisols, Inceptisols, Andisols, Alfisols, Mollisols, Andisols, Ultisols and Oxisols with wide ranges of soil characteristics (Tables 11.3, and 11.4). It can be grown on land with sandy texture (3 % clay) to clay texture (88 % clay); pH from 4.3–7.8; 25 % HCl extractable P of 6–194 mg/100 g and K of 1–344 mg/100 g; CEC of 3–41 cmol(c)/kg, exchangeable K of 1–56 cmol(c)/kg), exchangeable Al of 0–15.8 cmol(c)/kg), and base saturation of 20–100 %.

It has been reported by Bhag and Joshi (1991) that the plant can grow on all types of soils, but better growth was observed on light textured soils (sand 60–90 %), or the land with good drainage and aeration. They further reported that Jatropha can be adapted in marginal land and have the potential to grow on rocky, sandy, clayey, or eroded lands. In another study, Okabe and Somabhi (1989) found that Jatropha planted on sandy loam soil, yielded the highest seed production compared to other textured soils.

Later Jones and Miller (1992) argued that although the famous Jatropha can grow well in shallow soil and are generally found on gravely, sandy and clayey soils, but its growth is stunted on eroded soils, however, Jatropha grows well on sandy and well-drained soils. It can withstand very poor soils and grow in saline conditions. The use of organic fertilizers is suggested to obtain high yield (http://www.jatrophabiodiesel.org/jatrophaPlantation.php?_divid=menu2).

Heller (1996) states that Jatropha can tolerate unfavourable soil conditions including acid or alkaline soils, but it grows best at soil pH 5.5–6.5. Increasing the pH from 4.5 to 6.0 can increase the vegetative and generative growth (Joko et al 2007).

The observation areas (Table 11.3) ranges in elevation between 5 and 922 masl. It is well understood that at elevation of > 900 masl the plant can not produce seeds and above 1,500 masl the Jatropha seeds can not germinate. Rainfall where the Jatropha grew ranged from 527 to 4,154 mm annually, with the number of dry months (< 60 mm) ranged from 0 to 10 months and wet months (> 100 mm) from 2 to 12 months. In Indonesia, Jatropha grew well in areas with rainfall of more than 3,000 mm/year, as in Bogor, West Sumatra, and Minahasa. This finding is different from other researchers who have reported Jatropha growing in areas with the range

Table 11.3 Distribution of the characteristics of Jathropha growing areas. Samples were taken in areas with 11–17 months old Jatropha

Location	Soil Great group	Elevation	Rainfall	Clay	pH H_2O	P_2O5	K_2O	CEC	Sum of cation	Base saturation	Plant height	Dia-Meter	Sum of branches	Leaf area	Leaf weight
		m	mm	%		mg/100 g		cmol (c)/kg		%	cm			cm^2	gram
Cibadak-Cianjur	Epiaquepts	922	2,771	13	5.4	38.9	54.0	14.5	13.1	80.0	136.4	7.3	4.0	390.6	18.8
Cibinong_ Bogor	Kandiudox	125	4,154	86	4.9	39.1	4.1	14.8	6.1	40.8	109.4	5.1	2.6	430.5	17.2
Sandubaya, NTB	Haplustepts	38	1,663	8	7.5	127.4	344.3	9.8	9.6	85.8	175.3	6.4	4.0	462.2	25.4
Naibonat-NTT	Haplustepts	13	1,574	56	7.5	102.4	110.5	22.8	53.1	100.0	166.5	8.3	3.7	496.5	29.4
Sumba Baratdaya-NTT	Argiustolls	210	2,357	57	6.1	51.8	57.9	38.6	56.6	100.0	180.0	8.0	3.0	525.1	25.1
Sumba Tengah-NTT	Haplustepts	270	2,357	42	4.3	6.6	0.5	8.8	2.1	23.4	136.0	7.1	2.8	400.3	18.2
Sumba Barat-NTT	Haplustults	420	2,357	81	4.4	6.1	16.0	24.0	14.7	62.8	131.2	6.2	2.4	468.1	20.7

Table 11.4 Soil properties, elevation, annual rainfall, and the viscosity, oil content, and weight of 100 grains of Jatropha of 21–27 months old

Site/Province	Soil great group	Ele-vation	Rain-fall	Clay	pH H_2O	P_2O_5	K_2O	CEC	Sum of cation	Al-exch	Base Satur	Visco-sity	Oil content	Weight 100 grains
		masl	mm	%		mg/100 g		cmol(c)/kg			%	cPoice	%	g
Natar, Lampung	Kanhaplu-dalfs	127	2,401	0.54	5.09	17.28	7.14	8.22	4.69	0.78	55.87	80.00	52.98	66.60
Pakuon, West Java	Dystrudepts	480	2,771	0.72	5.09	76.16	99.12	21.70	8.91	2.17	42.56	76.00	53.48	71.50
Cibogo, West Java	Eutrudepts	66	1,922	0.68	5.73	23.28	21.36	25.48	27.60	1.20	93.70	82.10	59.10	68.50
Manyingsal, West Java	Dystrudepts	59	1,922	0.61	4.90	19.36	2.34	13.10	9.64	1.20	73.54	76.00	46.09	69.30
Ngemplak, Central Java	Eutrustox	30	760	0.88	5.50	194.37	13.20	10.37	9.00	0.01	86.63	72.00	53.05	70.80
Muktiharjo, Central Java	Rhodustalfs	59	527	0.82	5.28	74.83	31.31	13.43	9.94	0.38	73.89	78.00	47.85	67.80
Noborejo, Central Java	Melanu-dands	720	1,952	0.26	5.33	57.80	12.07	3.24	0.10	15.83	20.92	74.00	46.82	58.20
Banyumas, Central Java	Haplustalfs	100	3,079	0.72	5.96	85.44	47.05	41.15	49.24	0.10	100.00	72.00	56.64	71.50
Asem bagus, East Java	Ustipsa-ments	90	885	0.8	7.81	73.69	51.84	5.12	7.63	–	100.00	72.00	48.34	72.80
Pacitan, East Java	Udipsam-ments	5	2,254	0.3	6.67	42.98	30.24	2.57	4.42	–	100.00	78.00	50.72	67.20
Sandubaya, NTB	Haplustepts	38	1,663	0.8	7.45	127.36	344.33	9.84	9.59	0.00	85.81	86.00	54.47	64.70
Naibonat, NTT	Haplustepts	13	1,574	56	7.48	102.35	110.49	22.81	53.12	0.00	100.00	82.00	61.07	48.20

of annual rainfall from 200–2,000 mm (Heller 1996) or 480–2,380 mm (Jones and Miller 1992), but the best growth was in areas with rainfall of 900 to 1,200 mm/year (Beeker and Makkar 1999).

Whilst some areas in India report good crops with rainfall of 1,380 mm, along with irrigation of 1,500 mm annually. The 500–600 mm of rainfall is the limit. Below this level its production depends on the local water table condition. It will also stand for long periods without water of up to 2 years and then grow again when rains occur again (Jatropha World, 2011). However, Jatropha rooting system seemed very sensitive to poor drainage conditions. This was seen in Pacitan, where most land was inundated at certain times, causing stunted plant growth or plant death. This finding was in agreement with that of Henning (2004).

Observations on vegetative plant growth indicates that there is a trend where the altitude higher the smaller the leaf area and less leaf weight. Jatropha can withstand severe heat, however, under cold temperature it drops its leaves (http://www.jatrophabiodiesel.org/jatrophaPlantation.php?_divid=menu2). Furthermore, the higher the rainfall the lower the plant height, leaf area, leaf weight and stem diameter (Table 11.3). Oil content at Asem Bagus, East Java with 885 mm rainfall and 7 months dry months and Muktiharjo, Central Java with 527 mm rainfall and 10 months dry months, was relatively low (48.34 and 47.85 %). The highest oil content was obtained from Naibonat, NTT as 61.07 % in 1,574 mm rainfall and 6 dry months (Table 11.4). Jones and Miller (1992) states that the dry climatic regions can increase the oil content of seeds, but the prolonged drought will cause the plants to shed their leaves to conserve water that would otherwise lead to growth stagnation. The key factors that can influence the oil yield of Jatropha are climate, soil quality, irrigation, weeding, use of fertilizers, crop density, genotype, use of pesticide, and intercropping Jatropha World (2011).

11.5.2.2 Land Suitability for Detailed Level

Based on soil morphologies, chemical characteristics and their relationship with plant growth and Jatropha oil content from some planting areas (Tables 11.3, and 11.4), and some references from others countries, we have developed the criteria of land suitability for Jatropha at detailed level (1:50,000 scale) (Table 11.5). The important land quality criteria include elevation, water availability (rainfall and number of dry months), oxygen availability (drainage), rooting condition (texture and soil depth), nutrient retention (pH), and flood hazard (flooding). Additional land qualities include nutrient retention (CEC, C-organic, and base saturation), toxicity/salinity, and erosion hazard (ISRI 2003).

Threshold levels for certain parameters that greatly affect plant growth will be key for suitability classification (Tables 11.3, and 11.4). For example, elevation of 1,000 masl is considered unsuitable. Observation in Blora (Central Java), where soil pH is 8.2 the Jatropha still can grow and produced seeds, however this condition is considered as marginal suitability. Observations in Blora and NTT shows that where the soil is shallow and have lithic contact at 30 cm depth, it is suitable for plant

Table 11.5 Criteria of land suitability class for *Jatropha Curcas*

Land characteristics	Land suitability class			
	S1	S2	S3	N
Temperature (tc)	–	–	–	–
Avarage Temperature (°C)	25–28	22–25; 28–32	20–22;32–35	<20; >35
Elevation (el) masl	<400	400–600	600–1,000	>1,000
Water available (wa)	–	–	–	–
Rainfall (mm)	900–1,500	500–900;1,500–2,500	2,500–4,000	<500; >4,000
Dry month (month)	3–4	1–2; 4–5	6–8	>8
Oxygen available (oa)	–	–	–	–
Drain	Well, slightly well	Slightly poor, slightly excessive	Poor, excessive	Very poor
Rooting condition (rc)	–	–	–	–
Texture	f, m, sc		vf, c*	c
Coarse material (%)	<15	15–35	35–55	>55
Soil depth (cm)	>100	50–100	30–50	<30
Nutrient retention (nr)	–	–	–	–
CEC clay (cmol kg^{-1})	>16	≤16	–	–
Base saturation (%)	>20	≤20	–	–
pH H_20	5.5–6.5	5.0–5.5; 6.5–7.0	4.0–5.0; 7.0–8.2	<4.0; >8.2
C-organic (%)	>0.8	≤0.8		–
Toxicities (xc)	–	–	–	–
Salinity (dS m^{-1})	<2	2–3	3–4	> 4
Erosion hazard (eh)	–	–	–	–
Slope (%)	<15	15–30	30–40	>40
Erosion hazard	vl, l, m	H	Vh	–
Flooding hazard (fh)	–	–	–	–
Flooding	F0	F0	F0	> F1
Land preparation (lp)	–	–	–	–
Rockiness (%)	<5	5–15	15–40	> 40
Rock out crop (%)	<5	5–15	15–25	> 25

Texture: *f*=fine; *vf*=very fine, *sf*=slightly fine; *m*=medium; *sc*=slightly coarse, *c**=coarse from volcanic tuff/ash, *c*=coarse from non volcanic materials
Erosion hazard: *vl*=very low; *l*=low; *m*=medium; *h*=heavy; *vh*=very heavy

growth (Fig. 11.4). This condition can be understood because the Jatropha rooting system consists of 2 kinds of roots, the tap roots and lateral roots, such that it can still develop in shallow soils as lateral roots develop (Hasnam and Mahmud 2006; Mahmud et al. 2006). Therefore, the parameter of soil depth in criteria of land suitability is modified, from <50 to <30 cm for the class of not suitable (N). Figure 11.5 shows two soil profiles with contrasting texture and pH; Typic Ustipsamments with 85 % sand and pH of 7.8 and Typic Rhodustalfs with 82 % clay and pH of 5.2. The locations of these two profiles had <1,000 mm annual rainfall.

Land Suitability Classes **S1** (highly suitable): land having no significant or minor limiting factors to sustain a given land utilization type, **S2** (moderately suitable):

Fig. 11.4 Jatropha performance on Lithic Haplustolls in Blora District, Central Java with shallow soil depth (<30 cm), pH of 8.0 and karst parent material

Fig. 11.5 Typic Ustipsamments with 85 % sand, pH 7.8, 885 mm rainfall from Asem Bagus East Java (*left*) and Typic Rhodustalfs with 82 % clay, pH 5.2, rainfall 527 mm (*right*) from Muktiharjo, Central Java (*right*) on which Jatropha thrives

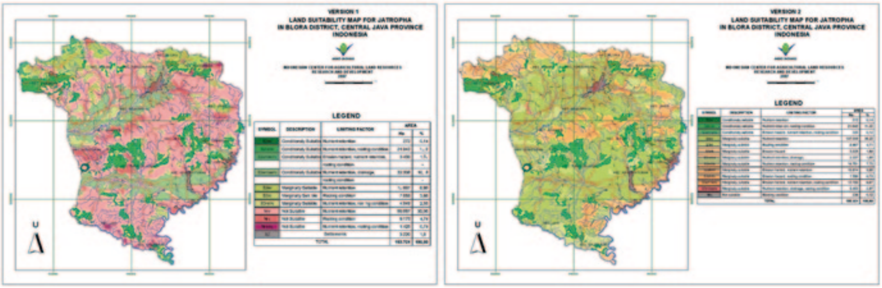


Fig. 11.6 Land suitability map for Jatropha in Blora District, before (*left*) and after validation with field verification (*right*)

land having limiting factors, which will affect productivity and require external inputs.

S3 (marginally suitable): land having many limitations which highly affect crop production, **N** (not suitable): land having many serious limiting factors such that crop production is unjustifiable.

Figure 11.6 illustrate the distribution of land suitability classes before and after field verification (validation). The results show that about 96,987 ha or (50.1 %) from total area of Blora District (193,721 ha) are not suitable for Jatropha with limiting factor of nutrient retention (pH) before validation. After validation in the field and the modification of criteria especially for pH (pH 8.2) and soil depth <30 cm are S3 class, a large part of land that had been classified as unsuitable (N class) changed to marginally suitable (S3 class).

11.6 Constraints of Jatropha Development in Indonesia

Jatropha is the only non food-producing commodity that produces biofuel, while other biofuels producing commodities such as palm oil, sugarcane, cassava, corn, sago, are also considered as food crops and the use of their products for biofuel will reduce food production. Presidential Instruction No. 1 of 2006 on the development of biofuel producing commodities, including the target of 2 mha for Jatropha between 2005 and 2015, has been issued, and the Indonesia National Team of Biofuel Development (2005) has been established. However, the development of Jatropha has been a lot slower than what was expected, although suitable land resource is available for its development. Developing of Jatropha in Indonesia have several constraints from technical and economic aspects. From the technical aspect, jatropha is a new commodity that has not been commonly cultivated (initially it was used as living fence or growing naturally without proper cultivation), so the cultivation techniques were not well understood by most of the people. Good quality seeds are limited and the post-harvest management was very traditional. Government assistance will be needed for the procurement of small-scale mill facilities for village level industry to operate. Furthermore, the existing subsidies for gasoline and diesel fuel make it difficult for Jatropha biodiesel to compete. If the seed can be sold immediately, the market is readily available; and the price is competitive with other commodities, then there will be a possibility for Jatropha to compete.

11.7 Conclusions

Jatropha can grow on various types of soils and wide ranges of climate. The land suitability criteria developed in this study is important to serve as a reference in the evaluation of land for Jatropha development in Indonesia. Indonesia has enough potential land for Jatropha development, but this commodity has not yet been developed because of lack of local capacity for cultivation, postharvest handling and processing, and marketing. The subsidized fossil fuel price makes it difficult for Jatropha to be competitive.

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Chapter 12
Physiological Adaptation of Alfalfa Genotypes to Salt Stress (One of Deleterious Impacts of Climate Change)

Masoud Torabi, Ridzwan A. Halim and Rajab Choukan

Abstract Plant physiological processes are invariably linked to the deleterious influences of climate change. This study seeks to identify the physiological responses of some salt tolerant ecotypes of alfalfa when exposed to salt stress during the mature phase of growth. Five Iranian alfalfa ecotypes representative of three climatic zones were evaluated for their response to salt stress in a split plot trial, with three replications, where the main plots were five ecotypes and subplots were the levels of salinity. The seeds were planted in plastic pots filled with sand and immersed in nutrient solution. After more than 2 months when the plant became mature the EC of nutrient solution was increased gradually by adding sodium chloride. At every 15 days the EC increased by 3 dS m^{-1}, and the final EC was 18 dS m^{-1}. The EC at each stage of salt addition was 6, 12, and 18 dS m^{-1}. At each stage of salinity the physiological characteristics of alfalfa ecotypes were measured including: crop growth rate, photosynthesis rate, chlorophyll content, stomatal conductance, and chlorophyll fluorescence. The results showed that the physiological parameters were affected by salt concentration and there were varying responses between genotypes. Salt stress resulted in a linear decline in the photosynthetic rate from 21 μmol CO_2 m^{-2} s^{-1} in control to 5 μmol CO_2 m^{-2} s^{-1} at 18 dS m^{-1}. Ecotypes showed similar responses in photosynthesis and stomatal conductance under salt stress. A positive correlation between CO_2 net uptake and stomatal conductance was observed. The chlorophyll content decreased with increasing salinity and there is a significant difference between ecotypes in terms of chlorophyll content. The results

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of Fv/Fm, ratio showed that up to 12 dS m^{-1} there were not significant changes in Fv/Fm ratio but after 12 dS m^{-1} the Fv/Fm ratio decreased with increasing of salt stress. There was a significant difference in Fv/Fm ratio among the ecotypes with increasing salinity. The study indicated that physiological responses to salinity varied among ecotypes, indicating genotypic differences in salt tolerance. In terms of physiological response the ecotype *Ghargholough* was identified as the most salt tolerant and should be chosen for areas that have become saline as a result of climate change.

Keywords Climate Change • Salt Stress • Alfalfa • Physiological Responses • Photosynthesis

12.1 Introduction

One of the world's most serious consequences of climate change is the expansion of saline areas where one-third of the world's cultivated land is affected by salt stress (UNESCO) Water Portal 2007). The Intergovernmental Panel on Climate Change (IPCC) reported that climate change across the world will result in faster-than-predicted extension of the saline zones, (IPCC 2007a). One of the direct influences of climate change is shifts in precipitation and evaporation patterns that result in increasing salinity (IPCC 2007b).

The breeding techniques and conventional selection that is based on differences in agronomic characters could not cover all responses of plants to salt stress, because those agronomic characters represent the combined genetic and environmental effects on plant growth (Torabi and Halim 2010; Parida and Das 2005). Physiological response and growth of plants to salinity can be partitioned to two phases of salinity: a rapid, osmotic phase that reduces or inhibits growth of young leaves and a slower, ionic phase that accelerates senescence of mature leaves. In order to understand the physiological responses of plant to salt stress one needs to know whether plant growth is limited by initial effects (osmotic influence) or the toxic effects (ionic influence) inside plants (Munns and Tester 2008).

Photosynthesis is affected by salt stress in the short-term and in the long-term so that at short-term after few hours and may be 1 or 2 days, the carbon assimilation is terminated due to closure of the stomata (Munns and Tester 2008). In the long-term, after several days there is a reduction in carbon assimilation owing to unbalanced ions and accumulation of salt in leaves (Munns and Termaat 1986). The reduction of photosynthesis under salt stress can be attributed to various factors such as reduced rate of leaf expansion, smaller leaf area, and shorter leaf duration, as well as by reduction in photosynthesis and respiration per unit leaf area (Manchanda and Garg 2008). Most of the reports have shown that salt stress suppressed the photosynthetic rate (Gama et al. 2007; Kao et al. 2001; Koyro 2006; Redondo-Gomez et al. 2007) although there are some reports that show photosynthesis is stimulated by low concentration of salt (James et al. 2002; Kurban et al. 1999; Rajesh et al. 1998).

Table 12.1 Ecotypes geographical information

No	Ecotype	Longitude *(Degree)*	Latitude *(Degree)*	Altitude *(Meter)*	Climate *(Zone)*
1	*Rehnani*	51	32	1,500	E
2	*Ghargholough*	44	39	1,180	A
3	*Shorkat*	48	34	1,370	A
4	*Bami*	48	34	1,750	F
5	*Nik -shahri*	60	26	450	F

Some results have shown that the rate of photosynthesis in the unit of leaf is unchanged under salt stress whereas stomatal conductance is reduced (James et al. 2002), this can be due to changes in cell anatomy in terms of increasing in thickness of leaf and chloroplast density (James et al. 2002). In a study on a legume plant (*A. pseudoalhagi*) under salt stress Kurban et al. (1999) indicated that the leaf CO_2 assimilation rate increases at low salinity, remains unchanged at moderate, and decreases at high levels of salinity. Agastian et al. (2000) demonstrated that when the mulberry plants were under salt stress, the net CO_2 assimilation rate, stomatal conductance, and transpiration rate declined, but intercellular CO_2 concentration increased.

Usually the chlorophyll content decreases under salt stress in leaves and subsequently the oldest leaf start to show chlorosis and leaf abscission (Agastian et al. 2000; Gadallah 1999; Hernandez et al. 1999) whereas Wang and Nil (2000) indicated that the content of chlorophyll increased in *Amaranthus* under salt stress.

Plant response to salt stress is an expression of the physiological changes that occur in the plant to overcome the environmental stress imposed by salinity. Hence understanding of these physiological changes is important in the evaluation of tolerance of ecotypes to salt stress and finally adaption with climate change.

12.2 Materials and Methods

The experiment was carried out during December 2008 till the end of April 2009 at hydroponics greenhouse located at farm 10 and laboratories of University Putra Malaysia. Five Iranian alfalfa ecotypes were evaluated to salt stress (Table 12.1) representing three climatic zones of Iran according to classification by Dinpashoh et al. (2004).

At first seeds were germinated in jiffy pots with four seeds per jiffy pot. Misting was carried out two times per day. After one week the jiffy pots were transferred to larger poly bags (30 × 15 cm) filled with sand and then thinned to two plants per pot which were then inserted in the hydroponic tray. All the pots were supplied with complete nutrient solution according to Peel et al. (2004) where the complete nutrient solution was prepared in the underground tank then pumped to hydroponic trays where the pots were immersed in the nutrient solution. At the first leaf until first trifoliate leaf stage, the concentration of nutrient solution was half of original concentration. After first trifoliolate leaf emerged the concentrations was increased to full rate and after two months from planting the plants were subjected to salinity by mixing salt (NaCl) with the nutrient solution. At the beginning, the amount of salt given was calculated to increase EC to 3 dS m^{-1}. The amount of salt given was increased gradually such that in every 15 days the EC will be increased by 3 dS m^{-1} and the final EC was 18 dS m^{-1}. The plants underwent three stages of salt increase bringing up the EC to 6, 12, and 18 dS m^{-1}. This experiment was a split plot with 3 replications with ecotypes as main plot and levels of salinity as sub-plot. Because of lack of space and facilities only one un-replicated row comprising all ecotypes was used as untreated for comparison with treated plants. Data were analyzed by the SAS (Statistical Analysis System) method using the analysis of variance (ANOVA) and treatment means were compared using Duncan's multiple rang test at $P \leq 0.05$.

To evaluate the physiological responses of alfalfa ecotypes to salt stress the parameters observed were: dry matter, photosynthesis rate, chlorophyll content, stomatal conductance, and chlorophyll fluorescence. Plants were sampled when they reached the three stages of salinity: 6, 12, and 18 dS m^{-1}. The photosynthesis rate and stomatal conductance were measured using a portable photosynthesis system (LI-COR 6400). A SPAD-502 chlorophyll meter (Minolta Co., Ltd.) was used to estimate the chlorophyll content of leaves. Chlorophyll fluorescence was measured by Plant Efficiency Analyzer, Handy PEA (Hansatech Instruments Ltd., Norfolk UK) at the same leaves that have been used for photosynthetic rate.

12.3 Results and Discussion

12.3.1 Influence of Salinity on Growth

The influence of salt stress on growth was negative where the crop growth rate (CGR) in all ecotypes was reduced under salt stress. The slope of reduction of CGR for all 5 ecotypes was sharp and the linear trend line showed that increasing salinity reduced the growth rate of alfalfa. Reduction of plant growth with salinity was almost same by ecotypes (Fig. 12.1).

Similar to our results, many researchers found that growth of plant declined under saline conditions but the degree of reduction depended on level of salt, environment condition, type of plant and stage of growth. The reduction of growth under salt stress was demonstrated in sugar beet (Ghoulam et al. 2002), in cotton (Ha and Martinez 2001) in tomato (Romero-Aranda et al. 2006; Romero-Aranda et al. 2001), in barley and wheat (Pessarakli and Huber 1991), in sultana vines (Fisarakis et al. 2001) and in beans (Kaymakanova and Stoeva 2008). The changes in root/shoot ratio with increasing salinity differed between ecotypes (Fig. 12.2) so that in

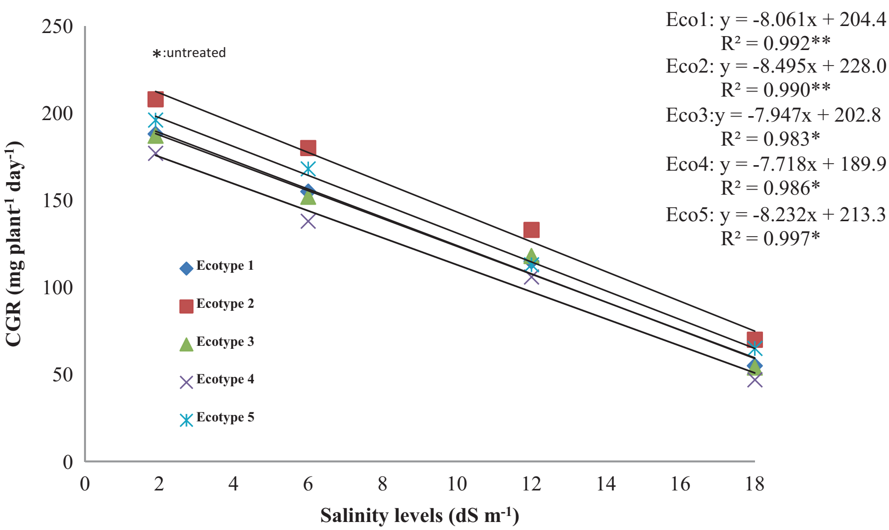

Fig. 12.1 Effects of salinity levels on CGR among the 5 ecotypes. (*$P<0.05$, **$P<0.01$)

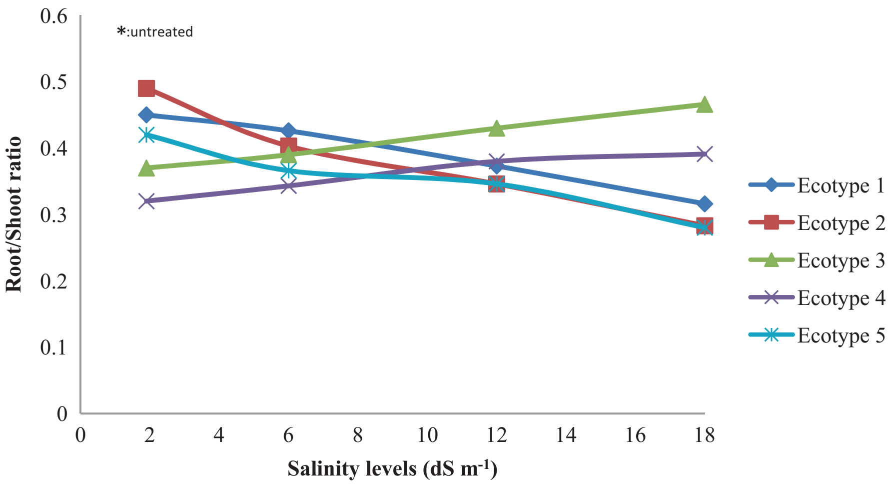

Fig. 12.2 Effects of salinity levels on root/shoot ratio among the 5 ecotypes

some ecotypes (Number 3, and 4) with increasing salt stress the ratio of root/shoot increased and in other ecotypes it was the opposite.

The ecotypes with reduction of root/shoot ratio can be more tolerant than ecotypes with increasing root/shoot ratio. The ecotypes that could allocate more assimilate to aboveground part under salt stress could be more tolerant to salt stress.

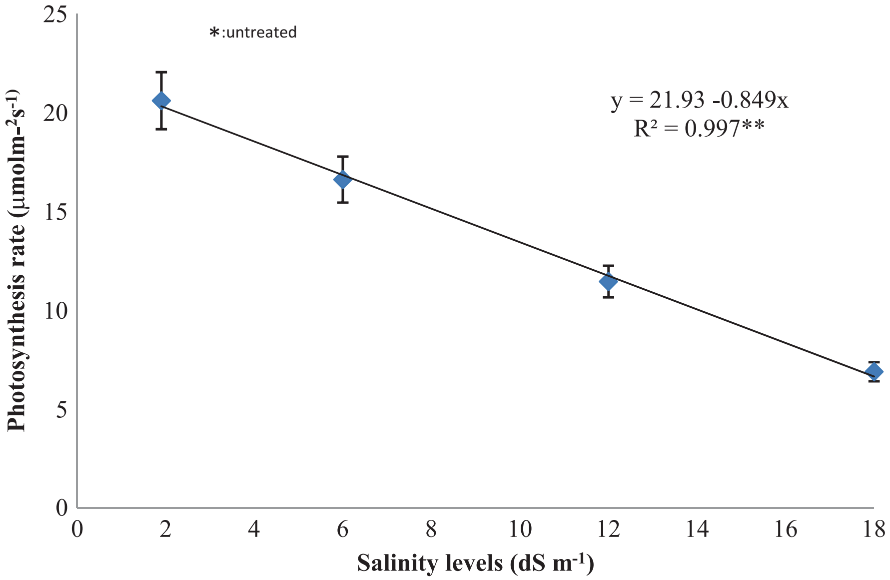

Fig. 12.3 Effects of salinity levels on photosynthesis rate (*$P<0.05$, ** $P<0.01$)

12.3.2 Influence of Salinity on Photosynthesis Rate

Increasing salinity reduced the photosynthesis rate from 21 to 5 µmol CO_2 m^{-2} s^{-1} (Fig. 12.3). The reduction of photosynthesis rate can be due to a decrease in stomatal conductance, subsequently reduction of CO_2 assimilation and respiration rate as was reported for various species and levels of salinity (Ashraf 2001; Kaymakanova and Stoeva 2008; Marler and Zozor 1996; Romero-Aranda et al. 2001).

The researchers (Parida et al. 2004) have shown that the reduction rate in photosynthesis and assimilation strongly depend on salt concentration (Fig. 12.3) and genotypes (Fig. 12.4).

The mechanisms of reduction of photosynthesis rate under salt stress is complicated (Muranaka et al. 2002) so that some evidence have shown that salt stress inhibits the apparent quantum efficiency of photosynthesis and suppressed photosystem II (PSII) activity whereas photosystem I (PSI) activity was stimulated by salt stress (Lu and Vonshak 1999).The main reasons of decline of photosynthesis under salt stress can be attributed to osmotic potential, toxicity of NaCl ions, shutting of stomata, changes in cytoplasmic structure and enzyme activity and reduction in sink activity as a result of negative feedback (Iyengar and Reddy 1996).

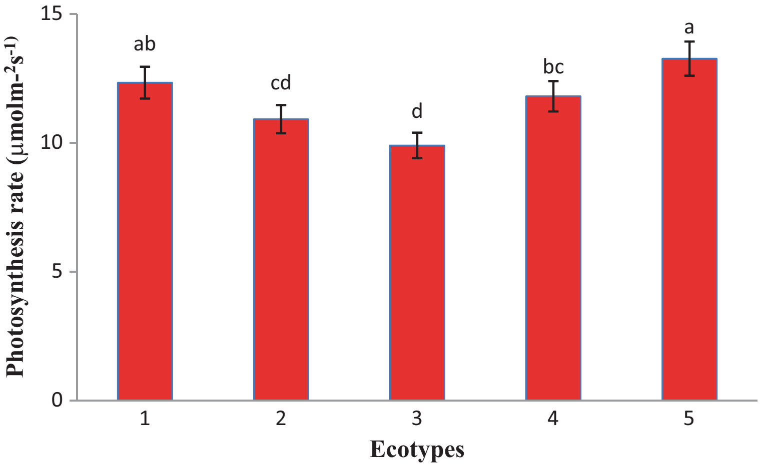

Fig. 12.4 Variation of photosynthesis rate among the 5 ecotypes in saline condition (Bars with a similar letters are not significant at $P<0.05$)

12.3.3 Influence of Salinity on Stomatal Conductance

When the plants were exposed to different levels of salinity stomatal conductance decreased whereas in the control at different harvest the stomatal conductance did not change (Fig. 12.5). The reduction of stomatal conductance under salt stress can be attributed to perturbed water relations and shortly afterward owing to the local synthesis of ABA (Munns and Tester 2008).

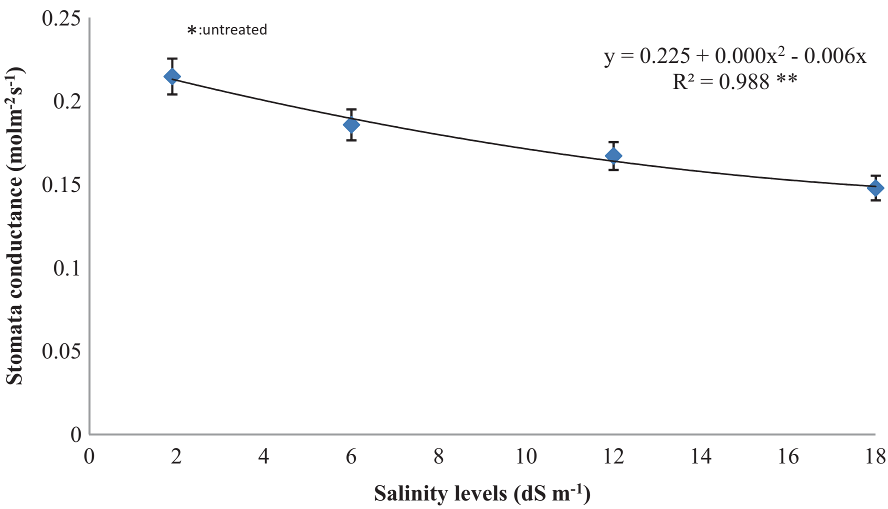

Fig. 12.5 Effects of salinity levels on stomatal conductance (*$P<0.05$, **$P<0.01$)

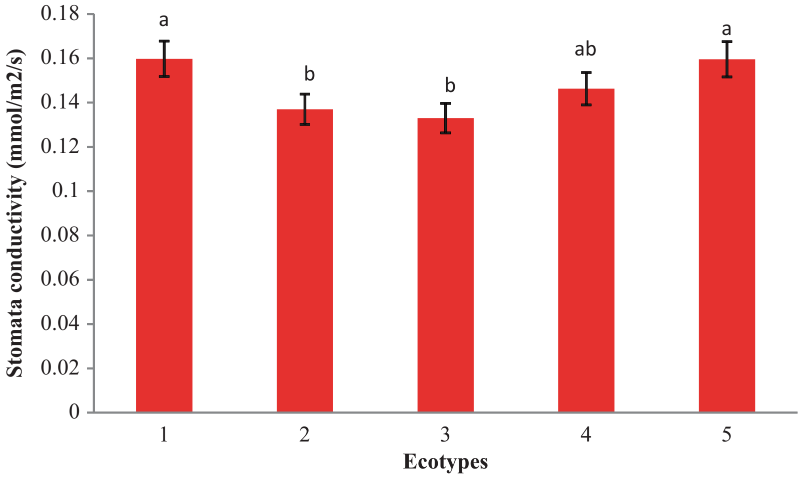

Fig. 12.6 Variation of stomatal conductance among the 5 ecotypes under saline condition (Bars with a similar letters are significant at $P<0.05$)

The reduction of stomatal conductance under salt stress and subsequently reduction of CO_2 assimilation and respiration rate have been reported in various genotypes (Fig. 12.4 and 12.6) in agreement with Agastian et al. (2000), Ashraf (2001), Marler and Zozor (1996), Romero-Aranda et al. (2001) and Turk (2007). Also there is some evidence that shows stomatal conductance at low levels of salinity remains unchanged and at high levels of salinity decreased (Parida et al. 2004).

Significant differences in stomatal conductance were found among ecotype (Fig. 12.6) and it was in agreement with Anand et al. (2000). They have shown that the rate of stomatal conductance and photosynthesis decreased in alfalfa under salt stress. There is a high correlation between reduction of stomatal conductance and photosynthesis rate under salt stress (Fig. 12.6) and it was supported by Fisarakis et al. (2001). A positive correlation between CO_2 net uptake and stomatal conductance was observed for all ecotypes (Fig. 12.7) which means that the rate of photosynthesis can be function of stomata conductance due to perturbed water relations and shortly afterward probably owing to the local synthesis of ABA (Netondo et al. 2004).

12.3.4 Influence of Salinity on Chlorophyll Content

The chlorophyll content decreased with increasing salinity (Fig. 12.8) with a sharp decline up to 6 dS m^{-1} followed by gentler reduction at higher levels of salinity. Many researchers have shown that the chlorophyll content under salt stress was reduced with chlorosis from oldest leaves (Agastian et al. 2000; Gadallah 1999; Hernandez et al. 1995) but in some plants like *Amaranthus. Sp* the evidence showed that salt stress caused chlorophyll content to increase (Wang and Nil 2000).

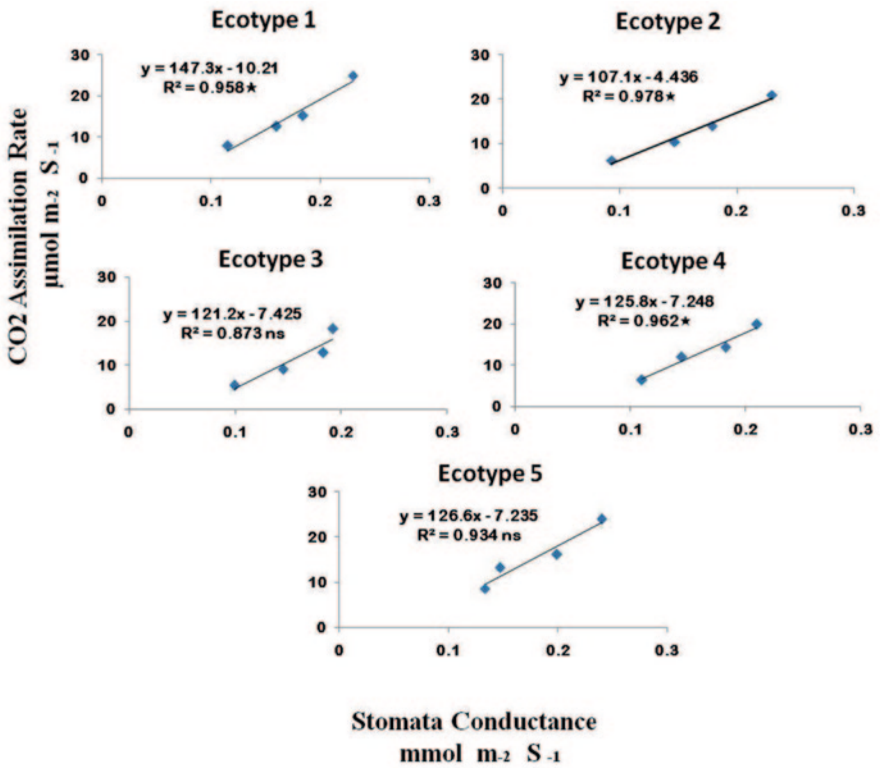

Fig. 12.7 Relationship between CO2 assimilation rate and stomatal conductance among the ecotypes under salt stress (*$P<0.05$, **$P<0.01$)

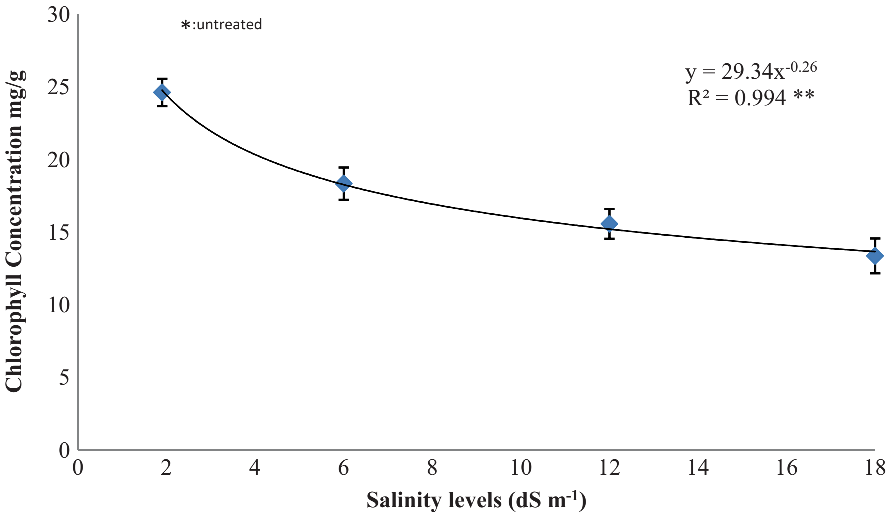

Fig. 12.8 Effects of salinity levels on chlorophyll concentration (*$P<0.05$, **$P<0.01$)

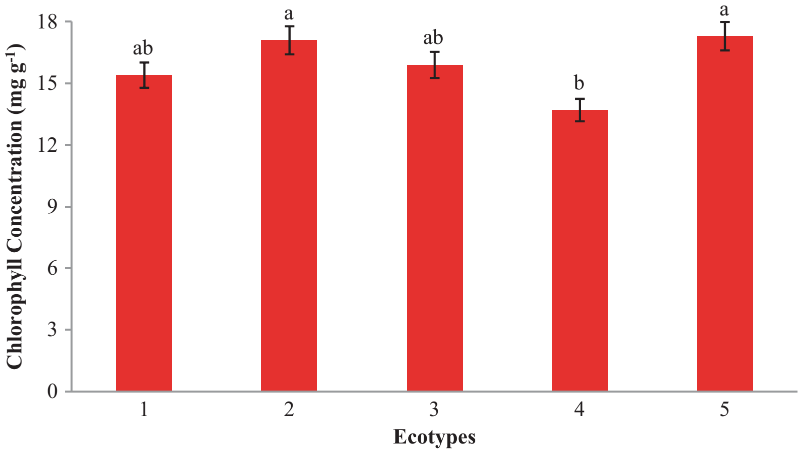

Fig. 12.9 Variation of chlorophyll concentration among the 5 ecotypes under saline condition (Bars with a similar letters are not significant at $P<0.05$)

The results show that there is significant difference between ecotypes in terms of chlorophyll content (Fig. 12.9) which means the ecotypes responded to salt stress in a different manner. Some reports have shown that the chlorophyll content increased at low levels of salinity due to induced chlorophyll degrading enzyme (cholorophyllase) but decline at moderate and high levels of salinity (Beinsan et al. 2008).

12.3.5 Influence of Salinity on Chlorophyll Fluorescence

One of the tools to evaluate salt effects and also response of ecotypes to salt is Fv/Fm (Belkhodja et al. 1994). The results showed that up to 12 dS m^{-1} there was no significant change in Fv/Fm ratio (Fig. 12.10) but above 12 dS m^{-1} the Fv/Fm ratio decreased with increasing of salt stress.

There was similar report for sorghum (Netondo et al. 2004), triticale (Morant-Manceau et al. 2004), and naked oat (Zhao et al. 2007) whereas up to 100–150 mM the rate of Fv/Fm did not changed. Because of variation of ability of ecotypes in terms of light efficiency there was significant difference between the ecotypes in terms of chlorophyll fluorescence (Fig. 12.11).

The results have shown that a study on plant physiological process under salt stress can lead to an understanding of salinity effects on physiology of the affected plants. It is confirmed by Cramer (2002), Fricke and Peters (2002), Fricke et al. (2006) that the physiological responses can be due to osmotic and ionic influence respectively as short and long terms effects under salt stress so that some of the physiological processes were affected by osmotic influence and some by ionic influence. The first response from plant to salt stress is reduction in stomatal conductance. The reduction of stomata conductance according to Fricke et al. (2004),

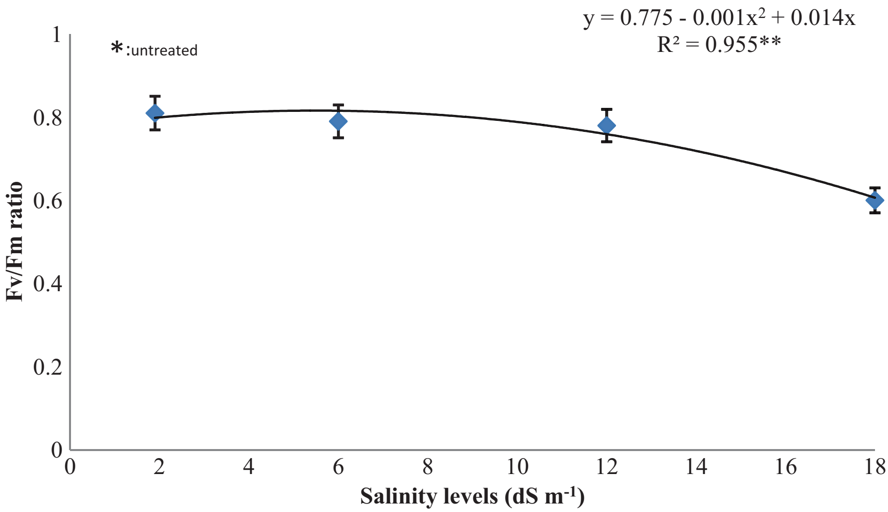

Fig. 12.10 Effects of salinity levels on chlorophyll fluorescence (*$P<0.05$, **$P<0.01$)

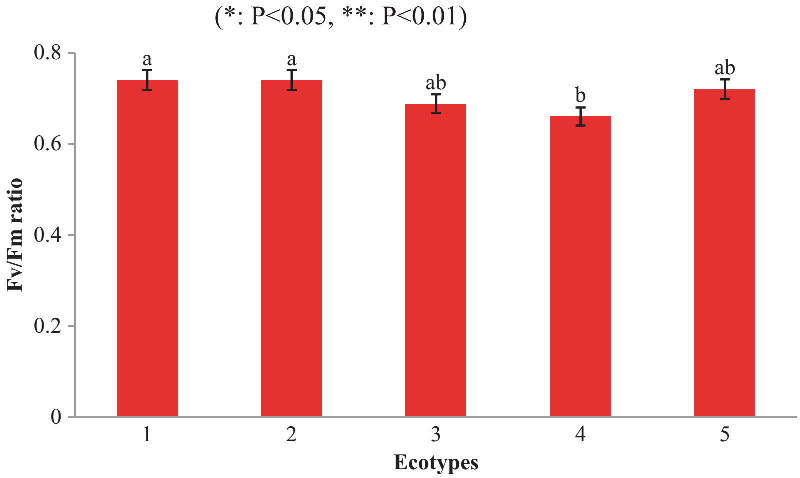

Fig. 12.11 Variation of chlorophyll fluorescence among the 5 ecotypes under saline condition (Bars with a similar letters are not significant at $P<0.05$)

Fricke et al. (2006) can be due to osmotic effects and subsequently the local synthesis of ABA. The response of ecotypes in terms of stomatal conductance under salt stress was the same, so that it can be due to relative tolerance among the alfalfa ecotypes. In the same case they have shown that the rate of stomatal conductance and photosynthesis decreased in alfalfa. Subsequently with reduction of stomatal activity the CO_2 assimilation rate was affected by salt stress and there is a high correlation between them. In other words, the rate of CO_2 assimilation can be a function of stomata conductance due to perturbed water relations and shortly afterward owing to the local synthesis of ABA (Netondo et al. 2004b). The results have shown that with increasing salt stress a serious reduction in CO_2 assimilation rate occurred. There was a significant difference between ecotypes in terms of photosynthesis rate under salt stress. As a result of reduction in stomatal conductance and subsequently CO_2 assimilation the CGR decreased significantly in all ecotypes under salt stress and the researchers such as Ha and Martinez (2001), Pessarakli and Huber (1991), Romero-Aranda et al. (2006) and Romero-Aranda et al. (2001) have shown that rate of reduction depended on level of salt, environment condition, type of plant and stage of growth. The ratio of root/shoot was affected by salt stress and ecotypes where the ecotypes with reduced of root/shoot ratio can be more tolerant than ecotypes with increased of root/shoot ratio. Other physiological parameter such as chlorophyll content and chlorophyll fluorescence was affected by salt stress significantly (Fig. 12.9 and 12.10) and this is corroborated by Beinsan et al. (2008). The remarkable point was that ratio of Fv/Fm up to 12 dS m^{-1} did not show significant change but after 12 dS m^{-1} the Fv/Fm ratio decreased with increasing salt stress and it was corroborated by Netondo et al. (2004) in sorghum, Morant-Manceau et al. (2004) in triticale, and Zhao et al. (2007) in naked oat. Based on our results ecotype 2 in terms of physiological responses to salt stress was superior to others and this ecotype able to develop in saline area and adapt with climate change.

12.4 Conclusions

It is concluded that plant physiological process under salt stress can lead to an understanding of salinity effects on physiology of the affected plants, this can be due to osmotic and ionic influence respectively as short and long terms effects under salt stress. The first response from plant to salt stress is reduction in stomatal conductance. With increasing salt stress a serious reduction in CO_2 assimilation rate was occurred, and there was a significant difference between ecotypes in terms of photosynthesis rate under salt stress. Chlorophyll content and chlorophyll fluorescence was also affected by salt stress significantly. Based on our results ecotype 2 in terms of physiological responses to salt stress was superior to others and this ecotype able to develop in saline area and adapt with climate change.

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Part III
Livestock Production Enhancement: Recommended Techniques

Chapter 13
Use of *Prosopis juliflora* Seedpod as Livestock Feed Supplement in the Arid and Semi-arid Rangelands of Kenya

Koech Oscar Kipchirchir, Ngugi Robinson Kinuthia and Wahome Raphael Githaiga

Abstract Trees and shrubs have provided many benefits. Currently these are disappearing in the arid and semi-arid areas of Kenya and affecting the livelihoods of pastoralist depending on livestock production. The climate change will affect it further. The trees and shrubs are under serious threat, especially in the Sahelian zone, owing to increased periodic droughts, rapid increase of population leading to overexploitation. The aim of the study is to assess the feasibility of incorporating *Prosopis juliflora* seedpods into a typical dryland livestock production system. Twenty weaner Galla goats of similar age (6 months) and weights (11–14 kg) were randomly assigned to four treatments of five weaners each. The treatments were PJP0-No *P. juliflora* (control treatment), PJP100- (100 g/goat/day *P. juliflora*), PJP200 (200 g/goat/day *P. juliflora*), and PJP400 (400 g/goat/day *P. juliflora*). The experiment lasted for 70 days. All the treatment groups exhibited higher average weekly weight gains than PJP0 (control) throughout the experimental period. However, for the first 3 weeks, these differences were not statistically significant ($P < 0.05$). From the fifth week onwards, however, the differences in growth rates were statistically significant ($P < 0.05$). Treatment PJP200 exhibited the highest total weight gain (3.96 kg), followed by PJP400 (2.70 kg). Group PJP0 had lowest weight by the end of the experiment. This study demonstrated that *P. juliflora* could be used as goats feed up to 200 g/goat/day giving good weight gains and no negative effects on feed intakes and digestibility.

Keywords Prosopis juliflora seedpods • Feed conversion efficiency • Body condition scores • Weight gains • Livestock supplementation

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13.1 Introduction

Among the trees and shrubs in the world, *P. juliflora* being one of them, have provided many benefits to human and animals throughout the ages. Their leaves, flowers, pods and tender twigs (browse) have been an important source of wildlife and livestock feed. In many arid and semi-arid lands, this component is sometimes the only source of forage for animals. Le Houérou (1978) pointed out that nearly one third of the world's land surface is natural grazing land and to varying degrees the shrub-tree component is a crucial source of animal feed. In the same document, analyzing data from various world locations, Le Houérou (1978) found a high dependence of rangeland grazing animals on trees and shrubs to satisfy their protein requirements, especially during the dry seasons. He concluded that without these plants to complement other forage plants, the entire livestock production system would be jeopardized.

The foregoing situation is most likely going to be amplified by the on-going climate change phenomenon. Already, these plants are under serious threat, especially in the Sahelian zone, owing to increased periodic droughts and fast growing human and animal populations leading to overexploitation. Other contributing factors include the emerging tendency of previously nomadic or transhumant populations to become sedentary resulting in increased pressure by human and animals on these plants through expansion of cultivated areas coupled with disappearance of fallows from cultivated areas.

In general, although trees and shrubs are the most visible plant life forms in arid lands, they have been neglected in almost all spheres of scientific research (McKell 1974) and land management policies (Le Houérou 1972). Motivated by a desire to increase livestock forage, numerous research efforts have been concentrated on methods of shrub eradication (Cook 1958) or control the spread of the invasive species (Texas Agricultural Experiment Station 1973). The magnitude of these efforts have inclined many students, research workers and land managers towards the myopic view that most, if not all, shrubs are of low-value and only by converting shrub lands to grasslands, a productive grazing system can be created. This view grossly overlooks the crucial role of trees and shrubs to, not only provide forage, but also 'even-out' nutrient supply fluctuations between the dry (dormant) and wet seasons in the dry lands. This prejudiced view towards ligneous plants in general may be attributed to the low appreciation of the tremendous value that they offer to mankind, inadequate knowledge of their biology and potential responsiveness to management.

Despite the past and current 'injustices' to trees and shrubs, it is obvious that they are crucial component of all natural pastures throughout the world. In fact, it is inconceivable to visualize natural grazing lands devoid of these plants. Unlike grasses and forbs, ligneous plants, especially the evergreen types, provide livestock with fresh (green) forage during the dry season which is more nutritious than the 'dead' (dry) herbage. They serve as rich sources of proteins, vitamins, energy and minerals at a time when the preferred grasses and forbs are either not available or unable to provide these nutrients. With no supplementation, browse represents at least 20 % of livestock diets during the dry season in the Sahelian and northern Sudanian zones. Livestock keepers have from time immemorial utilized these plants to make up for nutritional shortfalls that occur during the dry seasons. From a strictly pastoral point of view, without this vegetation component, there would be no pastoralism as we know it today.

The problem hinges around the inability of dry grazing areas to produce adequate high quality livestock forage throughout the year to support acceptable livestock weight gains or, at least, avoid weight losses. We argue the solution to this problem may come from prudent utilization of locally available fodder trees and shrubs that come at low cost. Thus, this study aimed to assess the effect of increasing dietary quantities of *Prosopis juliflora* seedpods on the performance of caged Weaner Galla goats, in the arid and semiarid areas, where goats are one of the most important livestock species due to their hardiness, high reproductive capacity and high quality products like milk, meat and skins.

13.2 Materials and Methods

13.2.1 Study Area

The experiment was conducted at Kenya Agricultural Research Institute, Marigat, Perkerra centre, in Baringo district, Kenya.

13.2.2 Experimental Animals, Supplements and Protocol

Twenty weaner Galla goats of similar age (6 months), sex (male) and average live weight (11–14 kg) were used in the experiment (Fig. 13.1).

The animals were randomly assigned in cages measuring 2.5 × 3.5 m with a cemented concrete floor. The cages were made of locally available *Prosopis juliflora* poles and posts, each house was assigned a different treatment, making a total of four treatments of five animals each. Each cage had a feeding and water trough.

Prior to bringing the animals to the facilities, all the animals were sprayed against ectoparasites. This was repeated after every fortnight. Deworming against endoparasites was done at 4 weeks interval during the study period. The animals were allowed to adapt to the cages for fourteen days. During this period, the animals were fed with mixed species hay purchased from Kabarak, Baringo district. However, the animals were progressively introduced to their treatment diets by giving 50 g/day in the last three days of the adaptation period. The experimental period extended for 70 days, and the animals being weighed every 7 days.

The supplement diet was *Prosopis juliflora* seedpods flour. The seedpods were harvested at the ripening stage during the fruit production season and stored in a

Fig. 13.1 Experimental weaner Galla goats feeding on *Prosopis juliflora* seed-pods meal

cool dry store. They were sun dried for three days for easy milling and storage for a longer period. The pods were ground in a 2–3 mm hammer mill to form seedpods meal.

The treatments comprised of; (1) Control: No PJP (0PJP), (2) 100 g/goat/day PJP (100PJP), (3) 200 g/goat/day PJP (200PJP), (4) 400 g/goat/day PJP (400PJP). The treatments were randomly assigned to the four groups. Hay, water and mineral block were provided *ad libitum* to the animals.

13.2.3 Data Collection and Digestibility Trial

The animals were weighed on a weekly basis; this was tabulated according to treatments. This was done in the morning after 13-hours overnight fast. Average Daily Gains (ADG) were later calculated and recorded. Intake of the hay was determined on daily basis, amount offered was recorded daily, and each morning before a fresh hay was offered, feed troughs were cleaned out and orts (refuse) weighed and recorded. The orts were then thoroughly mixed, a sub-sample taken for analysis and the rest discarded. The amount of hay consumed was then determined as the difference between the amount offered and the refuse. When a new batch of hay was brought in, a sample was taken for chemical analysis. Prosopis juliflora seed-pods meals samples were also taken for nutritional analysis by proximate analysis method.

The animals were fed twice per day, at 0800 (morning) and 1500 h (afternoon). At 0800 h, the animals were offered their corresponding supplement diets and 1 kg of hay. At 1500 h the animals received 1–1.5 kg of hay which was adjusted based on the previous day intake.

Digestibility trial was evaluated using three of the animals assigned to each diet. During the eighth week, three animals per treatment were selected at random and placed in a standard individual crates for metabolic studies. The animals were allowed to adjust to the crates for seven days followed by seven days of sample collection. During this trial, a sample of test diet was taken. This was bulked across days and stored for chemical analysis. The total daily faecal output from each animal was collected, weighed and a representative sample (about 10% of daily output) taken. Samples were sundried and packed in plastic bags for chemical analysis. The total 24-hour urine output from each animal was collected in plastic containers placed under metabolic crates. A volume of 15 ml of 1M H_2SO_4 was added into the troughs to reduce nitrogen loss through volatization. Daily urine output was measured volumetrically. A sub-sample of 15% (v/v) of the daily output was taken and bulked across the days. The samples were stored on a freezer set at −4 °C for nitrogen content analysis. Three animals from the control group were also included in the metabolism study.

13.2.4 Body Condition Scoring Procedure

At the end of study period, all the experimental animals in each treatment were assessed for body condition and assigned a score. The Spahr (2009) method of body condition was used which uses a 1–5 ranking, where, 1 represents an animal in bad body condition (very thin) and 5 represents an animal in prime body condition (well fleshed), as presented in Table 13.5. An average body condition score was calculated for each treatment group as the sum of the scores of each animal in the group, divided by 5.

13.2.5 Chemical Analysis

The diet samples and the faeces were oven dried at 60 °C for 24 h and then ground through a 1 mm Wiley mill during the preparation for chemical analysis. The Dry Matter (DM), ash and nitrogen were determined using the procedures of AOAC (1975), while Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) were determined following the procedures described by (Goering and Van Soest 1970). Nitrogen and DM determination of the faecal materials was completed on wet samples. The urine samples from the freezer were thawed and pooled according to different goats used, thoroughly mixed and then analyzed for nitrogen following the Macro-Kjedahl method. Mineral analyses of feed were completed according to (AOAC 1975) procedures. All the samples were analyzed in duplicates.

13.2.6 Statistical Analyses

The experimental data on growth performance and feed intakes of the feed rations was analyzed by one-way analysis of variance (ANOVA) (Steel and Torrie 1980). Mean separation was done using Duncan's New Multiple Range Test (Steel and Torrie 1980) at 5% level of significance.

Table 13.1 The average chemical composition of *P.juliflora* pod meal and hay in Dry matter basis

Chemical Component	*Prosopis* seed pods	Hay
DM (%)	88.4±0.3	99.4±0.2
OM (%)	83.2±2.8	90.0±4.6
CP (%)	18.5±0.3	6.1±0.3
ASH (%)	5.2±0.7	9.4±0.7
NDF (%)	51.8±4.2	59.0±5.9
ADF (%)	29.8±0.1	26.8±3.5
ADL (%)	3.2±0.4	8.1±0.5
Ca (%)	0.5±0.1	0.3±0.1
P (%)	0.2±0.1	0.1±0.1
K (%)	0.9±0.1	0.6±0.3
Mg (ppm)	760±3.0	917±5.5
Fe (ppm)	99±2.8	219±4.0
Zn (ppm)	1,279±6.4	1,365±29.9
Cu (ppm)	40±4.0	38±2.0
Na (ppm)	51±3.0	56±3.0

13.3 Results

The average chemical compositions of the *Prosopis* seedpod meal and the hay are presented in Table 13.1. *Prosopis* pod meal had about three times the amount of crude protein compared to the basal hay diet. The two feed components were similar in terms of neutral and acid detergent fibre. However, hay had about three times more lignin than the pod meal. The *Prosopis* seedpod meal was slightly higher in Ca, P and K than the grass hay. The Mg, Fe, Zn, Cu and Na were almost similar in the two feed components. Both feed components were notably supplying K, Ca and P, which were well above the daily requirements for sheep and goats.

The dry matter intake (kg) and live weight gains (kg) of the weaner Galla goats are presented in Table 13.2. Treatment group PJP0 (no *Prosopis* pods) had significant ($P<0.05$) effect on dry matter intakes in the four treatments. This group was not supplemented and had to take more DM to meet its nutritional requirements, but the weight gains were low. However, treatment PJP100 and PJP200 had about the same dry matter intakes that were not significantly different ($P<0.05$), despite the differences in treatments.

The weekly *Live Weight Gains* of the goats under different treatments for a 10-week feeding period are presented in the Fig. 13.2. Overall, all the treatment groups exhibited higher average weight gains than the control group. During the first three weeks there was no significant difference between the treatment groups in terms of weight gain ($P<0.05$). However, from the fifth week up to the tenth week, all the treatment groups exhibited significantly higher growth rates than the control ($P<0.05$)

Figure 13.3 presents the mean of weekly weight gains throughout the study period. The PJP200 treatment group had the highest mean weight gain rate and hence the best performance. This can be attributed to a combination of high CP and total

Table 13.2 Dry matter intake of hay, weight gains and feed conversion ratio

Treatment[a]	Total hay intake (kg)	Total seedpod intake (kg)	Total feed intake (kg)	Total live weight gain (kg)	Feed conversion ratio[b]
0PJP	24.0^c	0.00^c	24.0^c	0.65^c	36.9
100PJP	17.2^d	6.80^c	24.0^c	2.25^d	10.6
200PJP	17.5^d	13.6^c	31.1^d	3.96^e	7.85
400PJP	13.3^e	27.2^c	40.5^e	2.70^f	15.0

[a] PJP0-no *Prosopis*, PJP100–100 g/goat/day, PJP200–200 g/goat/day, PJP400–400 g/goat/day, Treatment means followed by same superscript within columns are not significantly different ($P<0.05$)
[b] kg feed: kg Gain

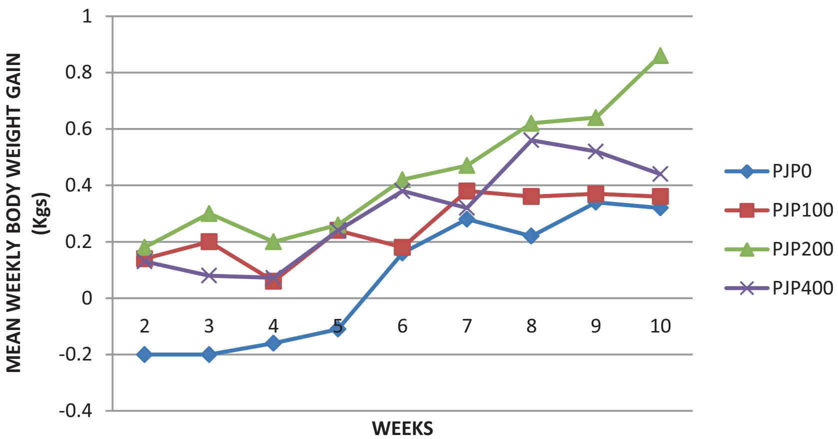

Fig. 13.2 Mean weekly live weight gain of the goats on increasing amounts of *Prosopis* seedpod meal

feed intake. As expected, PJP0 treatment had the lowest weekly weight gain. This is attributed to the low total feed intake as well as low CP intake due to lack of supplementation.

13.3.1 In Vivo Dry Matter Digestibility of the Diets

Table 13.3 presents the *in vivo* digestibility coefficients of Dry Matter (DM), Crude Protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL) and ash. Except for ADL, all the other nutrients showed a general increase in digestibility with increase in *P. juliflora* seedpod meal. Diet PJP0, with no *P. juliflora* seedpod meal supplement, gave significantly ($P<0.05$) lower DM, ash, NDF and ADF digestibility than other the diets. The *In sacco* dry matter digestibility of *Prosopis* seedpod meal was higher than that of hay, 74.5 and

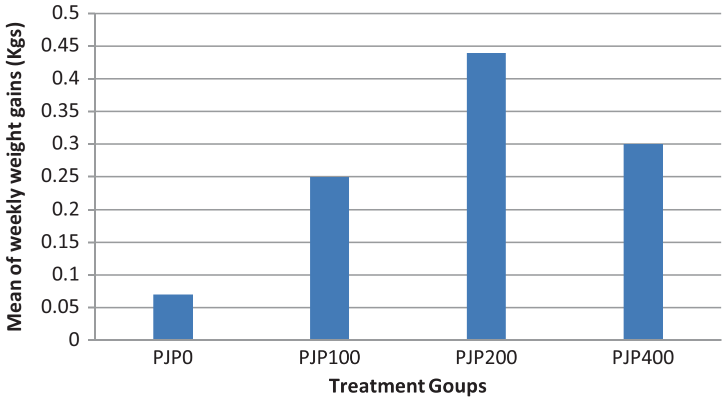

Fig. 13.3 The mean of weekly weight gains for different treatments

Table 13.3 Apparent *in vivo* digestibility (% DM) of diets

Treatment	DM	ASH	CP	NDF	ADF	ADL
PJP0	62.9[a]	24.2[a]	41.2[a]	61.6[a]	51.6[a]	31.4[a]
PJP100	68.3[b]	34.6[b]	64.3[b]	63.3[b]	59.1[b]	28.2[b]
PJP200	73.2[c]	42.1[c]	72.3[c]	71.8[c]	66.2[c]	25.3[c]
PJP400	75.4[c]	44.8[d]	74.5[d]	71.2[c]	70.3[d]	32.1[d]

Treatment means followed by same superscript within columns are not significantly different ($P<0.05$)

56.8% respectively. This can be attributed to the high CP that was present in *P. Juliflora.*

Table 13.4 presents the Nitrogen Balance status of the animals relative to the different levels of P. juliflora seedpod meal in their diets. Urinary nitrogen losses were significantly different ($P<0.05$) for all the treatment groups. There were also significant differences in the Nitrogen retained for all the treatment groups.

13.3.2 Body Condition Scoring of the Experimental Animals

Table 13.5 presents the average body condition score indices. The treatment group PJP0 had the lowest body condition score of 1 at the end of the experiment. The animals were thin and had poor body shape, i.e. easy to feel ribs. Treatment group PJP200 had good body condition score 3, it was smooth and well rounded. Treatment PJP100 and PJP400 had body condition scores 2, which was easy to feel but smooth.

Table 13.4 Nitrogen budget of goats supplemented with various levels of *Prosopis juliflora* pods

Diets[a]	PJP0	PJP100	PJP200	PJP400
W kg (Av weight of goats)	11.8[b]	14.6[c]	17.6[d]	14.4[c]
Ingested N gd^{-1}	3.2[b]	5.4[c]	6.7[d]	7.2[e]
gkg^{-1} $W^{0.75}$ d^{-1}	0.4[b]	0.5[c]	0.5[c]	0.6[c]
Faecal N gd^{-1}	1.7[b]	1.9[c]	1.2[d]	3.2[e]
gkg^{-1} $W^{0.75}$ d^{-1}	0.2[b]	0.2[b]	0.1[c]	0.3[b]
Urinary N gd^{-1}	0.9[b]	1.2[c]	1.0[d]	0.6[e]
gkg^{-1} $W^{0.75}$ d^{-1}	0.1[b]	0.2[b]	0.1[b]	0.1[b]
Total N loss gd^{-1}	2.6[b]	4.1[c]	4.5[d]	5.9[e]
gkg^{-1} $W^{0.75}$ d^{-1}	0.3[b]	0.4[c]	0.4[c]	0.5[d]
Retained N gd^{-1}	0.6[b]	2.3[c]	4.5[d]	3.4[e]
gkg^{-1} $W^{0.75}$ d^{-1}	0.1[b]	0.3[c]	0.4[d]	0.3[c]
Retained N as: % of N intake	18.8[b]	42.6[c]	67.2[d]	47.2[c]

Treatment means followed by same superscript within rows are not significantly different ($P<0.05$)
[a] PJP0-no *Prosopis*, PJP100–100 g/goat/day, PJP200–200 g/goat/day, PJP400–400 g/goat/day

Table 13.5 Average body condition score indices of goats according to the treatment groups

Treatment[a]	Body Score
PJP0	1
PJP100	2
PJP200	3
PJP400	2

[a] PJP0-no *Prosopis*, PJP100–100 g/goat/day, PJP200–200 g/goat/day, PJP400–400 g/goat/day

13.4 Discussion

The mineral contents for *Prosopis* used in our study were similar to those reported by Abdulrazak et al. (2006), who reported that that the CP and mineral concentration of *Prosopis* forage were satisfactorily high and warrant consideration of its use as supplement to low quality feed. The PJP200 treatment group had the highest total hay intake (17.5 kg) and average weight gain rate (3.96 kg) in supplemented groups. These findings are comparable to those of Mahgoub et al. (2005) who reported that goats fed 20 % Ghaf (*Prosopis cineraria*) had higher intakes than those on 30 % Ghaf. These high intakes of basal diet (hay) can be attributed to the fact that, *Prosopis* provided adequate energy protein ratio, which not only increased the essential nutrients to maintain optimal rumen activity, but was also more rapidly degraded in the rumen. It is reported (Ørskov and Dolberg 1984) that, supplement should be easily digestible by-product containing cellulose and/or hemicelluloses, and this will increase intakes and digestibility. Also, supplementary feeding provides animals with nutrients in amounts and combinations that the pasture is not providing at the time (Anderson 1978). It is important to ensure the whole diet of the animal, including both supplement and normal diet, is balanced.

The PJP400 treatment group exhibited lower hay intake than all the other treatments (0.196 kg/day) which also closely matched the findings of Mahgoub et al. (2005) where sheep fed on diets with increasing amounts of Ghaf at 0%, 15%, 30% and 45% demonstrated a sudden drop in feed intake when the amount of Ghaf approached 45%. Horton et al. (1993) also found Omani sheep on diets containing about 29% Ghaf pods had reduced feed intake. The reduction in feed intakes exhibited by animals on high proportion of *Prosopis* pods may be attributed to the increase of tannins and other phenolic compounds with the increase in proportions of *P. juliflora* pods, however in this study the tannin levels were not determined, but from literature, the species has been reported to have higher tannin content (Horton et al. 1993). Also, despite the contribution of the essential nutrients, it might have taken much longer to be broken down, hence the lower intakes of the basal diet (hay). Ingested fibre material must be broken down by rumination, microbial fermentation or both to produce particles which are small enough to pass through the reticulo-omasal orifice (Blaxter et al. 1956).

Diets PJP100, PJP200 and PJP400 with incremental levels of *P. juliflora* seedpod meal supplement at 100 g/goat/day, 200 g/goat/day and 400 g/goat/day, respectively, gave higher DM, CP and NDF digestibility than the control group that was not supplemented. The apparent increase in nutrient digestibility with increasing levels of *P. juliflora* in the diets was attributed to the corresponding increase in CP content of the diets. High protein diets supply adequate nitrogen for rumen microbial growth. This high rumen microbial population is, in turn associated with high rumen fermentation and overall digestibility of the ingesta. Weiss et al (2009) also reported an increase in the digestibility of nutrients with increasing amounts of protein content in the diets of alfafa silage and corn silage in cows. They also found that increasing metabolizable protein (MP) increases nitrogen digestibility. Delcurto et al. (1990) demonstrated that DM and NDF digestibility increased with an increase in supplemental crude protein of steer diets. Studies by Sultan and Loerch (1992) have also shown that protein supplementation to low quality diets increases nutrient digestibility.

In terms of feed conversion ratio, PJP200 treatment group was the best with a 7.85 ratio. Treatment PJP0 was the poorest with FCR 36.9. Diets with a low FCR are considered to be more economical in animal production and should be positive. These low FCR observed can be attributed to the fact that *Prosopis* contributed the fermentable energy to the rumen in the form of available cellulose and hemicelluloses which stimulate fibre digestion and hence nutrient released for growth (Ørskov and Dolberg 1984).

These improved animal performance exhibited by the goats in response to addition of *Prosopis* seedpod meal to their diets can be attributed to the high CP content of the meal. The PJP200 treatment group had the highest average total weight gain 3.96 kg followed by treatment PJP400 and 100PJP with 2.70 kg and 2.25 kg respectively. Treatment 0PJP had the lowest weight gain. The results here demonstrate a direct relationship between the CP content and animal performance. The results also show a positive relationship between CP content, the hay intake, and animal performance. The higher the CP content, the higher the hay intake and the higher the growth rate. The findings of this study were consistent with those of Mahgoub et al. (2005) who reported that goats fed 20 % Meskit (*P.juliflora*) pods had the highest weight gains whereas those fed 30 % had the lowest feed intake. They also reported that the goats fed rations with Rhodes grass hay as a major constituent of the diet, had lower feed intake than those fed 10 and 20 % Meskit pods, possibly due to relatively higher fiber content.

In this study the PJP400 treatment group had the lowest rate of weight gain and eventually lost weight during the 8th week. This can be attributed to the fact that the treatment group on the other hand had lower feed intake. The higher proportions of the *Prosopis* pod meal in the diet, most probably, may have caused a decrease in feed intake as a result of reduction in palatability. Mahgoub et al. (2005) found that goats fed 30 % Meskit lost weight by the end of his study.

The total nitrogen intake increased with the increase in the quantity of the *Prosopis* seedpod meal in the diets. Treatment PJP400 with highest amount of *Prosopis* pod meal and hence, the highest dietary N content, showed the highest level of fecal nitrogen (FN) loss and highest total loss which was significant ($P<0.05$) than the other treatments. The PJP0 (control) which was on hay only, and hence the lowest dietary N, demonstrated the lowest N retention and low total N loss. This outcome is similar to that of Freeman et al. (2009), who found that N retention was lower in un-supplemented goats than those that were supplemented.

There was a significant differences ($P<0.05$) in N retained between the supplemented groups and the control (PJP0). PJP200 had the highest N retention, hence, it was the best performing group in terms of weight gains, followed by PJP400 and PJP100 which were not significantly different ($P<0.05$). PJP0 (control) had the lowest N retention, consequently, the poor performance and weight loss at the end of experiment. The superior N retention rate depicted by PJP200 can be attributed to efficiency in the utilization of CP ingested, due to adequate amounts of hay intake that provided energy needed, which boosted the microbial population, which, in turn, increased the digestive activity to the ingesta. A study by Shukla et al. (1984), on Kakrei bullocks, offered a concentrate ration incorporating 0 %, 15 %, 30 % and 45 % levels of *Prosopis* pods, reported an increase in live weight gain and positive balances of N, Ca and P up to 30 % *Prosopis* content. However, 40 % *Prosopis* exhibited the lowest intake of hay, despite the high CP intake. Most probably the digestion may have been impaired at this level of *Prosopis* integration due to the low N retention rate. Shukla et al. (1984) also observed that at 45 % level of pod feeding, there was a slight negative N and P balance, and reduced live weight gain compared to animals at 30 % *Prosopis* seed pod level. As expected, PJP0 had low N retention due to poor quality hay (low CP content). Freeman et al. (2008) also observed low N retention in goats supplemented with secondary protein nutrients (SDN) at increasing proportion and attributed this to decreasing ruminal protein degradability.

Body Condition Scoring (BCS) for PJP200 was better than all the other groups, this was attributed to the high protein retention, and superior feed conversion efficiency depicted by the goats in this group. Also all this might have been possible by the balanced protein: energy ratio of the diets they consumed. The BCS helps adjust feeding for animals. However, this should be done gradually since ruminant animals are sensitive and any change greatly affects their rumen micro-organisms (Spahr 2009). This can result in problems such as diarrhea. Supplementary feeding can be adjusted up or down by using the body condition scores. Study by Zahraddeen et al. (2009) on the factors influencing milk yield of local goats under semi-intensive system in Sudan savannah ecological zone of Nigeria, they found that, body condition scores significantly influenced milk yield and it increased with increase in the doe's body condition score. This study shows that it is a parameter that is important in monitoring productivity of goats. Body condition scoring is one tool producers can easily use to monitor nutritional programs in a cowherd (Manuel and Greg 2000). This includes the supplementation interventions aimed at improving livestock nutrition. Adjusting the nutritional program to obtain desired body condition at different stages of production is necessary to enhance production efficiency (Manuel and Greg 2000).

13.5 Conclusion and Recommendation

The results of this study have shown that there is a benefit in utilizing the widely available *Prosopis juliflora* species as livestock feed supplement. This improves on animal nutrition and performance. *P. juliflora* seedpods contained high nutrient contents, having CP 18.5 %, DM 88.4 %, OM 83.2 %, Ash 5.2 %, ADF 29.8 %, NDF 51.8 %, and ADL 3.2 %, with good levels of calcium, phosphorus, iron, magnesium, potassium, zinc and copper required for animal growth and development. Therefore, the goat keepers in the dry lands should be advised to supplement their goats with this widely available *Prosopis* pods in the arid and semiarid lands of Kenya to improve on their weight gains and avoid weight losses during the dry seasons. This is one way of utilizing the tree species that grows in the ASALs and its full potential has not been explored.

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Chapter 14
Plankton and Common Reed- A Potential Resource for Domestic Animals and Fish in Northern Delta Lakes of Egypt

Abd El Aziz Mousa Nour

Abstract A concurrent study was conducted during 2005–2009 to evaluate the utilization of the natural resources available in Lake Manzalah, Dakahliah Governorate. The study was designed to rear silver carp (*Hypophthalmichthys molitrix*) fingerlings in cages alternatively with breading calves (males and females) on plankton and common reed *(Phragmites australis)* respectively. For intensive culture of *H. molitrix* fingerlings were stocked at a rate of 10 fish m^{-3}, and growing calves with a rate of 30 calves (2:1 cow: buffalo) with an initial average body weight of (10 g/fish, 155 kg/animal) respectively. The results showed that average body weight for fish reached 1,250 g/fish and each cage produced about 3 metric tons. However, as for the calves the weight increased with an average daily gain of 0.44 kg day^{-1}. By the end of the 4th year, the annual production reached for fish to 14,700 tons and for calves 53.6 tons of live body weights. The percentage of the annual profitability reached 387 and 88% for fish and calves, respectively. Thus, the present study indicates that the maximum production capacity reaching within 5 years could produce 34,000 and 808 tons of fish and calves, respectively. The finding of the present study, if applied to the other eutrophic Northern Delta lakes such as Burullus, Edku, and Maruit, this can certainly help ensuring the production of low cost animal protein for human consumption, creating new jobs in the rural areas around these lakes.

Keywords Lake Manzala • Northern Delta Lakes • Cage Production • Silver Carp • Plankton • Common reeds • Calves

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14.1 Introduction

The Northern Delta lakes (NDL) (Manzala, Burullus, Edku and Maruit) are located in the northern coast of Egypt on the Mediterranean sea of the Delta and cover about 6% of the non-desert surface area of Egypt. The lakes are an important natural resource for fish production in Egypt. Until 1991, these lakes have always been able to contribute more than 40% of the country's total fish production, but at present the production has decreased to less than 12.22% (GAFRD 2006). Tilapia species including *Oreochromis niloticus*, *O.aureus*, *Sarotherodon galilaeus* and *Tilapia zillii* ranked first followed by *Clarias gariepineus* in the fish production of these lakes. On the other hand, during the past few decades the lakes were subjected to a gradual shrinkage due to land reclamation and transformation of significant parts of the lakes to fish farms, particularly along the southern regions. In addition, large parts of the lakes have experienced an overgrowth of aquatic vegetation which reduces the open water to nearly half of its total area, speeding up the process of land transformation (Saeed and Shaker 2006).

The scarcity of the available agricultural land and water for irrigation with the rapid population growth led to a food shortage in Egypt, especially in animal protein products. Previous results by Nour et al. (2006), Darweish (2009), and Nour (2010) indicated the possibility of bridging the gap of the existing animal protein deficiency by utilizing the natural primary fodder production efficiently from the lake for feeding fish and livestock animals.

Sustainable agricultural approaches allow small enterprise holders to increase local food production at low-cost, with renewable resources and technologies that are environmental friendly and contribute to the increase in the agricultural land base (Badgely and Ivette 2007).

The severe shortage in animal protein production and the concentrate feeds required for feeding livestock animals in Egypt resulted in a sudden increase in its local market prices. Therefore, the objectives of the present study is to produce a sustainable, low cost animal proteins for human consumption through the advantages of the efficient utilization of the primary and secondary production (natural plankton and reeds) for feeding filter-feeding fish and growing calves.

The positive findings of the present study and their potential to successfully addressing the existing challenges, deserve their further application, therefore, more research is to be conducted in order to identify the best model that is environmental friendly and sustainable.

14.2 Materials and Methods

A concurrent study was conducted to evaluate the utilization of the natural resources available in one of the northern lakes of Egypt, lake Manzala, Dakahliah governorate, for 4 years from July of 2005 through December of 2009. The study aimed at rearing of silver carp (*Hypophthalmichthys molitrix*) fingerlings in cages alternatively with breading calves (males and females) on plankton and common reed *(Phragmites australis)* respectively.

14.2.1 Study Area

Lake Manzala is located on the north-eastern edge of the Nile Delta, between Damietta and Port Said. It is separated from the Mediterranean Sea by a sandy beach ridge which has three open connections between the lake and the sea, which allows an exchange of water between the lake and the sea. Lake Manzala is a shallow brackish with an area of approximately 1,000 km^2. The lake is highly eutrophic with both macrophytes and planktonic algae contributing to extensive carbon fixation. The nutrient input comes from fresh water inflows such that productivity decreases as salinity increases nearer the Mediterranean Sea.

14.2.2 Study Facilities

Locally made floating cages (10 m length × 10 m width × 3 m depth) were placed in the lake and stocked with silver carp (*Hypophthalmichthys molitrix*) fingerlings (10 g/fish) at a rate of 10 fish/m^3 for intensive culture. Reared fish feed on natural live food (planktons) in the eutrophic lake (Fig. 14.1). Water quality criteria, fish daily observations, fish growth parameters were all performed as described by Nour et al. (2006) and Darwish (2009). Growing calves (cow and buffalo) with initial average body weight of 135 kg/animal were purchased from the local market and treated with anti-helminthic drug for internal and external parasites elimination. Calves were fed *adlepetum* on freshly common reed (*Phargmites australis*) available in the lake. Growing calves were stocked at a rate of 30 calves with a ratio of 2:1 (cow: buffalo) with an initial average body weight of 155 kg/animal. Fish were purchased from a local hatchery and reared in the cages without any formulated feeds. Data was regularly collected and monitored (Nour 2008; Darwish 2009). Statistical analysis was carried out as per Snedecor and Cochran (1974).

14.3 Results

Results (Table 14.1 and Fig. 14.2) indicated a significant ($P < 0.05$) increase in the number of participants, cages, annual production, market fish price and net profit percentage over the 4-year study period (2005–2009). However, the values of average final fish body weight (g/fish/year), survival rate, and average yield per cage significantly ($P < 0.05$) decreased throughout the study period. Although, the annual

Fig. 14.1 Floating cages for silver carp culture (**a**), harvesting of silver carp (**b**), common reed (**c**), common reed for ruminant feeding (**d**)

Table 14.1 Observation data of sliver carp (*Hypophthalmichthys molitrix*) reared in floating cages in Lake Manzala, during the period of study from 2005 through 2009[a]

Observations	Year			
	1	2	3	4
Number of participants	10 d	25 c	56 b	98 a
Number of cages	30 d	75 c	280 b	490 a
Cage/graduate	3 b	3 b	5 a	5 a
Average final fish weight (g/fish/year)	1300a	1200 a	1190 a	1080 b
Survival rate %	98 a	98 a	96 b	95 b
Annual yield (ton)	114.66 d	264.60 c	959.56 b	1508.32 a
Average annual yield (ton/cage)	3.82 a	3.53 ab	3.43 b	3.08 c
Market price (L.E./ton)	4000 d	5000 c	7000 b	8000 a
Total operation costs (1,000 L.E.)	120	210	1100	1540
Total income (1,000 L.E.)	559	1323	6517	12066
Net profit (1,000 L.E.)	539	1113	5417	10526
Net profit (%)	449 d	530 b	493 c	684 a

profit percentages recorded an amount to 449, 530, 493 and 684 for the 1st, 2nd, 3rd and the 4th year, respectively. The increase in the fish market prices for the 4th year elevated the profitability by 150 % as compared with the 1st year.

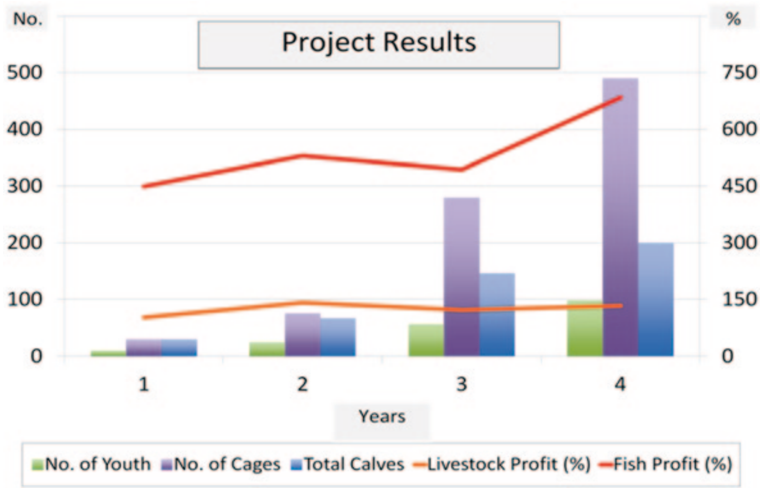

Fig. 14.2 Summary of El Gammalia youth project achievements (2005–2009)

Table 14.2 and Fig. 14.2 revealed that calves significantly ($P<0.05$) increased in numbers from 1 year to the other with increasing in (cow: buffalo) ratio from 2:1 to 9:1. However, growth rates were similar in cow and buffalo calves with an average of 0.44 kg/head/day. The survival rate was higher in cow calves (92.8 %) compared to buffalo calves (86.2 %). Moreover, calves body weights doubled during the growing season (365 days). The net profit of cow calves (89.7 %) was significantly higher than that of buffalo calves (50.1 %), which resulted in an increase in the numbers of cow calves over buffalos in order to increase profitability.

Figure 14.2 demonstrates the major achievements of the 4 year study period and reported: (1) amount of the annual profit percentages of combined integrated aquaculture and livestock production to be 449, 530, 493 and 684 for 1st, 2nd, 3rd and the 4th year, respectively, (2) average return on investment was 539 and 83 % for fish and calves respectively, (3) reared fish was 6.5 times more profitable than calves, however, both were more profitable than any other agricultural activities in the same area, (4) number of youth participants increased significantly from 25 in the 2nd year to 56 in the 3rd year and reached 98 in the 4th year, (5) total number of fish cages and calves were 75 and 76; 280 and 146; and 490 and 200 during 2nd, 3rd and 4th year, respectively.

The combined results of the two integrated activities during 4 years indicated that the average returns on investment were 539 and 83 % for fish and calves respectively. Additionally, animal production is considered as an extra activity besides fish production.

The present study was conducted in a 3 km long (33 person/km long) strip of the available water surface (41 km) in Lake Manzala, therefore it is expected that at its maximum capacity, the project will create 1,353 new jobs for youth (participants) to own 6,765 cages and 2,706 calves with expected annual production of 20,295 and

Table 14.2 Technical and economical evaluations of calves (Males and Females) fed on fresh common reed (*Phragmites australis*) from Lake Manzala, Egypt (2005–2009)

Observations	Year			
	1st	2nd	3rd	4th
Calves number	30	67	146	200
Cows	20	49	125	180
Buffaloes	10	18	21	20
Average initial body weights (kg/head)	155.5	138.8	164.3	156.5
Cows	150.1	126.0	157.8	147.4
Buffaloes	160.9	151.6	170.8	165.6
Average final body weights (kg/head)	312.5	301.3	324.9	315.3
Cows	314.4	293.9	325.7	311.7
Buffaloes	310.6	308.6	324.1	318.9
Average body weight gain (kg/head)	157.0	162.5	160.6	158.3
Cows	164.3	167.9	167.9	164.3
Buffaloes	149.0	157.0	153.0	153.3
Average daily gain (kg/head/day)	0.43	0.45	0.44	0.44
Cows	0.45	0.46	0.46	0.45
Buffaloes	0.41	0.43	0.42	0.42
Average survival rate (%)	85	90.5	90.1	92.3
Cow	90	92	94.4	94.6
Buffalo	80	88.9	85.7	90.0
Numbers of sales animals	26	61	136	188
Cows	18	45.0	118	170
Buffaloes	8	16.0	18	18
Average purchase price (L.E./kg)	16	17	18.5	20.5
Cows	18	19	21	23
Buffaloes	14	15	16	18
Average sales price (L.E./kg)	15	16	17.5	19.5
Cows	17	18	20	22
Buffalo	13	14	15	17
Total annual purchases (L.E.)	76,562	158,239	471,613	669,852
Cows	54,036	117,306	414,225	610,236
Buffaloes	22,526	40,932	57,388	59,616
Total annual calves sales (L.E.)	128,488	307,174	856,159	1,263,340
Cows	96,191	238,059	768,652	1,165,757
Buffaloes	32,297	69,115	87,507	97,583
Total annual profits (L.E.)	51,926	148,936	384,546	593,488
Cows	42,155	120,753	354,427	1,165,757
Buffaloes	9,771	28,183	30,119	52,033
Average annual profits (%)	67.8	94.1	81.5	88.6
Cows	78.0	103.0	85.6	91.0
Buffaloes	43.4	68.9	52.5	87.3

Data collected from El-Gammalia project, NGO's (2005–2009)

784 metric tons of fish and calves, respectively. These values could increase four times when the present research results are extended to the other NDL in order to create more than 5,000 employments to produce more than 80,000 tons of low cost fish, and more than 3,200 tons of live calves annually. Further research emphasis is required to:

- identify the primary aquatic plants suitable for fish and animal feeds, as well as surveying its predominance and potentialities
- evaluate its palatability in fresh, dry or silage forms (alone or mixed), chemical composition and nutritional values using in vitro gas production technique, and in vivo digestibility and balance trials
- long feeding trials to study the effect of the different production systems and feeding treatments on animals health and their productivities
- study the impacts on water quality, aquatic vegetation and safety of the produced products for human consumptions
- improve farm management, post-harvest facilities; improve value-adding activities; and adoption of appropriate low-cost farming technology
- conduct a socio-economic impact of the effect of the proposed project on youth and their families, and
- select the optimum management treatment to be implemented in the future operations in the lake or other Northern Delta Lakes.

14.4 Discussion

The present research examines the 4-year (2005–2009) results of a sustainable integrated aquaculture/livestock project for youth in the rural wetland areas of El Gammalia, Mataryia, Lake Manzala, Egypy. The results highlight the success of sliver carp (*Hypophthalmichthys molitrix*) rearing in floating cages by young culturists with a significant ($P<0.05$) increase in the number of graduates, cages, annual production, market fish price and net profit percentage from 1 year to another through the 4-year study period (2005–2009). The annual profit percentages of the aquaculture activities reached the amount of 449, 530, 493 and 684 % for the 1st, 2nd, 3rd and 4th years respectively. The higher fish market prices in the 4th year increased the profitability by 150 % as compared with the 1st year.

Also, cow and buffalo calves showed significant growth increase when fed on fresh common reed (*P. australis*) as a single source of fresh feed with an average daily gain per animal of about 0.44 kg. However, EL Naggar (1991) concluded that reeds could be used directly as green roughages or used in complete diets in hay form up to the level of 40 % for feeding dairy cattle. Fresh reeds contained 35 % dry matter (DM) and it also contained 10 % crude protein (CP), 31.4 crude fibres (CF), 3.1 % ether extract (EE), 45.1 % nitrogen free extract (NFE), and 10.4 % ash, on dry matter basis. The authors reported that the digestibility coefficients and the nutritive value of green reeds for adult rams were 47.05, 51.2, 54.9, 49.9, 32.1, 52.6, 54.5 and 5.5 % for DM, OM, CP, CF, EE, NFE, TDN and DP%, respectively.

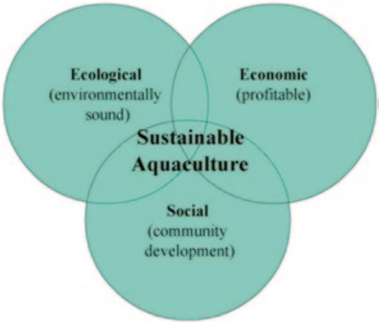

Fig. 14.3 Elements of sustainable aquaculture

The principal components reflect two main attributes, namely the diversified farm resources and economic opportunities for the youth. The farm visits and setting up of both formal and informal youth discussion groups could be used as a solid platform to advocate for this approach and to raise awareness among youth on the benefits of sustainable integrated fish farming projects in the rural wetland areas of the Northern Delta lakes. A training program on livestock farming and aquaculture extension good practices should then be followed on a regular basis, to ensure the sustainability of technical support to the youth.

Susan (2002) showed that developmental conserved lands, water, plant and genetic resources, are environmentally non-degrading, technologically appropriate, economically viable and socially acceptable. Sustainable aquaculture must consider the ecological, social, and economic aspects of development (Fig. 14.3).

Silver carp culture shows a great potential for reducing the risks of eutrophication, and as a beneficial for waste reduction in lake waters. Fish culture has proved successful in improving the standard of living of rural communities in Asia, where fish culture has a long tradition (Edwards 2000). For more than 1,000 years fish farmers in China have produced four of the most widely cultivated fish species together in the same pond: silver carp (a phytoplankton filter feeder), grass carp (a herbivorous plant feeder), common carp (an omnivorous feeder), and bighead carp (a zooplankton filter feeder). This type of system utilizes available food and water resources, with the effect of reducing costs and increasing efficiency and production.

Integrated aquaculture/livestock approach is both economic and cost effective, as it requires inexpensive input resources, limited land space and depends on low cost technologies and practices. This approach leads to the achievement of multiple benefits, including long-term profitability, increased youth employment and income generation, improved livelihood of local community and improved water quality. As a good practice it could be widely adopted for advancing sustainability at times of crisis to support existing international and national efforts towards overcoming threats against food deficiency, youth unemployment and environment degradation and thus creating socio-economic stability.

Youths are the main representatives for driving this project forward; they do not need to rely on any credit support or bank loans to operate their enterprises. Our direct cooperation with youth was optimized through their NGOs' they were provided free extension services on the usage of simple and low cost new and modern farm technology in addition to the introduction of new animal breeds and cultivars. Youth graduates were encouraged to intensify their facilities to increase the production of animal proteins on an annual basis.

The integrated results from this study clearly point out that livestock and fish are easy-to-change farm components. Livestock-keeping does not require much land area, as crop wastes or grasses/weeds represent the food source. The approach is environmentally sound with low risks, low-cost aquaculture technologies and aquiculture practices (Nour et al. 2006; and Nour 2008) based on growing filter-feeding fish on the natural phyto- and zooplankton in lake water at no cost. The high net profits obtained from the present silver carp cage culture and growing calves' project for youth will enhance the social benefits to their families and their rural community.

In reviewing the need to improve food security and alleviate poverty through aquaculture, Tacon (2001) listed the following:

- improve the documentation of potential and actual contribution
- increase the funds available for aquaculture for the poor
- do not create harmful impacts on food supplies
- improve farmer participation in extension and research approaches
- invest in knowledge building for management
- act within a framework of integrated natural resource management
- focus on low-cost products favoured by the poor
- emphasize on species which feed low in the food chain
- emphasize on local consumers and markets
- encourage community-based production (not individuals or corporations)
- promote aquaculture products from a nutritional point of view
- monitor the food security aspects of aquaculture projects

The role of NGOs in aquaculture in Egypt is of recent origin, although many fisher-based NGOs have been successful in protecting the rights of traditional fishers and demarcating areas for traditional fishing crafts and gears. However, the present NGO's have achieved the following successes:

- fish production and consumption, opportunities for employment, and family income have increased
- skills in resource management were developed
- illiterate people were able to practice aquaculture, including operating
- hatcheries
- the number of cages increased
- awareness on environmental and health matters was promoted
- living standards were gradually changing; and
- social dignity was enhanced

14.5 Conclusions and Recommendations

From the present findings it is concluded that policy makers specialized in developing wetlands around the NDL can benefit from the present results while developing new national policies, emphasizing the importance and effectiveness of engaging youth via training of graduates, and providing new and creative employment opportunities. The application of the present results to the other Northrn Delta lakes (Burullus, Edku and Maruit) will assist in overcoming the increased food scarcity problems, creating new jobs for youth, increasing national food safety; reduce the climate change impacts on delta of Egypt, and improving the national income and socio- economic stability. It is recommended to; (1) identify the primary aquatic plants suitable for fish and animal feeds and survey its predominance and potentialities, (2) evaluate its palatability in fresh, dry or silage forms (alone or mixed), chemical composition and nutritional values using in vitro gas production technique, and in vivo digestibility and balance trials, (3) conduct long feeding trials to study the effect of the different production systems and feeding treatments on animals health and their productivities, (4) study the impacts on water quality, aquatic vegetation and safety of the produced products for human consumptions, (5) improve farm management, post-harvest facilities; value-adding activities; and adoption of appropriate low-cost farming technology, (6) conduct a socio-economic impact of the effect of the proposed project on youth and their families, and (7) select the optimum management treatment to be implemented in the future operations in the lake or other Northern Delta Lakes.

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Chapter 15
Is the "Livestock Revolution" Achievable in Water Deprived Areas? A Reflection from Experiments with Irrigated Smallholder Farms in Morocco

Mohamed Taher Sraïri

Abstract A significant increase in the global demand of animal products is expected in the near future, because of changes in food consumption patterns in emerging countries. To fulfil the needs, a "Livestock Revolution" should occur and it will have to target in priority smallholder farms in developing countries, as they are the main actors in supply chains of milk and meat. To achieve an increase in milk yield and live weight gain at farm level, new tools of intervention have to be tested. In fact, in many developing countries, State services are currently withdrawing from their traditional support to farmers, and therefore innovative methods should be set-up. They will also require a more responsible implication of the stakeholders in supply chains, particularly with well-organized farmers' associations. In areas characterized by water stress and climate change, this should be a top priority issue in the agenda of agricultural development institutions. It is generally acknowledged that livestock production necessitates important volumes of water for forage production and rations conceptions. In this chapter, an example of an intervention research is presented from the Tadla large-scale irrigation scheme (centre of Morocco) as an illustration of intensive cattle dairy production in a semi arid region (less than 300 mm of annual rainfall). Results related to the evaluation of water productivity through cattle farming and trials to increase the average milk yield per cow are presented. A reflection on the possibilities to use "virtual water" and on the generalisation of such methods to whole dairy farmers in a supply basin (i.e. an irrigation scheme) is finally developed with its consequences on the resilience of smallholder units. Thus, a capacity building process is urgently required to upgrade farmers' performances. This will induce the adoption of on-farm practices, from irrigation systems to soil fertility management and forage biomass production. It will also rely on the continuous design of balanced dietary rations for lactating cows and their impacts on cattle load (number of cattle per ha of forage). Finally, more attention should be paid to the existing farmers' co-operatives, which would

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constitute crucial operators in disseminating innovation processes to face the challenges of water shortage in cattle production systems.

Keywords Animal production • Morocco • Smallholder farms • Farmers support • Water productivity

15.1 Introduction

The global demand for animal products is expected to increase significantly. For example, according to Thornton (2010), the annual meat consumption *per capita* in developing countries is expected to rise from 18 to 38 kg from 1990 to 2030. This trend should accelerate with better incomes that will generate changing consumption habits. In emerging countries like China, such a phenomenon is already occurring, as the economic boom coupled to higher rates of urbanization have induced recently a surge in milk and meat consumption (Beghin 2006). In order to face this growing demand in livestock products, adapted agricultural policies have to be implemented. These policies would also generate opportunities of higher income to millions of smallholder farmers, which shall continue to be prominent actors in animal products' supply chains. However, such policies must also focus at local levels on the effects of animal production intensification: resources needs, waste management, value chain, etc. In the hand, the recent food crisis in 2007 and in the beginning of 2011 has clearly demonstrated that the price of feed resources may remain volatile (Gilbert and Morgan 2010). That might induce higher production costs for farmers who use off-farm feed resources intensively and even more food dependency for water deprived countries (Sraïri 2011). On another hand, there are also increasing concerns about the effects of animal production intensification on the environment, such as nitrate pollution, greenhouse gases emissions, etc. (Tamminga 2003).

In spite of all these risks, in recent years, there have been many attempts to try to convince the international community on the need to intensify animal production worldwide and this has resulted on the call for a "Livestock Revolution" (Delgado 2003). Such a strategy has to be implemented globally, in a wide variety of environments and it has to avoid copying models which have been adopted in developed countries at the end of World War II, which mainly relied on intensive resources (feed, fertilizers, fossil energy, water, etc.) uses (Alary and Faye 2001). In fact, the expected "Livestock Revolution" will have to be green: producing more and better, but with fewer resources. One of the main challenges ahead is linked to water uses by the animal production sector. This is particularly true in areas with acute water stress, characterized by erratic levels of rainfall and growing threats on groundwater sustainability (Iglesias et al. 2007). In this context, like in the whole Mediterranean Basin, is the "Livestock Revolution" achievable?

In this chapter, we try to answer to this specific question by a synthesis of a research program conducted in an irrigated scheme in Morocco. As a first step, the context of the study is presented with a review of the problematic of water productivity through dual purpose cattle (milk and meat) in smallholder farms. Then, a case study relying on six farming units is presented. Finally, we investigate opportunities to alleviate water stress in cattle production under irrigation conditions and the means to contribute to increase lactating cows' milk yield.

15.2 Context of the Study and Methodology

Located in the Western part of North Africa, Morocco is characterized by water stress, because of its limited resources. Water availability is less than 750 m^3 *per capita* annually, under the threshold of 1,000 m^3, often considered as a limit for human development. The country already faces water supply problems (Blinda and Thivet 2009), particularly in the agricultural sector, which is a pillar for the domestic economy, with more than 50 % of total jobs. Agriculture is also the main consumer of water with almost 85 % of total volumes. As the country has launched recently a massive initiative to increase the productivity of its agriculture (the "Green Morocco Plan"), significant improvements of water use efficiency will have to take place. This might be achieved specially in irrigated areas, which are strategic for the supply of vital commodities such as cereal grains, vegetables, milk, meat, olives, etc. For instance, almost 60 % of the country's milk output comes from the large-scale irrigated schemes, which represent less than 15 % of its arable land. Therefore, the authorities have adopted a strategy that aims to substitute gravity by drip irrigation at farm level, as they subsidize up to 80 % of the investments (Agency of Agricultural Development 2011).

The Tadla large-scale irrigation area is located in the east central part of Morocco and covers 100,000 ha (Fig 15.1). It is characterized by a semi arid climate, as the average annual rainfall is about 310 mm. It represents about 11 % of the country's annual milk output (175,000 metric tons). Milk is produced by almost 17,000 farms (53,000 cows) based on alfalfa (about 25,000 ha) as their main irrigated forage. Nearly 80 % of these farms belong to smallholders, as they cultivate less than 5 ha of arable land (ORMVAT 2011).

Studying on farm water productivity through cattle in such a context necessitates a specific methodological approach. There is a need to consider a series of functions of production involved from water volumes used in forage plots to their effective conversion in cattle products (Fig. 15.2). First of all, water volumes and their origins (i.e. rainfall, surface and groundwater) used for forage production have to be measured throughout the year. Forage biomass has to be measured at each cut. The strategic goals of farmers in dedicating available feed resources to lactating cows and/or to growing calves have also to be specified by a continuous monitoring of the dietary rations used. In fact, under Moroccan conditions, the vast majority of cattle farms are not dairy specialized, as they produce both milk and meat from their herds, simply because calves have a market value which may be negotiated at the contrary of milk price (Sraïri and Kuper 2007).

Fig. 15.1 Situation of the Tadla irrigated area (Morocco)

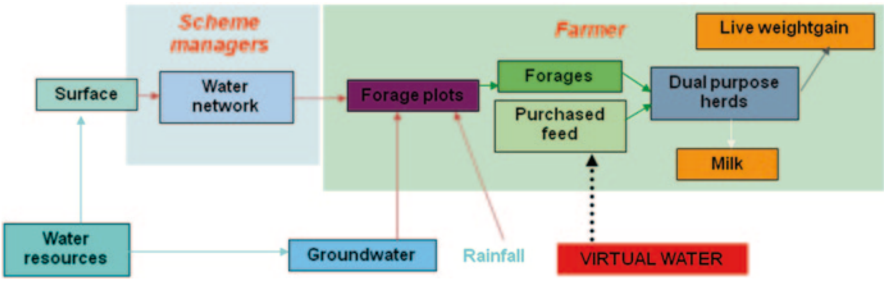

Fig. 15.2 Functions of production involved in water productivity through cattle in irrigated farms

In addition, the proportion of off-farm feed resources used in these dietary rations has to be characterized, as they correspond to imported water consumed elsewhere. This virtual water (Allan 1998) has to be evaluated and added to irrigation and rainfall volumes in order to calculate the total water (real and virtual) productivity of irrigated cattle farming. Finally, the output of milk and live weight gain has to be measured. Annual milk volumes per farm delivered to the dairy factory were obtained directly from the milk collection cooperatives and added to the amounts consumed within the farms. The milk used by suckling calves was not taken into account as it was considered as an intermediary input processed into live weight gain. The growth performance of calves and heifers was estimated indirectly using body measurements (heart girth) throughout the monitoring period. The following formula linking live weight to heart girth was used (Heinrichs et al. 2007):

$LW = 15.7 + (66.88 \times HG^3)$, where LW is live weight (kg) and HG heart girth (m).

At the end of this process of water productivity assessment through cattle in irrigated farms, an economic evaluation of these functions of production was realized. For that purpose, the economic return from milk volumes delivered to the collection cooperatives by each farm was calculated. The economic value of live weight gains was estimated from the market price of beef as follows: 2.2 € per kg of calves live weight, 3.1 € per kg of heifer live weight. Then, gross margins per cow and per m^3 of water were calculated. Water productivity was calculated for either milk production or live weight gain (m^3 per kg). Finally, the economic value of water productivity through milk and live weight gain were calculated as the gross margins for these products divided by the total amounts (real + virtual) of water used and expressed in € per m^3.

Following these economic evaluations, an assessment of the margins of improvement was realized. We compared the actual results with optimal performances of fodder and cattle, using a simulator program elaborated for farms in the same irrigated scheme (Le Gal et al. 2009). Some of the possibilities of improvement were tested on the ground, particularly those related to tactical decisions, like the conception of sufficient and balanced dietary rations. The effects of these diets changes on lactating cows' milk yield were assessed. At the end of all these investigations, we try to synthesize their results and assess their consequences on the initial challenge of producing more and better in smallholder cattle farms located in areas with water stress.

15.3 Study of Water Productivity in Smallholder Irrigated Cattle Farms

Six smallholder cattle farms were selected for the study. They did not have access to groundwater and therefore they relied on rainfall and on the surface irrigation network managed by a local State agency. During the study period (from September 2007 to August 2008), rainfall did not exceed 210 mm and the irrigation network was affected by frequent water shortages. All the farms delivered their daily milk production to a local dairy factory through a collection cooperative. Their herd varied from 2 to 7 crossbred (local x Holstein) cows with their progeny. The farmers had one of three strategies: they specialized in either dairy production, or in milk and meat production, or in meat production alone (Table 15.1). Average arable land covered 3.8 ha (from 1.4 to 6.5 ha), of which 55 % was cultivated with irrigated forage (alfalfa, berseem -*Trifolium alexandrinum*- and maize).

Irrigation water used to grow alfalfa (an average of 9,730 m^3 per ha) accounted for almost 82 % of the total volume of water, as it is mainly a summer crop, and as the rainfall was limited during the year of study (2,100 m^3 per ha). Irrigation volumes for berseem, which is supposed to be mainly a rain fed crop, represented about 60.0 % of the total water consumed (3,380 m^3 per ha), and 78.5 % for maize (4,320 m^3 per ha), which is mainly a summer crop with a short cycle.

Table 15.1 Main characteristics of the cattle farms surveyed

	1	2	3	4	5	6	Mean
Arable land (ha)	5.0	6.3	6.5	1.4	1.6	1.8	3.8
Alfalfa (ha)	2.0	2.0	2.2	0.8	0.8	1.0	1.8
Berseem (ha)	0.5	0.7	0.4	–	–	–	–
Maize (ha)	0.2	–	–	–	–	–	–
Lactating cows	6.0	7.0	6.0	2.0	2.0	3.0	4.5
Dairy (D), Beef (B) or dual (DB) strategy	BD	BD	BD	D	B	B	–

Table 15.2 On farm water uses ($m^3\ ha^{-1}$) and forage biomass yields ($t\ h^{-1}$)

Forage crop	Farms	1	2	3	4	5	6	Mean
Alfalfa	Water used	10,090	12,740	12,350	12,360	13,440	9,990	11,830
–	Biomass yield	33.2	38.2	39.9	40.9	40.1	35.0	37.9
Berseem	Water used	4,060	6,440	5,520	–	–	–	5,340
–	Biomass yield	23.1	13.3	33.7	–	–	–	23.4
Maize	Water used	5,500	–	–	–	–	–	–
–	Biomass yield	25.1	–	–	–	–	–	–

Green matter yields were highly variable, particularly for berseem (Table 15.2). They only represented 66 % of the potential production of these crops under Moroccan irrigated conditions (Baya 1997; Birouk et al. 1997). Many different factors may have limited growth: shortage of water because of the limited quantities delivered by the surface irrigation network and no access to groundwater, crop diseases, soil fertility deficiency, etc. Despite its low cost of irrigation (92 € per ha), maize was the most expensive crop, followed by alfalfa and berseem (respectively 548, 438 and 290 € per ha). Indeed, buying maize seeds, plus fertilization, weed control and harvest requires expensive inputs. Irrigation expenses accounted for 27 % (maize), 28 % (berseem) and 70 % (alfalfa) of the total cost. Alfalfa's high irrigation costs can be explained by its perennial status, which means low annual installation costs, but huge water requirements in summer when biomass production reaches its peak at temperatures frequently exceeding 45 °C and with almost no rain at all during more than 5 months (from May to October).

Cattle performances were weak, as the average annual milk yield did not exceed 2,170 kg per lactating cow, less than the average potential of F1 crossbred Holstein x local breeds, which exceeds 3,000 kg of milk per year. The average daily gain was 0.66 kg for growing animals. These weak performances can be explained by the limited availability of nutrients to feed cattle due to the high animal load (more than 2.4 lactating cattle with their calves per ha of forage), and low forage production due to the shortage of irrigation water and other agronomic constraints. These weak performances were also induced by the limited use of off-farm feed (only 13 % of total energy ingested), because of frequent economic problems in these farms. Growth and lactating performances were also hindered by imbalances in dietary rations. As these

Table 15.3 Physical and economic values of water productivity through cattle farming

Farms		1	2	3	4	5	6
Milk	Milk output (kg)	14,820	11,900	13,310	6,800	3,800	4,950
	Total water used (m^3)	31,170	25,950	22,200	7,750	5,740	8,970
	Water productivity (m^3/kg)	2.1	2.2	1.7	1.1	1.5	1.8
	Economic return (€/m^3)	0.02	0.03	0.08	0.14	0.09	0.09
Meat	Live weight gain (kg)	2,100	1,740	1,760	430	712	1,290
	Total water used (m^3)	19,710	22,500	9,980	3,820	6,720	10,800
	Water productivity (m^3/kg)	9.4	12.4	5.6	8.9	9.4	9.4
	Economic return (€/m^3)	0.21	0.14	0.37	0.26	0.24	0.24

were mainly based on legume forages (alfalfa and berseem), and given their protein content, animals often lacked an appropriate supply of net energy. The analysis of feed purchase strategies revealed marked differences among farms. Some of them, like farm F1, used off-farm feed resources to compensate for the lack of on-farm forage crops. Others (farm F5), limited their use of off-farm feed resources for financial reasons.

Consequently the amounts of off-farm feed resources and their corresponding virtual water values revealed considerable variability among farms. On average, a lactating cow consumed the equivalent of 1,276 ± 779 m^3 of virtual water per year, representing some 34 % of the total water used by lactating cows through feed consumption. The variability was higher for growing cattle, as each animal was provided with the equivalent of 1,065 ± 950 m^3 of virtual water annually (33 % of total water uses).

Total water productivity through milk accounted for an average of 1.8 m^3 per kg of milk considering the calculated volumes of virtual water consumption and the monitored volumes of water used to produce irrigated forage crops (Table 15.3). The average water productivity for live weight gain was 10.6 m^3 per kg. This value corresponded to some 19.2 m^3 per kg of carcass, considering a mean dressing percentage of 55 % for cattle. Both values of water productivity to get 1 kg of milk and meat were almost 70 % higher than those referenced by Hoekstra (2012), indicating margins of improvement under Moroccan irrigated smallholder farms conditions.

The overall economic productivity of water was 0.07 € per m^3 whenever irrigated forage were devoted to milk production and 0.25 € per m^3 for live weight gain. Meat production thus enabled dual purpose cattle farmers to obtain more than three times the margin of milk per m^3 of water. Such a result seems contradictory with the theoretical findings of a better metabolic efficiency of milk versus meat to exploit high quality forage (Vermorel and Coulon 1998), but it obviously reflects the distribution of actual value in supply chains of cattle products. Nevertheless, farmers maintain their dual purpose cattle farming system as milk and meat production play specific roles in farm management. Milk is compulsory to get calves (no calving, no possibilities of live weight gain). It also provides a steady daily income and it allows purchases of feed grain (Sraïri et al. 2009), whereas calf crop sales is a strategic source of income to face heavy expenses.

All together, these results emphasize that the expected "Livestock Revolution" may face serious constraints in water deprived areas, due to insufficient resources availability. However, possibilities for intervention exist throughout the sequence of processes involved in the chain of functions of production, from water use efficiency by fodder crops to cattle productivity (milk yield and growth rate). For instance, the improvement of the water productivity through cattle production may be achieved by a selection of fodder crops adapted to water scarcity, like the substitution of corn by sorghum (Doreau et al. 2012). To get a significant improvement in cattle performances within a majority of smallholder farms, the use of adapted support tools has to be tested.

15.3.1 Support to Smallholder Cattle Farms in Increasing Lactating Cows' Milk Yield

A simulation tool that takes into account the biophysical terms of production (water requirements for forage production, forage area, calving rates, cattle nutrient requirements for maintenance, growth and lactation) on a dual purpose farm was designed and tested (Le Gal et al. 2009).

A simulation was carried out for a 2 ha farm. It showed that replacing crossbred with Holstein cows allowed tripling real water productivity, even with higher annual virtual water expenses. Improved diets were however required to reach the optimal lactation performance of the Holstein breed (5,200 kg of annual milk yield). It means extra purchases of off-farm feed resources which increase the use of virtual water.

Another simulation scenario was based on a partial replacement of alfalfa by drip irrigated maize. It was also coupled with the substitution of crossbred cows by pure Holstein cows. It allowed further improvements in total economic water productivity. Similarly, the second scenario assumed that cattle-feeding techniques were efficient, with appropriate purchases of feed grain and oleoproteaginous feed (particularly with maize silage) at any time of the year. Given the results of these simulations, we chose to test a support program of a continuous monitoring of lactating cows' dietary rations.

For that purpose, five smallholder cattle farms were chosen. They were selected in order to represent the wide range of cattle breeding situations in the region: *i*) specialized dairy farms with pure Holstein cows, *ii*) mixed farming systems (cattle and cash crops) and *iii*) dual-purpose herds (both milk and meat). Each farm was visited twice a month. This schedule enabled the cows' true dietary rations to be compared with their total requirements calculated as the sum of their maintenance and potential production needs. Net energy and protein maintenance requirements were determined in relation with the cows' body weight (Fox et al. 1992). The potential energy and protein requirements for milk production were determined using existing models describing variations in daily milk yield during lactation (Wilmink 1987) and unitary needs to obtain a single kg of milk (Vermorel and Coulon 1998).

These were related to the herds' genetic merit and their average monthly lactation stage (LS), which was calculated as follows:

$$Lactation\_Stage_j = \sum_{k=1}^{m} Lactation\_duration_{k,j} / (Total\_Milked\_Cows_j \times 30.4)$$

With:

$Lactation\_Stage_j$ = lactation stage (in months) for month j

$Lactation\_duration_{k,j}$ = number of milking days from calving for cow k and month j

$Total\_Milked\_Cows_j$ = total number of milked cows for month j

In this study, the genetic merit of pure Holstein herds was considered to be 7,000 kg of milk annually, whereas an annual milk yield of 4,000 kg was used for Holstein crosses with local breeds. During each visit, all the components (i.e. forage and concentrates) of the cows' dietary rations were weighed. This implied regular evaluation of forage biomass production using a field quadrate method (Martin et al. 2005) throughout the study period. The nutritive contents of the rations were determined using feed composition tables. For concentrates, which were mainly imported, the INRA France table was used (Jarrige 1988), whereas for local forage crops (alfalfa, berseem and maize) and crop by-products (wheat bran and straw and dehydrated beet pulp), results from Guessous (1991) were used.

At each visit, the correspondence between cows' nutritional requirements and the true ration was evaluated using a simulation tool under Excel® (Table 15.4). Supplementation was suggested to the farmer when a gap was detected between the dietary ration and potential net energy, rumen degradable protein or metabolizable protein requirements. These two parameters were related to the protein status of the diet and were determined accordingly to the French system of the PDI—Protéines Digestibles dans l'Intestin -. Calculations assumed that whenever maintenance requirements were fulfilled (i.e.9.0 Mcal of net energy for a 620 kg Holstein cow and 420 g of proteins—either rumen degradable or metabolizable), the remaining dietary nutrients would be used to cover the effective dairy production, as a single kg of milk requires 0.76 Mcal of net energy and 48 g of proteins (Vérité and Peyraud 1988). The proposed rations took into account the context of the farm, i.e., the availability of on-farm fodder and the money needed to buy concentrates. The acceptance of the suggested balanced rations was tested by monitoring the herds' total milk yield and noting the farmers' opinions about the nutritional changes that were made. The effects on the profitability of dairy production were also assessed. The gross margin of milk production was determined monthly as the difference between milk income and the costs of inputs used to feed the cows.

The initial assessment of lactating cows' dietary rations revealed insufficient and imbalanced supply between energy and rumen degradable protein in all farms. In fact, the main forage used was alfalfa, which provides more protein than energy with respect to the average cow's net energy maintenance requirements. Table 15.5 shows an example of the dietary rations used in farm F1 for pure Holstein cows with a lactation potential of 27 kg of milk daily and an average body weight of 620 kg at

Table 15.4 Assessment of dietary rations distributed to lactating cows (part of Excel® application)

	Forage and feed concentrates	kg/cow. day	DM (g/kg)	kg DM/ cow.day	Net energy (Mcal/kg)	Total net energy (Mcal)	MP (g/kg)	Total MP (g)	RDP (g/kg)	Total RDP (g)
Forage diet	Lucerne hay	4.25	950	4.04	1.16	4.93	86	365	89	378
	Green lucerne	23.00	200	4.60	0.35	8.05	31	713	35	805
	Wheat straw	–								
Concentrates	Wheat	0.65	880	0.57	1.26	0.82	74	48	92	60
	Dehydrated beet pulp	1.00	890	0.89	1.70	1.70	81	81	61	61
	Compound Feed	0.85	930	0.79	1.52	1.29	84	71	84	71
Total ration distributed		–	–	10.89	–	16.79	–	1278		1375
Maintenance requirements[a]						8.20		373		373
Production allowed by the ration (kg of milk)[b]		–	–	–	–	11.20	–	18.9	–	20.8

DM: Dry Matter MP: Metabolizable Protein (g/kg) RDP: Rumen Degradable Protein (g/kg)

[a] Maintenance requirements for a crossbred cow (Holstein x local breed) weighing 550 kg

[s] Production allowed once the cow's maintenance requirements are covered

Calculating the milk yield per cow allowed by the energy and protein supplies highlights potentially imbalanced rations.

Comparing the cow's potential production based on its genetic merit and its lactating status with the yield enabled by the simulated ration allows detection of problems of under- or over-feeding

Table 15.5 Changes in the daily gross margin per cow and milk production cost during farm monitoring

	F1	F2	F3	F4	F5
IGM_0 (€/day)	−0.4	−2.2	−1.5	−0.3	−1.0
AGC (€/day)	0.3/0.8	0.2/0.7	0.4/3.0	0.04/0.8	−0.6/−1.0
IPC_0 (€/kg)	0.34	0.31	0.41	0.34	0.46
APC_a (€/kg)	0.17	0.22	0.27	0.23	0.41

IGM_0: Initial gross margin per cow
AGC: Average gross margin per cow after calculation of balanced dietary ration
IPC_0: Initial production cost of a kg of milk
APC_a: Average production cost of a kg of milk after calculation of balanced dietary rations

the beginning of the study. This dietary ration is largely representative of the situation observed in the other pure Holstein herds in this study. Its main characteristic is an insufficient supply of DM, which varies between 6 and 8 kg of roughage per cow, whereas a Holstein cow could ingest as much as 15 kg of dry matter (DM) from good quality alfalfa (Castillo et al. 2006). It is unbalanced, as alfalfa and berseem represent the bulk of the initial roughage intake, leading to a relative excess of rumen degradable protein whereas net energy is lacking. The amount of both energy and metabolizable protein supplied were thus insufficient to cover total requirements. For that reason, this dietary ration was not suitable to reach the lactation potential of the herd. Supplementation of the initial ration was proposed. It consisted mainly in adding sources of degradable energy in the diet, and, if possible, in increasing the supply of alfalfa, which is a cheap source of nutrients. Table 15.5 shows the proposed ration with a balanced supply of nutrients to match the herd's potential production. In one month, the supplementation increased the volume of milk per lactating cow in the herd from 11 to 19 kg. The concept of balancing the supply of nutrients in the dietary rations with changes in the herds' potential requirements was maintained in the five herds throughout the study period. Alternative forage such as on-farm reserves of alfalfa hay, berseem and green alfalfa (purchased from neighboring farms) or maize silage, were used during the cold months of December and January when alfalfa stops its growth. The effects of constantly correcting the dietary rations are shown in Fig. 15.3. Farm F1 adopted the strategy straight away and reached a milk yield equal to the potential milk capacity of the herd after three months. The farmer of farm F1 was able to judge the effects of the method on the profitability of the dairy herd (Table 15.5).

Similar results were obtained by the two other dairy specialized farms, F2 and F3. All three farmers were able to purchase alfalfa from neighboring farms, as this roughage provided nutrients (energy and proteins) that were cheaper than those available in purchased concentrates. The support process was also successful in farm F4 with crossbred cows, but it took more than 5 months to reach its potential milk yield (Fig. 15.3). This result highlights the quicker response of purebred Holstein cows to improved rations than that of crossbred cows. This can be explained by their better milking ability which allows them to convert nutrients in the diet into milk more efficiently than other cattle breeds (Delaby et al. 2009). Increasing

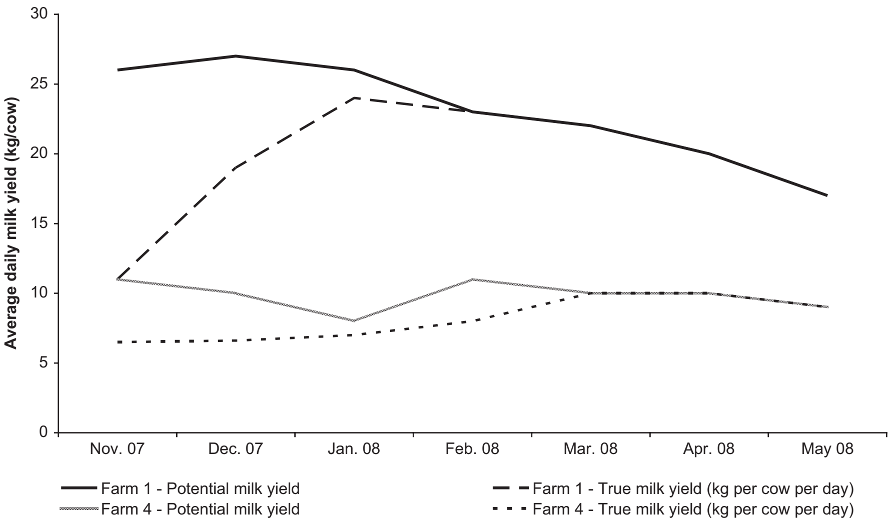

Fig. 15.3 Effect of the diet support programme on the average milk yield per cow for purebred Holstein cows (Farm 1) and cross bred cows (Farm 4)

milk yield to reach the genetic and physiological potential allowed milk production costs to be reduced below the farm gate milk price (0.27 €/kg), making this activity profitable before calf crop sales. However, the method failed within farm F5, as the farmer did not agree to change his feeding practices, because he preferred to maintain a balance between milk and meat production rather than increasing the milk yield of lactating cows. In his case, the gross margin of milk production remained negative throughout the study period and livestock profitability came mainly from cattle sales.

The results of this intervention research showed a reliable impact of a support process on the average milk yield per cow and the profitability of dairy production in smallholder farms. They also demonstrate that such a structure of production which relies on an fragmented offer (numerous small farms with a limited number of cows) may be compatible with industrial dairy supply chains in emerging countries, as long as they can benefit from some support and from input supply services (Arriaga-Jordan et al. 2002). But the milk supplies required by industrial dairy plants as well as the expected regional impact of dairy production on poverty alleviation imply that a large proportion of farmers must be reached if the existing situation is to be significantly improved (Bayemi et al. 2009). This study also revealed certain limits of such an approach. It was conducted on a very small sample of farms and was based on labor-intensive interventions: bi-monthly visits, direct measurement of critical variables that are rarely estimated by smallholder farmers, such as forage productivity, good knowledge of the farms visited, use of a simulation tool in a one-to-one relationship between researchers and farmers.

In Morocco, as in many other developing countries, State withdrawal from extension activities means that the generalization of such an experiment to a vast majority of cattle farms would involve dairy collecting cooperatives managed by the farmers themselves. This may also be achieved with the support of the dairy industry, as the latter urgently requires higher flows of good quality milk. The milk collection cooperatives already provide inputs such as feed concentrates and they could also recruit technicians to provide advice to their members based on a fee collected on each kg of milk delivered. Similar experiments have been conducted in West Africa with cotton-based farms and showed the importance of taking into account the different components of an advice institution in agriculture (governance, funding, training, advice methodology, advice tools) (Faure and Kleene 2004). Such institutions should facilitate the design of suitable advice tools and the collection of local references on dairy and fodder production, which are needed to provide efficient support to local dairy farmers (Pacheco 2006). The institutions should focus their support activities on farmers who wish to improve their milk yield like the specialized farms in our sample, since some farmers prefer to diversify their income by combining the dairy business with other products such as meat or crops.

15.4 Conclusions

This series of investigation on water productivity through cattle in irrigated smallholder farms located in semi arid areas and on the means to improve it have revealed the complexity of such issues. The results indicate that water shortages constitute a serious threat to the increase of cattle productivity in water stressed areas, and therefore it could hamper the achievement of a "Livestock Revolution". This might be even worsened by the expected climate changes. However, the existence of a wide range of farms' strategic goals and their effective farming practices imply interesting possibilities of intervention. Testing a close monitoring of lactating cows' dietary rations and their frequent adjustment to cows' potential milk yield has demonstrated that milk yield may be easily increased with the existing resources. That has also induced significant improvements in farms profitability, which may facilitate convincing other farmers to adopt the support program. All these achievements suggest real possibilities of improving the water productivity through cattle. Another mean to increase cattle performances with the same amount of irrigation water would be to design new forage systems, based on alternative crops, such as drip irrigated maize instead of alfalfa, if necessary attendant measures (balanced rations, control of pesticides residues in groundwater, etc.) are adopted. It can also be mentioned that an intervention on milk quality may also bear significant advances in the economic return per m^3 of water, as the current situation is characterized by raw milk batches generally of poor hygienic standards. All the improvements that are suggested in this study require however a close intervention in numerous farms, which will have to be convinced of the utility of such approaches. Moreover, the cost of such interventions and the nature of the partnership that will lead them (farmers' association, private operators, State services, etc.) have to be specified to get the expected improvements effective at a large scale (i.e. the whole dairy basin with some 17,000 farms). At a time of State agricultural services withdrawal from the extension activities, and because of the current soaring prices of food in international markets, ensuring the resilience of smallholder irrigated farms in Morocco is a crucial task. In order to ensure the supply of animal products (milk and meat) for rapidly growing cities, more attention and means should be devoted to the question of sustainable water uses in cattle smallholder irrigated farms. Otherwise, their resilience might be at risk with important social disturbances, such as rural exodus and illegal migration.

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Chapter 16
Colostral IgG As Affected By Nutritional Status for Border Leicester Merino Ewes Delivered in Kuwait

Tareq Al-Sabbagh

Abstract Sixty two Border Leicester Merino ewes were scored for body condition weekly till lambing. Body condition score and nutritional status, at lambing showed a suggestive influence on the colostrum concentration collected from the ewes within twelve hours of lambing ($P = 0.06$). Ewes scored 2.5–3.5 were superior regarding IgG concentration than both of those who scored higher and lower than this category. Lambs that were born to ewes with body condition score of (2.5–3.5) at lambing weaned heavier than those who were born to ewes of either higher or lower BCSL ($p = 0.02$). Weaning weights (at age of 95 days) for these lambs were heavier because of the quality of colostrum they were fed. Sex of lambs born was not affecting the quality of colostrum. In general, colostrum from ewes gave birth to twins is with higher quality than colostrum of ewes that gave birth to singles. Although not significant, male lambs tended to be born heavier than those female lambs whether they were born single or twins. Male lambs weaned heavier than female lambs (23.7 vs. 20.65 kg).Time of milk collection is a significant factor in colostrum concentration. Samples that were collected closer to the time of lambing tend to have higher colostrum concentration ($p = 0.002$).

Keywords Sheep • Colostrums • Kuwait • Body condition score • IgG

16.1 Introduction

Colostrum is the first milk suckled by newborn lambs. It is high in immunoglobulin, particularly immunoglobulin G (IgG), which provides passive immunity to the newborn lambs; the level of passive immunity attained is proportional to the concentration and quantity of immunoglobulin and the time interval after birth in

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which the colostrum is consumed (Esser et al. 1989). IgG is one of the five classes of humeral antibodies produced by the body in response to invasions by bacteria, fungi and viruses. Early ingestion of colostrum is essential for the newborn. The protective effects associated with transfer of colostral immunoglobulins have been demonstrated amply, both in the field and experimentally. The composition of colostrum changes rapidly to that of normal milk during the first days of lactation. Lambs should receive colostrum within 12 hours (hr) after birth. Slightly bloody colostrum can safely be given to them if it is otherwise normal. Grossly abnormal colostrum, such as from an ewe with acute mastitis must be discarded. Providing adequate amounts of colostrum will not necessarily prevent diarrhea, but it will aid in the prevention of subsequent septicemia and decrease mortality. IgG is absorbed from the intestine for only a short time after birth and the efficiency of absorption decreases linearly with time.

Tonjes et al. (1991) observed a small but negative relationship between the interval from calving to first milking and immunoglobulin content. The quantity of colostrum was positively related to the colostral IgG production (Esser et al. 1989; Shubber et al. 1979). Although Esser et al. (1989) did not find a significant affect of body condition score (BCS), litter size, and sex of the lamb and genotype of the ewe on the colostral IgG. Gilbert et al. (1988) observed higher IgG concentrations in yearling ewes than older ones. Gallo and Davis (1987) found a lower colostral production in single-bearing than twin-bearing ewes. AL-Sabbagh et al. (1995) found that colostral IgG concentration would diminish to zero mg/ml by 23 h postpartum depending on the linier regression analysis that was done at that time. They found that BCS at lambing (BCSL) that varied from 2.5–3.5 had neither affect on colostral IgG concentration, nor on the total weight of Polypay sheep lambs born and their mortality.

We live in a hostile world filled with many infectious agents; however, vertebrate animals possess an effective immune system which prevents the invasions of parasites such as bacteria, viruses, and cancer cells. The immune system specifically recognizes and selectively eliminates foreign invaders. The immune systems respond in a specific way to pathogens and display a long-term memory of earlier contacts with the disease agents.

Vertebrates are protected by a dual immune system known as cell-mediated immunity and humeral immunity. The two immune systems together provide an excellent defense against foreign invaders. Both systems are adaptive and respond specifically to most foreign substances, although depending on the antigen one immune response generally is favored over the other. Cell-mediated immunity is particularly effective against fungi, parasites, intracellular viral infections, cancer cells, and foreign tissue. The humeral immune response defends primarily against extra cellular bacterial and viral infections. The cells involved in both immune systems are lymphocytes which originate in the bone marrow and migrate to different lymphoid organs. There are two types of lymphocytes which are known as T cells and B cells. The two types of lymphocytes are responsible for a dual immunity phases. All lymphocytes are derived from bone marrow but those that pass through the thymus become T cells. (T-lymphocytes). The T cells are responsible for cell-mediated immunity. Since the immunity involving T cells is associated with the T cells themselves, this type of immunity is called cell-mediated immunity.

Other lymphocytes pass through the Bursa of Fabricius in birds or the bursa equivalent in mammals and become B cells (B lymphocytes). The Bursa of Fabricius is the primary lymphoid organ associated with the cloaca in birds but is not found in mammals. The bursa-derived lymphocytes (B cells) produce antibodies which can react specifically with antigen. Because B cells produce antibodies that circulate the immunity is called humeral immunity. Antigen specific antibodies produced in the humeral immune response can be used in immunological assays to detect various disease agents or antigenic molecules. With the development of monoclonal antibodies, greater specificity and reproducibility can be obtained with immunological assays.

16.2 Body Condition Score

The BCS and live weight are two systems for measuring nutritional status in livestock. BCS, the assessment of fat and muscle in the loin region, is a system which estimates the degree of muscling and fat development in an animal (Russel et al. 1969; Ducker and Boyd 1977). It is a subjective, accurate and an inexpensive estimator of nutritional status than body weight because the skeletal size adds to the live weight without being a determinant of the nutritional status. It is a good predictor of fertility and total fat deposits in the animal (Barth and Neumann 1991).

BCS was developed by Jeffries (1961), using a scale of one to five, where 1 is thin and five is obese where this was refined by Russel et al. (1969) by adding half point gradations. The procedure for scoring the condition of an animal's body is done tactically in the loin region, assessing the degree of muscle and fat that surround the vertebrae. This area is optimal in that it is the first area of the body to be covered with fat and muscle and the last part to lose it. This system has proven to be useful and reasonably repeatable (Oriordan and Murphy (1987)).

Three or more is important for embryonic development during early pregnancy, resulting in lower prenatal mortality (Alexander 1964; Nordby et al. 1986); and at mid gestation, it is necessary for optimal placental growth (Mellor 1990). The most crucial period is late gestation when the greatest fetal growth occurs (Robinson et al. 1977; Mellor 1990). Many studies have shown a positive correlation between BCS and embryonic survival (Guerra et al. 1971; Gunn et al. 1972; Gunn and Doney 1975, 1979; Cumming et al. 1975; Gunn and Maxwell 1989; West et al. 1991).

Coop and Clark (1969), Gunn et al. (1969), Gunn and Doney (1979), Rhind et al. (1984a, b), and Meyer (1985) observed a positive correlation between BCS and mean ovulation rate, follicular size during luteal and follicular phases. BCS directly affected hypothalamic activity and gonadotropin releasing hormone (GnRH) secretion (Rhind et al. 1991).

The growth rate of the new born lambs, dependent on milk yield has been reported to be higher when their dams have higher BCS (Molina et al. 1991). Body condition is not important for different animals. It is one strategy for grouping cows. In this strategy, all cows are challenged using lead factors in the first 45 days postpartum. Thus, the cows' milk yield potential can be estimated. Cows producing high amount of milk are maintained on the high energy—nutrient dose diet until body condition dictates movement to a lower energy nutrient group. Lower producing cows are moved to the low potential group. This strategy is based on body conditions eviler ion to move cows. It is becoming clear that BCSs and its changes, in addition to milk yield and days in milk, are important criteria for adjustment in diet formulations or the moving of cows among groups.

Proper energy management is a key priority for optimizing production and reproduction of dairy animals. The component of energy management which often receives the most attention is formulation of diets. Although diet formulation often is complex in terms of concentrations and interrelationships of nutrients, the condition of the cow is the best indicator of combined effects of diet formulations and feeding management. Body tissues serve as reservoirs for energy deposition when energy intake is excessive and for energy mobilization in times of shortages. During early lactation, when energy intake is deficient, organs and tissues are in a most dynamic state. Not only cow's loose tissue mass via both mobilizations of tissues and involution of the uterus, but they also are gaining tissue mass through increases in size of the udder and digestive tract. Dry matter intake (DMI) increases rapidly as well which camouflages tissue losses. As a result, BCS is superior to body weight (BW) changes in assessing nutritional management of fresh cows. If anything, BW loss under predicts energy loss of the animal.

The scoring system of Virginia Tech is commonly used in the US; although, the California system (Edmonson et al. 1989) works well where cows are kept in free stalls and palpation of the rump and tail-head regions are not practical. Both systems use a 1 to 5 scale with 1 representing very thin cows and 5 very fat cows. Assigning scores to individual cows at strategic times helps identify divergent feeding practices which can lead to health and reproductive difficulties.

BCSs and rate of BC loss are important predators of potential reproductive efficiencies. Suggested BCS are 3 to 3.75 at calving, 2.25 to 2.75 at peak milk yield and 3 to 3.75 at dry off. Cows that were over conditioned at dry off (BCS more than or equal to 4) were 2.5 times more likely to experience reproductive diseases (dystocia, RFM, meteritis, pyometra, cystic ovaries and abortion) in their next lactation than cows having a BCS between 3 to 3+. Cows losing a lot of BC within a short period of time also are candidates for reproductive inefficiencies. Twelve of 93 cows lost more than 1 BCS during the first 5 weeks (wks) postpartum resulting in delay of 13 days to first ovulation, delay of 11 days to first service, and a 17 % CR at first service compared with cows loosing less than 1 BCS which had a 59 % CR.

In a retrospective analysis, 30 cows loosing body condition (average 0.6 units of BCS) had lower first service CR (25 vs 62 %) than 46 cows gaining BCS (average 0.1 unit) during first 5 weeks postpartum. What type of cows are candidates for loosing this much BC in early lactation? Apart from cows fed poorly balanced diets in insufficient quantities, these are over conditioned cows. These fat cows are unable to increase DMI quickly postpartum. As a result, body reserves are relied upon heavily to help support milk production. It has been shown that over conditioned cows experienced peak DMI approximately 19 weeks later and positive energy balance 2 weeks later than cows in good body condition when high energy diets were fed. One BCS unit was lost in order to support milk production by over conditioned cows compared with a slight gain to BC for control cows over 10 weeks. In general, body condition loss should not exceed 0.5 units in early lactation in order to minimize negative reproductive effects. Excessive BC losses often result in greater negative energy states and longer delays in return to positive energy states.

Changing BC through dietary manipulations requires strategic planning. Under conditioned cows should be put on condition during the late lactation because they are more efficient at utilizing metabolizable energy during this time than during the dry period (75 vs 60 %), in addition the dry period may be too short to fully recover condition needed prior to calving. Over conditioned cows should not loose condition while dry as they must gain 1–1.5 lb/day simply to meet needs of rapidly developing fetus.

Overall, body-condition scoring is a method of to fine-tune sheep and dairy herd nutrition and health. Research and field experiments have shown that body condition influences productivity, reproduction, health, and longevity. Thinness or fatness can be a clue to underlying nutritional deficiencies, health problems, or improper herd management. If done on a regular basis, body-condition scoring can be used to troubleshoot problems and improve the health and productivity of the dairy herd.

Over-conditioning, or fatness, may result from poor nutrition or reproduction management. A fat animal is more susceptible to metabolic problems and infections and is more likely to have difficulty at calving or lambing. Over-conditioning usually begins during the last three to 4 months of lactation, when milk production has decreased, but grain and total nutrient levels have not been reduced accordingly. Other causes of over-conditioning are prolonged dry periods or overfeeding during dry periods.

Under-conditioning, or thinness, can frequently lower production and milk-fat levels because of insufficient energy and protein reserves. Thin cows often do not show heat or conceive until they start to regain or at least maintain body weight. In feeding these animals, care must be taken to maintain production while increasing body reserves.

Previous work at Kuwait Institute for Scientific Research, project number FA007C, and technical task 5 in particular named: Determination of factors affecting lamb survival earlier, good nutritional regimes for ewes before lambing to produce stronger lambs as well as after lambing to support quality colostrum development have been suggested. To gain more information in this field it will be good if we relate the BCS of the ewes at lambing (within a week of lambing) to the antibodies, mainly IgGs, concentration specially that Colostrum will be affected by the prepartum practices rather than postpartum since it is suckled immediately after parturition. It may be a good idea to highlight the affect of BCS on the IgG concentration of the Australian ewes and add more information to that industry.

The main purpose of this experiment was to provide more information about the effect of different parameters on the humeral immunity indicator namely IgG, which may enable to pin point use the best parameters to improve lamb immunity and hence improving survivability of the newborn lambs. In addition, training of Kuwaiti staff members to perform some techniques like radioimmunodiffusion and statistical analysis and body condition scoring was an important goal of this experiment. Results from such activity could be published in international journals boosting KISR's image and help adding building blocks in the efforts of developing the agricultural sector in Kuwait in the field of sheep production.

16.3 Methodology

This experiment took place in Kuwait Livestock and Trading Company (KLTC). A leading company that is importing more than one million lambs from Australia each year to Kuwait to compensate the gap between the demand and quantity of lambs raised locally. More than 90 animals were scored weekly from the beginning of the experiment till the day of lambing. The activity of scoring was repeated to insure the repeatability of the scoring system. The score just before lambing was recorded and considered to be the BCS at lambing. Scoring in lambs was done by using the balls of the fingers (feeling the end of the short ribs) and thumb (feeling the back bone). Assessment was done by feeling the muscle and fat cover around these areas as well as the fullness of the muscle at the loin region (Jeffries 1961; Russel et al. 1977).

During lambing season all ewes were weighed and scored for body condition. They were identified by special tags in their ears to specify later the type of breed, litter size and age of each ewe. Colostrum was collected from each udder immediately after lambing and before lambs had access to their dams. Not all scored ewes were sampled for colostrum since some of the samples were missed or more than 12 h were passed before sampling. Sixty two collected colostrum samples were identified and frozen at −20 °C for subsequent analysis of IgG concentration. The concentration of IgG is usually determined using the radio-immuno-diffusion (RID) method developed by Mancini et al. (1965) and modified by Fahey and McKelvey (1965). Colostrum quality can also be determined by enzyme-linked immunosorbant assay (ELISA) or radioimmunoassay (RIA), that are extremely precise, or less precisely by specific gravity (Tonjes et al. 1991). Overall, the RID method is simple and requires a minimal investment in equipment (Check and Pipers 1986). Data were analyzed using statistical analysis system. General linear model was used by using age, litter size, breed and body condition score at lambing as an independent variable and the immunoglobulin concentration and total weight of lambs born and total weight of lambs weaned as dependent variables. Weights of ewes were used as covariate to correct any weight differences that we started with in the model. Correlation coefficient analysis were used to variate BCS at lambing, time from lambing to sample collection, ewe weight, total weight of lambs born, total weight of lambs weaned, litter size, sex of litter and immunoglobulin concentration to each other using Pearson model.

Table 16.1 Means of colostrum concentration (mg/dl), total weight of lambs born (kg) and total weight of lambs weaned (kg) of different category (Body Condition Score at Lambing (BCSL), Litter size and sex of the lambs

Category	Colostrum	Total wt born	Total wt weaned
BCSL			
<2.5	1,273(4)	6.68(4)	23.02(4)[a]
2.5–3.5	2,748(41)	5.63(41)	26.70(36)[b]
>3.5	2,369(17)	5.38(17)	25.80(13)[c]
Litter size			
Single	2,358(39)	4.93(39)[a]	22.129(31)[a]
Twin	2,873(23)	6.81(23)[b]	31.927(22)[b]
Sex of lambs			
1	2,045(17)	2.27(17)[a]	23.70(15)[a]
2	2,599(22)	4.67(22)[a]	20.66(16)[a]
3	3,081(14)	6.89(14)[b]	29.60(14)[b]
4	3,219(2)	6.95(2)[b]	38.25(2)[b]
5	2,358(7)	6.60(7)[b]	35.33(6)[b]

Numbers between brackets represents number of samples collected
[abc]Mean in column in the same category with different superscripts. Differ ($P<0.05$)

16.4 Results and Discussion

BCS at lambing suggested its influence on the colostrum concentration collected from the ewes within twelve hours of lambing ($P=0.06$). Table 16.1 showed that ewes scored 2.5–3.5 were superior regarding IgG concentration than both of those who scored higher and lower than this category. This superiority was not a factor that affected on the total weight of lambs born. Rather, it was a factor in the total weight of the weaned lambs. That could be due to a better milk quality and general health accordingly. There was a tendency that ewes with high body condition score at lambing give birth to lesser total weight of the born lambs while the heavier lambs were born by ewes with lower body condition score at lambing within the window of scoring that we had worked with. That could be explained by the use of the lambs of the dam's reservoir directly to gain their weight and that is shown clearly at lambing. Lambs that were born to ewes with body condition score of (2.5–3.5) at lambing weaned heavier than those who were born to ewes of either higher or lower BCSL. That was in consistency with the superiority of the colostrum concentration within this BCSL category (2.5–3.5) as discussed earlier. Although the superiority in the colostrum concentration were suggestive there, the weaning weights of lambs fed on this colostrum showed significant superiority in weight at time of weaning ($P=0.02$). Weaning weights for these lambs were heavier because of the quality of colostrum they were fed.

Sex of lambs born did not affect the quality of colostrum. In general, colostrum from ewes gave birth to twins was with higher quality than colostrum of ewes that gave birth to singles. Male lambs tended to be born heavier than those female lambs

Table 16.2 Pearson correlation analysis of body condition score at lambing (bcsl), time of collection from lambing (time), ewe weights (ewewt), total weight born (Totborn), total of weight weaned (totwn), litter size (litter), sex of lambs born (sex), colostrum concentration (conc) with body condition score at lambing (bcsl), time of collection from lambing (time), ewe weights (ewe wt), total weight born (Totborn), total of weight weaned (totwn), litter size (litter), sex of lambs born (sex), colostrum concentration (conc)

	bcsl	Time	Ewewt	Totborn	Totwn	litter	sex	conc
Bcsl	–	−0.24	0.069	0.056	0.082	−0.024	0.173	0.051
		0.033	0.0001	0.662	0.548	0.055	0.166	0.658
Time	–	–	0.067	0.024	0.262	0.144	0.024	0.425
			0.602	0.851	0.052	0.248	0.847	0.0001
Ewewt	–	–	–	0.103	0.125	0.182	0.055	0.074
				0.425	0.372	0.156	0.669	0.567
Totborn	–	–	–	–	0.467	0.586	0.410	0.156
					0.0003	0.0001	0.0008	0.213
Totwn	–	–	–	–	–	0.577	0.511	0.241
						0.0001	0.0001	0.074
Litter	–	–	–	–	–	–	0.843	0.116
							0.0001	0.355
Sex	–	–	–	–	–	–	–	0.057
								0.652

whether they were born single or twins. Male lambs weaned heavier than female lambs (23.7 vs 20.65 kg). Twin lambs with same sex tended to be weaned heavier than lambs of different sex. That could be due to the harmony of lambs with the same sex.

Ewes that gave birth to twins tended to have higher colostrum quality than those who gave birth to singles, IgG being 2,873 and 2,358 mg/dl, respectively. That was consistent with earlier findings of the effect of sex that showed no matter what the gender of the lamb is but the litter size is the factor that has an effect on the colostrum quality.

Table 16.2 showed that time of milk collection is a significant factor in colostrum concentration. Samples that were collected closer to the time of lambing tended to have higher colostrum concentration ($p=0.002$).

Ewes with body condition ranges from 2.5 to 3.5 at lambing are superior in the quality of colostrum. Lambs born for these ewes were weaned heavier than those born for ewes out of this range. According to these results it is a good idea to keep the ewes at the range of 2.5 to 3.5 at the lambing time so that colostrum quality will be better and consequently survivability, although not measured here, expected to be higher accordingly. Consistent with that the weaning weights are higher for the lambs born for ewes within this category which means a better performance at least before weaning.

16.5 Conclusion

It is concluded that body condition score and nutritional status, at lambing showed a suggestive influence on the colostrum concentration. Lambs that were born to ewes with body condition score of (2.5–3.5) at lambing weaned heavier than those who were born to ewes of either higher or lower BCSL. Sex of lambs born was not affecting the quality of colostrum. In general, colostrum from ewes gave birth to twins is with higher quality than colostrum of ewes that gave birth to singles. Male lambs weaned heavier than female lambs. Time of milk collection is a significant factor in colostrum concentration. Samples that were collected closer to the time of lambing tend to have higher colostrum concentration.

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Part IV
Agro-Biodiversity, Climate Change and Livelihoods: Managing Interdependence

Chapter 17
Simulation of Carbon Consumption by Biological Models

Olaf Pollmann, Nelli Pollmann, Szilárd Podruzsik and Leon Rensburg

Abstract Since the 1970's, the shortage of available and usable resources has been seen as the 'limit to growth'. Since then, the regenerative-ability of the environment—its ability to absorb harmful substances and waste products, has achieved a similar standing. Critical ecological examination must take not only the beginning, but also the end of the production chain into consideration, and thereby give equal weight to the exhaustion of important production materials (energy, raw materials) as well as to the over-stretching of the ecological reproduction capacity of the Earth. To recognize the carbon influence in production processes, it is necessary to balance anthropogenic material streams. For production processes and material recycling, the smallest common and not further reducible indicator is carbon. With knowledge of requirements, it is possible to reduce carbon consumption as a becoming scarce natural resource and fossil fuel which is used in different production process. Therefore, the material fluxes as the product of density (mass by volume) and hydrologic flow velocity (distance by time) must be known for every place and time of the

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production process. This investigation shows that the annual input and output of carbon in processes are almost balanced. With this carbon-balance, it is possible to identify resources and depressions of carbon and to point out approaches for optimization. Mostly material streams show a flow of valuable materials which can be merchandized if the quality is still right. This also reflects the strategy of cradle-to-cradle. To evaluate these anthropogenic impacts of pollutants on the environment or material streams in the natural circle, it is indispensable to use the benefits of computer systems—in particular artificial intelligence. Most of impact factors are time related and therefore difficult to calculate and to optimize in a natural environmental system. Use of evolutionary algorithms as a part of the artificial intelligence to simulate, estimate and evaluate pollutants or specific materials makes it possible to evaluate the impact on the environment and to optimize material streams in nature or recycling streams.

Keywords Resources • Recycling • Cradle-to-cradle • Anthropogenic Material Stream Optimization • Evolutionary Algorithms

17.1 Introduction

To cover the global natural resource consumption of humankind, a productivity of about 1.5 earths is necessary. Prognoses say that we need 2 earths to cover our steadily raising resource consumption in 2030 (WWF 2010). Additionally the release of the report for the Club of Rome's Project on the predicament of Mankind in the 1970th the limits to growth are clearly mentioned and already predicted (Meadows 1972).

To antagonize this process, the total economy has to work more efficiently and regarding climate and resource protection even a total change is necessary.

In relation to the described problem, the aim of zero waste is a good goal for the future, but we have to accept that an affluent society will always produce natural and anthropogenically created waste. There are "three Rs"—Reduce, Re-use, and Recycle that are always mentioned and important, and with these the hierarchy of waste minimization is explained. But what should be done with waste without the use of recycling? In this case, the recycling itself has to be optimized to process the largest possible amount of waste products in the production process of new materials. This optimization allows a minimization of primary raw material and additionally a minimization of waste. Because of the use of more short-lived products, the affluent society always requires more resources to fulfill the need of the required materials. Because of such consumption, nature has too little time for recovery and regeneration. The use of secondary materials as a substitute resource can, for the most part, cover the bulk of the resource requirement while preventing overexploitation of the natural primary resources at the same time.

Fundamental to the argument for the effective use of secondary materials is an understanding of the product circle and the numerical calculation of the resource input. The boundaries of the production process and the qualities and quantities of the materials are also related. All these factors have to be considered in the calculation and have different impacts on the production process and the final product itself. Because of the great variability of mutually dependent parameters in the calculation, most of the common numerical calculation methods reach their limits (Pollmann 2007). As the main calculation module for the problem of optimization, evolutionary algorithms were used as a component of artificial intelligence. With these algorithms acting like the model of evolution, the input of secondary materials for the production of products with similar quality was optimized.

17.2 Carbon Cycle

In order to balance input and output material streams and to optimize the use of secondary materials in production, the process itself was investigated and reduced to the lowest common indicator—in this case carbon. This indicator is an element which cannot be reduced any further (Baccini and Bader 1996). Related to different products all proportions of carbon are calculated relative to the mass and balanced for each production step. This balance makes it possible to finally compare all carbon fluxes of sub-production steps to point out resources and sinks of resources and to prove that the results from the balance of input and output material respond to each other.

The composition of the determined materials was primarily reduced to carbon, sulfur, phosphorus and nitrogen. Because of focusing on the total production process of the product the source material is transformed by sub-processes to sub-products till it leaves the process as the final product. Essential part of this investigation chain is the element carbon. The included occurring side products and educts like air, water, energy, additives, waste water, exhaust air and slag but these elements are influencing the main process only little. Main aim is to focus and display the continuity of carbon as the main compound. Therefore, all focused treatment steps of production and recycling are investigated separately.

Carbon balances such as those described in this study are essential for environmental friendly and sustainable production processes. Not until the balance identified the sinks and sources the carbon consumption cannot be reduced nor substitute materials can be applied. To keep the environment in an equal carbon balance, forests and wood sources should be conserved while additional waste should be avoided. This study also highlights a method for comprehensive and consistent tracking fossil and renewable carbon sources and emissions. It also determined that such sources and emissions can vary significantly in response to changes in process practices and industry infrastructure.

As an example former research showed that the input of recycled paper in the process of paper production can be increased without getting the carbon out of balance and keep the required quality. For the waste and recycling industry this fact is both saving money and natural resources but also producing less waste and lowering the impact on the environment and the carbon footprint. If the carbon balance is known beforehand then the production can be more effective and more environmental friendlier. With this, the principles of cradle-to-cradle—to close all material loops are then fulfilled.

17.3 Waste Management Strategies for Carbon Saving

Waste was and is always a difficult product and also a difficult term—either it is something stinky, toxic or rotten that someone would like to get rid of or it is declared as some kind of resource with a market value. This difference is not in the eye of the beholder—it is defined by law. As waste is understood as a valuable resource, the idea of waste management is not up-to-date any more. In this case, material stream management is the more precise term for this problem. The consumer of different products has to accept that after use the product will be reused in similar processes and therefore the material cycle will be closed again for future and further uses. This process itself is not only a recycling, but also an up-cycle of quality and an optimized material management. In this regard, different strategies try to rule the waste management sector—first of all the antiquated strategy of cradle to grave which only down-cycles useful resources, followed by the strategy of reduction, reuse and recycle which tries to be eco-efficient. Then, beside others, Cradle to Cradle is a premium concept of material up-cycling and as an eco-effective and intelligent process of production (Braungart and McDonough 2009).

Instead of the above mentioned strategies, recycling itself has to be optimized to process the largest possible amount of waste products in the production process of new materials. This optimization allows a minimization of primary raw material or even a prevention of waste. That means saving carbon. The use of secondary materials as a substitute resource can for most part cover the bulk of the resource requirement whilst preventing overexploitation of the natural primary resources at the same time.

Waste in general has always been treated and managed in different ways. One of the successful strategies was Cradle to Grave with the idea of monitoring different waste streams. This strategy was one of the first really planned systems. Till resources got limited, this strategy was replaced by the strategy Reduce, Reuse, Recycle followed by the strategy Cradle to Cradle which is the most advanced strategy till now.

17.3.1 Strategy 1: "Cradle to Grave"

Cradle to Grave is also mostly known as eco-balance or life cycle assessment (LCA). This strategy is an investigation and evaluation of the environmental impacts of a given product or service caused or necessitated by its existence. But with

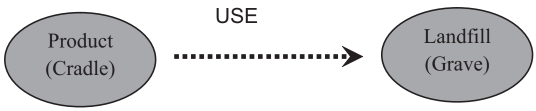


Fig. 17.1 Strategy of cradle to grave

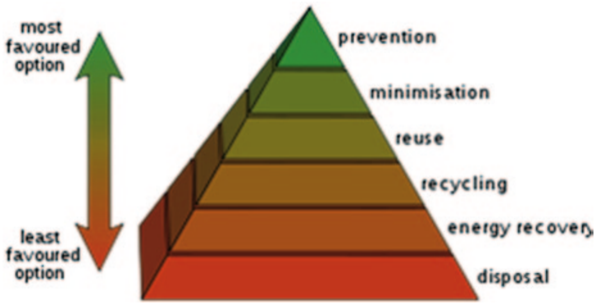


Fig. 17.2 Strategy of reduce, reuse, recycle

the specific characteristic that the product cycles are not really cycles but mostly only half cycles in which products after their useful life, are put out of sight in landfill sites (Fig. 17.1).

17.3.2 Strategy 2: "Reduce, Reuse, Recycle"

This strategy refers to the 3Rs as the meaning of *Reduce, Reuse and Recycle*, which classify waste management strategies according to their desirability (Fig. 17.2). This integrated waste management strategy focuses on the waste hierarchy and shows the validity of the waste itself. Recently a 'fourth R': "Re-think" was incorporated, to exclude the fundamental weakness, and that a thoroughly effective system of waste management may need an entirely new way of looking at waste.

17.3.3 Strategy 3: "Cradle to Cradle"

The *Cradle to Cradle* strategy is the antidote to the *Cradle to Grave* strategy (Fig. 17.3). The purpose of this strategy is to restore continuous cycles of biological as well as technical nutrients with long-term positive effects on profitability and the environment and human health (Braungart and McDonough 2009). This advanced strategy invents intelligent designed products with the aim and function as a temporary product and future product at the same time. With this strategy, the idea of waste management totally switched to the terminology of material stream management and material stream optimization.

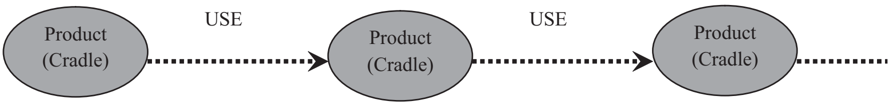


Fig. 17.3 Strategy of cradle to cradle

Based on the strategy of *Cradle to Cradle,* all materials in the production process—fresh and secondary materials—should be monitored. In order to optimize the use of secondary materials in the production, the process itself has to be investigated and reduced to the lowest common indicator—this is in most of the anthropogenic cases of material stream optimization of the element carbon.

With research and the described application, it could be shown that a rethinking of waste management strategies is needed. The up-to-date and future terminology of waste treatment will be material stream management combined with the intelligent design of products as covered by the strategy of *Cradle to Cradle*. Differing strategies or denial of the comparison waste with resource will lead the whole waste industry away from internationally accepted strategies.

17.4 Information Technology Tools

The challenge of using information technology tools is acceptance and usability. In this application of carbon consumption as an indicator for anthropogenic impact evaluation and material stream optimization, economy is directly related with the ecology and the impact on the environment (Fig. 17.4). The customer or user has to decide where the focus of evaluation and optimization should be. This decision can also manipulate the main aim of use while focusing only on one of the related aims. All extremes—economy, ecology and environmental impact itself—deliver unacceptable results. The following implementation will show how the application of evolutionary algorithms contributes to the strategies of waste reduction and environmental protection.

17.4.1 Evolutionary Algorithms for Evaluation and Optimization

The composition of different anthropogenic impacts and material streams requires an algorithm which is able to solve equations with ten or more unknown factors which are additionally interdependent and time related. With common numerical methods these calculations are solvable only with long calculation time, if at all. Because of this fact, evolutionary algorithms were used as a solver, functioning in the biological model of evolution (Gerdes et al. 2004).

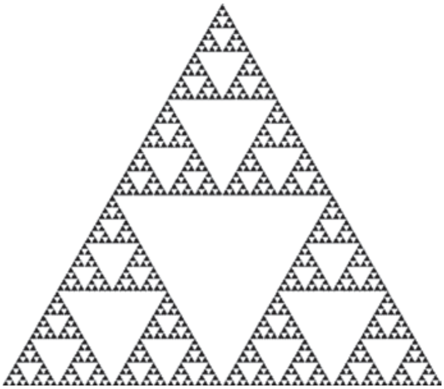


Fig. 17.4 Fractal triangle for process evaluation. (Based on Sierpinski 2000)

The benefit of evolutionary algorithms is the objectives-orientated, fast and precise calculation of local and global optima by consideration of different evolutionary internal and external influences (Fig. 17.5). To calculate the application of evaluating anthropogenic impacts or optimizing material streams, the following parameters have to be determined: computational accuracy, size of search area, objective function, amount of individuals, amount of generations, impact of mutations, crossover, fitness, selection, time relevance and definition of an abort criterion. With these specifications it is possible to optimize and evaluate different input values relative to different output quality requirements (Pollmann 2006).

As input, all the different impact factors for impact evaluation or primary and secondary material streams need to be available for material stream optimization. From these the optimized or evaluated composition related to the focused aim can be calculated (Fig. 17.4). The start vector of the initial population (individuals from the start generation) will be chosen randomly from the mix of input values.

The principle flowchart was used and implemented for the application of evolutionary algorithms (Fig. 17.5). In this regard the following steps were followed:

- Defining of input and output variables, constants and functions.
- Random generation of lists with start populations.
- Suitability for each list of the population. This implies defining how good the items in the lists comply with the requested task.
- Executing the selection by fitness function.
- Executing the gene exchange (crossover, mutation, reproduction), so that correct lists are always generated.
- Repetition of steps 3 to 5 till the defined abort criterion is achieved.

Important for the flow is that mutation and crossover should be used at same time to eliminate the premature convergence, a disadvantage of evolutionary algorithms.

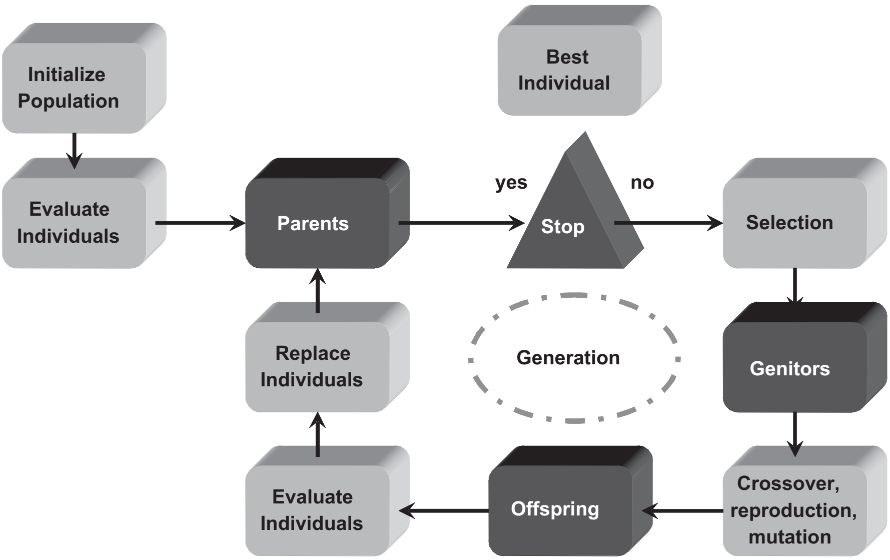
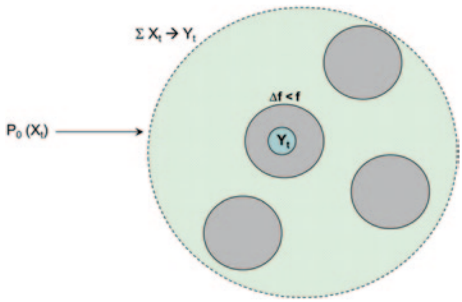


Fig. 17.5 Sequence diagram of evolutionary algorithms. (Pollmann 2007)

Fig. 17.6 Stray field of potential results. (Pollmann 2007)



Otherwise an occurrence of local optima or of the same individual as a result of the optimization is possible but undesirable.

The results of this application, the impact evaluation and the material flux optimization are a calculated matrix which achieves the desired quality of results. The evolutionary algorithms calculate randomly, by generating a batch of acceptable results within the restricted boundaries, which is the best result for the solution of the problem (Fig. 17.6). The benefit of calculating a system like this with evolutionary algorithms is the very fast detection of possible restricted global optimum (Y_t) out of the total sum of possible results ($\sum X_t$).

17.4.2 Optimization by Evolutionary Algorithms

The optimized material input was calculated (Eq. 17.1) with three different algorithms: GASteadyState- GA, GACrowdingGA and GADemeGA as part of artificial intelligence. The calculated values were all in the same range with small insignificant deviations. These deviations in different types of algorithms probably reflect the influence of variable boundary conditions.

$$f(x) = \sum_{i=1}^{n} x_i * V_i * U_i \tag{17.1}$$

where: x_i = concentration (as relative fraction), V_i = volume, U_i = environmental factor (UWF)

The result of this investigation was an increase of secondary material input, for example the paper classes: sanitary papers and paper and board for technical and special usage without any loss of quality in the paper itself.

17.4.3 Anthropogenic Impact Evaluation

Similar to material stream optimization, anthropogenic impact evaluation has to transfer impact factors with fluctuating, interacting and time related values into a mathematical optimization matrix to solve a poly-optimization problem. The aim is again related to environmental, economical and social factors which are dominated by external groups and companies (Pollmann 2009).

17.4.4 Approach of Anthropogenic Impact Evaluation by Evolutionary Algorithms

The implementation of this complex problem into the computer model for optimization fundamental data collection is currently done. In parallel, the algorithms are reconfigured to fit and fulfill the requirements of this problem. A database to exchange the interrelated data with the algorithms has to be configured to transfer the static situation to the dynamic and time related mashed problem. The challenge in this application is the huge time-depending number of impact factors, the different investigations and the requirements of government and mining companies to fit under the roof of global acceptance. Those requirements have to be translated into measurable parameters that can be determined in praxis.

Setting the environmental impact in closer relation to economy and ecology—as usual in business processes—the correct fulfillment of the optimization or evaluation aim gets more into focus and increased emphasis. With the support of tools like these algorithms, it is possible to reveal the anthropogenic impact on the environment by the origin of processes to improve waste management and rehabilitation strategies.

17.5 Conclusion

The simulation of carbon consumption by biological models is an important part in resource and climate protection. The result of a study like this is a combination of different research disciplines and a step forward towards a society of reduced waste production, waste upcycle in quality and closed loops. Different strategies such as *Cradle to Cradle* scientifically proved that a closed loop production is effective and economically suitable for some selected products. That production procedure of intelligently designed products with the support of biological models like evolutionary algorithms can save carbon and recycle materials with high carbon content.

Scientific studies showed the basis of carbon cycles, carbon simulations and carbon use optimization. Now the economic sector has to take over and transfer scientific results into applications. Real applications for optimization are available and necessary in agriculture, production and energy.

The responsibility of the imbalance equilibrium in nature is global responsibility. International research has shown the importance of finding and adapting solutions to the environmental concerns so that it is applicable to under-developed and developing countries. The negative environmental effects and altered conditions, especially in natural areas like soil, water and air must be reversed to obtain a state as close as possible to the previous natural state. Long-term and linked solutions must be in place to avoid further irreversible interferences between human beings and nature.

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Chapter 18
Biodiversity Conservation and Carbon Sequestration in Cocoa Agroforest in Southern Cameroon

Louisa Zapfack, Jean Kotto-Same, Amougou Akoa and Gaston Achoundong

Abstract The study is conducted in semi deciduous rain forest zone of southern Cameroon to appreciate the impact of cocoa agroforest on plant biodiversity conservation and carbon sequestration. Twenty-four transects of 1.5 km long and 10 m wide were established in eight villages to evaluate the cover percentage of cocoa compare to other land use system (LUS). Forty five plots of 625 m^2 (25 m x 25 m) each were surveyed in these villages. In these plots, all the individuals with DBH (Diameter at the Breast Height) greater or equal to 4 cm were recorded. The destructive method was used to evaluate carbon sequestration in different LUS for herbaceous plants, small woody plants, litter and roots, while the allometric equation of Brown was used for all individuals with DBH ≥ 4 cm. Seven LUS were identified in the Yaounde region: 23 % of these were cultivated land, 36 % were fallows, 16 % were cocoa field and 5 % represented the secondary forest derived from the slash and burn practices. In the regions of Mbalmayo and Ebolowa, eight LUS were identified, of which six shared with the region of Yaounde and two different, the degraded forest and swampy forest. Species encountered in cocoa agroforest represent 33.78 % of the total flora of the area. Fruit trees were abundant in those villages which have access to market (*Persea americana, Dacryodes edulis, Citrus spp*), while in Ambam region, original forest species mostly timber species were encountered (*Baillonella toxisperma, Guibourtia tessmannii, Terminalia superba, Milicia excels*). This agroforest can accumulate about 251.14 t C/ha. Theobroma cacao hosted about 21.51 t C/ha. The root system of cover species stocks an important quantity of carbon.

Keywords Cocoa agroforest • Land use system • Biodiversity • Carbon sequestration • Cameroon

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18.1 Introduction

Tropical deforestation proceeds at a rate of 154,000 km^2 yr^{-1} (Aldhous 1993) with approximately 0.32 Gt C yr^{-1} (Giga tonnes carbon per pear) being lost to the atmosphere due to land use in Africa (Brown et al. 1993). The classification of Letouzey (1985) showed that the Cameroon rain forest is subdivided into three important types: the evergreen rain forest; the mesophyllous rain forest and the semi-deciduous forest. These types of forests are subjected to an important transformation of shifting cultivation, the creation of industrial plantations and timber operations. Thenkabail (1995) identified 7 classes of land use systems which are derived from these transformations in the semi-deciduous rain forest.

The humid forest zone in Cameroon covers more than 20×10^6 ha (Cenadefor 1989) of land and represents about 42 % of the total area of the country. Agricultural production is dominated by slash-and-burn characterized by longer period of fallow over shorter period of cropping (Sanchez 1976). In general, after land clearing and burning, the soil is cropped for one year, then allowed to fallow for several years. The fallow period ranges from 4 to 9 years with an average of 7 years depending on the population pressure on the land and the accessibility to the market. The fallow period allows the accumulation of aboveground biomass and increased the plant and animal diversity. Soil fertility, forest type, frequency and intensity of disturbance, may all affect the rate of forest recovery (Szott et al. 1994). During the first 10 years of fallow, published data showed that the total biomass accumulation varies considerably, ranging from 48 to 168 t C ha^{-1}. Bartholomew et al. (1953) while presenting data collected from the Congo basin showed that the biomass accumulation reached a steady state after 15 years of fallow. The shortening of the fallow period reduces the amount of nutrient accumulation and also the yield and contributes to land abandonment among other factors such as weed encroachment and pest infestation. This chapter intends to assess the plant diversity and the stock of carbon in cocoa agroforest system.

The objective of this study is to evaluate the rate of biodiversity conservation in cocoa field compared to other LUS. It may also permit to evaluate carbon stock in this LUS compare to others.

18.2 Material and Methods

18.2.1 Site Selection

South Cameroon from Yaounde to Equatorial Guinea is a forest area where slash-and-burn agriculture is practiced. The area is characterized by a north-south vegetation gradient. Population density and land-use intensity are both high. Vegetation is mostly semi deciduous rain forest, but the north of the region is characterized by *Imperata cylindrical*savanna, and the south by the dense Congolese rain forest.

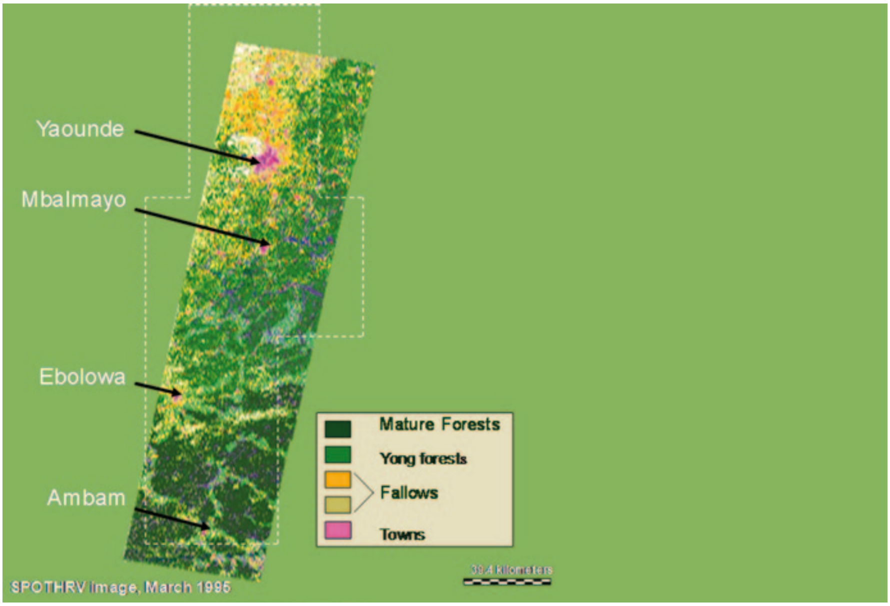

Fig. 18.1 Satellite images of the study site (March 1995)

Population densities, according to the 1995 census, vary greatly from 65.9 inhabitants per square kilometer in the Monatele subdivision north of Yaounde to only 3.8 in the Ambam subdivision south of Yaounde near Equatorial Guinea. Fallow length is still high in the south (around 15 to 20 years) but is decreasing to less than 3 years in the north. This gradient was the main reason for selecting the area as alternatives to slash-and-burn benchmark site (Manga 1994).

Deforestation within the benchmark area takes different forms and has different impacts, with a number of different slash-and-burn practices. Here we look at how these practices are influencing the landscape, as observed by satellite sensors. Therefore we look both at the process involved from a historical perspective and at the actual landscape pattern.

The study was conducted in the forest margins benchmark area of the humid forest zone of Cameroon located at 2° 20′N to 4° 30′N latitude and at 11° 00′E to 11° 15′E longitude. Transects were selected in three regions namely Yaounde, Mbalmayo and Ebolowa located in the semi deciduous rain forest domain (Letouzey 1985; Fig. 18.1). The domain can be assimilated to the Guineo-Congolian rain forest (White 1983). Annual rainfall in the area is less than 2000 mm and the climate is tropical bimodal type. The minimum temperature is 17.5 ˚C and the maximum 32.5 ˚C making an average annual temperature of about 25 ˚C.

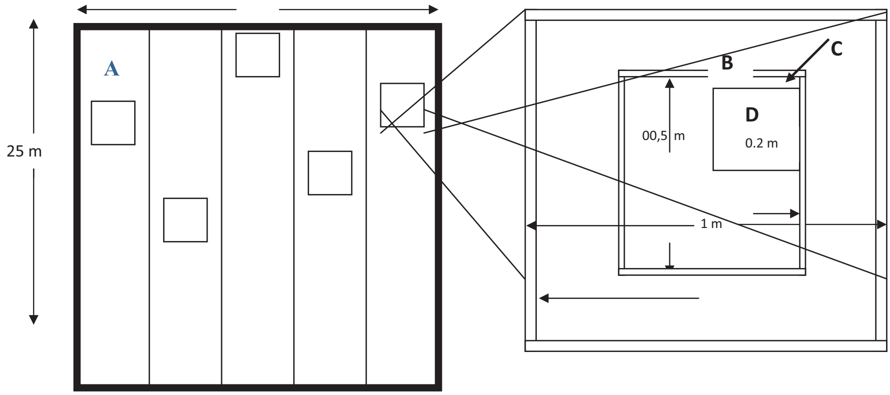

Fig. 18.2 Diagrams of biodiversity inventory and evaluation of carbon stock in cocoa agroforest system of the Cameroon semi deciduous forest : *A* = woody species biodiversity and carbon evaluation, *B* = understory carbon, *C* = litter carbon and *D* = roots carbon (C). (Adapt from Woomer and Palm 1998)

18.2.2 Field Methods

18.2.2.1 Sampling Strategies

The basic sampling approach was used to identify the cocoa agroforest systems in the villages and randomized field replicated quadrates were established within them. The size of the major quadrate was 25 × 25 m (Fig. 18.2) and was replicated 16 times. Quadrate locations were marked for later plot identification. Quadrates were not allowed to cross one another or to extend beyond their designated land use. This sampling method was described by Kotto et al. (1997) and Woomer and Palm (1998).

18.2.2.2 Plant Diversity

Three quadrates of 25 × 25 m (625 m^2) were established at each of the main land use systems found in the zone. Altitude and the geographical co-ordinates of each quadrate were identified. The 625 m^2 was further subdivided into 5 blocks of 125 m^2 each (5 × 25 m). Inventories were made from the first block to the last.

Scientific names and vernacular (given by a traditional local practitioner) were annotated. Uses of each species (medicinal plants, nutritive, fertilizers, timber etc) were also determined. Species which could not be identified in the field were collected, pressed in between newspapers and conserved in alcohol for later identification and storage in the National Herbarium of Cameroon (YA), and Royal Botanic Garden Kew (K).

18.2.2.3 Aboveground Tree Biomass

Aboveground carbon was measured for trees, understory and surface litter (necromass) and roots. Tree diameter measurements were used for estimating tree biomass. Diameter at breast height (DBH) was measured using diameter tapes and recorded for all diameters greater than 4 cm within 16 quadrates of 25 × 25 m each. Trees with at least 50 % of their diameters falling within the quadrates were measured. Tree buttressing was corrected by measuring the diameter above the buttress. For trees branching below the breast height, the diameters of all the branches were measured separately. Tree biomass was estimated from the allometric equation of Brown et al. (1989) for moist tropical forest with the yearly rainfall above 1500 mm.

$$\text{kg Biomass tree}^{-1} = 38.4908 - 11.7883 \cdot \text{D} + 1.1926 \cdot \text{D}^2 (\text{adj R}^2 = 0.78)$$

Where

D DBH (cm) for $D > 5$ cm

18.2.2.4 Understory and Surface Litter Measurements

Understory vegetation and surface litter was measured within two sub-quadrates located at random within each of the five 100 m^2 quadrates. Understory biomass included trees with DBH < 4 cm and all herbaceous vegetation. All vegetation occurring within the borders of the quadrate was cut at ground level and collected. Two 1.0 × 1.0 m sub-quadrates were randomly positioned 50 cm from the central quadrate from the central axis of the major quadrate. Surface litter including rotting logs and charcoal was collected within a 50 × 50 cm frame centrally placed each 1.0 m^2 sub-quadrate. Samples were weighed, sub-sampled, oven dried at 65 °C to constant weight and corrected for moisture content. Live vegetation was assumed to contain 45 % C on a dry weight basis and surface litter was ground and analyzed for total organic carbon (Anderson and Ingram 1993).

18.2.2.5 Root Sampling

Root sampling was recovered from an area 20 × 20 cm and to a depth of 50 cm within each sub-quadrate replicated 5 times. All samples and roots from the hole were placed in bags and transported to the laboratory. Roots were oven dried at 65 °C to constant weight, weighed, ground and ashes. Ash -corrected dry weight was assumed to contain 0.45 % C.

18.2.3 Data Compilation and Analysis

Data on floristics was subjected to a factor analysis in order to determine the affinity between land uses. The diversity indices of Shannon-Weaver, Simpson indices and the equitability of Piélou were used to describe and compare the diversity of the various land use forms (Piélou 1966; Daget 1976; Dajoz 1982; Frontier and Pichod-Viale 1993).

18.3 Results and Discussion

18.3.1 Biodiversity in the Cocoa Agroforest System Compared to Other LUS

18.3.1.1 Cover Percentage of Cocoa Agroforest System Along the Transects

In each region, height transects of 1500 m long by 10 m wide were open. Seven LUS were identified in the Yaounde region and height in each of the two other regions (Mbalmayo and Ebolowa). Cocoa agroforest system covers about 16.32% of the vegetation in Yaounde region, 8.32 in Mbalmayo and 15.80% in Ebolowa region (Fig. 18.3). This makes an average of 13.36% for the whole semi-deciduous rain forest domain. This cover percentage of Cocoa agroforest system conserves which plant biodiversity? Anthropics factors, which refer to sustainable use of the biodiversity in this LUS may influence the rate of species richness in the three regions of the semi deciduous rain forest. The pressure of the population (density of population) on the vegetation is also an important factor for biodiversity conservation in cocoa fields.

18.3.2 Yaounde Region

18.3.2.1 Vegetation Structure in Cocoa Agroforest at the Yaounde Region

The vegetation structure is made of three main layers: the upper layer is composed of coverage species, average layer of fruit trees like *Dacryodes edulis*, and the shrub layer of cocoa trees. The herbaceous layer is frequently cut in order to maintain the clean planting. 1561 individuals of trees per hectare, with DBH greater than or equal to 4 cm were surveyed, 1422 belonged to the species *Theobroma cacao*. The rest is made up of individuals of species coverage (65 feet) and cultivated woody species such as *Dacryodes edulis, Mangifera indica* or young feet of useful species protected by the farmer when cleaning the cocoa. *Trilepisium madagascariense* (103 cm), unique representative of class A, host the most important DBH of cocoa

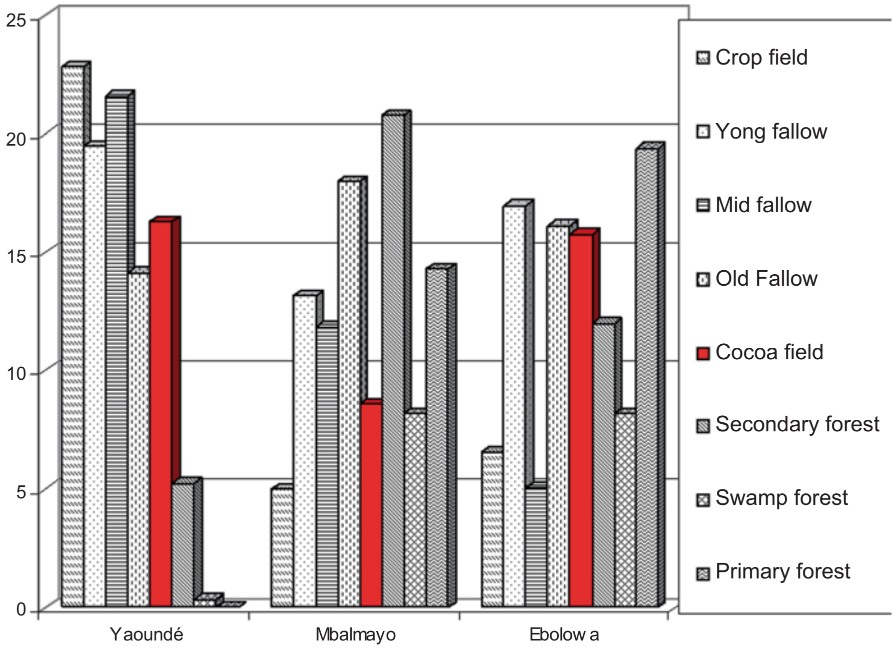

Fig. 18.3 Main LUS encountered in different transect of semi deciduous rain forest domain express as cover percentage of the vegetation

field of the region. Class B count 31 individuals with the most important been: *Ficus mucuso* (95.4 cm), *Albizia zygia* (84.0 and 79.5 cm), *Terminalia superba* (79.5 cm), *A. ferruginea* (73.5 cm) and *A. adianthifolia*. Classes C (79 individuals), D (876) and E (574 individuals) are dominated by *Theobroma cacao*.

18.3.2.2 Species Richness

The composition of the herbaceous layer depends on the rate of clearing the understory. The least diverse fields were those who have the greatest density of cover trees. The flora composition stands between the secondary forest and the old fallow (Fig. 18.4).

The following woody species are always encountered in the cocoa agroforest system in the Yaounde region: *Albizia adianthifolia; Albizia zygia; Anthocleista schweinfurthii; Antidesma laciniatum; Bridelia micrantha; Ceiba pentandra; Celtis tessmannii; Citrus grandis; Dacryodes edulis; Elaeis guineensis; Fagara macrophylla; Ficus exasperata*; *Ficus mucuso; Mangifera indica; Margaritaria discoidea; Massularia acuminate; Milicia excels; Newbouldia laevis; Persea Americana, Pseudospondias microcarpa, Rauvolfia vomitoria, Spathodea campanulata, Terminalia superba, Trichilia heudelotii, Trilepisium madagascariense, Triplochiton scleroxylon, Vitex ferruginea.*

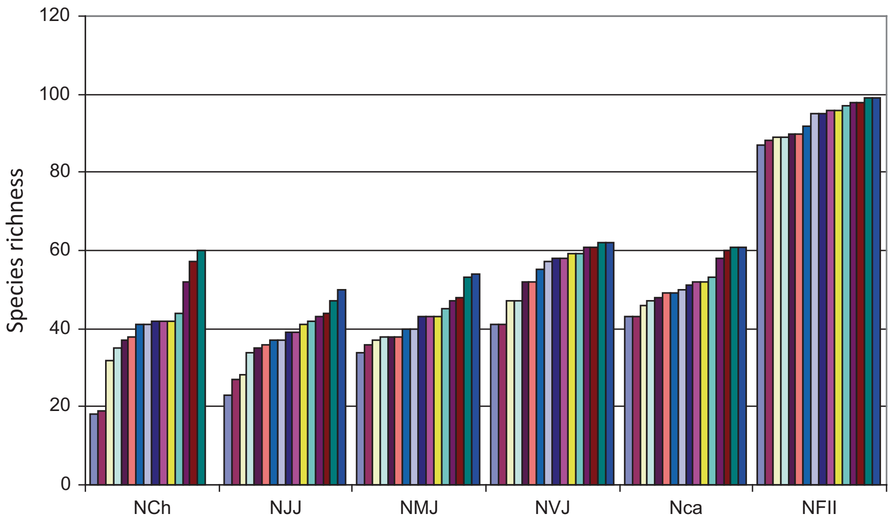

Fig. 18.4 Species richness along the transect surveyed in the different LUS at Yaounde Region. (*NCh*=Crop Field, *NJJ*=Yong Fallow, *NMJ*=Mid Fallow, *NVJ*=Old Fallow, *NFII*=Secondary Forest)

Table 18.1 Variation of species within each LUS and SD in the region of Yaound

LUS	Number of species per plot			
	Maximum	Minimum	Average	Standard Deviation
Crop Field	60	32	40	11.61
Yong Fallow	54	23	41.28	2.20
Mid Fallow	54	34	42.31	5.87
Old Fallow	62	41	52.09	7.36
Cocoa Field	61	43	51.43	5.88
Secondary Forest	99	87	92.5	5.50

The difference between the minimum and maximum values of species richness of different LUS can confirm that the floristic diversity is not only a function of age of the LUS, but also a function of other environmental factors (Table 18.1 and 18.2). The standard deviation shows that in general these values are widely dispersed around the mean.

Species (39.12 %) found in the different LUS are in cocoa agroforest system. These species were identified at 81.63 % at the species level, to 13.26 % at the generic level, 2.55 % at the family and 5 species were not identified. The standard deviation is equal to 5.88. This value is low and shows that species richness varies relatively little compared to the average which is equal to 51.43. These values are based on the frequency of cleaning the undergrowth. Plantations frequently cleaned with fewer species and those who are neglected with young shoots of species spread by animals and win.

Table 18.2 Values of Shannon Index (ISH), Piélou equitability (EQ), Simpson (D) and his son inverse D' in different LUS of Yaoundé

	CF	YF	MF	OF	CO	FII
S	155	148	167	251	199	348
ISH	5.23	5.02	4.49	5.07	3.23	6.17
EQ	0.56	0.48	0.42	0.49	0.28	0.65
D	35.28	30.42	12.06	25.83	2.66	49.65
D'	0.02	0.03	0.08	0.03	0.37	0.02

S number of species encountered in different LUS, *CF* crop field, *YF* yong fallow, *MF* mid fallow, *OF* old fallow, *CO* chromolaena odorata, *FII* secondary forest, *FI* primary forest

18.3.3 Mbalmayo Region

18.3.3.1 Vegetation Structure in Cocoa Agroforest at the Mbalmayo Region

Approximately 1969 plants ha^{-1} were counted in the cocoa agroforest system of this region. The three class categories in diameter are present: 0.33 % of individuals are large trees belonging to the class A, means diameter trees represent 1.69 % of the woody vegetation while small trees whose DBH is between 50 and 100 cm represent 5.34 %. They are cover species most of which are exploited for their fruit or bark. Categories D and E, consisting essentially of cocoa feet are best represented with respectively 24.64 % and 67.97 % of the vegetation. The species most used as a cover crop are: *Triplochiton scleroxylon, Terminalia superba, Ceiba pentandra, Cordia platythyrsa, Musanga ceropioides*.

18.3.3.2 Species Richness

In one type of land use, species richness varies depending on several factors including the cultural past that uses the history of the plot, the age of the plot, the vegetation, the effect of recent human and even the nature of the soil (Fig. 18.5). In this region, most cocoa fields are well maintained. Weed control is effective and plant biodiversity conserve in these cocoa fields are mostly pioneers and original forest species (Fig. 18.5). Fruit trees are scare. Species collected were: *Albizia adianthifolia, Ceiba pentandra, Celtis tessmannii, Cordia platythyrsa, Ficus mucuso, Ficus* sp., *Lannea welwitschii, Macaranga assas, Margaritaria discoidea, Milicia excels, Musanga cecropioides, Pteleopsis hylodendron, Pterocarpus mildbraedii, Pycnanthus angolensis, Ricinodendron heudelotii, Staudtia stipitata, Terminalia superba, Trilepisium madagascariense, Triplochiton scleroxylon, Xylopia aethiopica.*

In the region of Mbalmayo, 622 species were identified in the LUS prospected. Species richness is high in the forest; when a forest is convert to cocoa field, about 15 % of original forest species are saved.

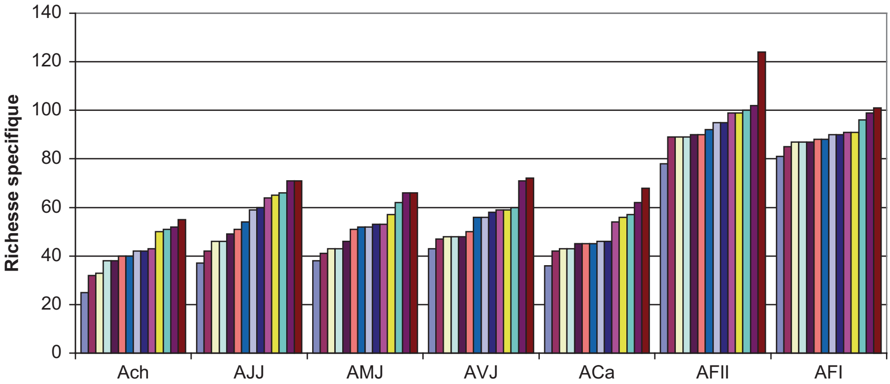

Fig. 18.5 Species richness along transects surveyed in the different LUS at Mbalmayo Region. (*NCh*=Crop Field, *NJJ*=Yong Fallow, *NMJ*=Mid Fallow, *NVJ*=Old Fallow, *NFII*=Secondary Forest, *AFI*=Primary Forest)

Table 18.3 Variation of species number within each LUS in the region of Mbalmayo

	Number of Species per Plot			
LUS	Maximum	Minimum	Average	standard deviation
Crop Field	55	25	42	7.95
Yong Fallow	66	37	54.91	10.83
Mid Fallow	66	38	50.57	7.90
Old Fallow	72	43	54.3	8.91
Cocoa Field	68	36	49.75	9.49
Secondary Forest	124	78	97.5	13.40
Primary Forest	101	81	91.37	6.96

Standard deviations are very large and show that the values of that species richness are widely dispersed around the average (Tables 18.3 and 18.4).

The flora of cocoa contributes about 29.58 % in the flora of all LUS inventoried. The species were identified in 89.13 % at the species level, to 7.35 % at the generic level and 0.05 % at the family level. Four species remained undetermined. Species richness ranges between 36 and 68 with an average of 49.75 species per plot. The value of standard deviation (9.49) shows that species richness of various statements differs from the average. Higher values are observed in the statements made in plots abandoned for 18 months and minimum values in plots maintained fourth a year.

18.3.4 Ebolowa Region

18.3.4.1 Vegetation Structure in Cocoa Agroforest at the Yaounde Region

A total of 1180 plants ha^{-1} have been identified. Approximately 79.54 % of individuals are Theobroma cacao. The rest is composed of cover species that are in categories A, B, and C accounting for 0.80 %, 3.27 % and 7.90 %. They are mostly

Table 18.4 Values of Shannon Index (ISH), Piélou equitability (EQ), Simpson (D) and his son inverse D' in different LUS of Yaoundé

	CF	YF	MF	OF	CO	FII	FI
ISH	5.36	5.50	6. 43	5.12	3.09	6.23	6.03
EQ	0.56	0.57	0.61	0.50	0.28	0.59	0.57
D	41	19.32	40.33	24.5	2.10	53.29	43.81
D'	0.02	0.05	0.02	0.04	0.47	0.01	0.02
S	177	270	291	326	245	528	510

S number of species encountered in different LUS, *CF* crop field, *YF* yong fallow, *MF* mid fallow, *OF* old fallow, *CO* chromolaena odorata, *FII* secondary forest, *FI* primary forest

species of forest left up during the creation of the cocoa or individuals grown after its creation and protected in order to control the shade of cocoa. The real emerging as *Ceiba pentandra* (170 cm and 165.5 cm) is encountered. The feet of cocoa trees forming the bulk of the understory are divided between the categories D and E as 43.84 and 44.18 % respectively of the woody vegetation of cocoa field. These can be observed in the understory saplings of fruit trees as *Mangifera indica, Persea americana, Dacryodes edulis, Vernonia amygdalina.*

18.3.4.2 Species Richness

The species richness of different LUS varies according to the same factors mentioned in Mbalmayo region (Fig. 18.5). In general, we found that species richness increases from the fields to forests.

The following forest species were encountered in those cocoa fields: Albizia adianthifolia, Alstonia boonei, Antiaris Africana, Antrocaryon klaineanum, Bombax buonopozense, Ceiba pentandra, Cordia platythyrsa, Ficus exasperate, Funtumia Africana, Milicia excels, Myrianthus arboreus, Petersianthus macrocarpus, Pterocarpus soyauxii, Pycnanthus angolensis, Ricinodendron heudelotii, Spathodea campanulata, Terminalia superba.

In this case, we notice that the species richness is not constant in different plots surveyed. Non maintain fields bear more species than those who are permanently clean (Fig. 18.6)

The species encountered in the cocoa represents 33.78 % of the flora of all the LUS prospected. A total of 83 % of species have been identified at the species level, 16.91 % in the generic, 1.10 % at the family level and a single species could not be identified. Species diversity in cocoa is a function of the frequency of cleaning: those that are maintained twice a year are less diversified, whereas those that are cleaned once a year are the richest. Those who have been abandoned for at least two years have not been explored and would be even more diversified. The high value of standard deviation (Tables 18.5 and 18.6) shows that the number of species per plot survey varies and deviates from the average (57.16).

In general, plant biodiversity of cocoa agroforest system is situated in between the old fallow and the primary forest. The factor analysis obtained after the input of

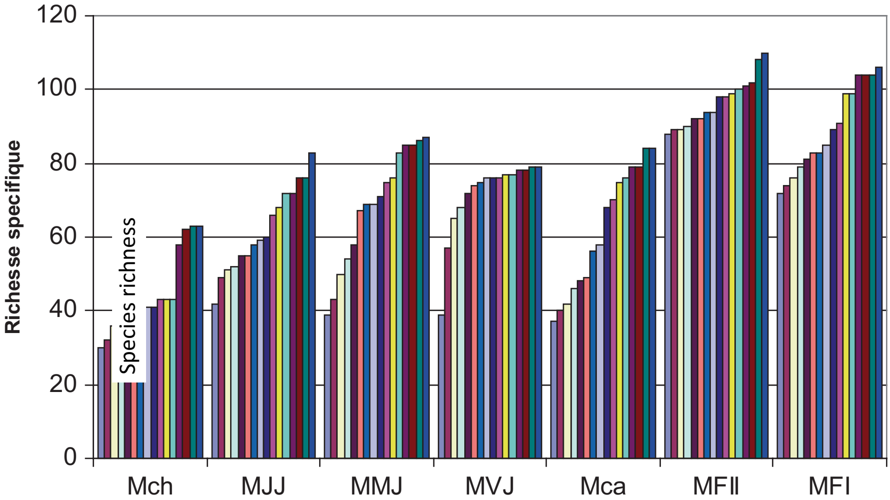

Fig. 18.6 Species richness along transect surveyed in the different LUS at Ebolowa Region. (*NCh*=Crop Field, *NJJ*=Yong Fallow, *NMJ*=Mid Fallow, *NVJ*=Old Fallow, *MCa*=Cocoa Field, *NFII*=Secondary Forest, *MFI*=Primary Forest)

Table 18.5 Variation of species within each LUS in the region of Ebolowa

LUS	Number of species per plot			
	Maximum	Minimum	Average	Standard deviation
Crop Field	58	30	43.25	15.86
Yong Fallow	83	42	61.23	12.49
Mid Fallow	87	37	64.84	15.08
Old Fallow	79	39	68.2	12.19
Cocoa Field	84	37	57.16	16.51
Secondary Forest	110	88	96.6	10.27
Primary Forest	106	72	89.31	11.83

data on floristic composition of each vegetation type reveals, following the X-axis, an opposition of the Forests I and II to the fallow fields and the farmland (Fig. 18.7a, b). This axis was positively influenced mainly by Forest I which harbored almost 160 species. It was negatively influenced by 64 species of the farmland. We thus notice a decreasing gradient of species richness from primary forest to the farms. The cocoa fields comprised numerous species specific to this kind of vegetation use. This explains its isolation in relation to the other vegetation types. The same observation can be made on the figure obtained from axis 1 and 3 (Fig. 18.7a, b). Some species are more related to particular types of land use system than others. They are supposed to be characteristic for their habitats and may function as indicators of the conversion of land use.

More than 30 % of the original forests are conserved in this LUS as far as woody and herbaceous species are concerned. We noted with Zapfack et al. (2002) that

Table 18.6 Values of Shannon Index (ISH), Piélou equitability (EQ), Simpson (D) and his son inverse D’ in different LUS of Yaoundé

	Ch	JJ	MJ	VJ	Ca	FII	FI
S	236	270	316	379	362	458	426
ISH	5.51	5.74	5.69	5.82	3.97	6.28	5.78
EQ	0.57	0.57	0.54	0.57	0.37	0.67	0.5
D	58.93	50.26	34.14	41.2	4.36	53.66	32.33
D’	0.01	0.01	0.02	0.02	0.22	0.01	0.03

S number of species encountered in different LUS, *CF* crop field, *YF* yong fallow, *MF* mid fallow, *OF* old fallow, *CO* chromolaena odorata, *FII* secondary forest, *FI* primary forest

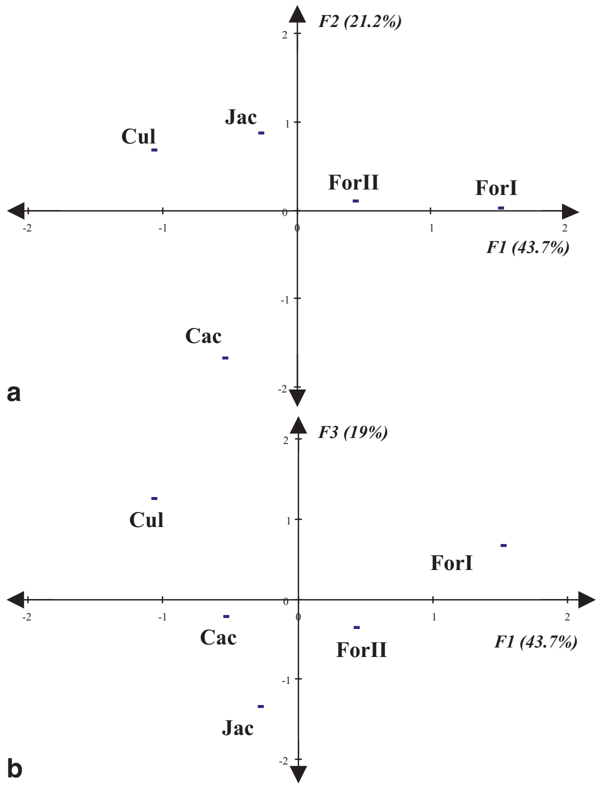

Fig. 18.7 Distribution of some types of land use system of the Cameroonian semi-deciduous rain forest within a factor analysis based on floristic data. A: performance of axis 1 and 2; B: performance of axis 1 and 3. *For I*=forest I, *For II*=forest II, *Jac*=Fallow fields, *Cac*=cocoa fields, *Cul*=farms.

emergent trees carry an important epiphytic flora which, most of the time increase the species richness of cocoa field. The rest of the flora is made with weed and pioneer species.

Species preserved in the cocoa agroforests are mostly PFNL (used in local medicines) or used to fertilize and maintain the soil. Their conservation is not a random process but it is perfectly controlled by the farmer. This LUS represents the best bet when regarding the conservation of biodiversity and carbon stock. It will replace the forest where people have destroyed all private forests.

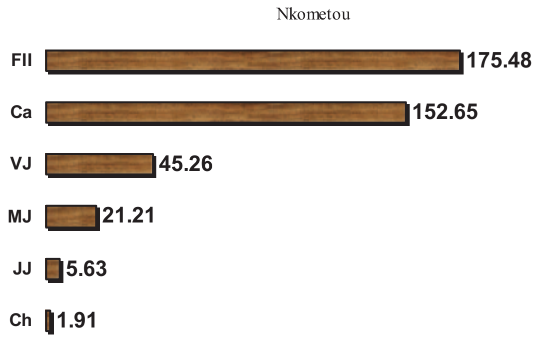

Fig. 18.8 Carbon stock in woody plants with DBH higher than 4 cm in Yaounde region (*Ch*=Crop Field, *JJ*=Yong Fallow, *MJ*=Mid Fallow, *VJ*=Old Fallow, *Ca*=Cocoa Field, *FII*=Secondary Forest)

18.4 Carbon Stock in Different LUS of the Three Study Sites

18.4.1 Yaounde Region

Carbon stock in different LUS increase from the crop field to the secondary forest. Cocoa agroforest system carbon stock is very close to the one of secondary forest as far as tree carbon is concern (Fig. 18.8).

In this type of land use, carbon stock is estimated 3.32 times the value found in old fallows. Indeed, 152.65 t of carbon were calculated per hectare. This value depends especially on the density of cocoa trees and the one of cover species per hectare. Species whose contribution to the sequestration of carbon is highest in this LUS are: *Theobroma cacao* (53.53), *Ficus mucuso* (13.24), *Terminalia superba* (10.67), *Albizia zygia* (10.54), *Mangifera indica* (9.85), *Albizia ferruginea* (8.02), *Trilepisium madagascariensis* (5.40), *Albizia adianthifolia* (5.11), *Margaritaria discoidea* (3.54) and *Persea americana* (3.34).

The herbaceous layer dominated by ferns stocked approximately 6 t C ha^{-1}. This value is naturally low in comparison to old fallows. This low value is explained by the fact that in the cocoa field, the undergrowth is cut regularly. The biomass of grasses is very low. In the litter, this quantity is almost three times higher (19 t C ha^{-1}). This litter is mainly composed of leaves of *Theobroma cacao* which decompose slowly and reduce the grass which can grow under the feet of cocoa. Roots of cocoa trees and those of cover trees increases the amount of carbon sequestered in the soil. It is 8 t per hectare.

18.4.2 Mbalmayo Region

The density of *Theobroma cacao*, added to that of cover species lead to a high biomass value, which explains the quantity of carbon sequestered in this LUS. It escrow approximately 227.05 t C ha^{-1}. The feet of cocoa accumulate about 12 % of that value. The same is true for *Ceiba pentandra*. Other important cover species are:

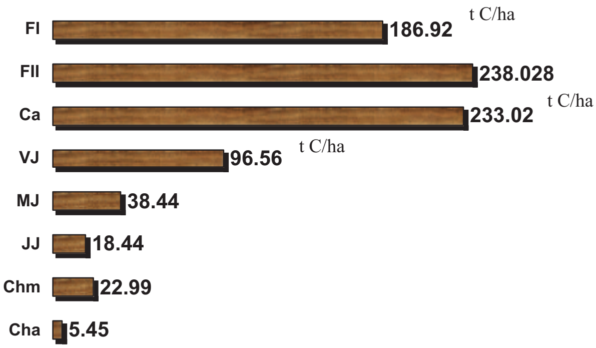

Fig. 18.9 Carbon stock in woody plants with DBH higher than 4 cm in Mbalmayo region (*NCh*=Crop Field, *Chm*=Cassava Field, *NJJ*=Yong Fallow, *NMJ*=Mid Fallow, *NVJ*=Old Fallow, *MCa*=Cocoa Field, *NFII*=Secondary Forest, *MFI*=Primary Forest)

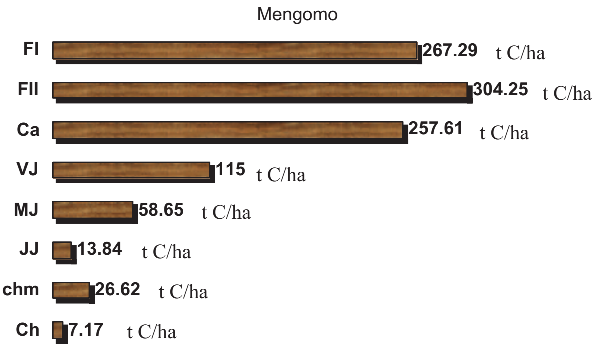

Fig. 18.10 Carbon stock in woody plants with DBH higher than 4 cm in Ebolowa region (*NCh*=Crop Field, *Chm*=Cassava Field, *NJJ*=Yong Fallow, *NMJ*=Mid Fallow, *NVJ*=Old Fallow, *MCa*=Cocoa Field, *NFII*=Secondary Forest, *MFI*=Primary Forest)

Triplochiton scleroxylon (17.96), *Terminalia superba* (15533.65), *Musanga cecropioides* (13.37), *Cordia platythyrsa* (11.66), *Pycnanthus angolensis* (6.40), *Staudtia stipitata* (4.22), *Persea americana* (3.96) and *Macaranga assas* (3.13).

The average amount of carbon sequestered in herbs is 0.59 t ha^{-1}. This value is generally based on the frequency of cleaning of the cocoa understory and on the quantity of litter. When trees are abundant and cover a significant recovery, herb biomass is low. The amount of litter limits also herbs growth, when it is important, the ground is covered and the grass can't grow properly. Litter accumulated about 2.95 t C ha^{-1} while in the soil, the roots of cocoa trees and those of cover species sequester 2.43 t C ha^{-1} (Fig. 18.9).

18.4.3 Ebolowa Region

Plant biomass is greater in the region of Ebolowa. The amount of carbon sequestered will be significantly different when compared to that obtained respectively in the first two regions. The minimum (7.17 t C ha^{-1}) obtained in the plots and the maximum (304.25 t C ha^{-1}) in the secondary forest (Fig. 18.10). Significant amounts also come in the secondary forest and in cocoa.

The high density of *Theobroma cacao* in this region increases the amount of carbon sequestered in the cocoa LUS. Approximately, 251.14 t C ha^{-1} were evaluated in this LUS. *Theobroma cacao* stores around 21.51 t C ha^{-1}. The most important cover species which storage high quantities of carbon in this LUS are: *Ceiba pentandra* (29.73), *Terminalia superba* (18.95), *Cordia platythyrsa* (17.66), *Pycnanthus angolensis* (12.96), *Ficus exasperata* (10.31), *Spathodea campanulata* (9.29), *Petersianthus macrocarpus* (6.77) and *Albizia adianthifolia* (4.63).

The grasses of the understory sequester very little carbon because cocoa field is frequently cleaned. Those which are regularly cut store near 0.54 t C ha^{-1}. The carbon stored in the litter is more important because it is very thick in this LUS. About 2.66 t C ha^{-1} were measured. The root system of cover trees is very extensive. It stores a large quantity of carbon (3.26 t C ha^{-1}) (Fig. 18.10).

18.5 Conclusion

The cocoa field, that permits the peasants to increase their revenue, has a potential richness in terms of medicinal and edible plants. A good management in this area will permit the amelioration of the standards of living of the peasants and stabilize them in order to protect the forest, if it considers the selection of forest species which had to be protected during the implantation of the cocoa trees or had to be reintroduced. This study, based on the conservation of biodiversity in cocoa agroforests, actually shows that, a certain number of primary forest species are preserved this land use system. Their seeds will accelerate the conversion of fallows to a tree land. This land use system also helps maintain and increase carbon stocks. The cocoa agroforest system represent the best bet as far as the REDD+process is concern. An increase in their size (cocoa agroforest coming from fallow) would increase forest area, conserve biodiversity and carbon stocks and allow farmers to diversify their sources of income. The payment for environmental services (carbon sequestration) may also booster local people adopting this farming system.

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Chapter 19
Agroforestry Systems in Morocco: The Case of Olive Tree and Annual Crops Association in Saïs Region

Khalid Daoui and Zain El Abidine Fatemi

Abstract Climatic change and demography represent important challenges for agronomists. They have to discover more innovative systems and technologies to fulfill food, feeding and energy demands. Such innovations may mime nature and couple advantages from soil biology and plant diversity and mutual advantages between the whole systems: soil—plant and plant to plant and the ecosystems. Forests systems give us examples of natural performances to discover and transfer elsewhere. Because of negative impacts of monoculture oriented intensification, agroforestry (association of perennial—annual crops and livestock) has created an interest in the international scientific community. This Traditional and also natural innovation has many advantages (preservation of biodiversity, diversification of productions, C sequestration, alternative solution for climatic change, enhancing agricultural land profitability, livestock integration, and erosion control). In Morocco such practice is adopted in the mountainous and oasis regions where water and/or land resources are limited. In these locations many crops are mixed and hence their monitoring is complicated. Unfortunately, few scientific studies were dedicated to such system and someone might describe it as primitive, non productive and must be changed. In this chapter focus has been on, the determination of the importance of olive tree and annual crops association in Saïs region, determination of annual crops cultivated between olive trees, agronomic evaluation of the associations, determination of advantages/ disadvantage according to farmers point of view and our observations, and proposition of some technical solutions to perform olive tree—annual crops associations.

Keywords Agroforestry • Biodiversity • Olive tree • Monoculture • Morocco

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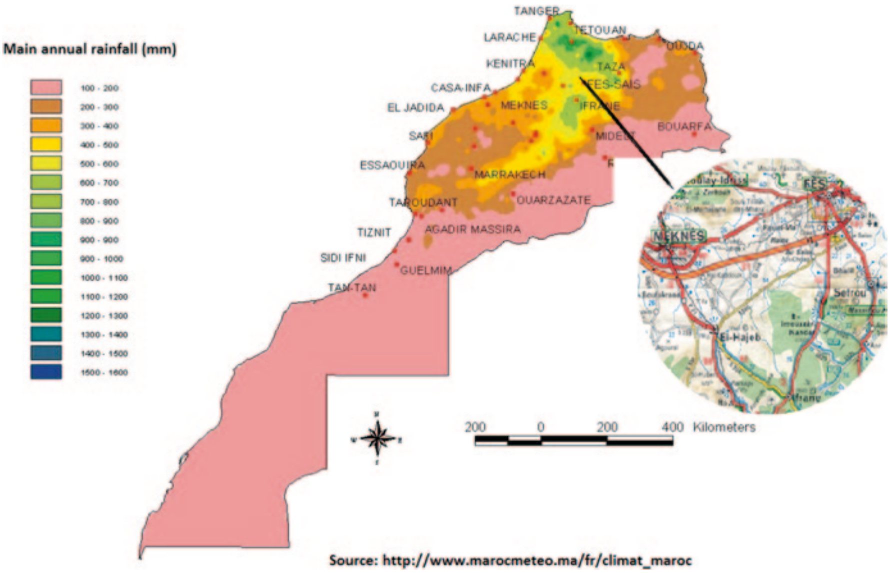

Fig. 19.1 Site location map

19.1 Introduction

Agroforestry which is the association of trees and crops on the same piece of land is a traditional practice. In some cases, man has eliminated forests to establish agriculture; in other situations he has associated many crops (annuals, perennial or both) to investigate narrow lands in his possession. Recently, this practice has created an interest in the international scientific communities who are trying to reintroduce it as ‘a new practice’ to achieve many benefits it contains. According to Workman and Allen (2004) “Agroforestry is a new way of thinking about and old way of farming”. In Morocco, agroforestry exists in oasis and also in mountainous regions where in both situations agricultural lands and water resources are scarce.

Morocco has a Mediterranean climate characterized by cold and rainy winters and hot summers. Annual rainfall varies between 100 and 1,600 mm (Fig. 19.1). The plain Säis, which is localized in the north part of the country, has a favorable climate for rainfed agriculture. The annual rainfall varies between 300 and 600 mm. The main activity in this region is agriculture. Annual crops constitute the main cultivated crops; cereal represents 50 % of covered area followed by legume crops, forages and vegetables. Fruit trees are important where olive and almond trees are dominant. Important water resources are available, but the pressure of agricultural demand is becoming important. Soils are deep and fertile, texture ranges between clay and silt. Soils are moderately rich in organic matter (2.5–3.5 %), poor in phosphorus (< 10 mg P_2O_5 kg^{-1} soil) and rich in potassium (250–350 mg K_2O kg^{-1} soil). The pH is in alkaline range (> 7.00) (http://www.fertimap.ma/map.phtml).

In the Saïs region, the average rainfall passed from 600 mm per year during the period 1960–1980 to 440 mm for the period 1981–2000 (Karrou and Boutfirass 2007). The weather forecast studies show that those conditions are likely to increase with climate change (FAO 2008). To face this situation, Moroccan government plans the conversion of 1 million ha of cereals to olive tree. To achieve this goal we do have to study the actual practice of olive tree in Moroccan agriculture and also to learn from different experiences In fact, during the last decades in Saïs region, introduction of olive trees at locations dedicated to cereal crops pushed farmers to exploit rows between trees by annual crops. The importance of such practice is unknown due the absence of established advantages/disadvantages. It is, therefore, essential to evaluate such importance to sustain political orientation for the extension of olive trees production area.

The adoption and the practice of such system by farmers is a proof of its performance. As scientists we must investigate to learn about farmer's experiences and views. At the end of this investigation we will be in a better position to propose technical solutions in order to make it more profitable by enhancing advantages and reducing disadvantages on the basis of international knowledge and also local scientific experience.

The objectives of this study are to:

- evaluate the importance of olive tree and annual crops association practice in Saïs region
- evaluate advantages and disadvantages of such practice according to farmers perceptions.

19.2 Methodology

To evaluate the importance of agroforestry, including olive tree practice in Saïs region, a prospecting has been made on 2008, covering the region of Meknes—Fes—Imouzer and Bhalil (Fig. 19.1). During the survey we recorded:

- Crop species cultivated between olive tree rows
- Olive tree density
- Distances left between olive tree and the first line of the intercrop.

We also made agronomic observations on fields and interviewed farmers to assess their views about the advantage and disadvantages of this practice.

The total annual rainfall received on 2007–2008, was 334 mm while the main rainfall from 1997 to 2007 was 455 mm.

19.3 Results

The density structures of olive trees in the selected region varies between 6.50×6.50 m (42.25 m^2) to 12.0×9.2 m (110.4 m^2), however, the common density was recorded as 10×10 m $=100$ m^2. These densities correspond to a number of trees

Table 19.1 Cultivated species as intercrop on olive according to water irrigation availability

	Cereals	Legume crops	Forage	Vegetables
Rainfed	*Triticum aestivum* *Triticum turgidum* *Hordeum vulgare*	*Vicia faba* *Cicer arietinum* *Lens culinaris* *Phaseolus vulgaris*	*Avena sativa* *Hordeum vulgara*	
Irrigated	*Zea mays*			*Solanum tuberosum* *Allium cepa*

Table 19.2 Plant density and number of trees per hectare

Density	Trees per ha
6.5 × 6.5 m	238
8 × 8 m	156
10 × 10 m	100
12 × 10 m	83

per hectare variant between 83 and 237 trees/ha. The survey revealed that, most of the fields visited comprised of olive trees in association with other crops such as cereals (wheat, maize), forages (barley, oat), legumes (faba bean, chickpea, pea, bean), and vegetables (potato, onion) depending on irrigation availability (Table 19.1).

The distance left between olive tree and the first line of the cultivated crop varies between 0 and 2 m for cereals while it varies between 0.50 and 2.5 m for crops cultivated on more large lines (0.5 m as for legume crops or 0.5–0.7 m for potato or onion) Table 19.2.

According to this situation it is clear that cereals my compete more with olive tree than other crops. Farmers report that legume crops like faba bean, lentils or peas did not affect olive production, while cereals may reduce it. In fact, the first ones could be sown a part from olive trunk. While cereals are sown with no respect to olive tree occupation area (Fig. 19.2), this situation is more pronounced when those crops are hand sowing (Table 19.3).

So, on average, every tree occupies approximately an area of (5×5 m = 25 m^2). If we consider one ha of olive tree with a structure density like 10×10 m, which represents 100 trees/ha, this will represent an occupation of 2,500 m^2, the remaining 7,500 m^2 could be used for intercrop between olive alley. This area depends on olive tree structure and age. We estimated that this area will vary between 4,075 and 7,925 m^2 (Fig. 19.3). In this estimation no consideration has been taken for area subjected to negative impacts of both crop on each other, so to determine suitable land part for olive tree and the intercrop.

The exploitation of inter rows depends on farmers. Small ones who try to exploit all land they possess cultivate inter-rows with rainfed crops like cereals or fodder and with irrigated crops like potato and other vegetables when irrigation is possible. While other farmers may cultivate inter-rows mainly during the first years of plantation. In some cases, land may belong to one farmer while the plantation belongs to another, so each one of them will be more interested in one production (crop or olive) than both.

Fig. 19.2 Olive tree associated with different crops; Wheat (**a**), Barley (**b**), Faba bean (**c**), Peas (**d**), Onion (**e**), Potato (**f**)

Table 19.3 Distance (m) left from olive tree trunk to the first line of intercrop

	Minimum	Maximum
Cereals	0	2
Legume crops	0.50	2
Vegetables	0.50	2

Although some farmers found that association of olive tree and annual crops may have negative effects on the production of this combination, they adopt it for the following reasons:

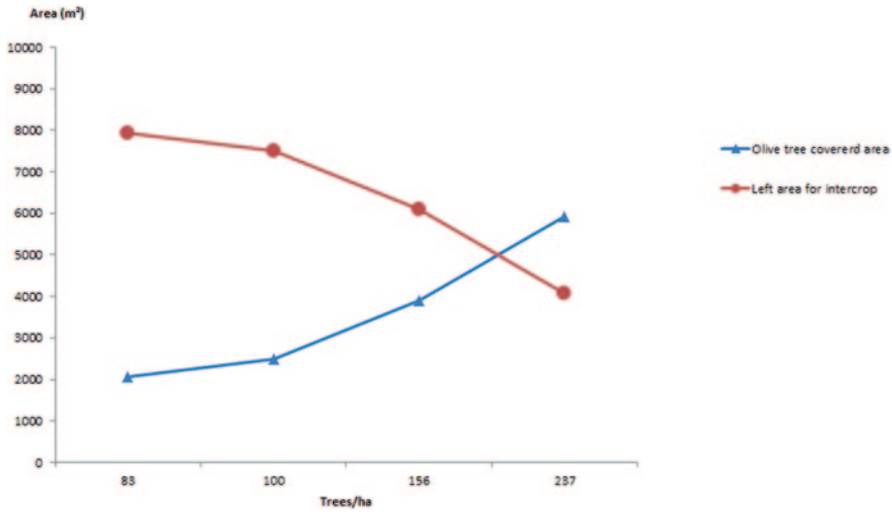

Fig. 19.3 Estimated covered area by olive tree and intercrop according to olive tree density

- Management of olive tree production (plowing, fertilization, weed control …) may be more profitable if it is practiced on crop cultivated between rows.
- Management of inter rows crops profit also to olive tree.
- Plantation of olive tree alone may be subjected to damage due to grazing, cultivating intercrops may prevent such risk.

19.4 Discussion

As arable land has become scarce and length of forest fallow periods has declined, simultaneous associations of trees and annual crops have been investigated as alternatives to shifting cultivation systems (Liebman and Staver 2004).

Agroforestry systems exist in Morocco in different parts of the country and are much diversified according to agro climatic conditions where they are implemented and also according to farmer's practices. At national level, few scientific involvements have been made to study these systems as a hole. Chebli et al. (2012) and Chryaa and El Mzouri (2004) demonstrate benefits from introducing fodder shrubs in low rainfall area of Morocco, alley cropping (*Atriplex nummularia* and *Hordeum vulgar*e) permit an increase in yield per unit area, diversification of species; a decrease of feeding cost in addition to the increase of economic efficiency of land with low potential; an improvement of animal performance and a rehabilitation of marginal land and fauna and flora (Chryaa and El Mzouri 2004).

At regional level, in Tunisia for example, Karray et al. (2008) studied the water balance of the olive tree and annual crop association, while Alary et al. (2007) studied modeling impact of spineless cactus in alley cropping. At Mediterranean level, in Italy Rosati et al. (2012) studied the performance of an agroforestry system basis on organic farming including: olive tree a wild asparagus species (*Asparagus acutifolius*) as an understory crop together with raising meat chicken. At international level, scientists demonstrate that agroforestry may have many advantages: diversification of ecosystems which can preserve and enhance: biodiversity, C sequestration, efficient use of inputs (land, fertilizers, water). Palma et al. (2007) estimate that this practice may reduce soil erosion up to 65 % and reduce nitrogen leaching by about 28 %. In agroforestry the components of the system depend on the same pool of reserve for growth as: sunlight, water and nutrients, so every component of the system will influence the performance of the other component as well as the performance of all the system (Kumar et al. 2006). Mechanization of the inter row crops could damage plantation. Associated crops may shelter special parasites or pests to a component of the couple. Also, association of different crops with different growth cycles and requirements may enhance competitiveness for inputs: sun light, nutrients and water. Allelopathic interactions may occur between associated plants.

Our study indicates that, olive tree is, in most case, not planted alone (Fig. 19.2). The species cultivated in alley are diversified as species and as cultivating techniques. For cereals we do have autumn sown crops like wheat and barley and spring sowing ones like maize which requires irrigation. For those crops we observed that, no area is left between olive tree and intercrop to reduce competitiveness effects on both crops.

For crop cultivated on more large lines, like legume crops or vegetables, competitiveness between olive tree and intercrop may be reduced. More for legume crops, olive tree may benefits from biological nitrogen fixation performed by legume crops. Among, legume we can distinguish also, autumn sowing crops (faba bean, lentils, peas and winter chickpea) and spring sowing like chickpea and beans. For the last ones, competitiveness for water resource may be enhanced as last part of season receives less rainfall.

For vegetables, even if irrigation, which is necessary for their production in our context, may be profitable to olive tree, the risk of pathogen transmission between potato for example and olive tree make this combination less profitable. In fact, Verticillium wilt, caused by the soil-borne fungus *Verticillium dahliae* threatens olive-growing in several Mediterranean Basin countries (Hiemstra and Harris1998) and became the most important threats to potato crops in North America (Rowe and Powelson 2002).

Intercrop may reduce soil erosion, water loss, weeds impact on olive tree and could be an alternative in organic farming for olive oil. In farmers fields we observed that according to olive tree orientation, inter rows crops may benefit from shading that can reduce evaporation. Shading may also enhance grain yield of some crops by enhancing their reproductive cycle (Nasrullahzadeh et al. 2006; Stirling et al. 1990). Genotypic variation for shading adaptation among crop species or among the same specie (Nasrullahzadeh et al. 2006) may exist and could be explored for alley cropping. Aromatic and medicinal plants offer a large genetic diversity among crops more suitable for alley cropping. The cultivation of those crops in association with perennial ones may offer many advantages: diversification of productions, enhancing farmer income (Thakur et al. 2009; Chandelia and Sharma 2009)

Filtered water from rainfall or from irrigation of inter rows crops may profit olive trees reaching deeper horizons. Association of perennial and annual crops may reduce the negative impact of rainfall variation; according to species and their growth cycles, we can choose between those that have different critical growth periods. Minimum tillage (conservation agriculture) could be a good option for crop production in this way we can prevent damage to olive tree roots.

The adoption of olive tree and annual crops association by farmers demonstrate the benefit of such system. So advantages and disadvantages should be evaluated according to scientific and measured data. The conditions (zone, climate, topography …) where the association of perennial and annual crop is used, should be indicated. Also, the species that could be more profitable to be associated as inter rows crop should be named or discovered. Adequate agronomic practices to enhance the profitability of such system should be studied.

19.5 Conclusions

Association of perennial crops and annual is a common practice adopted by farmers and might be more important in future due to land scarcity. Scientific involvement to analyze such system is necessary. Positive and negative interactions should be elucidated to choose more profitable combinations in more adaptable conditions. Association of perennial and annual crop might be an interesting option to face climate change. Also, it could enhance land profitability.

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Chapter 20
Sacred Mangrove Forests: Who Bears the Pride?

Mwita M. Mangora and Mwanahija S. Shalli

Abstract While mangroves have since been regarded as natural wastelands, the need for their conservation is strongly felt today as their invaluable services and functions are being unveiled primarily due to increasing demand for their products and the forest land. Appraising various models of management institutions to enhance conservation and sustainability of these valuable resources has thus been advocated over the recent past. Social taboos exist in most cultures, and they demonstrate forms of informal institutions, where traditional norms, rather than state institutions (laws, regulations), determine human behavior toward exploitation of natural resources. Despite the ill-recognition of these traditional management practices by the state organs, traditional communities have for centuries maintained these practices to ensure the survival of the forests on grounds of spiritual and ecological values. In this chapter we reviewed the state of knowledge of the functional conservation values of sacred mangrove forests in Tanzania and how they are being conceived as models for the promotion of community based conservation (CBC). The discussion is based on the perspectives of forest dependency, traditional access and use rights, traditional ecological knowledge, socio-ecological integration of culture and forest, and the traditional power relations. We argue that traditional people, who have maintained strong ties to their cultural norms and kept the sacred groves outshining the contemporary models of conservation, should bear the pride and honor in the renaissance of conservation tenets.

Keywords Conservation • Local Communities • Mangrove Forests • Traditional Knowledge

20.1 Introduction

Mangroves are tidally influenced wetland ecosystems within tropical and subtropical latitudes. They can also occur in areas without a tidal regime e.g. in some choked coastal lagoons and in the supralittoral zone (Spalding et al. 2010). Among the many functions, mangroves offer shelter, food and breeding grounds for a large variety of

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fish, shrimps and oysters for at least part of their life-cycle. Mangroves also stabilize the coastline—protecting it from erosion, act as sinks which concentrate pollutants such as sewage, toxic minerals, pesticide, herbicides and trap sediments. In recent years, the rate and variety of human influences on the mangrove forests in Tanzania have increased to the extent that they are threatened in many places. One of the most pressing issues facing mangrove forests is the loss of mangrove areas due to conversion for other land uses such as rice farms, salt pans; aquaculture ponds; and clearance for urban and industrial development (Semesi 1998). Other threats include over-exploitation of resources, mainly through clearing of mangroves for firewood and construction purposes (Banyikwa and Semesi 1986; Masalu et al. 2010).

While in many places mangroves are legally protected, current rules to manage coastal resources especially in developing countries are weakly enforced due to limited financial and human capacity (Peres and Terborgh 1995; Walsh et al. 2003). Appropriate state agencies responsible for monitoring and enforcement in developing countries are often distant, understaffed and under-funded to be effective and are based solely on scientific approaches (Johannes 1981; Berkes et al. 2000). Due to this management incapacity, there are emerging suggestions to consider traditional management approaches in natural resource conservation (Ruddle 1998; Johannes 2002; McClanahan et al. 2006; Shalli 2011). This increased recognition on the role of traditional knowledge in the management of natural resources has come on the realization that such knowledge has allowed people to live in their specific surroundings throughout history (Veitayaki 2004).

Coastal communities in Tanzania as elsewhere in many parts of the world have traditionally reserved forests for a range of reasons including religious, sacred, customary or traditional reasons (MNRT 2006; Shalli 2011). For instance, it is common to find certain tree species being protected and managed for traditional reasons. Likewise, small patches of forests are commonly retained by various tribes and are used as venues for traditional rituals, such as initiation, prayers and fortune telling. Despite the ill-recognition of these traditional management practices by the state organs, traditional communities have for centuries maintained these practices to ensure the survival of the forests on grounds of spiritual and ecological values. Nonetheless, the concern remains as to what has happened with the state led institutions and conservation models that promote participation, and now that, efforts are turned to sacred groves that once were functionally considered as just relics of forests that were to be relinquished.

In this chapter we reviewed the state of knowledge of the functional conservation values of sacred mangrove forests in Tanzania and how they are being conceived as models for the promotion of community based conservation (CBC). To deliver on this, first we conceptualize the idea of sacred forests. Second, an overview of the mangrove forests of Tanzania is briefly described. Thirdly, the perspective of managing sacredness in mangrove forests in terms of traditional access and use rights, traditional ecological knowledge, socio-ecological integration of culture and forest, and the traditional power relations is discussed. From this discussion, the conclusions on why sacred mangrove forests should be considered as models for the promotion of CBC and who should bear the pride of conservation are drawn.

20.2 The Concept and Ideology of Sacred Forests

Since time immemorial, conservation of natural resource has been an integral part of diverse cultures in different ways. The traditional worship practices show the symbiotic relation of human beings and nature. Traditional communities all over the world lived in harmony with the nature and through traditional practices, they conserved natural resources. A good example of such traditional practices is the conservation and protection of small forest patches by dedicating them to the local deities. Such forest patches are "sacred forests". Different scholars have defined sacred forests including sacred mangrove forests variably. According to Saikia (2004) sacred mangrove forests are forests that vary in size from a few hectares to a few square kilometers protected by local communities as being the sacred residences of local deities and sites for religious and cultural rituals. The designation of a forest as sacred is a widespread traditional practice in Africa. They provide the inextricable link between present society to the past in terms of biodiversity, culture, religious and ethnic heritage. While sacred forests were not created for biodiversity conservation, their complex social-spiritual association with deities and spirits of dead ancestors has contributed to the protection of some ecosystems (UNESCO 1998). Some scholars make close link between the sacred and biodiversity conservation and argue that the sacred value attached to the forests is a way to allow their successful conservation (Wadley and Colfer 2004; Wild and McLeod 2008) and may fulfill similar functions as legal protected forests.

Local level control has been instrumental to the protection of sacred forests. In this regard taboos, rituals and beliefs supplemented with spiritual folk tales associated with the forests have been the prime reason in preserving the sacred mangrove forests in pristine condition. The concept of sacred forests that revolves around the spiritual beliefs has brought some significance in conservation. The traditional rules established by the local communities with respect to sacred forests have paved a way for conservation of biodiversity since the past time. For instance, people have the belief that any damage to the sacred forest or felling a tree from the sacred forest may bring the anger of local deity, which may cause hazard or misfortune to the surrounding community (Masalu et al. 2010). As a result, forests that are managed using traditional knowledge and practices are accorded high respect by concerned communities and are thus relatively not subject to human impacts. It is therefore the purpose of this chapter to express why local communities should be respected and recognized as stewards of sacred mangrove forest ecosystem goods and services and bears the pride of conservation.

20.3 Mangrove Forests of Tanzania

20.3.1 Distribution

Mangroves occur almost along the entire coastline of Tanzania which span for over 1,000 km from the border with Kenya in the north to the border with Mozambique in the south (Fig. 20.1). In the mainland Tanzania, Semesi (1992) reported that the

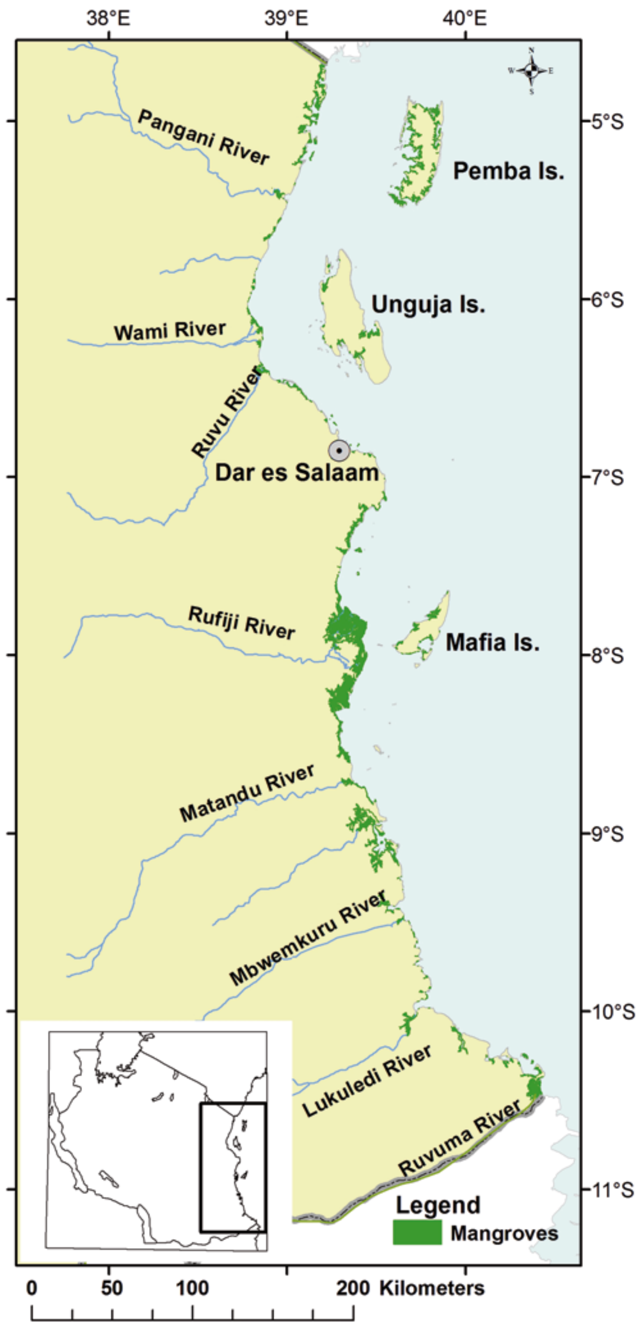

Fig. 20.1 Map of Tanzania coastline showing important mangrove areas

Table 20.1 Mangrove forest area coverage along the coast of mainland Tanzania as designated in the national mangrove management plans

District/Region (Block)	Area of mangroves found in 1989 forest inventory (ha) (Semesi 1992)	Area of mangroves found in 2000 from analysis of remote sense images (ha) (Wang et al. 2003)
1.Mkinga and Tanga	9,403.3	9,313
2. Pangani	1,755.6	3,879
3. Bagamoyo	5,635.8	5,051
4. Dar es Salaam	2,168.2	2,516
5. Mkuranga	3,858.3	4,092
6. Rufiji	53,254.8	48,030
7. Mafia	3,472.9	Not assessed
8. Kilwa	22,438.7	21,755
9. Lindi	4,546.5	4,044
10. Mtwara	8,941.5	9,458
Total	115,475.6	108,138

Table 20.2 Proportional distribution of forest area (hectares in thousands) by type in Tanzania. (Source URT 1998; Wang et al. 2003)

Forest type	Area (ha)	Proportion (%)
Forests (other than mangroves)	1,141	3.4
Mangrove forests	112	0.3
Woodlands	32,299	96.3
Total	33,552	100.0

total area covered by mangroves was about 115,475 ha including those of the island of Mafia (Table 20.1). This account for only 0.3 % of the total forested land in Tanzania (Table 20.2). However, shortly over a decade later Wang et al. (2003) reported a reduced area coverage of mangroves of about 108,138 ha (excluding Mafia island). In the two islands of Zanzibar (Unguja and Pemba), mangroves are estimated to cover about 19,750 ha (Leskinen et al. 1997). About 50 % of the mangrove area in Tanzania is confined in the Rufiji River Delta which is the largest single mangrove forest in the eastern Africa region. Other important mangrove areas include the river estuaries and sheltered lagoons of Tanga, Pangani, Wami and Ruvu and Ruvuma (Mtwara) (Fig. 20.1). There are ten species of mangrove trees that occur in Tanzania. The most common species are *Rhizophora mucronata*, *Avicennia marina* and *Sonneratia alba*. Others are *Bruguiera gymnorrhiza, Ceriops tagal, Heritiera littoralis, Lumnitzera racemosa, Xylocarpus granatum, X. moluccensis* and *Pemphis acidula* are the rarest species.

20.3.2 Mangrove Forest Dependency: Goods and Services

Many coastal communities in the tropics are characterized by relative geographic isolation, chronic poverty and significant dependence on the harvest of marine and coastal resources for their livelihood (Kunstadter et al. 1986). The majority of people living in or near mangrove areas derive their principal income from fishing and related activities. The direct harvest of mangrove wood and plants is rarely a full-time occupation for them, but a great many rely on these products to meet subsistence needs for fuel and construction materials, and for others the harvest and sale of mangrove forest products is an important income supplement (Lacerda et al. 1993; Glaser 2003; Walters 2005; Lopez-Hoffman et al. 2006; Spalding et al. 2010).

Principally, coastal communities of Tanzania have been using mangrove species of mainly Rhizophora, Ceriops, and Bruguiera as poles in constructing houses. Mangrove wood can produce excellent charcoal of high calorific value. Coastal city areas of Tanzania such as Tanga, Dar es Salaam, and Zanzibar provide major markets for charcoal (Mainoya et al. 1986). People in coastal villages also use mangrove wood for firewood in their homes. At the same time, mangrove wood is used as fuel for the production of burnt bricks, salt making and in lime burning where alternative sources of fuel wood are not available. Grant (1938) identified the best mangrove timber to come from Heritiera species, which is the only species commonly found in large dimensions. The other uses of mangrove products by the coastal people include fences for livestock pens and fish traps. In addition, the Tanzania coastal people use Avicennia foliage as fodder for goats and cattle and Rihizophora leaf extract as a medicine for hernias (Mainoya et al. 1986). Tannin is also for a long time extracted from mangrove bark and used locally by the leather-processing industries and it is reported to be a source of revenue for local communities and nation in general (ibid).

Ecologically, mangroves habitat provides suitable breeding and nursery grounds for a variety of marine living organisms such as fish, crabs and molluscs. They also support a variety of insects and birds. For instance, in the Rufiji Delta villagers use mangrove trees for bee-keeping (Semesi 1989). Furthermore, the presence of mangroves has been demonstrated to provide an efficient buffer for coastal protection: their complex structure attenuates wave action and control soil erosion. Mangrove ecosystems have also been shown to be effective as nutrient traps and ‘reactors’, thereby mitigating or decreasing coastal pollution. The feasibility of using (constructed rather than natural) mangrove wetlands for sewage or shrimp pond effluents has recently been demonstrated (Wu et al. 2008) and could offer a low-cost, feasible option for wastewater treatment in tropical coastal settings.

Due to the many uses of mangroves by the coastal communities, degradation of these important resources especially in developing countries has been accelerating year after year. Further efforts with regard to community empowerment on mangrove forest management need to be done to halt the intensive use and negative impacts on the mangrove forest and the surrounding, marine environment in the near future.

20.4 Managing Sacredness in Mangrove Forests

20.4.1 Traditional Access and Use Rights

Culturally, sacred forests symbolize the links between the spiritual world of ancestors and people. Rituals and ceremonies which draw on forest symbols often serve to link people with their cultural heritage, as well as their ancestral past (FAO 1990).

Fig. 20.2 Kwamdoe sacred mangrove forest, Pemba

In Tanzania, law does not recognize sacred forests (Akida and Blomley 2008). They are thought of as either communal or private forest reserves that have not undergone any official establishment process. There are no written rules or guardian to regulate sacred forests use and management (Falconer 1992). In this respect, access and use of sacred forests are often governed by traditional powers through a combination of taboos, prohibitions, beliefs and restrictions. People willing to access and use sacred forests had to fulfill a certain number of conditions.

Worship, spiritual consultation and sacrifice are the most common non-consumptive uses of sacred forests. The level of extractive use varies; in some sacred forests no extraction of forest products is permitted while others provide people with a great variety of products such as hunting for wild animals, collection of wild plant foods, medicinal plants and water (Gombya-Ssembajjwe 2000). The rules and regulations regarding access and use of each sacred forest vary between communities (Falconer 1992). For instance, restrictions in the Kwamdoe sacred mangrove forest of Kojani, Pemba (Plate 1) include total ban on cutting or collecting mangrove cuts/woods. In addition, pregnant women are prohibited to cross-by this area, and if they do so could amount to miscarriage (Shalli 2011). Rules and regulations in Kitoipi and Kwakibibi sacred mangrove forests of Kipumbwi, Pangani include getting consent of the three elders responsible for the forests to enter the sacred area and exploit or do other activities (Nurse and Kabamba 1999).

Spiritual sanctions, in combination with material fines and penalties, enforce the norms and rules related to the use of sacred mangrove forests in Tanzania. Community members are taught the do's and don't's relating to the scared forests. Elders constantly remind the community of the dangers that await those who abuse the sacred forests. Generally, when disobeying to the traditional rules the dangers include misfortune, sickness and even death to the violator. For instance, when disobey the rules in Kwamdoe sacred mangrove forest the violator is beaten with sticks by unseen spirits while still in the forests or the criminal may cry throughout until the illegally harvested produce is returned to the forest (Shalli 2011). In Kitoipi and Kwakibibi sacred mangrove forests when people come to worship and succeed with their prayers, they have to leave a small offering at the sites (Nurse and Kabamba 1999).

In this regard, traditional access and use through cultural norms and rules helps to build the social capital that is necessary to prevent overexploitation of forest resources and ensure the conservation of biodiversity (Gombya-Ssembajjwe 1997). Coastal communities living around the sacred mangrove forests therefore have an important role to play in the conservation of mangrove forests through traditional prohibitions.

20.4.2 Traditional Ecological Knowledge

Traditional Ecological Knowledge (TEK) is a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission. It concerns the relationship of living beings (including human) with one another and with their environment (Berkes et al. 2000). Traditional knowledge and practices have sustained the livelihoods, cultures and forest resources of local communities for centuries. Interest in TEK has been growing in recent years, partly due to a recognition that such knowledge can contribute to the conservation of biodiversity (Gadgil et al. 1993), rare species (Colding 1998) protected areas (Johannes 1998), ecological processes (Alcorn 1989), and to sustainable resource use in general (Berkes 1999).

The use of TEK in the form of customary ecological management practices has been recognized as a potentially powerful conservation mechanism, particularly in countries where indigenous cultures are still largely extant (Harkes and Novaczek 2002; Hickey and Johannes 2002). Community support for conservation plans consistently emerges as one of the most important factors in maintaining the plans' long-term efficacy, and programs that incorporate customary ecological management practices in their design, draw more support from local people (Aswani and Hamilton 2004). Results of studies in areas of the Pacific (Johannes 2002) suggest that local-based management can have beneficial impacts for the marine environment and that, in comparison, community-based management plans tend to work better than top-down approaches (Cox 2000).

However, sacred forests and related traditional knowledge do not exist and function in isolation, they are thus increasingly challenged by external factors that stress and often lead to its failure in achieving its functions. The increase of socio-economic pressures such as rapid population growth, changing land use pattern, priorities and commoditization has contributed to a depletion of sacred forests. For instance, the rise in the price of land has tempted some local people to sell their sacred areas (Shalli 2011). In this respect, although sacred forests undoubtedly contribute to the conservation of biodiversity, it is uncertain whether the traditions that have created and maintained these areas can be operationalized as a model for further conservation efforts. Kay and Alder (1999) viewed traditional knowledge as only applicable in the past due to low population densities, and are now inefficient to effect resource conservation. It is however advised to integrate traditional and modern knowledge to counteract the challenges (Johannes 1989; Shalli 2011).

It is then logical that people who live around sacred mangrove areas and who are dependent on mangrove forests for their livelihood and other cultural needs should be central actors in forestry conservation. It is also obvious that biodiversity conservation cannot be achieved only through the current formal approaches such as provisioning for national parks and reserves. Biodiversity occurring in a variety of cultural landscapes such as sacred forests equally contributes to the conservation (Saleh 2000). Because of their knowledge and traditional practices, local communities have a vital role in environmental management and development. State and other conservation agencies should recognize and duly support their identity, culture and interests and enable their effective participation in the achievement of sustainable development.

20.4.3 Socio-ecological Integration of Culture and Forest

Culture is an expression of the interaction between communities and their natural, historical and social environments over time (Bélair et al. 2010). From this point of view, traditional knowledge is embedded in complex cultural environments (Berkes et al. 2000). These environments not only satisfy people's material needs, but also provide the bases for ethical values, concepts of sacred spaces, aesthetic experiences, and personal or group identities derived from the local surroundings (Kassam 2009). Social, ethical and spiritual relationships thus have an ecological foundation; and the practical manifestation of cultural values can have consequences for the ecological system (ibid.). Failure to recognize this interaction means ignoring the role that cultural practices play in the shaping of landscapes and the maintenance of biodiversity and ecosystem services.

Most of the world's biodiversity is not in protected areas but on lands used by people (Poudel 2010) employing a variety of subsistence strategies to sustain their livelihoods. Some of these strategies are compatible with conservation aims. In this respect, biodiversity conservation requires an understanding of social systems and their interactions with ecological systems. People have been maintaining and protecting some areas as untouched on different conservation structures and management strategy. For instance, indigenous communities have been conserving sacred forest areas under the strong religious, cultural and spiritual belief. This is because faiths can have a major impact on the way people view the protection of nature. These protected areas contain neither any written conservation rule nor any formal governing structure. However, they are harboring the valuable flora and fauna. The conservation of protected areas in the future will depend on our ability to understand, harness and support those practices that are beneficial to the maintenance of the diversity and resilience of natural ecosystems.

Despite of socio-cultural, religious and ecological significance, sacred forest areas are nowadays at the risk of disappearance due to high human pressure and the breakdown of cultural values. People's activities in a changed context have reshaped their conservation belief on traditionally managed sites. The spiritual taboos are now taken as superstitious due to rational education system. In the changing social system, we cannot at the moment depend only in social taboos to protect the disappearing sacred forests. There is incompatibility in faith system between the people who believe in traditional, religious and spiritual taboos and those who do not. The fear of the elder generation for example, is that the rituals may be renounced when ecological consciousness is promoted because many people may discard traditional activities as superstitious (ibid). Integrated approach is necessary that those who do not believe on existing faith of taboos should be aware of ecological value of those sacred forest areas, and those elders who fear about renouncing of rituals should be convinced by the conservation effort as it doesn't mean keeping away from the traditions. This integration of traditional belief and ecological rationale brings all people in the same cornerstone of conservation. All people have vital interest in the preservation of the ecosystems, though many are not aware of it at present. It is essential that every effort should be made to make people conscious of the need for the conservation of our bio-resources (ibid) albeit which institutional model is pursued.

20.4.4 Traditional Power Relations

During the pre-colonial era in Tanzania, there were no formal national policies to control and coordinate natural resource management. Communities had their own traditional systems based on their customs and practices (Torell 2002). These customs were enforced by elders, clan leaders (and in some areas kings) who performed both civic and spiritual duties. The community determined the powers exercised by the clan elders. These powers included keeping peace, settling disputes (involving marriage, divorce, the marital status of women, the rights of children, inheritance, election of customary heirs and land), performance of rituals, protection of Gods and shrines and guarding against drought, famine and other disasters. There are examples of villages that initiated strategies to protect wildlife, forests and fishing stocks. In some villages, a strong group of elders would play a significant role, while in others cultural practices and myths played an important role in the protection of natural resources. These belief systems were passed down from generation to generation.

Throughout Tanzania, traditional leaders gained power through heredity and/or consensus. Mokgoro (1994) iterated that African traditional leadership has always been hereditary and therefore not subjected to the electoral process that characterizes modern governance. Political power was centralized to varying degrees, from lineage and ward elders responsible for local affairs to representative councils and hereditary kings responsible for village or town affairs at large. Natural resource arrangements during pre-colonial times were thus in the form of top-down arrangements whereby a few individuals, i.e. the chiefs and appointed elders of clans, families, and tribes, enforced beliefs and traditional institutions while others in these communities were required to comply with the institutions (Kirk 1999).

20.5 Synthesis and Conclusions

Community-based approaches, which capitalize on traditional knowledge and management systems, and catalyze stakeholder support for requisite conservation measures, are suitable in some regions (Ormsby and Bhagwat 2010). Stakeholders will be more likely to comply with restrictions on their traditional resource use activities if they understand and support the rules which can be accomplished through direct community participation in monitoring, planning, and management decision-making. The rural conditions, including relatively small population size, high dependence of local communities on coastal and marine resources, social cohesion, customary tenure and traditional use of coastal and marine areas and resources, existence of strong and intact traditional authority, and low conventional government management capacity of some sites make local community-based management through collaboration between local government and the local community (e.g. clans or individual villages) appropriate (White et al. 1994; Whyte 2001). However, in more urban areas, the larger and more heterogeneous the local community, more complicated and numerous the multiple resource uses and users are, more numerous external threats to the coastal and marine environment, less recognition of customary tenure and traditional governance, and generally the more complex the site is, there will be a larger need for central government management, where community-based management would be less effective (Huber and McGregor 2001). The optimal approach to manage adaptation to mangrove responses to climate change effects will depend on the local context. As such, recognizing the environmental concerns of rural communities and supporting their efforts to protect threatened forests and regenerate degraded ones may be the most important, least costly strategy available to national governments and donors alike.

On the premise of the present review, we conclude that sacred mangrove forests may be considered as a better model for the creation of CBC on the notion that local communities who live around the sacred areas benefits with economic, cultural and ecological uses of the forests yet at the same time applies cultural and traditional beliefs to conserve the forests. People living around sacred areas see themselves as owners of the resources. Therefore, further efforts with regards to community empowerment on sacred mangrove forest management need to be enhanced to avoid the intensive use and negative impacts on the mangrove forest and the surrounding marine environment in the near future. For instance, in an effort to promote conservation of sacred forests, cultural tourism should be promoted in sacred areas as a way of compensating traditional communities and enhance their moral and cultural conduct to traditionally manage their resources.

The current failure of modern science (especially in developing world) to deal effectively with environmental issues of increasing magnitude and complexity such as the onset of climate change phenomenon, has opened the door for incorporating other sources of knowledge. Local communities and scientists ought to mutually collaborate in the assessment and monitoring of forest resources. The modern society can learn a great deal from the traditional skills in sustainably managing complex ecological systems. Traditional access and use through cultural norms and rules helps to build the social capital that is necessary to prevent overexploitation of forest resources and ensure the conservation of biodiversity. States and other conservation agencies should recognize and accordingly support traditional knowledge and their practices and enable local community participation in the achievement of sustainable development. In this regard, it is necessary to strengthen traditional rules and customs by aligning them with state laws and regulations so as to complement contemporary management measures at least at the local level.

Given the socio-economic changes worldwide, social-ecological integration approach is necessary for the protection of sacred mangrove forests. Existing faith of taboos and the strong community beliefs and cultural norms had formed the bases for effective resource management. We therefore argue that traditional people, who have maintained strong ties to their cultural norms and kept the sacred groves outshining the official models of conservation, should bear the pride and honor in the revival of conservation tenets. To strengthen this, support for the continued practice of the tradition of sacred mangrove forest protection is needed in order to provide a culturally sensitive model for community-based natural resource management. Traditional leaders who are the key instrument in the survival of traditional knowledge should be recognized and respected; this is because traditional decisions made by traditional authorities have a higher likelihood of success. We however, conclude that the adoption of these kinds of traditional management systems should not be construed as a panacea rather a complement for mitigating the emerging conservation problems related to the inefficiency of the current state strategies.

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Chapter 21
Adoption and Utilization of Ethno-postharvest Technologies by Smallholder Farmers in Semi-arid Regions of Zimbabwe: Case of Buhera District

Thomas Marambanyika, Timothy Mutekwa and Winmore Kusena

Abstract One of the major challenges to enhance food security amongst rural populations in developing countries including Zimbabwe is the continued existence of high postharvest losses, accompanied by low yields due to climate change, among other factors. It therefore becomes imperative to investigate the level of adoption and utilization of ethno-postharvest technologies in a bid to evaluate their strengths and weaknesses to safeguard yields before consumption. Data was collected in Buhera district through triangulation, which involved semi-structured interviews with five elderly people snowball sampled and purposively chosen Agritex officers as well as questionnaires administered to 100 purposively selected smallholder farmers. Crops and technology observations during fieldwork also constituted an important component of the data gathering techniques. Research results show that although some long established and effective traditional methods like "tsapi" were abandoned, there are some residual traditional technologies still in use such as drying on "ruware", threshing of small grains by cattle trampling and storing all crops in a traditional hut called "hozi" with the aid of pest repellents like cactus ash. Major factors leading to the demise of most traditional technologies include the absence of suitable education and information dissemination structures and competition from vigorously promoted western methods among others. It was concluded that in order to effectively minimize postharvest losses, indigenous technologies must be studied, documented and promoted by both practitioners and external agencies such as Agritex, and non-governmental organizations. Where possible, they can be augmented by modern day technologies to reduce the costs of post harvest storage for marginalized and poorly resourced smallholder farmers in the area.

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21.1 Introduction

Food security is one of the twenty-first century's key global challenges. In developing countries, household food security is precarious for large numbers of people particularly in the rural areas. Food production levels are inherently low and of late worsened by climate change and variability as well as high postharvest losses among other factors. The World Bank (2011) points out that one of the main sources of food insecurity in Sub-Saharan Africa (SSA) is postharvest crop loss. Postharvest losses occur during any of the stages in the postharvest operations such as assembling, drying, threshing/shelling, storage, packaging and milling (Appiah et al. 2011; World Bank 2011; Hodges et al. 2010; Sargent et al. 2000; Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP) 2010; Harris and Lindbald 1978). Therefore, reducing postharvest food losses must be adopted as one essential component in any strategy to make more food available without increasing the burden on the natural environment (Hodges et al. 2010; Wold Bank 2011). At the same time, reducing food losses in developing countries can contribute to rural development and poverty reduction by improving agribusiness livelihoods (Hodges et al. 2010).

Generally, data and information on post harvest losses are scarce (Hodges et al. 2010). This has generated debate on the magnitude of postharvest losses at various scales. It is estimated that a total of 20–40 % of all crops in developing countries is lost to postharvest losses (World Bank 2011; Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP) 2010; Usman 2009). However, there are variations in postharvest losses for different crops, at different times and at different stages of postharvest practices. For example, maize postharvest losses in the tropics have been estimated at about 20 % (World Bank 2011). Quantitative postharvest losses of rice in Sub-Saharan Africa are estimated to be between 10 and 22 % while qualitative losses could be as high as 50 % (Appiah et al. 2011). In Southeast Asia, losses in rice after harvest are estimated between 10–37 % (Madrid 2011). In Southern Africa Development Community (SADC), postharvest losses for cereals is on average 25 % at storage level whilst it is higher for perishable crops such as fruits, vegetables and root crops (Masarirambi et al. 2010). Osunde (2008) observed that storage losses in yams vary from 10–15 % during the first 3 months and reach a peak of 50 % after 6 months. This shows that the rate of food loss at storage stage is also significantly affected by time.

Postharvest pests also cause an estimated loss of 30 % at storage level (Bett and Nguyo 2007). Therefore, in Sub-Saharan Africa it was observed that the amount of grain lost due to decay and pests can feed up to 48 million people (World Bank 2011). The World Bank (2011) and African News (2011) further confirmed that grain losses also cost about $ 4 billion a year in Sub-Saharan Africa and this amount is roughly equivalent to the value of annual cereal imports in the region. This implies that reduction in postharvest losses will enhance food security in Sub-Saharan Africa where millions of people are in critical need of food, and help mitigate the problems faced by policy makers on food security issues at local, national, regional and international levels (World Bank 2011). Generally, most of the postharvest losses incurred are due to spillage, decay, mechanical damage and physiological disorders during drying, threshing, storage and transport (Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP) 2010).

It is important to note that postharvest losses have severe impacts on the livelihoods of rural people as well as rural development since most farmers rely on income from farming. This calls for intervention strategies to be put in place in order to reduce production costs and the number of households which are food insecure. The World Bank (2011) observed that only 1 % reduction in post harvest losses can result in annual monetary benefits of US$ 40 million in Sub-Saharan Africa. Meanwhile, the global population is predicted to increase to 9.1 billion by 2050 with the developing world expected to provide the bulk of projected growth (World Bank 2011). The implication of this situation is increasing food scarcity which is likely to adversely erode the resource base for food supply.

Since the 1970s, global attempts have been made to minimize the impacts of postharvest losses on food security at international level. In 1975, the United Nations declared that further reduction of postharvest food losses in developing countries should be undertaken as a matter of priority (World Bank 2011). This was in response to the global food crisis in the early 1970s. Therefore, from the mid-1970s and 1980s, substantial efforts to invest in reduction of postharvest losses were made until these initiatives were abandoned in favor of market liberalization as an economic incentive to enhance food production in the 1990s (World Bank 2011). However, reduction in global food production due to the multiple effects of climate change (African Ministerial Council on Science and Technology 2011) among other noticeable factors like food price increase between 2006–2008, pushing prices beyond the reach of the majority, especially poor people in Sub-Saharan Africa resulted in recognition for the need to revive forgotten investment in postharvest technologies in order to boost household and individual food security (World Bank 2011).

It is crucial to note that the impact and success of any postharvest operations and postharvest loss reduction interventions are influenced by social and cultural norms (World Bank 2011; Ofor and Ibeawuchi 2010; Harris and Lindbald 1978). Harris and Lindbald (1978) warned that policy makers and development planners must erase the stereotype view of culture as stubborn adherence to tradition and resistance to change, as all cultures contain the seeds of change. This means that people must be able to improve on the gains associated with the adoption of culture based innovations, including postharvest technologies and practices without necessarily embracing foreign technologies whose cost may be unbearable to the majority of cash-strapped poor people in the developing world. The World Bank (2011) further hinted that more research and piloting was needed in postharvest technologies to make sure that the steps taken were sensitive to local conditions.

On the other hand, the World Bank (2011) observed that there has been low adoption and success of postharvest technologies initiated by the government and donor community in Africa. Reasons for low adoption of postharvest technologies initiated by governments and the donor community include lack of cultural acceptability, short term support for exotic postharvest technologies as assisting organizations incorrectly assume that change can occur in a short period and unsustainably high financial costs associated with their implementation (World Bank 2011; Bett and Nguyo 2007; Harris and Lindbald 1978). In brief, exotic postharvest technologies did not address the needs of the vulnerable groups in society, especially women and the poor in general who are at the centre of food production in developing countries (Ofor and Ibeawuchi 2010). Meanwhile, there is dearth of literature on postharvest loss reduction in Zimbabwe, a country where agriculture is the backbone of the economy, providing employment and livelihoods to approximately 70 % of the population, where only 60 % of food requirement is produced and 60 % of the population live on less than US$ 1 per day (FAO 2010). Therefore, development practitioners, national policy makers, and other professionals promoting agriculture-related improvements need to start thinking in terms of optimizing postharvest systems, with both food security and income enhancement in rural areas of developing countries as primary objectives (World Bank 2011).

It is against this background that the research focused on how Zimbabwe's main traditional food crops such as pearl millet, finger millet, sorghum and different types of legumes could be sustainably conserved using ethno-postharvest technologies and practices to improve the food security of smallholder farmers in semi-arid areas. In this context there is a need to understand the cost-effectiveness of traditional postharvest crop preservation technologies which are founded on long-established traditional practices. Traditional postharvest knowledge and practices largely remain untapped and in some cases forgotten whilst possibilities nevertheless exist for their continued utilization in this modern day and age. Thus this chapter examines the levels of adoption and utilization of ethno-postharvest technologies and the strengths and weaknesses of current practices, and identifies opportunities for improving these long-established local innovation systems in the semi-arid district of Buhera, Zimbabwe.

21.2 Location and Description of Study Area

The study was specifically undertaken in Wards 22 (Mawire) and 23 (Chirozva) in Buhera district of Manicaland province, Zimbabwe (Fig. 21.1). The population characteristics of the two wards according to the Central Statistical Office (CSO) (2004) are shown in Table 21.1. These two wards fall in Zimbabwe's semi-arid natural farming region 4 that receives an unreliable and unpredictable annual average rainfall ranging from 450–650 mm distributed in a unimodal pattern between November and April (Zinyama et al. 1991). Natural farming regions are a classification of the agricultural potential of Zimbabwe, from natural region 1 (> 1,000 mm of rainfall per annum) which represents high altitude wet areas to natural farming region 4 which receives low and erratic rainfall averaging 550 mm per annum (Vincent and

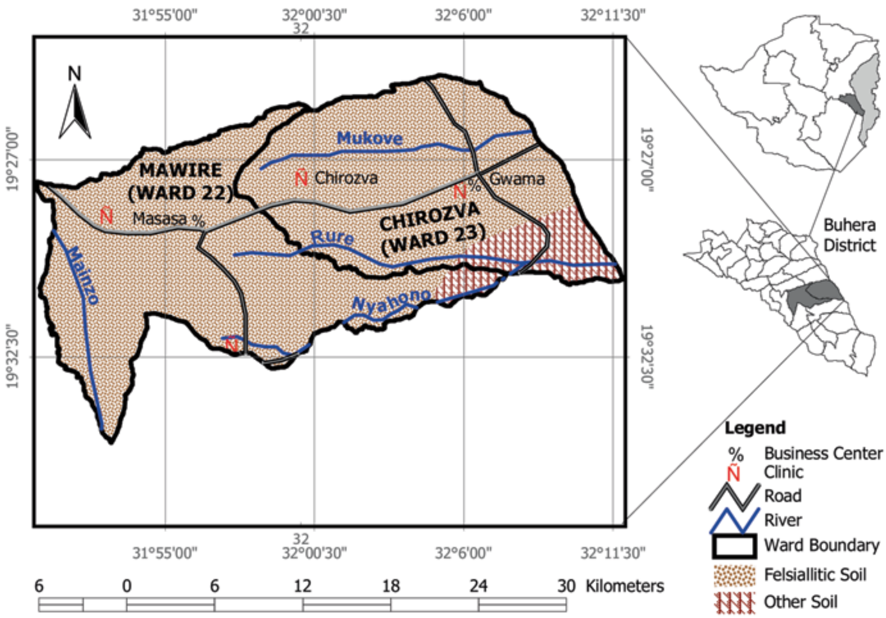

Fig. 21.1 Location of Wards 22 and 23 in Buhera district, Zimbabwe

Table 21.1 Study wards population characteristics (Central Statistical Office (CSO) 2004) and sample size

Place	Population size	Number of households	Average household size	Sample size
Ward 22	10,917	2,236	4.88	53
Ward 23	9,409	1,993	4.72	47
Total	20,326	4,229		100

Thomas 1960 in Mugabe et al. 2007). The changing weather patterns are further complicating the already existing food security problems because in some years semi-arid areas are simultaneously affected by drought and excessive rainfall that affect smallholder agricultural productivity (Mutekwa 2009), hence the need to minimize or eliminate postharvest losses in order to improve household food security.

Nyamapfene (1991) pointed out that the soil types in the two wards are fersiallitic, hence promote high leaching, minimizing amount of water available for plant growth. Zinyama et al. (1991) classifies the soils as arid soils that tend to be light colored because of limited humus additions from vegetation.

Wards 22 and 23 are food deficit areas. The majority of households cannot meet their annual food requirements from their own crop production even in a normal rainfall year (Agritex Report 2010). Zinyama et al. (1991) state that region 4 should be restricted to drought resistant crops such as finger millet, pearl millet, sorghum, roundnuts, groundnuts and cowpeas. Vegetables are grown for subsistence as well as for trading within the community. Other economic activities include selling of goats and chickens or exchange of these with livestock for food (Mararike 1999). Cattle are sold or slaughtered by those who are wealthy or in food crisis (Agritex Report 2010). Mararike (1999) established that Wards 22 and 23 with their poor agricultural potential inevitably have 57 % female headed households due to high rates of male out migration to towns in search of employment.

21.3 Data Collection and Analysis

The research generated qualitative data and to a lesser extent quantitative data. Qualitative data assisted in giving a detailed description of existing ethno-postharvest technologies and practices. This data was generated through triangulation, whereby semi-structured interviews, questionnaires and direct observations were the key instruments to acquire relevant information on postharvest technologies. The key issues that determined the structure of the data collection instruments were the adoption and utilization of ethno-postharvest technologies, the strengths and weaknesses of current practices, identification of opportunities for improving the local innovation systems as well as how the technologies can be mobilized to benefit the majority of the people. Quantitative data predominantly consisted of socio-economic information solicited through the closed-ended questions of the questionnaire.

Video camera was used to acquire ethnographic information during the semi-structured interviews with the selected elderly people. Elderly people above the age of 75 were interviewed since they were assumed to have a rich history of how ethno-postharvest technologies evolved overtime. Since the elderly were few in number, it was difficult to identify or distinguish homesteads with an elderly person from those without, prompting the use of the snowball identification method. This involves identifying respondents who then refer the researchers to other respondents as a means of overcoming the problems associated with sampling concealed populations (Mutekwa and Kusangaya 2006). (For more details about the method and procedure see Blaxter et al. 1999; Atkinson and Flint 2001; Faugier and Sargeant 1997; Thomson 1997). In this study, snowball sampling was used only as a means of identifying elderly respondents without having to visit all the households. Five elders were therefore sampled using this method. The first elderly person was identified with the help of the local traditional leader. This elderly person then referred the researchers to the next person who did the same and so on.

One hundred (100) questionnaires were proportionally administered to household heads using the quota sampling method. Therefore, 53 and 47 questionnaires were administered to purposively selected household heads in the two wards as shown in Table 21.1. Purposive sampling was adopted in order to target farmers who were known to be very productive. Household heads provided information on existing ethno-postharvest technologies and practices being employed and their effectiveness.

Key informants for semi-structured interviews included purposively selected technical people such as Agritex officers as well as local leadership; councillors, headman and NGO officers involved in food production activities. Observations were made using an observation checklist to identify the types of technologies and practices in use and the data collected complemented that acquired through other instruments.

21.4 Results and Discussion

21.4.1 Background Information of Farmers

Most household heads (67 %) who responded to questionnaires were married and the remaining proportion consisted of widow(er)s who constituted 33 % of the target population. However, 61 % of the household heads were females due to the fact that either the husband was deceased or had immigrated to town for employment compared to 39 % of households which were male headed. This confirms findings by Mararike (1999) who observed a similar pattern in the sex composition of household heads. More than half of the farmers (55 %) were above the age of 46 with the remaining proportion being between the age of 22 and 45 years. Almost all farmers had only primary education, except for 7 % who had secondary education qualifications. The secondary qualification holders were mainly young farmers whose ages did not exceed 33 years. The average household size was 5.7.

The primary source of income for all farmers was farming. However, about 28 % of the farmers supplement their farming income through remittances from husbands, children or relatives employed in both formal and informal sectors in urban areas as well as in the diaspora. All farmers were involved in communal subsistence farming since birth. About 8 % of the farmers supplement their farming income by providing any form of labor required by other people in their community, locally known as *maricho*. The other 12.5 % of farmers derive their income from selling locally abundant *adansonia (baobab)*, *berchemia zeyheri (red ivory) and azanza garckeana (snot-apple)* indigenous fruits either locally or in urban areas. Only 1 % of the farmers indicated that they received pensions from their previous employers.

21.4.2 Major Crops Grown and Yield (Harvest) Obtained

Different type of crops are grown in wards 22 and 23 of Buhera district. The main classes of crops grown are cereals (pearl millet, finger millet, sorghum, maize, rice), legumes (roundnuts, groundnuts, cowpeas), tubers (sweet potatoes) and vegetables. However, the thrust of this research was on traditional cereals and legumes grown in dryland fields. The commonly grown food cereals as indicated by farmers were sorghum (77 %), pearl millet (72.5 %), finger millet (45.8 %) and maize (31 %). The leading significance of sorghum in the study area was also confirmed by Agritex officers who provide technical assistance to the farmers. The main factor behind the choice of crops by farmers was the prevailing semi-arid climatic conditions which

Table 21.2 Estimated average postharvest loss per crop at storage stage using indigenous methods

Crop	Average harvest (kg)	Average yield loss (kg)	Average percentage loss (%)
Pearl millet	126.48	25.38	20.00
Finger millet	97.00	20.90	21.54
Sorghum	140.00	28.33	20.23
Groundnuts	467.50	13.10	2.80
Roundnuts	394.20	17.33	4.40
Cowpeas	73.00	32.70	44.70

are suitable for drought resistant crops. However, the growing of sorghum and pearl millet was also strengthened through the provision of seed inputs by donors. Farmers who grow maize were mainly trying to evade the high labor demand associated with small grain crops.

Leguminous crops serve a dual purpose for local farmers, that is, provision of food and income generation. The number of farmers who grow leguminous crops varies as follows; roundnuts (60.4 %), groundnuts (66 %) and cowpeas (6 %). The average yield per crop grown per farmer varies significantly (Table 21.2). Groundnuts and roundnuts provide most of the income for farmers. The yields from these crops are relatively high and the surrounding cities of Mutare and Harare provide viable ready markets. However, 85 % of the farmers reported a sharp decline in harvests from small grains and leguminous crops in recent years. This was attributed to increasing rainfall variability and aridity, high temperatures, lack of draught power, land shortage and lack of inputs especially seeds since farmers rely on those from the previous season.

21.4.3 Indigenous Postharvest Technologies and Practices

21.4.3.1 Drying Methods

Drying of harvest from small grain cereals like pearl millet, finger millet and sorghum was done in-fields or off-fields, especially by spreading harvest on whaleback ("*ruware*" or large granite rock surfaces) that are a common feature in the area (Fig. 21.2). All farmers acknowledged that drying on whaleback was the most popular method for small grains since minimum losses were experienced as there was no mixture of grain with soil during natural detachment of grain from millet-heads before threshing. Normally small grains were transported to whalebacks using harvesting baskets or scothcarts. However, drying of small grains on whaleback has been associated with visible losses through consumption of harvest by stray livestock. These losses were difficult to quantify since they occur before threshing and were sporadic in nature. Some farmers however claimed that they lead to losses equivalent to a family's food requirements for several months.

Major causes of small grain losses at drying stage on whaleback were uncontrolled or stray livestock (cattle, donkeys, goats and chicken), wild animals (baboons and monkeys), wild birds (especially quelea bird), mice, thieves, winds and rotting due

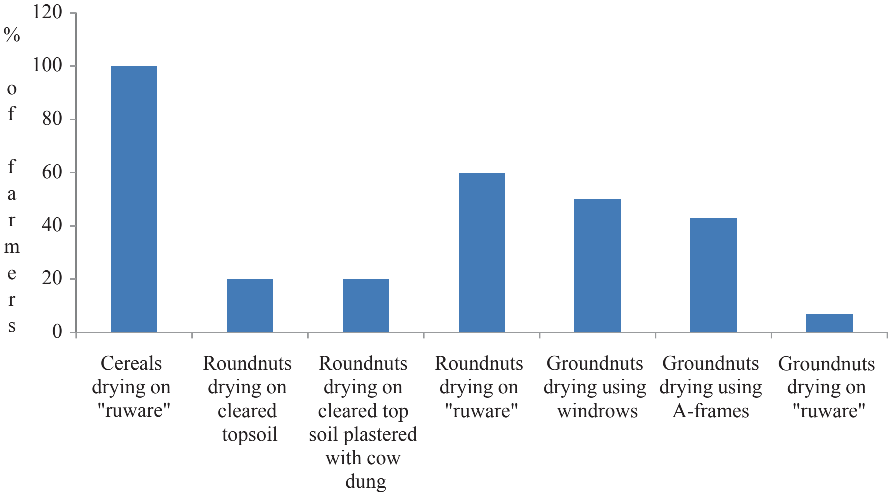

Fig. 21.2 Variations in farmers' level of adoption of traditional drying methods

to moisture in the event of unexpected winter rains. These grain losses were experienced because they were no structures put in place to safeguard yield against these animals and agents. Around 13 % of the farmers, however, temporarily pile harvest from small grains, especially pearl millet in their fields on spread stems of the same crop. Again significant grain losses are incurred especially during transportation of the in-field dried harvest to whaleback for threshing as grains detached from millet-heads and mixed with soil are difficult to separate. Therefore, the use of *'ruware'* for drying grain saves farmers from these losses.

However, interviews with elderly people confirmed that losses of small grains at the drying stage used to be insignificant. In the past, harvested yield before threshing was put in a hut traditionally known as *"tsapi"*. This hut was built on whaleback using wooden poles, anthill soil and thatched with grass as a storage and drying facility before threshing. Threshing was normally done between July and August after farmers had successfully completed harvesting of other crops like roundnuts and groundnuts which demanded a lot of their labor. Therefore, the *'tsapi'* method eliminates losses from small grains as well as leguminous crops since farmers were able to distribute their labor equitably. "*Tsapi"* was constructed on whaleback to retain heat during the night hence facilitating the drying of stored grains. The roof was thatched in order to allow for adequate ventilation and protect the yield from winter rains. The structure of "*tsapi"* enabled farmers to safeguard the small grains harvest against stray livestock and wild animals like baboons and monkeys. No major losses were therefore incurred from crops stored and dried in *'tsapi'* before threshing.

Since the location of *'tsapi'* was determined by the availability of a suitable whaleback, it was sometimes constructed away from homesteads, necessitating the use of traditional medicines (*'juju'*) to protect the stored grain from thieves. Anyone who attempted to steal from a 'protected' '*tsapi*' would invite terrible misfortunes or suffer from an incurable ailment. As a result, few theft cases were recorded. Despite the significant ability of "*tsapi*" to reduce yield losses at the drying stage before threshing, today no farmers are using this method mainly because of low yield obtained due to increased climatic variability, erratic rainfall and droughts. Secondly, very few modern farmers are able to use traditional medicines to protect "*tsapi*" from thieves since no mechanisms were put in place to pass on this knowledge from generation to generation. Thirdly, some of the traditional medicines are no longer available due to increasing biodiversity loss as human pressure for settlement and farming land have markedly increased over the years.

Whilst 60 % of farmers dry roundnuts on whaleback, the remaining 40 % dry in-field (Fig. 21.2). Twenty percent (20 %) of farmers who dry in-field remove topsoil and spread their shelled harvest on a hard subsoil surface. The other 20 % of farmers use cow dung to plaster on top of subsoil where again they spread their harvest. Removal of topsoil and plastering were done to avoid loss of harvest into the ground during drying. In both in-field and off-field drying, the methods result in losses of no economic importance unless unpredictable winter rains were experienced which could weaken the soil structure; hence losses can be realized from in-field drying if there is no timely intervention by farmers. Moreover, some cause of loss during drying of roundnuts was untimely attack by mice.

About 93 % of the farmers dry groundnuts after uprooting them in their fields using windrows and A-frames (Fig. 21.2). These two methods have been in existence since time immemorial. In the case of windrows, farmers simply pile uprooted groundnuts forming an arc shape to resist dispersal by wind with cocks facing the sun. A-frames were constructed using wooden poles and groundnuts were piled on either side of the A-frame with cocks facing inside. This method was developed in order to safeguard yield from rains as well as minimize loss of nutrients from sun scotching as in the case of windrows. Recently, through the advice of Agritex, 11 % of farmers now use a method called groundnuts hallow curing cocks which are constructed using 25 l jugs to form a cone shape for drying. According to Agritex, this method is cheap and effective as well as environmentally friendly as there is no need for wood when constructing the structure as in the case of A-frames. The remaining 7 % of farmers dry their groundnuts on whaleback. Although postharvest losses were said to be insignificant, the major causes of leguminous postharvest losses in-field were stray livestock (donkeys, cattle, goats and chicken), dogs, jackals, mice, termites and thieves. Cowpeas were dried on whaleback and no losses were recorded. It is important to note that all interviewed farmers were not able to quantify the amount of losses incurred from both small grains and leguminous crops at drying stage, although they indicated that they were insignificant.

21.4.3.2 Threshing Methods

The most common traditional threshing method for small grains especially pearl millet was organized cattle trampling of dried yield spread on whaleback, locally known as "*kutsikisa*". In operationalizing this threshing method, people spread and surround the dried harvest on whaleback and one or two individuals chase around cattle in either clockwise or anticlockwise direction continuously until the grain is separated from the chaff. However, the popularity of this method is gradually declining as it is now mainly confined to years of bumper harvests, which is no longer the case today for most households. Unquantified grain losses were recorded through crushing of grain by cattle hooves, consumption of harvest by livestock as well as soaking of dried yield with cattle mud if the process was not well controlled. Additional grain losses were experienced when threshing was done on harvest which was not well dried; hence yield was lost together with the separated waste. If millet harvest was well dried and the process was well controlled, no meaningful losses were recorded. Winnowing using winnowing trays was done immediately after threshing to separate grain from waste.

Almost 97 % of interviewed farmers indicated that they use tree branches (*kupura*) to thresh their small harvest especially for sorghum, finger millet and cowpeas on whaleback. However, in terms of grain losses, crushing is the most dominant. Wind splitting was also done later after threshing using winnowing trays. Generally, farmers, elderly people and Agritex officers agreed that these two threshing methods were the most ideal ones as they were meant to minimize loss of yield through spillage, an objective they achieved. Shelling of groundnuts and roundnuts was done after storage as storage with their shells reduced loss of yield from pests. In the case of groundnuts, farmers crack the shells with their hands in order to separate them from the nuts inside. Roundnuts were shelled using mortar and pestle (*duri nemutswi*) and later winnowing as in case of small grains. Farmers were not able to quantify yield losses during threshing and shelling as losses were said to be both quantitatively and qualitatively insignificant.

21.4.3.3 Storage Methods

Small grain losses at storage stage were said to be low or even zero for some farmers. About 12 % of the farmers said the existence of zero yield loss was due to low yield obtained which could be stored safely using modern storage facilities like sacks. In addition, these sacks were stored in traditional huts used as kitchens where the smoke from fire places tends to repel pests from attacking the stored grain, making the use of chemical insecticides irrelevant, a positive development for the poor rural communities. Therefore, smoke provided a cost-effective means to preserve yield.

However, elderly farmers indicated that they used to store their harvest from different crops in traditional huts called *"hozi"*. This hut is built on rocks (acting as pillars on corners) with wooden poles and mud to avoid transfer of moisture from the ground. The hut has subdivisions or compartments inside which are first plastered with anthill mud and coated with cattle mud. This material was used as it made the compartments inaccessible to pests or insects likely to destroy the yield. In the event of bumper harvest, either small grains or legumes were poured into these compartments which were later sealed to protect against pests and kept for

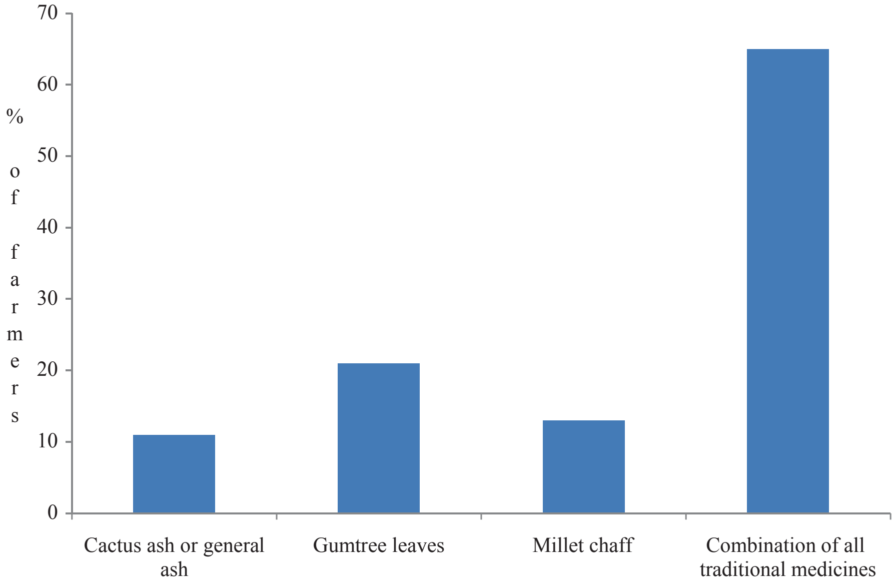

Fig. 21.3 Traditional medicines used preserve small grain crops at storage

future use. The produce remained un-degraded as long as these compartments were not opened and no losses were incurred. During storage, no traditional medicines or modern chemicals were added to these sealed compartments. The roof of the hut is thatched with grass to allow for ventilation. Elderly farmers indicated that this method conserved yield for a period between 1 and 3 years depending on the type of crop, with small grains being less durable than shelled leguminous crops.

Increasing climatic variability has been causing a decline in crop yield in recent years since 2001. Despite this problem, 88 % of the farmers again acknowledged that they still use "*hozi*" for storing their yields since these structures were put in place when they used to record high harvests. However, they no longer seal compartments after putting in their yield because storage would be temporary as they would need the food for daily sustenance. Lack of compartment sealing has been exposing the harvest to degrading pests like rats, weevils and grain-borers. In order to control these pests, 44 % of the farmers confirmed that they primarily use traditional chemicals to conserve their grain yield compared to 41 % who preferred modern chemicals and 15 % who want both.

Of the farmers who use traditional chemicals, 11 % use ash of cactus tree or general ash from fireplaces which they spray on the yield whilst 21 % use eucalyptus or gumtree leaves and 13 % use chaff of pearl millet or finger millet spread in the stored yield at defined intervals like 30 centimetres (Fig. 21.3). These traditional chemicals are said to repel pests for a period between 6 months and 1 year, the time within which most farmers would have exhausted their yield for consumption. About 65 % of the farmers use a combination of all these traditional methods.

The proportion of farmers (47.5%) who prefer to use modern methods have been experiencing huge losses since they cannot afford the relatively high prices of modern chemicals like agricura, *chirindamatura* and rat pellets. Estimated postharvest losses at storage for different crops by farmers who use indigenous methods are shown in Table 21.2.

Low yield loss is realized from legumes like groundnuts and roundnuts as shown in Table 21.2 despite the fact that no additional traditional and modern chemicals are added. Low losses have been attributed to storage of groundnuts and roundnuts in shelled state, hence their ability to resist pests. However, percentage loss for roundnuts is relatively higher than that of groundnuts due to weak shells which will gradually become vulnerable to pests with time, normally after 8 months from harvest. Of significant concern to farmers is the inability of both modern and traditional methods to protect cowpeas from weevils since they are stored in unshelled form. Estimated postharvest losses for all crops as shown in Table 21.2 are relatively lower than the average of SADC which is 25% (Masarirambi et al. 2010). Therefore strengthening of these ethno-postharvest technologies and practices could result in a further reduction of losses.

21.5 Challenges Associated with the Use of Post-harvest Indigenous Technologies and Practices

Whilst great potential exists for ethno-postharvest technologies and practices to cost-effectively minimize postharvest losses, there are several problems which affect their continued effective use at present and in the future. Most farmers indicated that they do not have adequate knowledge of traditional chemicals which can be used to repel pests or the knowhow for their safe use. For example, improper handling and application of cactus ash could distort the taste of food by making it sour or injure the user. Therefore some farmers have been confining the use of cactus ash to protect seeds for the next farming season. Some farmers are cautious about the use of eucalyptus leaves as these are reported to have health risks such as diarrhea if one consumes food milled with these leaves. Secondly, the mixture of eucalyptus leaves or ash with grains at milling results in the preparation of thick porridge *(sadza)* difficult, as it does not thicken as expected. About 77% of the farmers who use modern technologies and practices argued that traditional practices and technologies were less effective as the results do not last long compared to modern chemicals such as agricura, *chirindamatura* and rat pellets, a view which was denied by most elderly farmers who said these modern farmers especially those below the age of 40 lack prerequisite knowledge on the existence and effective use of traditional practices. Some farmers confirmed that they were merely reluctant to adopt and utilize traditional methods as biodiversity loss was making it difficult for them to access some important plant species like cactus.

21.5.1 Future of Indigenous Postharvest Technologies

Farmers, elderly people and Agritex officials had mixed feelings on the future of ethno-postharvest technologies. Around 63 % of farmers who responded to questionnaires as well as the elderly people consulted, concurred that the future of indigenous practices was bright considering the fact that these technologies and practices were readily available locally and cheap. This means that with the high poverty levels amongst farmers, their solutions were likely to remain grounded in traditional methods; hence there exists a need for them to be strengthened. Therefore it was observed that it is necessary to equip children and other farmers with prerequisite traditional knowledge, especially those who are not familiar with traditional methods and have no capacity to buy modern chemicals. About 13 % of the farmers indicated that they were not quite clear about the likely continued existence of traditional practices in the future as information dissemination structures were poor. Today there are no formal structures for the dissemination of traditional knowledge as it was mainly carried out through informal interactions and observations. Elderly people and Agritex officials therefore hinted that formal education structures as well as projects for regeneration of ideal tree species should be put in place in order to pass on this wealth of information from generation to generation. However, the remaining 24 % of farmers said that traditional methods were ineffective and need to be abandoned.

21.6 Conclusion

Farmers in Wards 22 and 23 of Buhera district in Zimbabwe revealed that various traditional methods were used at drying, threshing and storage stages of both traditional cereal crops like pearl millet, finger millet and sorghum and leguminous crops such as cowpeas, roundnuts and groundnuts. Although farmers could not quantify the postharvest losses at drying and threshing stages, estimated losses especially at storage stage confirmed that ethno-postharvest technologies remains a panacea for minimization of losses amongst poor small scale farmers in semi-arid areas. Despite the obvious potential of indigenous postharvest technologies for farmers, improvements are needed in safeguarding against known health risks as well as establishing a sustainable means of passing on knowledge and skills to use these technologies and practices. Therefore it is imperative that indigenous technologies must be preserved and where necessary fussed with modern day technology as they are most appropriate for local conditions.

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Chapter 22
The Importance of Non Wood Forest Products for Rural Livelihoods: The Case of South Kordofan State, Sudan

Taisser H. H. Deafalla, Dafa-Alla M. Dafa-Alla and Mustafa M. El Abbas

Abstract Due to overemphasis on timber production in past decades, Non-Wood Forest Products (NWFPs) were neglected by foresters and policy makers leading to lack of attention on their values, although their uses are less ecologically destructive than timber harvesting. This study was conducted to emphasize the contribution of NWFPs to rural livelihood in South Kordofan State (Sudan) in terms of their values to provide subsistence, employment and income generation. The state is rich with various tree species which grow naturally. This research focused on the much precious species according to local knowledge, namely, *Zizyphus spina-christi.*, *Balantites aegyptiaca, Adansonia digitata*, *Tamaraindus indica*, *Acacia nilotica*, *Grewia tenax, Acacia Senegal*, *Croton zambesicus* and *Sterculia setigera*. Data was collected through a questionnaire with a sample size of three hundreds households. Descriptive statistics were applied to analyze the data using Statistical Package for Social Sciences (SPSS) software. The study came out with quantitative results declaring the high dependency of households on NWFPs for subsistence and income generation. More emphasis of forest management for such products could contribute to both sustainability and conservation objectives.

Keywords Non wood forest products • Rural development • Local knowledge • Forests sustainability • Semi-arid region

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22.1 Introduction

Non wood forest products (NWFP) refers to "goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests" (FAO 1999). For the vast majority of the world's rural households, NWFPs provide essential food and nutrition, medicine, fodder, thatch and construction materials, mulch and non-farm income. Africa has the highest percentage worldwide of people live on less than one dollar per day (FAO 2005; CIFOR 2002). NWFPs play indispensable role in the daily lives and overall well being of rural and urban people in Africa. Large number of rural people particularly those living in forested areas depend on NWFPs for various levels of uses. Moreover, NWFPs are also significant elements of cultural, spiritual, religious and recreational needs in many societies. Recently, NWFPs have attracted considerable international attention. This is due to the increasing recognition that NWFPs can provide important and basic community needs for improved rural livelihood without destroying the forest resource, providing buffers against environmental and economic adversities as well as support biodiversity conservation (CAF 2008) where they play a key role in enhancing the general environment through encouraging conservation of the tree cover and in the long run will lead to more land being converted to tree cover thereby reversing the current trend of tree cutting for crop cultivation. This is specially a valid expectation in areas where other land-based resources are meager or are of lower value.

At the subsistence level, NWFPs are major sources for food, medicines, fodder, gums, fiber, and construction material. Arnold (2002) stated that "NWFP are particularly important in reducing the shortages suffered during the 'hunger periods' of the agricultural cycle as they help to even out seasonal fluctuations in the availability of food". Furthermore, many of NWFPs are important traded commodities at local, national, regional and international levels, providing employment and income at each level, especially where the majority of the poor people, particularly women, find NWFPs activities attractive because of the low technical and financial entry requirements, freely available resource base and instant cash in times of need. In addition they constitute a poverty trap, a safety net, or a potential but underutilized resource for rural development and poverty alleviation ((in KSLA, AAS and FAO, 2005). The major issue at stake is that the commercialization of most highly valued NWFPs has been identified to cause major impacts on the sustainability of raw material production. One reason suggests that the benefits of processing and marketing NWFPs are small at the level of local producers. This hinders the ability of local producers to financially support sustainable production. Furthermore, such poor local revenue capture can neither lead to an improvement in their income and livelihoods nor to the accumulation of capital for investment in the development of such products. Therefore, much of the revenue is earned at the processing end, usually located outside the raw material production areas (Gaia/Grain 2000; Wynberg 2004; CARPE 2001).

NWFPs are important and are a significant part of the economy of many countries especially in sub-Saharan Africa, contribute to foreign exchange earnings as an example in Sudan; over 13 % of the foreign exchange earned is generated from the Gum Arabic trade alone according to Tieguhong and Ndoye (2004). Though in national economies and resource accounting, it is an acknowledged fact that rural people have relied on NWFPs for centuries meanwhile little is known about the extent of use, availability and sustainability of the products (Godoy and Bawa 1993). In recent years, NWFPs started to gain considerable importance in Sudan due to many reasons such as: the exponential development in the use of NWFPs in many industries and Medicine besides the use of NWFPs as food and drink are becoming more familiar. Moreover, these products are particularly important during the critical periods of droughts and famine (e.g. the famine of 1982 some of the NWFPs were the only available food stuff), in addition to NWFPs are developing good market value as well as increased public awareness about the socio-cultural use of the NWFPs (Sulieman and Eldoma 1994).

The objective of this research was to investigate the role of NWFPs to help in designing sound, valid management and policy guidance. Data, which was collected using questionnaire of households, was statistically analyzed using SPSS. Results showed that NWFPs were used to great extent in almost all households interviewed in the study area. They include gums, fruits, fibers, medicine, flowers, aromatic plants, raw materials for local industries, fodder for animals and wildlife products. The majority of respondents were subsistence poor farmers who suffer scarcity of food supplies and health care and therefore rely on NWFPs which provide them with critical subsistence in addition to job opportunity especially during the dry season when other alternatives are unavailable.

22.2 Research Problem

The trees that are harvested in the study area are growing naturally with no apparent management intervention. Due to overemphasis on timber production, foresters and policy makers negligence of non-wood products has lead to lack of attention to their values. Additionally, various constraints facing the conservation and management of NWFPs in South Kordofan State such as; tree clearance for cultivation, climatic factors, fire, grazing, civil war, inadequate forestry extension, forest pests and diseases in recent times (El Tahir and Gebauer 2004). Moreover, there are no clear mechanism and extension services to improve the quantity through afforestation and/or to improve the quality through development of best practices of pre and post- processing of collected NWFPs (KSLA, AAS and FAO 2005). In addition to that, there is a huge lack of reliable data on their production and trade and on the number of people involved, which makes it hard to assess the effective contribution of NWFPs to rural livelihoods (Chikamai and Tchatat 2004). The products are not adequately treated and there is lack of processing and storage technologies and facilities; quality standards of products are often poor. Moreover, they usually involve low-value products, which make them less attractive to larger forestry entrepreneurs. Obviously, there is a serious lack of research and technology development related to NWFP, in addition to lack of clear and appropriate policy support for NWFP development in spite of their positive attributes and potentials in the study area.

Fig. 22.1 Location of the study area

22.3 Materials and Methods

22.3.1 Study Area

The study area (Fig. 22.1) is located in Southern Kordofan State in western Sudan. The state lies between latitudes 9° and 12 °N, and longitudes 27° 25′ and 32 °E, with a total area of 135,696 km^2 (Ahamed 2008). Southern Kordofan State is bordered by Darfur in the West, Abyei, Northern Bahr el Ghazal, Warrap, Unity and Upper Nile States in the South, and White Nile and North Kordofan States in the North. The State capital is Kadugli. The State is administratively subdivided into 9 localities, Dilling, Kadugli, Lagawa, Rashad, Talodi, Abujubayha, Keillek, Assalam and North Abyei Localiy (IOM 2009). According to Sudan Central Bureau of Statistics (CBS) total population of South Kordofan state in 2008 was 1.3 millions distributed into 120,986 households (CBS 2009). The vegetation zones in the area include semi-desert in the northern parts followed by poor, medium and wet savannah belts as rainfall increases to the south. There is also some mountainous vegetation on the area, where elevation reaches 1,000 m. Rainfall is adequate and there are extensive plains of clay soil. The livelihood activities found in the area are agro-pastoralism, nomadic pastoralism and rain-fed agriculture, both traditional farming for subsistence and mechanized farming for commercial operations. In addition to that, a third source of livelihood is derived from the natural forests in form of woody and non-woody production derived from various trees (UNDP 2006).

22.3.2 Research Methods

In order to achieve the objectives of the study, data was collected through a questionnaire of households. Twenty two villages were randomly selected. Villages were distributed among different strata; 4, 13 and 5 villages in Rashad, Elabasia and Abo Karshola units, respectively. Sample size of respondents (households) was three hundreds distributed between villages according to the principle of Population Proportional to Size (PPS). Accordingly 37, 190, and 74 households were selected in Rashad, Elabbasia and Abokarshola units, respectively. The questionnaire was designed with closed multiple-choice and open-ended questions concerning social characteristics and respondents perspectives about different aspects of the NWFPs activities to attain information on matters such as products uses, seasonal patterns and income generation from NWFPs in relation to other occupations. Data collection period extended for 8 days during the field visit in order to interview 300 responders with the aid of some facilitators. Descriptive statistics analysis of data was made using SPSS, which was organized as a series of modules and add-on applications.

22.4 Results and Discussion

22.4.1 Source of NWFPs

Non wood forest products play important roles in the daily life of households in the study area. Like in other rural areas in the region, many of poor people in the study area live in conditions where a nearby forest is the only accessible source of livelihood. They depend on it as major source of food, medicines, fodder, gums and raw materials for local industries. Results (Fig. 22.2) showed that, approximately the average of more than three quarters of households attain their needs from direct collection of NWFPs from scattered trees and shrubs surrounding their settlements. The exception was related to *Croton zambesicus* fruit where the buyers are a little bit more than collectors, this directly related to difficulties of product collection due to the far distant locations of the forests from their villages.

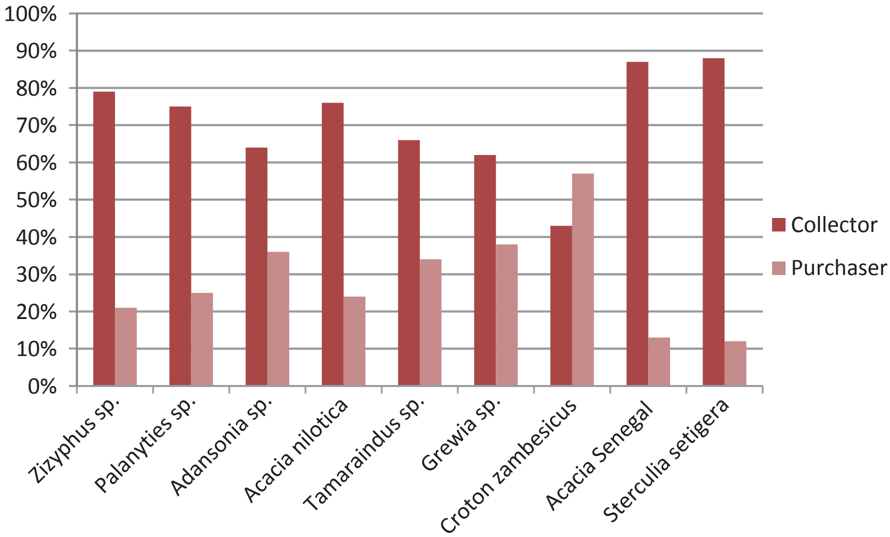

Fig. 22.2 Source of NWFPs for each product (%)

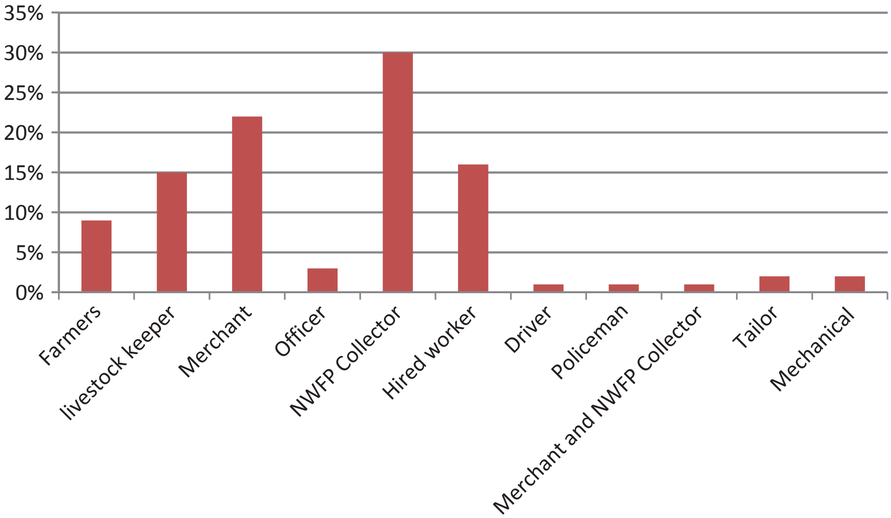

Fig. 22.3 Percentages of secondary occupations in the study area

22.4.2 Employment and Income Generation

Non wood forest products provide employment opportunities for youth, women and elderly members of households. That could be supported by the relative importance of NWFP's collection being the single most important secondary occupation in the area where 30% of households (Fig. 22.3) were involved, followed by commerce.

Table 22.1 Uses of NWFPs (%)

Uses products	1	2	3	1 & 2	1 & 3	1, 2 & 3	4	5	Total
Zizyphus sp	84.60	0.50	3.50	1.00	5.50	0.50	1	3.5	100
Balanites sp	19.90	2.90	34.90	1.90	25.70	10.20	1	3.4	100
Adansonia sp	2.60	9.20	65.30	1.50	3.60	15.80	0	2	100
Acacia nilotica	0.00	0.70	92.40	0.00	1.40	0.70	1.4	3.5	100
Tamaraindus sp	2.80	11.30	75.10	0.00	4.00	4.50	0	2.3	100
Grewia sp	0.80	21.30	66.90	1.60	4.70	3.90	0	0.8	100
Croton zambesicus	1.20	19.80	69.70	1.20	1.20	5.80	0	1.2	100
Acacia senegal	13.20	0.00	64.70	2.90	14.70	2.90	0	1.5	100
Sterculia setigera	0.00	0.00	33.30	0.00	0.00	55.60	0	11.1	100

Legend: *1* represents foods, *2* drinks, *3* medicine, *4* animal feeding, *5* for all uses

The annual income of household from collection of NWFPs in this research was estimated as US$ 215.0. According to Adam (2006) the NWFPs must be considered as provider of employment during the summer season when other alternatives (rain-fed agriculture) are unavailable. Also it could play a vital role in rural areas where resources are meager and the weaker categories in the community cannot migrate to seek employment elsewhere or cannot engage in the more labor demanding activities (Awad 2000).

22.4.3 Uses of Non Wood Forest Products

The state is rich with various tree species which grow naturally. However, this research focus on much precious species according to local knowledge, namely; *Zizyphus sp.*, *Balantites aegyptiaca, Adansonia digitata*, *Tamaraindus indica*, *Acacia nilotica*, *Grewia tenax, Acacia senegal, Croton zambesicus* and *Sterculia setigera*. The importance of NWFPs to rural livelihoods can take several forms of benefits. These can entail products that are collected directly for subsistence to enhance their direct needs of foods, medicine, raw materials for local industries and livestock feeding, or those for sale in order to earn an income. Table 22.1 clarifies the most important products that were used in the study area for livelihood subsistence and categorize them according to their manner of uses. Roles of the NWFPs in survival and poverty alleviation were tackled declared in this research. Most of harvested NWFPs were used as medicine, foods and nutritional supplements. On the other hand, the limited quantities of products collected for livestock feeding reported here may refer to the strategy of their direct grazing on the tree's fodders and fruits instead of products collection.

According to Elasha et al. (2009) through the experience of forest communities, forestry professionals have recently rediscovered the great importance of NWFPs (ranging from food, fruits and fibers, dye stuffs, flavors and medicines) for meeting people's needs. In recent years, a growing body of scientific research has suggested that, given certain basic conditions, NWFPs can help communities to meet their

Table 22.2 Common uses and the part used of NWFPs

Scientific name or botanical name	Local name	Part utilized	Uses
Ziziphus spina-christi	Nabag, Seder	Fruits	Food, drink, illness treatment and animal feeding
Balanites aegyptiaca	Laloub, Hegleg	Fruits	Food, drink, illness treatment and animal feeding
Adansonia digitata	Gunglaize, Tabaldi	Fruits, seed	Food, drinks, medicine
Acacia nilotica	Garad, Sount	Fruits, bark	Food, drink, illness treatment, feeds and raw materials for local industries
Tamarindus indica	Aradeib	Fruits	Food, drinks and medicine
Grewia tenax	Gudiem	Fruits, leaves	Drinks and medicine
Croton zambesicus	Umglaila	Fruits, leaves and Seed	Food, drink and illness treatment.
Acacia senegal	Hashab	Gum, bark	Food, drink and illness treatment
Sterculia setigera	Tartar	Gum, bark	Food, drink and illness treatment

needs without destroying the forest resource (FAO 1995). Furthermore, the study found some NWFPs were consumed throughout the year by the rural households. These usually occur at the end of the dry season, they are also valued during peak periods of agricultural work from June to October and when less time is available for cooking also. As described in Table 22.2 NWFPs can play an important role in the prevention of malnutrition, eaten fresh or left to dry for consumption at a later date like Nabag (fruit of *Zizyphus sp.*) and Gudiem (fruits of *G. tenax*) are used in form of drink too. Garad (fruit of *Acacia nilotica*) and Umglaila (fruits of *Croton zambesicus*) are used for illness treatment, especially to treat chest infections and cough. Malaria was treated by Aradieb (fruit of *Tamaraindus sp*) while some stomach diseases are treated by Laloub (fruit of *Balanites aegyptiaca*) and Gunglaize (fruit of *Adansonia sp.*) gynecology was treated by *Adansonia digitata* seed oil. Kidney stress and stone is treated by gums of *Acacia senegal* and *Sterculia setigera*. Gudiem (fruits of *G. tenax*) is used to heal anemia, which reported that is contains a large amounts of iron (Maydell 1990).

22.5 Conclusions

The wide spread of NWFPs shows great potential in providing multiple needs and income generation that are clearly supported by the current findings. Adequate innovative research and development are needed to encourage the investments on NWFPs through maintenance and use of indigenes knowledge, industry and gene banks development, particularly for the above mentioned species. Although the quantities of some products involved may be small, their nutritional contribution is often critical, especially at certain times of the year; during droughts or other emergency periods when cultivated foods are unavailable (FAO 1989). Securing sustainable NWFPs supply by conserving identified species, improving their market value through pre to post processing, expanding their marketing opportunities (ICRAF 2004) and protecting identified NWFPs uses and users' knowledge are foundation stones toward improving their environmental benefits in a sustainable manner that leads to ecosystem stability. At the national level, contribution of NWFPs to the Gross Domestic Product while exporting the products or cost saving through local exploitation should motivate the Sudanese government to maintain environmental integrity while managing NWFPs on sustainable basis. Finally, there is a need for Sudan and other developing nations to consider legal mechanisms for the standardization and certification of NWFPs utilization and collection processes, with well defined patent rights. A legal protection would protect the rights of local communities and protect their local knowledge from use by commercial interests.

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Chapter 23
Co-management of Forests and Forest Land Under Decentralization Process in Central Vietnam

Tran Nam Tu, Paul Burgers and Annelies Zoomers

Abstract With global concerns over climate change and forest degradation, poverty reduction in and around forest areas seem to be less prominent on the agenda, even though there is an intrinsic link between poverty and deforestation. In this highly complex context, where forests must fulfill roles that range from global to local ecological and socio-economic services, forest policies face new challenges, depending on the institutional, legal and economic conditions in different countries. Vietnam has already taken up this challenge to integrate rural development with issues for sustainable natural resource management from the early nineties onward through their Forest Land Allocation (FLA) policy. After almost 20 years of FLA policies implementation, this chapter analyses the impacts of these decentralization FLA policies have on forest protection and socio-economic improvement of selected rural communities in and around the bufferzone of the Bach Ma National Park (BMNP), Central region of Vietnam. It pays particular attention to the effects of FLA policies on long existing customary institutions at the community level to sustainably use and protect forest resources. The research argues that the policy was a good initiative to create resource use rights as well as co-management for local communities. However, local people do not benefit from the implemented "decentralized" measures, shown by continuous illegal encroachment into the core zone of the BMNP. The main reason is that active participation of local people is absent, and policies do not fit the local needs and priorities. This chapter critically examines the process of decentralization as it has taken place in central Vietnam, focusing on the buffer zone surrounding (BMNP), where the Government and international organizations have implemented projects on decentralized forest land management, following along the policy framework and

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donor agendas. The study emphasizes that the decentralization process in forest management is to achieve success if participation of local people is given more attention.

Keywords Decentralization • Co-management • Participation • Vietnam • Buffer Zone

23.1 Introduction

Decentralization in forest land management has been implemented in Vietnam since the early 1990s (Sikor 1998; Castella et al. 2006; Clement and Amezaga 2008; Gomiero et al. 2000; Tan 2006). The government considers decentralized policies as positive toward sustainable forest management and poverty reduction to combat illegal logging, ineffectiveness of state forestry system, and low participation from local communities. Decentralization projects have been implemented by various donor organizations. The aims of the projects are to implement forest land allocation in a participatory way and to enable local people to participate in the decentralization process.

This chapter critically examines the process of decentralization as it has taken place in central Vietnam, focusing on the buffer zone surrounding Bach Ma National Park (BMNP), where the Government and international organizations have implemented projects on decentralized forest land management, following the policy framework and donor agendas. The buffer zone as defined by IUCN (in Wells and Brandon 1992) as a result of the 1982 World Parks Congress, is composed of "*areas adjacent to protected areas on which land use is partially restricted to give an added layer of protection to the protected area itself while providing valued benefits to neighboring rural communities*". A next section analyses the role of different actors, particularly participation of different local groups in relation to the decentralization process and what the relationship between decentralization process and participation of local people has been.

Decentralization is a process by which power is transferred from the central government to local authorities (Evans et al. 2010; Wollenberg et al. 2005; Agrawal et al. 2008). The purpose is to increase decision-making for local people by allowing them to manage and use natural resources. However, decentralization of both political and economic power of the central government may not lead to sustainable economic growth. It has been recognized that local governments are in a better position to represent the needs of the local population, that local governments could be more efficient and that the benefits of public resources would be distributed more equally among the local population.

Both administrative and political functions are involved in decentralization. The former involves the transfer of mainly administrative responsibilities to lower government levels, which are accountable to the central government. In contrast, political decentralization is also known as democratic decentralization. This occurs when local authorities, who represent local population and are downwardly accountable to the population, actually obtain decision-making power and control over resources. This latter form of decentralization also implies that the local population can participate in decision-making, as their local government should represent their interests (Barr et al. 2006).

In the last few decades, co-management of forests has been a main concern within the international community. Co-management involves the setting of specific goals by resource users and the government in an attempt to reach these goals on the basis of shared power and responsibility (Melissa and Phillip 2009). Many studies on co-management of natural resources pay attention to the role of local people, with many authors emphasizing that local people feel highly enthusiastic about ownership of decentralized resources (Nygren 2005; Barr et al. 2006). Additionally, different approaches for the decentralized management of forests have been promoted by the FAO and other international policy organizations to increase the participation of communities for sustainable forest management (Ros-Tonen et al. 2007).

Participation of stakeholders has been a central issue in the development of forest management plans (Baskent et al. 2008). Effective participation of local communities in sustainable forest management requires both benefits going to local people and objectives of the Government being met. Participation in decentralization processes promotes effective communication among various stakeholders to identify expectations and democratic discussion on rights and responsibilities (Conley and Moote 2003). Such decentralization requires the forest administration to set up the criteria for forest management and protection (Sarah 2006). Participation is considered an important element in decision-making. First of all, local people have extensive specific knowledge of resources use (Ananda 2007). Secondly, it is assumed that implementation of policy will be more effective if people have been included in the process of policy formulation. Thirdly, the "empowerment argument" is that participation of people contributes to democratization and the empowerment of people (Cleaver 1999).

Participation of the local community is recognized to be a key cornerstone of the decision-making process. The success of decentralization depends on the capacity of local communities to realize their interests and formal rights to forest land use (Sikor 2001). Successful decentralization relies heavily on transferred power and responsibility to the local communities in which financial capacity and technical knowledge play an important role in making autonomous investment decisions (Nijenhuis 2006; Sarah 2006).

A brief presentation of the legal framework of decentralization in Vietnam is given below, followed by the method used for data collection and analysis, and the characteristics of the research sites. The results and discussion begins to make connections between customary and legislation laws in shaping forestry decentralization. It also offers a discussion of different decentralization processes and the evidence of its implementation in practice. The analysis focuses on the implementation of undertaken decentralization program by Helvetas—Extension and Training Support Project (ETSP), the Ministry of Agriculture and Rural Development (MARD), and Netherlands Development Organization (SNV), involving allocation of forests and forest land to village communities, groups of households, and households, respectively. The different approaches and participation of local people are also analyzed and discussed. Finally, presenting establishment of boundaries for forest co-management and development is analyzed to understand impacts of decentralization policy.

23.2 Brief Legal Framework of Decentralization Policy in Vietnam

The forestry policy of Vietnam has undergone major changes. It changed from state forestry to decentralized forestry management (Phuong 2008). The underlying state forestry regime has led to degradation of forest resources by commercial timber harvesting, illegal logging for agricultural land expansion.

The renovation policy (Doi Moi) implemented in 1986 to transform from a centrally-planned to a market-oriented economy created an economic liberalization for all socioeconomic sectors, including forestry sector. The Government decentralized rights and responsibilities for forest management to local levels. Hence, community-based forest management replaced state-managed mechanism of forestry organizations, such as state forest enterprise, forestry companies. Additionally, the local people are encouraged to transfer from shifting farming practices to fixed cultivation activities and plantation forest development through the legislation system.

Decentralization in Vietnam's forestry, under the Land Law and Forestry Law in 1991 and 1993, and their revised versions of 1993 and 2004, respectively, is expected to contribute to forestry development by transferring rights for institutions and local people; increasing local people's participation in decision-making; building capacity for institutional staff and local people; strengthening responsibilities, transparencies and accountabilities of the government in co-management regime. Thus, decentralization provides the legal framework of implementing sustainable forest management and development as well as poverty reduction strategies. By the laws, forests and forest land, consisting of protection and production forest, are partly allocated to different ownerships at local level. Households are given forests and forest land for planting. Village communities and groups of households are received natural forest for protection. While special-use forest is managed by National Park and Natural Reserve offices.

The characteristic of decentralization in Vietnam's forestry is that the government has been gradually developing policy documents, so-called forest land allocation. This detailed policy was constructed and updated through systems of law enforcement from central to local government and consultations with international donors. In 1994, the government performed the form of forest land allocation to organizations, households and individuals under Decree 02/CP. It is this experience that provided the base for decentralization. Change highlighted sentence to: In 1995, Decree 01/CP, regulated that state forest organizations ought to make a contract with local people for protecting the forest to meet the need of local people and to fulfill the purposes of the government. For purpose of giving full interests to local people, the government issued Decree 163/ND-CP in 1999, replaced Decree 02/CP, on allocation and lease of forests and forest land to organizations, households and individuals for long -term forestry purposes. Additional, in 2001, the government has promulgated detailed regulations of benefit sharing and the obligation of the beneficiary households and individuals under decisions 178/QD-TTg. Accordingly, the decentralization started a process that increased local democratic implementation and participation in decision-making of local people.

23.3 Methodology

This chapter analyses the results of a survey in the mountainous villages in Nam Dong district in the buffer zone of Bach Ma National Park to describe the process of decentralization at local level and participation of local people in the process. First of all, the research is based on a review of published literature, legal documents and project's documents as well as recommendation of local government authorities and project experts to identify the research areas. Next, the research used participatory method to collect data through key informant interviews, focus group discussions, and questionnaires. Focus group discussions were organized to identify previous activities of local population in forest use. Three case studies were done, each under different forms of forest management: household level in village 3, group of households in Doi village, and village community in Ta Ring village. Each case was investigated by means of personal interviews with local people practicing in forest decentralization process at the same policy framework. In addition, the research conducted a questionnaire survey of 90 randomly selected households. The research also organized two workshops at district level to present preliminary results of the field work as well as to obtain feedback from participants. The participants at the workshops were the representatives of local governments (from province to commune), state forest organizations and local people.

23.4 Research Setting

The buffer zone of Bach Ma National Park was established in 1991. It is located in Phu Loc and Nam Dong Districts of Thua Thien Hue Province and a part of Dong Giang district of Quang Nam province (Fig. 23.1). It includes 15 communes and towns and is a good example of a protected area in Central Vietnam. The average population density for this area as a whole is 159 people km^{-2}. In reality, the population density ranges from 790 people km^{-2} at its highest to 10 people km^{-2} at its lowest. The population in this area is over 75,000 people with annual growth at rates from 0.6 to 1.8 %. The population inside and outside the buffer zone has rapidly grown since the late 1970s due to migration of lowland people and resettlement of ethnic minorities, as two main groups occupy most of the land surrounding BMNP. There are four ethnic groups living within the buffer zone, including Kinh, Co Tu, Van Kieu, and Muong, but the Kinh (dominant majority of Vietnam) and Co Tu (ethnic minority) occupy almost all of the local population.

Most people in the buffer zone make a living from agriculture and forestry. For agriculture this includes animal husbandry and the cultivation of rice, maize, vegetables, industrial plants and trees, and other annual crops. With regard to forestry this includes plantation forests and forest protection activities.

Nam Dong district is a mountainous area of Thua Thien Hue province. It has an important location in the buffer zone with 65,194.6 ha of total natural area in which forest and forestland occupy 54,064.5 ha (82.92 %) (Table 23.1; Fig. 23.2)

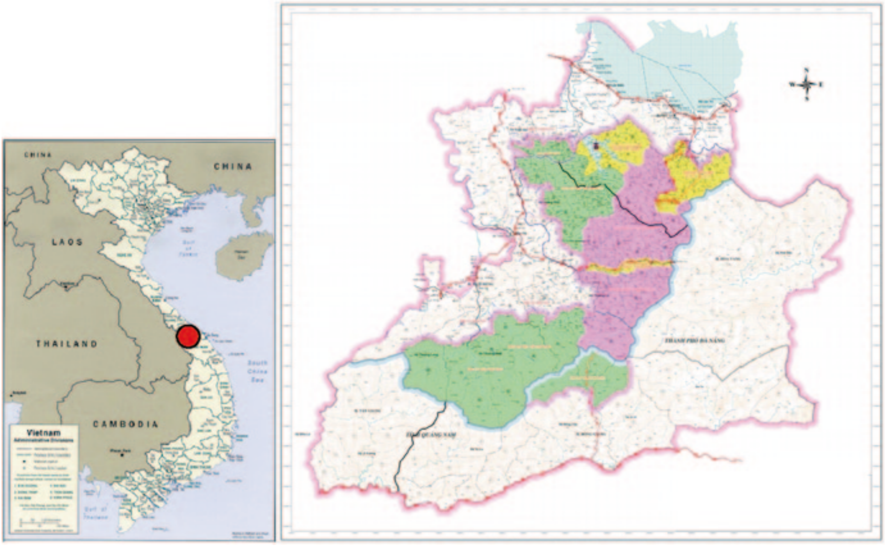


Fig. 23.1 Bach Ma National Park

Table 23.1 Forest and forest land management by actors in Nam Dong. (Source: Forest Land Allocation Report of Nam Dong DPC 2009)

TT	Forest land actors	Natural land area	Forest land area	Area (ha)			Other
				Natural forest	Plantation	Bare land	
1	Nam dong protection forest management board	17,599.40	16,057.10	14,954.40	404.10	698.60	1,542.30
2	Bach Ma national park	24,605.00	24,394,.50	21,624.80	167.30	2,602.40	210.50
3	District people's committee	22,990.20	13,612.90	8,601.91	3,411.34	1,599.65	9,377.30
	Household	3,824.94	3,768.04	350.70	3,407.34	10.00	56.90
	Village community	570.50	570.50	566.50	4.00		
	Household group	1,502.60	1,502.60	1,422.60		80.00	
	Non-allocation	17,092.16	7,771.76	6,262.11		1,809.65	9,320.40
	Total	65,194.60	54,064.50	45,181.11	3,982.74	4,900.65	11,130.1

A report from the district government in 2009 shows that near a quarter of district-managed forest land was allocated to households, group of households and village community. Of this land, there was 2,499.8 ha of natural forests, 3,407.34 ha of plantation forest land and 90 ha of bare land. The remaining forest

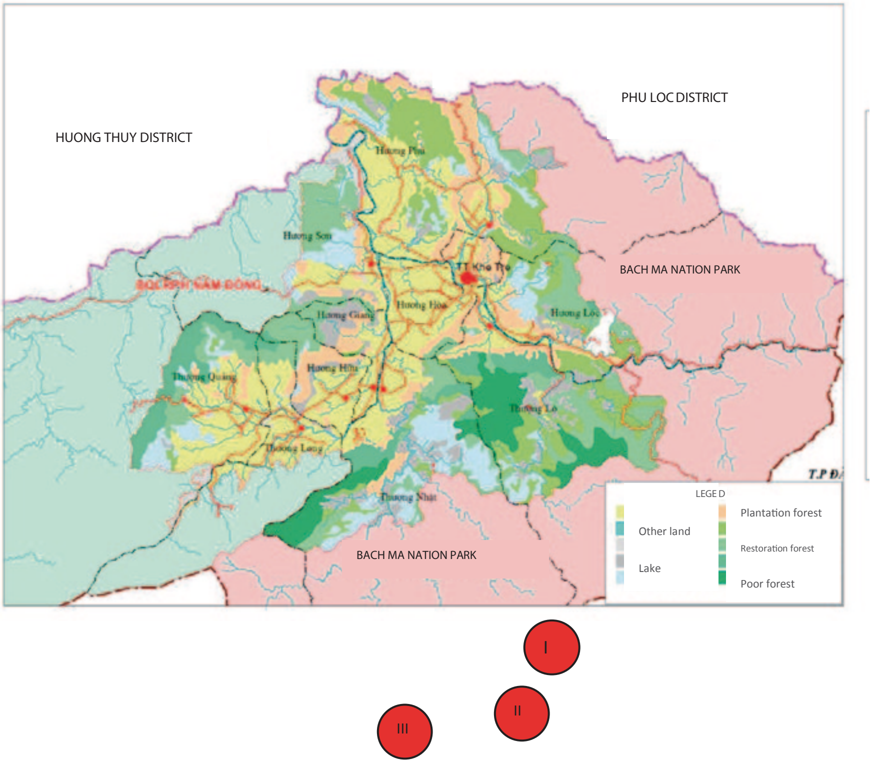


Fig. 23.2 Research sites

land area of 17,092.16 ha (74.3 %) is planned for continuing allocation in coming years.

In general, the land and forests in the buffer zone is managed by three main groups of forest owners, consisting of the State Forest Organizations (Bach Ma National Park, Protection Forest Management Board), Local Governments District and Commune People's Committe (or CPC), and local population (household, group of household and village community) (Fig. 23.2).

Village 3 (I) has been recognized after unification in 1975. The village is composed of 95 households and 405 inhabitants. Most of them are Kinh migrants from low-land areas. The allocation of natural forest to households was supported by the Dutch development organization (SNV[1]) in 2004. The allocation was based on

[1] SNV (Netherlands Development Organization) positions itself as a global organization of advisors in over 30 countries worldwide, with its original office in the Netherlands. SNV focuses on various themes, including health, education, energy, tourism, agriculture, water and sanitation, and forestry. With regard to forestry, the objective of SNV is to develop employment in forestry at the local level, amongst others by strengthening local people's access rights to forests (SNV 2008). In Vietnam, the focus of SNV is also clearly on the reduction of poverty at the local level, rather than

criteria that households should have enough labor forces to manage the forests. With the financial support of the SNV, the general land use planning activity with participation of the local people was carried out in the village. The objective of this method is improving more effective forest management, enhancing capacity of local authorities and encouraging the participation of local people. The main partner of SNV in implementing the project is the District Forest Protection Unit and a consultant team from the province. The district government plays an important role to select villages under recommendation of the consultant team. The natural forest was allocated to 29 households each receiving 146.4 ha.

Doi village (II) was officially established in 1974. This village has 127 households composed of 608 inhabitants, all Co Tu ethnic minority. About 23 poor households occupied 18.11 % of total village population. Doi village is located inside the buffer zone of BMNP. It is located about 1.5 km to the boundary of the Park area. In the past, shifting cultivation was traditionally practiced in this village. By funding of the Government, the allocation of natural forests to groups of households was a unique form for managing forests in this village. The decentralization of natural forest management was implemented in 2003 for improving forest quality, water source protection, food security, creating employment for local people, and socializing the forestry sector. The proposal of FLA had cooperated between the commune authority and District Forest Protection Unit to allocate a part of forest and forest land through Decree 02/CP to groups of households in Doi village. The household's group consists of several households living near one another in the village, about 6–7 households each. These groups are selected by almost all villagers at the village meeting after being registered in commune authority about forest-use demands. These groups are directly managed by CPC, therefore, they have to report results of forest management and protection to CPC directly.

Ta Ring Village (III) is located 10 km south of the district center, and was established in 1975. All people in this village are part of the Co Tu population group. In total, there are 74 households, including 27 households, classified as poor under government definition. The group of poor households mainly consists of newly established households, and old, ill and disabled people who lack labor capacity.

The allocation of 118.4 ha of natural forest to the entire village community was implemented by Helvetas[2] in 2006–2007 (Boxes 23.1–23.3). This village was selected for introducing the adapted Community Forestry Management (CFM) approach. This method combines indigenous knowledge of local people and external knowledge of consultants. Based on the agenda of the project, the working group and project consultants support the village in CFM development of forest management regula-

focusing mainly on the protection of forests. One of important consultant activities is to pursue in the Land Use Planning and Land Allocation project supporting forest land allocation. It is also important to notice that posing poverty reduction as the main objective might conflict with the forest protection interests of the government.

[2] Helvetas is a Swiss independent organization for development cooperation in 20 countries. The sectors Helvetas focuses on are infrastructure in rural areas; sustainable management of natural resources; education and society; and civil society and the state (Helvetas 2008). The forest land allocation method for community forestry management developed by Helvetas has partially been formalized in national law.

tions. The working group mobilizes policies and legal papers related to rights and responsibilities on forest protection as well as its implementation process. The village community forest management board and its members were selected by villagers and consultancy of forestry staff. The management board is responsible for managing the Forest Protection Teams (FPT), of each for about 5 to 7 members. The obligations of the FPT are to organize the patrol in their own forest areas and report their results to local authorities.

Box 23.1 The activities of FLA process at Ta Ring village

1. Establishing the working group in which Forest Protection Unit was a major partner of the Helvetas project
2. The working group did generally evaluate forest area to be allocated to the village
3. Organizing the meetings at the village and commune level to inform the plan of NFA, decide area of natural forest, and select forms of forest management and management board and members.
4. The WG informs policy papers as well as rights and responsibilities on forest protection and management to the villagers
5. ETSP project provides the training courses on laws, techniques of forest protection and management
6. Organized natural forest allocation in the field with representatives of local authorities and villagers
7. Set up the forest management plan and patrol in the forest by village forest management board and forest protection teams.
8. Completed allocation procedures
9. Getting forest land use certificate (Red Book)

Box 23.2 The natural forest allocation process in Doi village

1. The method of forest status inventory was implemented by the Provincial Department of Forest Inventory and Planning cooperated with FPU staff, CPC staff, village leaders and key farmers to survey current forest situation
2. The forest use planning
3. The the choice of allocation forms: A village meeting is organized to all villagers in order to inform allocation policies as well as analyze advantages and difficulties of forms of NFA
4. The allocation in the field: The proposal and form of NFA are approved by DPC and then they conducted allocation to household group in the field
5. The issuance of Red Book
6. The activities of post-allocation: organizing patrols in the forest, usually 2-3 times per month

Box 23.3 Steps of natural forest allocation process at village 3

1. Preparation of institutional establishment, secondary data collection
2. Announcement about forest policies to local people in the village meetings
3. Participatory planning for forest use and management; selection village forest management board and members (households)
4. Implementation of natural forest allocation in the field
5. Completion of natural forest allocation procedures for approval
6. Issuance of land use certificate
7. Stakeholder workshop at the commune

23.5 Results and Discussion

23.5.1 Customary and Legislation Law in Shaping Forestry Decentralization

Decentralization of forestry policies had become a widely known feature of forest governance (Agrawal and Ostrom 2008). As above introduced, decentralization, in forest and forest land management, was introduced in Vietnam in the early 1990s. Vietnam established the Forest Land Allocation (FLA) program. This program enabled the Government to allocate forest land to organizations, households and individuals for long-term (50 years) use in accordance with the uses stipulated. People were able to own formal rights to forest land (through so-called Red Books) and the main rationale was that decentralization would be the best way of managing and conserving forests. Farmers, who received forest land, were sometimes paid for protecting the forests and they were given subsidies for tree planting. However, it was still the Government which decided how the forests were going to be managed and used. The Government and other major stakeholders had a very "biological" focus. This "biological" focus, which has been propagated by many outside agents, did not pay sufficient attention to the local communities living in these forests. The Government mainly paid attention to conservation and biodiversity (McElwee 2001; Hardcastle 2002; Nguyen 2009; Sikor and Nguyen 2007).

Almost all forests and forest land were managed by state organizations in which local people have a seasonal contract to protect the forest. They can develop mix-crops in agriculture in the forest area. Other people received cash directly who participated in the protection activities for the forest. By this regime, households can reclaim as many forest land plots as possible, but these plots were legally belonging to their local government and should not be used by other villagers. For example, villagers in Doi village have average of 3–5 plots whilst villagers in Ta Ring village have from 5–7 plots. Non timber forest products (NTFPs) sites can be claimed by the ones who found it. Other people cannot make use of it, once it is marked by the new owner. Moreover, the expansion of the national park in 2008 has decreased the availability of forest plantation land. This has perhaps addressed competition and disputes that led to forest conflicts between local population and officials.

Additionally, forest resources under government management, forest and forest land are controlled by the government, are through state forest organizations. Administratively, the National Park Management Board is responsible for the management of Bach Ma National Park (BMNP) and the districts, communes, and State forest enterprise for the management of the buffer zone. Previously, almost all forests in the buffer zone, classifying two categories: production and protection, were managed by Khe Tre State Forest Enterprise (KTSFE). It performed tasks of logging, wood trading, reforestation and forest restoration in which commercial logging was the main duty. The enterprise also produced rules under which villagers were not allowed to cut trees within its territory. By 1994, nearly all forests have changed from forest exploitation to forest management. However, this circumstance was not implementing without problems. The SFE has not enough its staff to protect a large forest area. This led to a negotiation between KTSFE and local government, even villagers, on contract for forest protection and management. Indeed, a very significant forest management in the buffer zone is reformed through provision of protection functions. Local people are considered as contract-forest protectors to fulfill the regulation of forest protection. While BMNP officials are not involved in any decision-making in the buffer zone, it does collaborate with the districts and communes in the implementation of government development programs in order to reinforce the link between the park and buffer zone. These programs are what distinguish the buffer zone from other lands outside of the core area of the national park. In conversations with BMNP staff and representatives from district forestry, agricultural and land departments, it became apparent that the buffer zone is really a buffer zone in name only. There are no specific rules of resource use present in the area that distinguish it from areas outside the buffer zone. It is simply that in the area demarcated as the buffer zone, the park conducts outreach activities that are aimed at (1) getting local people to not enter the park illegally and (2) to diversify their livelihoods away from forest resources. By the contract, local people are restricted rights of access to forest resources, although all of them depend on these forests for providing subsistence goods such as land for shifting cultivation and animal grazing, NTFPs, firewood, and wood for building houses. In other words, under the contract for forest protection policy, they have formally lost control over forest. Thus, the benefits of local people under government management on forest resources are insufficient compared to other types of land use such as agriculture or shifting cultivation.

Forest management structure is adapted to enable a cooperative approach, so-called community-based forest management, combining customary law and legal law. Community-based management of forest resources is founded on the authority of local governments to set aside areas for forestry within their land territory. Such areas must be on common resources, i.e. natural forest land owned by the community as a whole. The government is responsible to allocate forest use rights to different target groups through forest land allocation. By the early 2000s, local people in the buffer zone received forestry land for long-term use not exceeding 50 years, with the exception of special-use forest which remains under the authority of provincial government and national park. For instance, natural forest has been allocated to groups of households in Doi village, to village communities in Ta Ring village and to households in village 3. Plantation forest land has been allocated to households. With this management regime, in reality, the government cannot control best forest without participation of local people. In contrary, community in forest management is ineffective without contribution of the state. Therefore, this model of forest management can meet the aims of the government and its population. On the one hand, the government tries to protect forest in order to archive goals of biodiversity conservation as well as economic development goals. On the other hand, local people expect to generate income sources for their subsistence. They always do diversity forest activities as main income generation.

23.5.2 Forest Land Allocation Process in Research Sites

In the buffer zone, the underlying three forms of land-use include special-use forests (national park and natural reserve), protection forest and production forest. Protection forest has been allocated to collectives (groups of households or village community), Production forest has been allocated to households (not exceeding 30 ha/household with an allocation time of 50 years) and state forestry organizations. Special-use forest is governed under the authority of the Government through management board of National Park or Natural Reserve.

The implementation of forest land allocation was initiated in the early 1990s with financial and technical assistance from international donors to improve the productivity of forest resources and sustainable development of forest-dependent villages. Three different projects are focused on forest land allocation: SNV, the national project and Helvetas project. With regard to forestry development, the objectives of all projects are to enhance access rights of local people to forest (SNV 2005, 2008), improvement of knowledge in sustainable forest management and community-based forest management (Helvetas 2005, 2006, 2007) or forest protection and poverty reduction. The projects gave local authorities and local people access to regulating forests, ensuring equitable benefits and solving village conflicts. They also provided finances for FLA implementation and skills improvement through special trainings and institutional linkages.

23.5.2.1 The Allocation of Forest Land for Production

The method of forest land allocation has been defined under legal papers of the Central government and adapted law papers of local governments (Table 23.2). The law defines forest land as "*a type of agricultural land category being identified as silviculture, forest regeneration, reforestation, timber, nurseries, forestry research*

Table 23.2 The process of forest land allocation at grass-root level by the government laws

Steps	Content	Activities
1	Preparation for coordination	Establishing the district function board, work group in the field (WG) and commune land registration committee (CLRC) Planning forest and forest land allocation by WG and CLRC Preparing relevant documents such as maps, legal papers, training materials, budgets, equipment Training on technical deployment, field survey, necessary procedures
2	Field survey, evaluation of current situation	Organizing the first village/commune meeting Interviewing household Field survey to build current situation map (field work) Desk studies
3	Land use planning and forest land allocation at commune level	Drafting land use plan based on field work database The second village meetings Official meeting at Commune People's Council Approval of land use plan at district level
4	Forest land allocation in the field	The third village/commune meeting The fourth village/commune meeting Conducting in the field
5	Assessment, approval submission of procedures, issuance of land use rights at the district level	Re-checking allocation procedures Submitted to approve the plan Approval and decision on the final land use plan
6	Set up cadastral documents, acceptance and award certificates of land use rights to households	Issuance of land use certificate
7	Post-allocation process	Evaluated process of forest land allocation Set up forest development plan Call for investment

and experimentation". Forest land does not necessarily mean the presence of forest cover. Forest land can be classified in natural forest as both protection and special-use forests where there is very poor forest cover. In the past, most forest land was managed under state forestry organizations. Local people illegally reclaimed forest by encroaching into state forest land to get additional land to enable the growth of various crops, including hill rice, corn and cassava.

The Land and Forest Law in 2003 and 2004 respectively defined allocation of forests and forest land, actually, as a general legal concept for forest and forest land.

> The State shall allocate and lease land and forest land for production to organizations, family households and individuals for use for the purpose of forestry production (article 75, the Land Law 2003) and … assign protection forests, natural production forests and planted production forests without the collection of forest use fees to households and individuals living therein and directly involved in forestry labor and … (article 24, 2004 the law on Forest Protection and Development)

According to survey results, the process of allocation of forest land for plantations that previously had been used by people for cultivation is mainly implemented by local authorities themselves. Forest land allocation to households is implemented in two main ways: firstly, if households do not have forest land yet, they have to register and get bare land. The area of land received is completely dependent on available land resources of the commune. Secondly, if households have land area without land use certificates (Red Book), they must apply for registration of land use rights.

In three research villages, the allocation process of plantation forest is supported by national programs and international donors. These programs support financial and technical conditions to measure forest land and issue land use rights. The program also provides training courses and forest extension services to develop plantation forests. In principle, the process of forest land allocation has to follow legal guidelines. Thus, the approach of forest land allocation is not much different in the research villages. However, according to the Forest Protection Unit, the allocation of forest plantation differs between Kinh and Co Tu people. For ethnic minorities, allocation is based on the real situation of land area use. It is said that people from the Co Tu minority group in the past cleared a lot of forest for shifting cultivation. People want to get Red Books for this land for their own relatives; they do not want to share it with others. Therefore, the areas of land are unequally divided among ethnic minority population in Doi and Ta Ring village. For Kinh people in Village 3, the working group in the field has a lottery system used to decide which area the people get, which enables the division into equal plots. It is thereby assumed that Kinh people did not use the land yet, or that people are prepared to divide the land they already used.

23.5.2.2 The Allocation of Natural Forest

The method of natural forest allocation process is basically similar to the process of forest land allocation. The District People's Committee (DPC) issues the decision of establishment of the groups which help DPC working in the field. They include working groups comprised of representatives of Sub-DARD, Sub-DONRE, FPU, CPC authority.

The next step of the process is an allocation planning that is prepared by CPC. The CPC has to develop forest use plan and also assess needs of local people on forest use. This plan then is submitted to DPC for approval. The working group suggested a village meeting to announce the plan of forest allocation activities. The working group and local people commented and agreed on the implementing plan. Next, they conducted inventory of forest resources to identify quality and species composition in the forest. The inventory results would be presented in the next village meeting for selecting the forest receiving forms. Then, they implement forest allocation in the field, and sign on the minutes before completing procedures to submit to DPC for issuance of forest use certificate.

The Land Law of 2003 and the Forest Protection and Development Law in 2004 defined a village community as a group of people living in a certain area under the common traditional culture, custom, regulation with capacities to manage forest and forest use demand. The forest areas that would be allocated to the community are being effectively managed, along with watershed protection and common benefits for the community.

The allocation of natural forest has been implemented by different approaches under the same policy framework. Natural forest was separately allocated to households, household groups and village communities for forestry development purposes. Natural forest was allocated under three different forms in research villages, allocating to household in Village 3, to group of household in Doi village, and to village community in Ta Ring village.

23.5.3 The Different Approaches in the Allocation Process

The different approaches in the decentralization process are often part of the related policy frame, in which central government agencies transfer rights and responsibilities to more localized institutions. Natural forests with three different identified forms of decentralization were allocated to households, groups of households and village community. There are two methods of natural forest allocation: conventional method and community-based forest management (CFM) method.

With respect to the conventional method, the households in village 3 had applied conventional method in forest management. Most of the process was implemented by external consultants with a small group of key farmers together. They supported local groups to conduct forest inventory and propose allocated forest areas. Following the agenda of the project, village leaders and key villagers received new rights and responsibilities related to the decentralization process. However, the selection process was often poorly executed because of inadequate internal monitoring and evaluation of all villagers. Therefore, this method did not receive much participation from local people.

The CFM method of decentralization concerns the relationship between village community and local government authorities. The community-based forest management method is based on a working group consisting of consultants and local people to implement forest inventory in the field. This method helps local people to understand the technique of forest measurement in practice through guidelines from consultants. The method combines customary institutions and government regulations can be implemented in the case of natural forest management in Ta Ring village. It is assumed that the government encourages local communities to create a new form of forest management.

23.5.4 Participation of Local People

The implementation of the allocation process of natural forest and forestry land in the research sites was different. In general, the methods on allocation of forest and forest land comprise three stages: planning, implementation, post-allocation management. The participation of people during the FLA process is efficient to protect and develop forests. In theory, the expectation of FLA that participation of local people will be encouraged in all steps of the process.

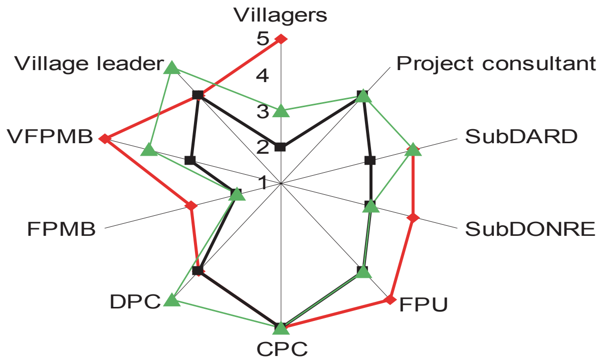
A ranking exercise had identified participation of stakeholders, even villagers by the differential methods in the entire process of forest land allocation. This exercise was conducted at three separate villages through focus group discussion method. Fifteen villagers in each village, including village leading and villagers, who have been participated during the process, were invited into the meetings for discussing participation of stakeholder involved in FLA process. The ranking score is from 1 (no participation) to 5 (highest participation). The results of this exercises showed that the decision-making in the process, such as forest use planning—implementation—post-allocated forest management, is different under different FLA methods.

Forest use planning is a key tool for the interaction between local people and local authorities. This approach has been introduced by SNV in village 3. On the one hand, forest use planning is to encourage the participation to forestry, by increasing decision-making rights at the village level. The people are invited to meetings at the village and commune levels. The working group and commune authorities inform the villagers about the objectives and opportunities of the approach. On the other hand, if the local people agree to receive forest and forest land, they can state their opinions in the decision-making process, consisting of forest use plans and forest land allocation forms. The plan has to be presented to the whole village for comments before submission to higher levels of government for approval.

The implementation of FLA is the transitional step of FLA process from the planning to post-allocated forest management. Forests and forestland are allocated to people in terms of differential forms as decision of previous meetings at the village and according to the plan. For the forest of village community and group of household, in principles, the working group and project staff create the participation of local people as much as possible. In fact, a few villagers and village group leaders were invited to work in the field. They are representative of village/group to receive forests from local government. The participants of village community or/and group of households in forest allocation process consist of village management board or/and group leaders, head of village and heads of neighbor villages.

In comparison with three villages in process of planning and implementation (Fig. 23.3), participation of villagers in Ta Ring village and village 3 was less than Doi's villagers. Participation of local people in these processes is restricted. A small group of villagers are the only ones participating. The remaining people have limited chances to voice their opinions on the provisions of the plan. Even though SNV and Helvetas agenda provided for participation of local people, neither one of the methods has been implemented in a very participatory way. However, many decisions have been taken at district level, without active participation options for villagers. Therefore, almost all processes of FLA are proposed by the working group, a small team consisting of representatives of Forest Protection Unit staff, local authorities and village population which conducts measurement activities in forest

Fig. 23.3 The participation in forest use planning and implementation



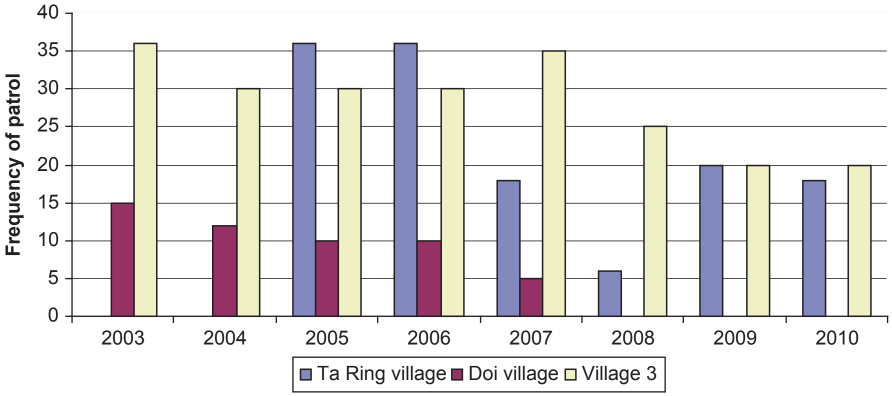


Fig. 23.4 Frequency of patrol in forested area

area by agenda of the project. Villagers did not have the ideas that they could influence propositions of the commune and district authorities.

Post-allocated *forest management:* Participation of local people in post-allocated forest management is performed through activities of forest patrol (Fig. 23.4). As the result of group discussion, although the forest has been allocated as a collective form in Ta Ring and Doi village, actually only key persons from the village or group is responsible for patrolling the forests, i.e. the members of management board in community forest or members among group of households. The patrols are conducted one to two times per month because of damage caused by outsiders. They were not provided with technical training in community forest development, depending largely on natural regeneration. There were limited funds available for forest protection activities that villages are not certain when they participate in forest protection and development. Thus, the villagers are not personally involved in patrolling the forests; rather they indirectly participate by signing the village regulation on forest protection. For example, the activities of allocated forest management by villagers decrease each year. Such forest patrols were actually limited in Doi village from 2008 whilst these activities are still being conducted in Ta Ring village and village 3.

From the analysis it appears that besides the villagers, the responsibility of the District People's Committee (DPC) and Commune People's Committee (CPC) in FLA process was the highest involvement by the project agenda. In fact, the DPC was not directly involved in implementation of the allocation. The chairman of the DPC just had the duty of signing the forest management land and the certification. The CPC is responsible for communicating guidelines from higher government levels to villages. The CPC also has a lot of power according to the participants, because they have told people how forest land allocation would be implemented, and they have steered the process in the village. The participants recognized that the DPC just has to make the final decision to issue the Red Book. The role of the Forest Protection Unit was much more important in FLA process. They have attended meetings and conducted regular visits to the village. The other stakeholder of the district agencies, including the district forestry and agricultural agencies were not actively involved in the meetings organized in the village.

With regard to external stakeholders, people are quite well aware of the role of different external stakeholders in the process as these have taken place at the local level. However, local people lack insight in the part of the process that takes place at higher levels of government. Furthermore, almost all the information that is provided about the forest land allocation process is coming from government agencies that are entitled with the task to promote forest land allocation in the villages. Villagers therefore sometimes do not have a realistic view about the power and interests of different stakeholders. This lack of insight might work in the disadvantage of the village, as in reality many decisions are taken at the district level.

The Forest Protection Unit (FPU) appeared to have a lot of power in decision-making in forest land allocation by SNV and Helvetas. As was concluded previously, the interests of the Forest Protection Unit in forest land allocation seem to conflict with the interests of local people. The mandate of the Forest Protection Unit is to secure the implementation of the Forest Protection and Development Law, instead of meeting the forest use needs of local people. With allocation under the pilot MARD program the role of the Forest Protection Unit has diminished, while the role of the Agriculture and Rural Development Office increased.

The village forest protection management board (VFPMB) is not directly involved in decision-making with regard to forest land allocation, but it is established as part of the process of forest land allocation to manage the allocated forest after allocation. Both in Ta Ring village and Doi village, the village forest management board was composed of leaders of mass organizations, which can be considered as the existing political village elite. The needs of marginalized groups therefore might not be represented well.

To sum up, the process of FLA in three villages has not taken place without some problems. The results of group discussion and individual interviews show that many households were not involved in this process. They therefore were not clear about the boundaries of forested area and the real situation of forest resources, especially cases in Ta Ring and Doi village. Like the Helvetas method, land use planning is not included in the method of the Government program. The method focuses on forest land allocation implementation and on post-allocated management whilst the method of SNV puts more attention on three basic periods of the whole process.

23.5.5 Establishment of Boundaries for Forest Co-management and Forest Development

A diversity of forest land institutional changes has transferred from contract mechanism for forest protection to decentralized forest and forest land management, ranging from state-owned forests to forest co-management. State forest enterprise had returned parts of their forest and forest land to allocate to local people.

Co-management in forest resources is one option for the benefist of involved stakeholders. This is necessary to establish different forest management systems based on capacity of both local people and local governments. This implies that the balance between benefits of local people and expectations of the State are not uniform because there are many limitations of management capacity, financial conditions, and especially local livelihoods. In this context, co-management will be successful if local people are partly supported by special mechanisms for forest development in both forest land and natural forest.

In the three research villages, FLA had significantly created the formal boundaries of local forests and state forests. The boundaries of forest between local and state have been identified as an informal traditional way. However, the boundaries of these villages were not recognized among neighboring villages without resource maps. Forest resources, therefore, were accessed free by local people as well as external villagers. By officially establishing the boundaries of forests, members of the forest protection team were allowed to enter the forest for NTFP collection as in Doi village. Most villagers in Ta Ring village could share forest products in village community forest area as collection of NTFPs and wood for housing with permission of local government. Meanwhile, households in Village 3 had exactly recognized their forest boundaries as owned property, and they used to harvest NTFPs and planted trees on bare land area.

Co-management in forest resource is defined after FLA, which also set up new rules to manage and use those resources. By these rules, the neighboring villages or villagers are not allowed to access the forest for any activities. Also, members among communities or groups of household are prohibited from shifting cultivation on forest land. Thus, households that are dependent on shifting cultivation are faced with problems of food security, especially ethnic minorities in Ta Ring and Doi villages. The forest boundary of households in Village 3 was significant, because they have the opportunity for planting acacia on bare land in natural forest area. However, villagers that were forest protection members could not prevent other villagers from encroaching upon remote forest land area for expanding crop fields in violation of protective rules. Furthermore, they did not have an obligation to protect forest areas outside their territory.

For forest plantations that are managed by households, either with or without a Red Book, generally, most of the plantations in research villages are acacia and rubber tree. Most of them are planted on the hilly and sloping land, as a buffer between the agricultural and flat resettlement area on one side and the natural forest on the other side. Some households also started planting acacia trees in their garden, although these gardens are a lot smaller than the plantations. Almost all households have plantation forest area. Based on local government statistic, the average of plantation forest area was around 1 to 2 ha per household. However, there is exception for Kinh people in Village 3, as few households have more than 30 hectares of plantation forest. Meanwhile, the ethnic minority people have a small plantation forest area.

The development of forest plantation began after FLA implementation with planting of acacia and rubber trees. The kick-off phase had raised concerns about incentives by the provision of seedlings and even finance by the government to local people, also carried out by forestry agencies, mainly Forest Protection Unit and SFE. During this period, a small local population expressed interest in planting acacia while many other households were still cultivating food crops. In general, one productive cycle of planting and harvesting of acacia takes between 6 and 7 years. Technically, the plantation forest is paid more attention for the first 3 years by taking care to combat tree thinning, grass clearing and branch cutting. The rubber tree is one of major planted products for livelihood of local people. Many plantation forest areas of acacia and shifting cultivation land had converted to rubbertree plantations.

Almost all households have plantation forest area, intercropped with agricultural species for food supplements in Ta Ring and Doi village. That is, ethnic minorities could not quit their traditional cultivation. In Village 3, around two thirds of the plantation forest is acacia species. The households are most able to access financial sources for the investments.

In general, the allocated natural forest is located on high slopes, as less steep forest land has been cleared for cultivation in the past. These forests are also used illegally by people from other villages. They are of poor quality, and therefore do not provide many forest products. People are only allowed to harvest wood for housing, but some people illegally cut wood. People are allowed to collect Non Timber Forest Products (NTFPs), but the forest is so poor that NTFPs are scarce. Most households in Ta Ring and Doi village were more likely to harvest NTFPs than households in Village 3. NTFPs were collected both inside and outside.

23.6 Conclusions

This chapter has analyzed the process of forest land allocation in three villages which are representative of forest land allocation policy in the buffer zone with the different methods from both the pilot of the national program and international project agendas. These cases also showed that forest land allocation had been implemented to improve forest management and plantation forest development through enhancing power for local people. Several related contents are used in this chapter for insight understanding from decentralization to co-management in forest and forest land: These are: (i) decentralization of government power, as combining customary law and legislation law to shape community-based forest management regime, to enhance role for local levels; (ii) process and participation of stakeholders, even local people, in policy implementation by providing different approaches; and (iii) recognizing use rights and boundaries of forest resources referred to cooperative management in forests through enhanced accountabilities of local people. Previous forestry policies focused on commercial timber production through state forest management regime. It did not therefore succeed to meet the increasing diversity of demands from local population. Therefore, the government produces decentralization policy for improving forest management and regarding sustainable use.

Decentralization cannot ensure that local people will receive more benefit and be more interested in forest management. For instance, the villagers in natural forest management are not allowed to cut tree down for trading. They must have permission from local authorities, if timber will be used for housing or/and common use in the community. With benefit sharing mechanism, the villagers have to access forest resources under the agreement between community and local authorities as Ta Ring village's case.

Opportunity for participation of villagers in practice was limited. The three case studies are introduced through participatory methods by international donors and national program. The local authorities and project's consultants make decision, such as location of forest and forms of forest allocation, for local villagers. Participation is restricted to those villagers, who are involved in the village meetings. Therefore, they lack of local representative at higher levels of government. It does seem to still implement top-down approach. Furthermore, monitoring and management of post-allocated forests and forest land are also lacking. The reasons that local communities are not yet interested in implementation included limited financial resources and inefficient transfer of powers. Although local communities have power, they are still limited and depend on the local governments.

The approaches of allocation create opportunities for local villagers to increase their participation for forest management. Different forest land allocation approaches as developed by international donor organizations have attempted to provide options for the participation of local people in natural forest land allocation, by providing government agencies with tools for the participation of local people, and by improving the implementation capacity of government agencies. The Helvetas and the Dutch development organization SNV has developed forest land allocation methods that amongst others have been applied in Ta Ring and village 3. Based on experiences with these approaches, the Ministry of Agriculture and Rural Development (MARD) has developed a new pilot program for community forest management in Doi village, which should secure the participation of local people. Involved government agencies argued that the forest land allocation method for community forest management as used by Helvetas is more participatory than the 'conventional method' used by SNV. The community forest management pilot program of

MARD, of which the objective is to form a legal basis for participatory community forest allocation and management, therefore has been based on the method used by Helvetas. However, it appears that SNV integrates participatory land use planning at commune level in the process of forest land allocation. Integrating options for participatory land use planning in forest land allocation is important, because in the land use planning stage it is decided that forest will be allocated to local people, and which area will be allocated. Helvetas and the pilot MARD program do not integrate land use planning at commune level into their methodologies; forest land allocation should be based on existing land use planning. On the other hand, Helvetas and the pilot MARD program integrate forest management after allocation, whereas this is less covered by the SNV method. Integrating forest management plans, and in particular the creation of forest protection systems, corresponds with the protection interests of the Vietnamese government, as this helps to ensure that the forest is protected well after allocation.

The success of co-management directly in the buffer zone also entails the full involvement and participation of local communities. However, the existing problem of the decentralization policy is that local people still access forest areas illegally. They can't recognize their responsibility on allocated forest area. For subsistence reasons, they often go to further forest areas. The co-management methods in forest management are still to give benefits to different stakeholders, so there must be a balance between the power of the state and benefits derived by local people.

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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. Additionally human behavior 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 million 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 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

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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; favorable 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.

In continuation to three international conferences held in 2009, 2011, and 2012, the fourth in the series has been planned in 2015 in Morocco, which will provide ample opportunities to international experts to share their recent works on the most important issue of climate change impact on agricultural production and food security.

Editors

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