

FARMERS' STRATEGIES FOR ADAPTING TO AND MITIGATING CLIMATE VARIABILITY AND CHANGE THROUGH AGROFORESTRY IN ETHIOPIA AND KENYA



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Editors: Caryn M. Davis, Bryan Bernart, and Aleksandra Dmitriev

Oregon State
UNIVERSITY

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Executive Summary

Climate change is real and happening in East African countries including Ethiopia and Kenya. Climate change is manifested in the recurrent drought, floods, and famine that have threatened millions of people and livestock in recent decades. Subsistence farming practices are the main livelihood for most people living in this region, which is characterized by degraded soils, small farm sizes, and low agriculture outputs. Agroforestry, which is an ecologically based traditional farming practice, integrates trees into the farming systems to increase agricultural productivity and ameliorate soil fertility, control erosion, conserve biodiversity, and diversify income for households and communities.

In early 2011, Oregon State University was invited by the World Agroforestry Center to renew institutional collaboration for student and faculty exchanges, exchange scientific information, and to collaborate in agroforestry research and outreach. As part of this initiative an Agroforestry synthesis paper was proposed on farmers' adaptation and mitigation to climate variability and change through agroforestry practices in Ethiopia and Kenya. The purpose of the synthesis paper was to document traditional and scientific knowledge on how farmers cope with climate variability and change. Four case studies were identified from highland farming and dryland pastoral systems in both Ethiopia and Kenya. The Gedeo Home garden from Ethiopia and Meru highland farming from Kenya were identified as good representatives of highland farming. The Afar pastoral system and Kibwezi district dryland farming from Kenya were identified as good representatives of dryland farming systems. The lead authors for each chapter were selected based on their experiences working in the case study areas, and are knowledgeable of the farming systems and constraints thereof.

The synthesis paper has helped us document information from the respective case study areas, including both the traditional ecological knowledge and the current agroforestry practices in the context of climate change. By no means is the information in this paper exhaustive, but it gives a better understanding of the situation currently faced by these countries. The paper suggests scaling up some of the already available agroforestry practices in these countries and identifying gaps in knowledge, which then point to what kinds of agroforestry research should be conducted to address climate change mitigation and adaptation in the future.

This paper has brought together scientists from various education and research institutions in Ethiopia and Kenya with expertise in agriculture, agroforestry, plant genetics, agroforestry, and economics and social sciences. This concourse has helped us understand the importance of interdisciplinary work to address complex natural resources management issues from ecological, economic and social issues. We hope this collaborative effort will continue beyond the literature synthesis and create opportunities for future collaboration in agroforestry education, research, outreach, and student and faculty exchange among the involved institutions.

Acknowledgements

I would like to thank the World Agroforestry Center (ICRAF) for providing funds through the USAID Linkage Project to initiate collaborative research, student and faculty exchange, and the exchange of scientific information between Oregon State University and the World Agroforestry Center. Special thanks go to Dr. August Temu, ICRAF Director of Partnership, for inviting OSU to work as its partner in promoting agroforestry education, research, and outreach. I would also like to thank Dr. Steven Sharrow and Dr. Ray William, both OSU professors Emeritus in agroforestry and horticulture, respectively, for reviewing the manuscript and providing valuable input and insight to improve it. My thanks go to Ms. Caryn Davis, Senior Editor, College of Forestry, OSU, for her continued and relentless efforts in reviewing this manuscript and getting it to where it is now.

Working together on this project has helped strengthen collaboration among partner institutions and build a stronger network among experts in agriculture and forestry, and between natural and social scientists in Ethiopia, Kenya, and the United States. This multi-institutional and multi-country collaboration should also contribute toward stronger global networking among other agroforestry educators and researchers working to improve livelihoods and build capacity in developing countries. It also provides an example for interdisciplinary work that is necessary for solving complex problems in the biophysical, economic, social, and ethical aspects of natural resources management.

Dr. Badege Bishaw, Oregon State University

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The 2003 maize crop in Arba Minch, Ethiopia, failed because of drought.

Chapter 1. Introduction

Dr. Badege Bishaw, Dr. Jeremias Mowo, Dr. Jonathan Muriuki, Dr. Habtemariam Kassa, and Dr. Henry Neufeldt

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2007c) includes increased evidence that current climate change is to a large extent due to human activity and that it will profoundly alter the living conditions for all humans, flora, fauna, and ecosystems. Climate change in Africa is already apparent in changing precipitation patterns and more frequent or erratic extreme weather events such as floods, droughts, and heat waves. These impacts may have diverse effects on forests and farming systems, including compositional and functional changes and changes in their capacity to provide ecosystem

functions, products, and services (Bodegom et al. 2009).

The average global surface temperature has warmed 0.80°C in the past century and 0.60°C in the past three decades. The IPCC has projected that if greenhouse gas (GHG) emissions, the leading cause of cli-

mate change, continue to rise, mean global temperatures will increase 1.4–5.8°C by the end of the 21st century (IPCC 2001 a,b).

Future GHG emissions will continue to rise as long as no effective mitigation policies are put into place. In order to stabilize global average

¹ When referring to the 2°C stabilization target, we refer to a global average temperature that is less than 2°C above pre-industrial levels (normally 1860). Considering that we are currently already nearly 0.8°C above that value and are committed to something in the order of another 0.6°C through past emissions that are not yet apparent due to considerable inertia of the global climate system, the temperature increase related to future emissions may not be higher than another 0.6°C over the course of this century.

² The chance of reaching the 2°C target falls with increasing greenhouse gas (GHG) concentrations in the atmosphere. The total concentration of GHGs can be expressed in terms of the radiative forcing (RF) of all gases as if it were caused by CO₂ alone (the so-called “CO₂-equivalent concentration,” CO₂e). The current net RF of the atmospheric components is surrounded by high uncertainty but probably similar to the current CO₂ concentration, i.e., 386 ppmv (IPCC 2007c).

temperatures at no more than 2°C above pre-industrial levels¹ with greater than 70% chance of success (Hare and Meinshausen 2006), current projections indicate that the total GHG concentration of the atmosphere must be stabilized at below 400 ppm_v

CO₂e.² Achieving such an ambitious target is technically feasible and economically viable, but will require forceful and internationally coordinated action in the next few years (Knopf et al. 2010). However, current emissions are at the upper end of all projections,

and continuation of such a “business-as-usual” trajectory would likely lead to 3-4°C above pre-industrial levels (Figures 1.1, 1.2).

These changes may prove especially devastating for developing countries that historically have been vulnerable to extreme climatic events such as droughts and floods. Increases in the frequency of these events are projected to negatively affect local crop production in regions such as eastern Africa, especially in the lowland and dry areas (IPCC 2007a). Overall agricultural productivity loss in Africa due to climate change is estimated to be between 17% and 28% as compared to 3% to 16% for the world as a whole (Cline, 2007).

The adverse effects of climate change are already evident in developing countries where population growth, lack of food security, and other socioeconomic factors exacerbate families’ vulnerability to impacts. At the same time, agricultural land is often scarce in these countries, leading to continued encroachment of crop farming on forests. The continued loss of forests makes people more vulnerable to the consequences of climate change—even as deforestation and other environmental degradation continue to contribute to the problem. The rapid population growth in many developing countries and the need to increase cultivated and grazing land to provide food override major environmental considerations.

The ability of smallholder farmers in developing countries to cope with the effects of climate change is impacted by limited capacity, few alternative sources of income, lack of expertise, and lack of appropriate public policies and financing. Moreover, there are very few studies on the economic and environmental impact of climate change on Ethiopian and Kenyan agriculture or on the farm-level adaptations that farmers may make to mitigate the potential impacts of climate change (Center for Environmental Economics and Policy in Africa [CEEPA] 2006). Accord-

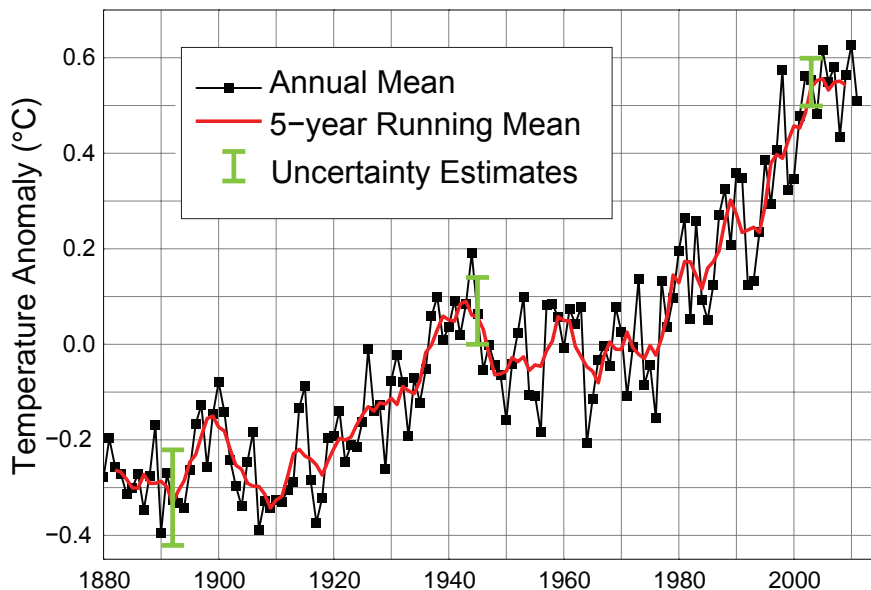


Figure 1.1 Global mean land-ocean temperature index, 1880 to present, with the base period 1951-1980. Source: GISS NASA (2012).

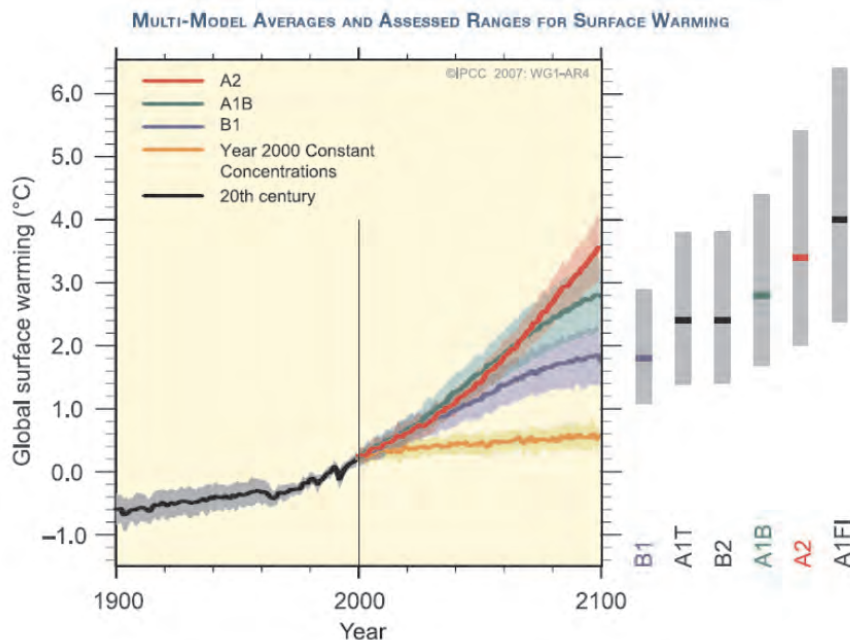


Figure 1.2 Solid lines are multi-model global averages of surface warming for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes ± 1 standard deviation range of individual model annual averages. The orange line shows the temperature evolution with year 2000 forcing held constant. The grey bars at the right indicate the best estimate (solid line) and the likely range assessed for six SRES marker scenarios. Source: IPCC 2007c.



Mixed-farming agroforestry system in Wondo Genet, Ethiopia.

ingly, little is known about how climate change may affect these countries' agriculture and forestry sectors. This lack of knowledge seriously limits policy formulation and decision making concerning adaptation and mitigation strategies.

To alleviate the threats from climate change and overall ecosystem degradation, research, education, and development strategies should provide mechanisms that will increase the resilience of both rural communities and the natural environment, while reducing vulnerability of both. These strategies should stipulate the rational development, management, and use of the many resources of developing countries in order to enhance their capacities to adapt to climate variability and change.

Key to strategies to improve natural resources management may be the use and expansion of agroforestry—an ecologically based, traditional farming system. In this document, we explore the potential of agroforestry to address climate change, food security, and livelihood challenges in Ethiopia and Kenya. We also investigate farmers' indigenous knowledge of crops, livestock, and trees, and how they are used in farmers' adaptive strategies in two contrasting agroecological zones in Ethiopia and Kenya.

This document is the product of a collaborative project aimed at strengthening institutional collaboration between the World Agroforestry Center (also known as the International Centre for Research in Agro-

forestry or ICRAF) and Oregon State University. As the project progressed, experts from other institutions were invited to collaborate. The final version of this document thus includes contributions by scientists from Wondo Genet College of Forestry and Natural Resources (WGCF-NR) of Hawassa University, the Ethiopian Institute of Biodiversity Conservation (IBC), and the Center for International Forestry Research (CIFOR), in addition to scientists from ICRAF and Oregon State University.

The overall goals of the collaborative engagement were to better understand the current status and to explore options for enhancing the resilience of these traditional farming systems in order to identify potential coping mechanisms for climate vari-



ability and change that use both indigenous and science-based knowledge. Our main objective was to synthesize the available information on how agroforestry contributes to helping farmers adapt to and mitigate the effects of climate change in Ethiopia and Kenya.

The specific objectives of the project were as follows:

- Review current knowledge of climate change and its impacts on the livelihoods of farmers and pastoralists in Ethiopia and Kenya
- Through four case studies, review how highland farmers

and lowland pastoralists in Ethiopia and Kenya manage their environment and cope with climate change

- Review the potential of existing agroforestry practices in crop and livestock farming systems to adapt to and mitigate climate change
- Discuss gaps in knowledge and identify potential agroforestry projects for adapting to and mitigating the effects of climate change

In the first six chapters of this document, we describe the rationale behind climate change adaptation and

mitigation strategies and outline the role agroforestry can play. We also briefly explore what is meant by adaptation and mitigation in relation to situations in Ethiopia and Kenya. We then outline the scope and impact of climate change on livelihoods of smallholder farmers and pastoralists in these countries.

Chapter 7 outlines the approach we took in examining the cases. The cases (chapters 8 through 11) discuss examples of possible agroforestry adoption sites and incorporate applicable information on local, regional, and global institutions and policies. Case studies drawn from highland farming, based on home gardens, and from pastoralist systems in the lowlands are used to show the potential of agroforestry practices in two agroecological zones. In Ethiopia, the Gedeo home gardens and the Afar pastoralist system represent the highland and dry farming systems, respectively. In Kenya, “evergreen agriculture” in Meru represents the highlands and Kibwezi represents the dryland areas.

In the final two chapters, we discuss lessons learned and knowledge gained through this partnership/project, and propose agroforestry practices that would be suitable for helping smallholder farmers adapt to and mitigate the effects of climate change on crop and livestock farming systems in Ethiopia and Kenya.



Chapter 2. Agriculture, Forestry, and Land Use in East Africa

Dr. Badege Bishaw, Dr. Jeremias Mowo, Dr. Habtemariam Kassa, and Dr. Jonathan Muriuki

For most countries in East Africa, small-scale agriculture is the main economic activity and source of livelihood for most people living in rural areas. Agricultural development is therefore likely to play a crucial role in the future development of this region. Strategies for this type of development must consider ways to help small-scale farmers cope with climate vulnerability. Climate variability and change is devastating for East African countries such as Ethiopia and Kenya, where smallholder farmers depend on rainfed agriculture. In 2011, for example, the worst drought in 60 years affected millions of people in Somalia, Ethiopia, and Kenya, causing widespread hunger. The Horn of

Africa region has a high rate of deforestation as well as severe land degradation. The agricultural sector in these areas is particularly vulnerable to adversities of weather, not only because farmers depend on rain, but also because farming is subsistence-oriented and is practiced with relatively basic technologies on small pieces of land. These smallholder farmers thus already operate under pressure from food insecurity, increased poverty, and water scarcity (Oxfam 2010, CEEPA 2006, Regassa et al. 2010).

A science-based approach to agricultural development is needed in order to increase crop and livestock production in this region (Ejeta 2011);

however, equally important is to consider the traditional ecological, economic, and socio-cultural knowledge of farmers. We argue that farmers, pastoralists, and agriculture and natural resources professionals should revisit their approach to agricultural development in East Africa. For centuries, farmers in the region have been farming and rearing livestock while coping with natural disasters such as drought and floods. Ethiopia and Kenya have rich biodiversity of fauna and flora and very diverse agroecology. The rich biodiversity and indigenous knowledge accumulated through the years should be used to identify coping mechanisms for climate change.



2.1 Background: Ethiopia

Prominent features of the Ethiopian topography are the extensive highlands, with their undulating plateaus and deep river gorges, and the Great Rift Valley, which divides the country into the central/western and southern/eastern highlands. Altitudes range from 110 m below sea level in the northern parts of the Ethiopian Rift Valley to more than 4,600 m in the Semien Mountains. Despite Ethiopia's proximity to the equator, the highlands enjoy a temperate climate, with a mean annual temperature rarely exceeding 20°C. The more sparsely populated lowlands have subtropical and tropical climates (Abebe and Abdelkadir 2010).

Climate variability in Ethiopia is not new. Its diverse agroecological zones are characterized by a dazzling variety of micro-climates and corresponding weather patterns. Over

centuries, its people have developed agricultural systems adapted to Ethiopia's diverse environment. However, the rapid pace of climate change, along with increasing socioeconomic pressures, threatens to overwhelm their ability to cope. Ethiopia is especially vulnerable to climate variability and change because large segments of the population are poor and depend on agricultural income, which is highly sensitive to rainfall variability. Most have low access to education, information, technology, and basic social and support services, and, as a result, have low adaptive capacity to deal with the consequences of climate variability and change (Oxfam 2010, The World Bank Group 2010, Regassa et al. 2010).

Agriculture provides the livelihoods for the great majority (83%) of the population in Ethiopia (Guillozet 2011). It is extremely important to the country's economy: in 2010–2011, the sector contributed 46% of the

country's gross domestic product (GDP). It generates over 80% of the export earnings and supplies around 73% of raw materials requirements of agro-based domestic industries (Central Statistical Agency 2011). It is also the major source of food production and hence the prime contributing sector to food security (CEEPA 2006, Deressa 2009).

Agriculture also plays a crucial role in the nation's economic development goals, as formally outlined in the government's Agricultural Development Led Industrialisation (ADLI), which highlights "the central position of agriculture in economic planning and prioritization and heighten[s] the significance of investments in the country's productive land base" (Guillozet 2011). The importance of this sector is also emphasized in subsequent major government documents, such as the Rural Development policy and strategy, and the current five-year Growth and Transformation Plan.

There have been significant efforts made to develop Ethiopian agriculture over the past 50 years. These include developing human capacity in agriculture, introducing high-input agricultural systems through the use of improved varieties of crops and fertilizer, improving livestock and animal husbandry practices, and increasing capacity for technology transfer. Yet despite these efforts, average yields for many crops remain relatively low, and Ethiopian agricultural productivity remains one of the lowest in the world (Gebre-Kidane 2011). Despite major productivity gains of a few crops over last 10 years, millions remain chronically food insecure, and Ethiopia continues to be seen as a country that is still unable to feed itself.

Some of the measures that were implemented with the hope of improving agricultural productivity in Ethiopia have inadvertently exacerbated existing problems of natural resources degradation. The recently issued strategy of the government toward building a green economy recognizes that the current agricultural development strategy is based on agricultural area expansion—and if the same path is followed, meeting food demands by 2030 would result in the clearance of millions of hectares of forests and woodlands. With the thrust to produce more food to feed the rapidly growing population using high-input and single-crop farming, today's farmers grow only one or two crops in monoculture systems. The traditional diversification of farmlands, which arguably has been the source of sustenance in rural Ethiopia since time immemorial, has largely been abandoned. The land-use system now is associated with a decrease in the size of holdings both for arable and grazing lands because of socioeconomic and environmental factors. This has in turn meant a continued trend toward the conversion of additional forested and marginal lands to agricultural lands, resulting in massive environmental degradation and seri-

ous threat to sustainable agriculture and forestry (Achalu and Negash 2006; Bishaw and Abdelkadir 2003). If not quickly and properly addressed, the combined problems of land and natural resource degradation and hunger, famine, and malnutrition present the greatest threat to the survival of the nation (Bishaw and Abdulkadir 2003). The low level of economic development, the high population growth rate (about 2.7% per annum), and heavy dependence on agriculture further compound these chronic problems (CSA 2011).

Climate variability coupled with the low agricultural productivity and the low technological and capital base of rural households makes the country particularly vulnerable to adverse effects of climate change. The severity of the impacts of such changes are expected to be more evident in the drylands of Ethiopia and will affect the poorest and most destitute segments of the population. With its vast swath of drylands and its already impoverished people, Ethiopia faces a gloomy future in terms of the negative effects of natural resource degradation, which include increasing moisture stress, declining soil fertility, and soil erosion, coupled with climate change. Without appropriate responses, climate change is likely to constrain economic development and poverty-reduction efforts and exacerbate already pressing difficulties.

Some authors have suggested that solutions to these multiple problems may be found by seeking traditional agricultural practices and incorporating them into new, science-based plans for agricultural development. Over generations, local people, especially those in the drylands, developed their own specific natural-resource management systems. These include mechanisms for coping with harsher local conditions, as well as more recent changes in the climate (Achalu and Negash 2006). Field studies conducted by Meze-Hausken (2004, p. 19) on contrasting climate variability and meteorological drought

in northern Ethiopia “showed that local authorities, farmers and pastoralists perceived regional climate to have changed during the last few decades. Farmers explained that they have been changing their farming strategies by shifting to more drought-resistant crops as well as to a shorter agricultural calendar.”

This type of traditional ecological knowledge, accumulated by farmers and pastoralists through generations in the region, should be tapped to help inform solutions for adapting to and coping with climate change. Understanding the impacts and vulnerabilities of local communities and ecosystems to climate variability and change as well as generating indigenous and science-based information for mitigation and adaptation options will enhance the adaptive capacity of local communities and help build a climate-resilient green economy in Ethiopia.

Recognizing the need for a sustainable agricultural and national development, Ethiopia in 2011 launched its strategy to build a climate-resilient green economy. This strategy focuses on forestry and agroforestry development and on improving agricultural productivity and energy efficiency. Currently, agriculture and forestry are the major source of GHG emissions from Ethiopia. If the current practices continue, GHG emissions would more than double, from 150 Mt CO₂e in 2010 to 400 Mt CO₂e in 2030. Of the 150 Mt CO₂e in 2010, agriculture and forestry respectively accounted for 50% and 37% of GHG emissions. This will also have a major consequence on the nation's natural resource base, as demand for agricultural and grazing lands will increase substantially. Projections in the strategy document also show that with the current path of development (“business as usual” scenario), an area of 9 million ha might be deforested between 2010 and 2030 for agricultural land. Over the same period, annual fuelwood consumption will rise by 65%, requiring more than

22 million tonnes of woody biomass, which in turn will further aggravate forest degradation.

Thus, under the current development path, GHG emissions will more than double—from 150 Mt CO₂e in 2010 to 400 Mt CO₂e in 2030. With the current agricultural development path, the country will face resource constraints—there will no more be land available to graze the cattle population and a significant percentage of the GDP might be consumed in importing fossil fuels (hence financial challenges). To address these grave issues, the country plans afforestation on 2 million ha and reforestation on 1 million ha, and will undertake forest management on 2 million ha of forests and 2 million ha of woodlands (FDRE 2011).

2.2 Background: Kenya

Kenya has seen high population growth since gaining independence from the British Empire in 1963. At 3.8%, the country had the highest population growth rate in the world from the 1980s to the early 1990s, due to a sustained improvement in

health care, which resulted in high and rising fertility, coupled with decreasing mortality. Although the population growth rate has now decreased to 2.7%, rapid growth over the last five decades has resulted in an overall population increase of 400% since 1963, with youth making up a large percentage of the population (Njonjo 2010).

The country's GDP draws mainly from the service sector at 60%, while agriculture contributes 24% and industry 17%. Tourism accounts for a huge proportion of the service sector and is among the leading sources of foreign exchange. Kenya's tourist assets are its wildlife, mostly accessible through a system of parks and reserves, extensive coastal sand beaches that are protected by coral reefs, and contrasting dramatic scenery, from deserts to tropical rain forests.

This sector is seriously threatened by climate change and by massive land degradation and deforestation, which has reduced the country's gazetted forests to less than 2% of the land area, down from 12% at the time of independence. Tourist attractions, such as Lake Nakuru (flamingo

sanctuary) and Maasai Mara (wildbeest migration), have been negatively impacted by this environmental degradation, as rivers emanating from the country's major water sources, notably Mau Forest escarpment, have diminished. The low-lying Kenyan coast is among the world's most vulnerable to sea level rise; it is estimated that about 17% of Mombasa (4,600 ha of land area) will be submerged with a sea level rise of only 0.3 m.

Agriculture remains central to the economy and the growth of the sector is positively correlated to growth in the overall economy (Figure 2.1). According to the Agricultural Sector Development Strategy (2009–2010), the sector contributes 24% of the country's GDP and employs 70% of the population in both basic production and industry (Government of Kenya 2009). The sector is also given priority under the economic pillar, one of the three growth pillars envisioned in Kenya Vision 2030, the road map by which the country hopes to arrive to at a newly industrialized status by the year 2030 (Government of Kenya 2007).

Growth in the agriculture sector is influenced by various biophysical, economic, social, and institutional factors that have defined both the propensity for and the magnitude of the risk under which agriculture is practiced. Only 16% of the land area has good agricultural potential (medium to high), as defined by continually receiving over 750 mm of rainfall per annum. The rest of the country is arid or semi-arid, with fragile ecosystems characterized by low and erratic rainfall (usually less than 650 mm), hot and dry weather with high potential evapotranspiration, and soils of low and variable fertility and texture. Although agricultural practices differ in the two agro-climatic contexts of the country, the majority of the population practices subsistence agriculture and is vulnerable to shocks due to the lack of adequate moisture



(Irungu et al. 2009). Although the areas of medium- to high potential make up less than 20% of the land area, they are occupied by 80% of the population.

Land fragmentation to less than 0.4 ha per household, coupled with continuous cropping of the same plots of land, define agriculture in these areas. Low soil fertility due to erosion and the loss of soil nutrients has ensured that yields average about 1.3 metric tonnes per ha for maize, the staple food of the country. A sharp increase in agricultural inputs, especially fertilizer, around 2008 has significantly increased production costs, which in turn has increased levels of poverty. Population growth rates are still high, leading to the loss of forest lands as adjacent communities push the agricultural frontier farther into the forests, and while other farmers migrate to the marginal areas. These practices, coupled with climate change, have resulted in devastating changes to areas of high potential for agriculture, including the drying of rivers and increased frequency of droughts and flooding due to irregular, unpredictable and at times more intense rainfall. This variability not only affects the production of staple foods such as maize, but also reduces export-earning crops such as tea and coffee, thereby further increasing farmers' vulnerability, as well as reducing the country's balance of payments.

The arid and semi-arid lands (ASALs), previously characterized by high biodiversity based on natural regeneration, support over 70% of the livestock population in Kenya (Doti 2010). Overstocking and the breakdown of customary resource conservation practices, however, have resulted in serious land degradation and scarcity of pasture. Additionally, high levels of charcoal production have reduced the tree population in these areas, while efforts to promote tree planting—that have mainly focused on exotic species—have reduced the resilience of these ecosystems. The

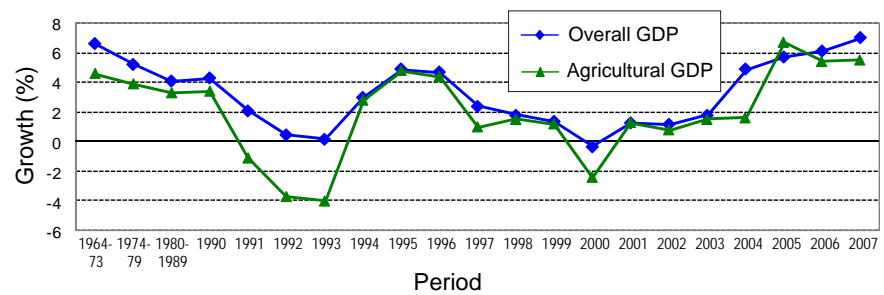


Figure 2.1 Economic and agricultural growth rates in Kenya, 1964-2006. Source: Gitau et al. (2009).

frequency of droughts has increased from the previous known cycle of about 10 years to far shorter intervals: the country experienced drought in 2005, 2009, 2011, and 2012, with the 2012 drought considered the worst in 60 years. Livestock deaths occur frequently and on a large scale, and government efforts to destock ASALs to sustainable levels have been largely unsuccessful.

Government and private sector responses to drought and vulnerability in ASALs have largely been *ex post facto*, meaning that communities remain vulnerable to climatic shocks. Some government initiatives do have the potential to increase food security and agricultural production in arid

and semi-arid regions, however, if they are well implemented and up-scaling is supported (Irungu et al. 2009). Examples include emergency seed support, the Hunger Safety Net Programme (HSNP), and the Njaa Marufuku Kenya (NMK) Programme to eradicate hunger in Kenya.

Agriculture in Kenya is mainly rainfed and is practiced by smallholders, who have noticed changes in weather patterns and have employed various coping mechanisms (Macharia et al. 2010; Kuria 2009). These farmers have poor access to technical or financial supporting mechanisms, however, and they lack the capacity to strategically confront future challenges. Therefore, they need support





to help them understand the reasons why they are affected and to recognize their own past and current mistakes (AdapCC 2010). Some practices that farmers are adopting to cope with climate change include diversifying both crops and farming practices, such as the adoption of fish farming, kitchen gardening, hay stacking, and bio-intensive agriculture (Participatory Ecological Land Use Management Association Kenya [PELUM-K] 2010). Farmers are supported in these and other practices, such as tree planting in both communal and private landholdings, by government ministries, private sector initiatives, and many non-governmental organizations. Mutimba et al. (2010) as well as Ochieng and Nakoloo (undated) have profiled some of these supportive initiatives.

At the policy level, the NCCRS (Government of Kenya 2010b) recommends a number of interventions to help adapt to and mitigate the impacts of climate change. Investment in early warning systems as well as in the construction of water harvesting dams and food storage facilities is proposed. Agricultural practice options include the promotion of underutilized crops that are drought- and salt tolerant and pest- and disease resistant, such as millet and cassava, as well as the protection of the natural resource base through soil and water conservation efforts such as the promotion of conservation agriculture (National Environment Management Authority [NEMA] 2007). The Kenya Agricultural Research Institute (KARI) has established a specialized climate change unit to

deal with the emerging challenges in order to intensify research and develop both mitigation and adaptation strategies. Seeds of drought-tolerant crop varieties are being produced and promoted by KARI's seed unit, while studies are underway on improving the productivity of livestock such as camels, indigenous chickens, small ruminants, bees, and guinea fowl (WREN Media 2010).

Other proposals aimed at reducing the vulnerability of farmers and pastoralists include developing special livestock insurance plans, the breeding of animals that adapt well to climatic vagaries, regular vaccination campaigns, and the promotion of economic livelihood diversification especially by pastoralists (Government of Kenya 2010b). Two innovative insurance projects are underway (WREN Media 2010): Kilimo Salama ("safe farming" in Swahili) is an insurance plan that protects farmers' investments in seeds, fertilizers, and other inputs. Piloted in 2009, the plan pays when experts monitoring local weather conditions and rainfall determine that crops have died. The other pilot insurance plan involves using satellite images of vegetation in northern Kenya to determine when pasture has become so scarce that animals are likely to perish, triggering automatic payments to insured livestock keepers. Several pastoralist communities have also adopted crop cultivation or have deepened relationships with farming communities to facilitate the exchange of goods as a coping strategy (Doti 2010).



Chapter 3. Adaptation and Smallholder Farmers

Dr. Kathleen Guillozet and Dr. Henry Neufeldt

This section provides an overview of the challenges and opportunities associated with climate change adaptation, particularly in relation to smallholder farmers. It briefly describes current adaptation strategies employed in Ethiopia and Kenya, and explains policy processes surrounding their development.

3.1 Adaptation

3.1.1 What is meant by adaptation?

Ambiguity over commonly used terms such as vulnerability and adaptive capacity presents a growing communications challenge in discussions related to climate change (Adger 2006; Hinkel 2011). Definitions of adaptation vary from institution to institution,

with distinctions often attributed to political differences and negotiations-related concerns (Levina and Tirpak 2006). In this document, we use the United Nations Framework Convention on Climate Change (UNFCCC) definition, which describes adaptation as the “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates, harm or exploits beneficial opportunities” (UNFCCC 2011).

3.1.2 Climate change adaptation and smallholder farmers

Adaptation is central to many proposed strategies for reducing the negative impacts of climate change. Adaptive capacity building is increas-

ingly embraced by governments and other institutions as a means to improve economic and ecological resilience. Policymakers draw linkages between a country’s financial, human, and institutional capital and its adaptive capacity (Roberts et al. 2009). Evidence from available studies indicates that high income nations are most likely to adapt, the most vulnerable are least likely to adapt, and proactive adaptation is often government driven (Berrang-Ford et al. 2011). The task of distinguishing climate change impacts from economic ones is tremendously challenging, leading to calls for the mainstreaming of climate adaptation in development (Conway and Schipper 2011).

Factors commonly cited as exacerbating household vulnerability in

Ethiopia include drought, commodity price fluctuation, crop pests, and death and illness of family members (Calvo and Dercon 2005). Investigations by social scientists and others into the efficacy of rural development programs have led to a gradual expansion in the types of factors considered relevant to household vulnerability. Although livelihood interventions tend to focus on micro-level aspects of household economies, there are increasing calls to also include “knowledge, politics, scale and dynamics” (Scoones 2009, p. 190), thereby situating land use and livelihood change as the outcome of social relations (McCusker and Carr 2006). Collectively, Sub-Saharan Africa is responsible for just 5 percent of global GHG emissions (Bryan et al. 2008). Given this relatively small contribution to climate change, adaptation and mitigation measures should be presented and implemented in ways that do not place undue blame on smallholders or obscure causal factors, such as economic and political marginalization (Ribot 2011).

Smallholder farmers are targeted for adaptive capacity-building programs because of the central position of agriculture in the economies of many developing countries. In Africa, an estimated 65 percent of people are engaged in agricultural livelihoods, the vast majority of which are small scale (International Food Policy Research Institute [IFPRI] 2004). The high dependence of farmers on non-irrigated agriculture makes them especially vulnerable to the harmful effects of climate change. Collectively, smallholder farmers are a powerful agent of land-use change; adaptive responses that yield beneficial impacts may also lead to enhanced landscape-scale resiliency. Three key features of an “adaptability and resiliency framework” developed by Fraser (2007) include agro-ecosystem robustness, availability of alternative livelihoods, and adequate institutional support. Many adaptation interventions targeted at smallholder farmers

focus on developing agro-ecosystem robustness through the implementation of conservation measures and the provision of services to enhance agricultural productivity.

3.1.3 Challenges and opportunities

Policy analysts, social scientists and development experts have expressed concerns over inequity and the presence of complicating factors with respect to climate change adaptation (see, for example, Mearns and Norton 2010). Gender experts fear that climate change will exacerbate existing inequalities because adaptive capacities are linked to things that women already lack, such as access to and control over money, technology, education, information, and land (Demetriades and Esplen 2010). Hidden costs associated with adaptation may have disparate impacts within families and may not be reflected in typical measures such as agricultural yields or incomes (Roncoli 2006). People who are already disadvantaged through socio-political and economic exclusion will likely feel the deleterious impacts of climate change most acutely (Ribot 2010). This may necessitate a needs-driven rather than opportunistic approach to funding (Parks and Roberts 2010).

Mitigation projects that restrict access to land may limit livelihood opportunities and adaptive capacities (Roshetko et al. 2007). Approaches that help farmers adapt to climate change in one aspect of their livelihoods can undermine another. For example, adaptation policies that encourage farmers to graze livestock near streams during periods of drought (Table 3.1, line 19) may degrade riparian vegetation and contribute to stream-bank erosion, with consequences for water quality and availability. Adaptation should therefore be approached as a value-based decision-making process with associated costs and tradeoffs.

The IPCC Working Group on Impacts, Adaptation and Vulnerability

describes the need for “no regret” policies¹ which bring benefits to communities irrespective of climate change. Still, it can be difficult to predict or account for the multiple interacting factors that may shape the outcomes of such strategies. The effects of policies associated with trade globalization, such as the elimination of price protections for staple commodities, may counter the positive impacts of adaptation strategies that increase production (O’Brien and Leichenko 2000). Some argue that globalization will likely continue to contribute to the erosion of subsistence economies, as well as to the growing disinterest of youth in traditional lifestyles through developments that also bring benefits, such as infrastructure expansion, media exposure, and land-tenure change (Roberts et al. 2009). Weighing competing benefits in the context of changing social and cultural circumstances is a difficult undertaking. One study demonstrated that, while climate change will likely yield higher net food production in Ethiopia, population growth and weak purchasing power associated with slow GDP growth may offset the positive food security impacts of production increases (Liu et al. 2008); this highlights the complex nature of uncertainties inherent to livelihood interventions.

Some question the legitimacy of adaptation and mitigation programs that are administered by institutions that also invest heavily in technologies known to accelerate climate change. For example, while The World Bank has led efforts to strengthen markets for global emissions reduction (The World Bank 2010a) and maintains a principal voice in funding allocation and priority setting related to adaptation (e.g., The World Bank 2010b), the World Bank Group’s investment portfolio in the fossil fuel industry reached

¹ A “no regrets” policy is defined as one that “would generate net social and/or economic benefits irrespective of whether or not anthropogenic climate change occurs” (IPCC 2007d).

Table 3.1 Adaptation activities at different levels, as described in Ethiopia and Kenya's National Adaptation Programs of Action and Poverty Reduction Strategy Papers (adapted from Nzuma et al. 2010).

Level	Adaptation strategies already adopted or planned for adoption	Ethiopia	Kenya
Household	Changing eating behavior by reducing number of meals per day, rationing food, and consuming wild food		
	Conserving soil by building infiltration ditches around homes, planting grass cover, terrace farming, trenching, mulching, and tree planting		
	Growing crops most sensitive to fungal diseases during seasons with low rainfall, or even during dry seasons		
	Growing soybean, yams, and sunflowers; market gardening		
	Moving herds along the rivers to find better fodder during drought		X
	Reducing overall livestock numbers by sale or slaughter		X
	Safeguarding certain local species by incorporating them in agroforestry		
Integrated	Cross-breeding, zero-grazing, and keeping smaller livestock		X
	Adopting traditional methods of conserving natural forests		
	Conserving genetic resources		
	Delimiting protected areas to avoid clearing through encroachment		X
	Developing and promoting guidelines for herbal and alternative medicine		X
	Harvesting rainwater using small check dams, irrigation	X	X
	Inaugurating community-based natural resource management programs		X
National	Developing and promoting drought-tolerant, early-maturing crops	X	X
	Adopting Integrated Disease Surveillance Response systems and emergency preparedness	X	
	Enforcing laws and regulations to protect and prevent pollution and ensure local factories are environmentally friendly	X	
	Exploiting renewable energy sources, such as solar- and hydropower	X	X
	Increasing agriculture extension activities		
	Instituting national conservation and restoration of vegetative cover of degraded and mountain areas	X	
	Introducing preventive measures to restrict malaria transmission such as mosquito nets, treatment/drying up of breeding sites		X
	Launching environmentally sound investment and other programs that foster CDM funding, including emissions trading	X	
	Promoting and strengthening aquaculture, poultry raising, and the like as alternative livelihood options		X
	Promoting value-addition, storage, and postharvest techniques for agricultural products		
	Protecting the seashore by building barrier walls and using integrated coastal management		
	Strengthening meteorological services to provide timely weather and climate information early-warning systems		

its highest levels on record in 2010 (Mainhardt-Gibbs 2010).

Adaptation is “deeply and complexly linked with economic and social development paths and stresses” (Wilbanks and Kates 2010, p. 727). Studies reveal high variability in the exposure of farmers to extreme climate events and in their responses to those events, even when demographic characteristics are similar, indicating that policy makers should avoid overly prescriptive approaches (Roncoli 2006). The relative ease with which farmers will be able to adapt will vary from place to place, based on local ecological conditions, information access, capacities to interpret changes, and technology and investment-related concerns such as path dependence (Chhetri et al. 2010). Strategies found to be successful in one context may not be in another, necessitating flexible, location-specific programs (Barnett and O’Neill 2010). Approaches that are grounded in local socio-cultural circumstances, move beyond knowledge transfer, and acknowledge institutional and economic constraints have the potential to enhance the livelihoods of millions of smallholder farmers. Climate change will increase stressors in many parts of the world, but may also catalyze needed financing for reforms and investments that could lead to greater livelihood security for smallholder farmers.

3.1.4 Adaptation at national and household levels in Ethiopia and Kenya

Adaptation will occur irrespective of planning and funding, as people and institutions adjust to ecological, po-

litical, social, and economic conditions shaped by climate change. National institutions play a central role in strengthening adaptive capacities through their role assessing risks and vulnerabilities, prioritizing actions, coordinating responses, and managing information. Initial processes for guiding formally driven adaptation programs have already been outlined in the UNFCCC. One component of these is the National Adaptation Programs of Action (NAPA). NAPA formulation occurs through a process that engages country experts in the development of a ranked list of priority adaptation activities and projects that are integrated into Poverty Reduction Strategy Papers (PRSPs). These documents identify urgent and immediate activities for coping with climate change and are presented to the international donor community for support. Their purpose is to provide a process for developing countries to identify priority needs in terms of climate change adaptation and solicit funding for implementation. The process of NAPA development is often funded through grants from the World Bank’s Global Environment Facility (GEF).

Table 3.1 describes adaptation activities that are occurring or are planned for adoption in Ethiopia and Kenya. These strategies were compiled by Nzuma et al. (2010) from a regional assessment of NAPAs and PRSPs. We associate strategies with different levels: household, integrated and national. These levels exist on a spectrum, and are often highly interdependent. This document focuses on farmer adaptation to climate change (reflected at the household level in table 3.1), but we recognize

that many strategies for increasing adaptive capacity, such as improved farmer access to extension services, development of drought-resistant crop varieties and strengthened early warning systems, typically rely upon national-level action or integrated approaches that involve cooperation among farmers and higher level institutions. An assessment of these factors is beyond the scope of this project; but see Dixit et al. (2012) for a comprehensive approach to assessing institutional aspects of national-level adaptation capacity.

Many of the activities listed in Table 3.1 are familiar rural development strategies that require coordination at multiple scales. Higher-level actors will need to assist in the coordination of input delivery, as in the introduction of improved seeds and livestock. The delimiting of protected areas and enforcement of laws will depend largely on institutions. The promotion of traditional ecological knowledge is reflected in a number of activities and can be considered a “tried and true” adaptation strategy. Disease-surveillance systems and emissions-trading programs will require external funding and technical coordination. Adaptation strategies geared towards smallholder farmers require the cooperation and dedication of local, regional, national, and global actors in order to succeed. Other strategies, such as meal reduction and livestock grazing near streams describe coping mechanisms that deplete other types of capital (i.e. meal reduction conserves financial capital while depleting human capital, and livestock grazing in riparian areas conserves financial capital while depleting natural capital).



Chapter 4. Mitigation of Climate Change in Africa

Cheikh Mbow and Henry Neufeldt

On the African continent, while adaptation to climate change is seen by most observers as the most preeminent issue, there is a strong parallel development of initiatives that aim to contribute to mitigation in connection with adaptation needs (Muys et al. 2009). Many mitigation options will also provide adaptation benefits and several adaptation strategies can lower the release of GHG into the atmosphere. The question is how to balance between the two considerations in an African context, i.e., according to their development priorities

vis-à-vis their responsibilities as part of the UNFCCC.

The relationship between land use and climate change is bidirectional, with feedbacks that either enhance or reduce a landscape's climate sensitivity. Although agriculture and forestry are vulnerable to climate change and will be strongly hit by climate impacts, these sectors also contribute strongly to the emission of GHG. Figure 4.1 shows that CO₂e concentrations have been increasing over the past decades and that CO₂ emissions, mainly from fossil fuels

and deforestation, contribute to over three-quarters of all emissions. Methane and nitrous oxide (N₂O) together are responsible for most of the remaining radiative forcing. Globally, the agriculture and forest sectors combined contribute about 30% of the total emissions (Figure 4.1). In Africa, the land-use sector is the biggest contributor to GHG emissions (about 20% of the total global emission of GHG).

The main sectors and gases contributing to the changing climate through “anthropogenic” GHG are

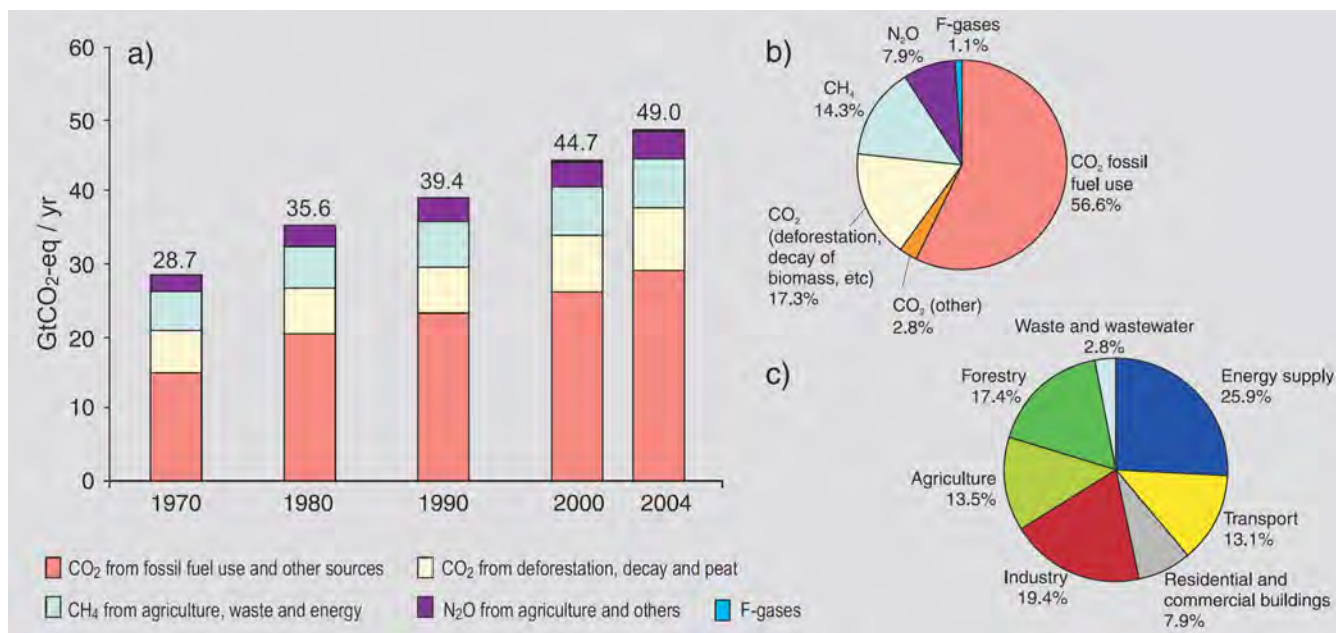


Figure 4.1 Global anthropogenic greenhouse gas emissions. (a) Global annual emissions of anthropogenic GHGs from 1970 to 2004. (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of carbon dioxide equivalents (CO₂e). (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO₂e (forestry includes deforestation). Source: IPCC (2007).

depicted in Figure 4.1. It shows that CO₂e concentrations have been increasing over the past decades and that CO₂ emissions, mainly from fossil fuels and deforestation, contribute to over three quarters of all emissions. Methane and nitrous oxide (N₂O) together are responsible for most of the remaining radiative forcing. Although the majority of emissions are produced from energy supply, industry, transport, and buildings, agriculture and forestry (including land use change) together add up to over 30% of current emissions.

Within the agriculture, forestry and land use (AFOLU) sectors, major emissions occur through the clearing of forests for other land uses, use of nitrogen-based fertilizers, senescence of peat soils used for agriculture, topsoil degradation and erosion, methane emissions from livestock, and rice production, as well as energy-related emissions such as irrigation, heating, fertilizer production and feed. Due to strong drivers like population growth, a rising share of animal products in the diet and continued demand for forest products, the emissions from land-use based sectors

will continue to rise in a business-as-usual scenario.

4.1 Mitigation

Mitigation therefore relies mainly on tackling GHG emissions from the land use sector. There are a number of possibilities within the AFOLU sectors for reducing carbon emissions. Agricultural and forested lands are believed to be a major potential sink and could absorb large quantities of carbon if trees are maintained or reintroduced to these systems and judiciously managed, together with crops and/or animals. This chapter briefly describes the mitigation options related to land use, forestry, and agriculture, and the challenges that arise for Africa.

Appropriate activities related to agriculture, forestry and other land uses (AFOLU) can help reduce GHG concentrations in the atmosphere by increasing biotic carbon storage, decreasing GHG emissions from operations, and producing biomass as a substitute for fossil fuels (Bloomfield and Pearson 2000). Potential activities include reducing deforestation,

increasing forest cover and agroforestry, improving forest and agricultural land management and producing sustainable renewable energy.

4.2 Agriculture, Forestry and Land Use (AFOLU)

It is generally agreed that a post-2012¹ land use, land-use change and forestry (LULUCF) agreement should aim to reduce emissions from land-use change (including reducing emissions from deforestation and forest degradation in developing countries, REDD+) and enhance carbon reservoirs. Mitigation strategies in the forest sector fall under two main areas, the maintenance of stored carbon through REDD+ and the sequestration of carbon from the atmosphere

1. In December 2012, the Kyoto Protocol (United Nations Framework Convention on Climate Change 2007) was slated to come to an end, and was expected to be followed by a post-Kyoto agreement that would enter into force in 2015. Instead, however, an agreement was reached to extend the Kyoto Protocol to 2020, with 2015 set as the target date for the development of a successor document, which is to be implemented from 2020.

through afforestation, reforestation, and restoration (A/R). Both REDD+ and A/R activities can be either funded through the compliance markets or the voluntary over-the-counter (OTC) market. According to Diaz et al. (2011), over 90% of forest-related mitigation is currently reported under the voluntary market because the available standards—e.g., Verified Carbon Standard (VCS), Plan Vivo, Brazil Mata Viva, Forest Carbon Standard International, Carbonfix, etc.—offer greater flexibility than the regulated market instruments that cover land use sectors, Clean Development Mechanism (CDM), NSW Greenhouse Gas Reduction Scheme (NSW GGAS), and the New Zealand Emissions Trading Scheme (NZ ETS). It is not clear how the development of the REDD+ mechanism will interact with LULUCF, but it is possible that REDD+ will include afforestation and reforestation activities in an all-encompassing mechanism (called REDD++ or AFOLU). However, for the purposes of this report, afforestation and reforestation are treated separately from REDD+ in accordance with the current structure under LULUCF.

In order for agriculture and forestry to effectively contribute to climate change mitigation, deforestation must be reduced and eventually stopped (while meeting the demands for forest products), productivity must rise (relative to land use and emissions), biofuel production must increase (without competing for agricultural and forest lands), and land degradation must be stopped. Next to technological advances, such as in plant breeding and bioenergy conversion, improved management options, like conservation agriculture, minimum tillage, drip irrigation, or agroforestry systems, can significantly contribute to GHG emission reductions. However, the complexity of achieving emission reduction while increasing food security and reducing its climate vulnerability necessitates an integrated approach in order to address the multiple challenges.



Addressing measures to reduce GHG emissions from land use and farming practices requires tackling the drivers of emissions. The factors leading to carbon emissions in land use are dominated by the increase in the area of agricultural lands, forest extraction, fires, land degradation, etc. (Food and Agriculture Administration of the United Nations [FAO] 2010). The mitigation options are almost all related to improved agricultural systems and the reduction of deforestation or the restoration of degraded lands. These options require land-management alternatives in land-based activities related to agriculture and forestry (Golub et al. 2009).

Agricultural lands are believed to be a major potential sink and could absorb large quantities of carbon if trees are reintroduced to these systems and judiciously managed, together with crops and/or animals (Albrecht and Kandji 2003). Many agricultural practices can potentially mitigate GHG emissions, the most prominent of which are the improvement of crop- and grazing-land management and the restoration of degraded lands and cultivated organic soils (Smith et al. 2008). Agroforestry is seen as having the highest potential for carbon sequestration (above- and belowground), including soil carbon among the land-use options, particularly when short-rotation for-

estry is applied (Calfapietra et al. 2010). In dryland agroforestry systems, a major portion of the total amount of carbon in the system is stored in the soil (Takimoto et al. 2008). The potential of soil carbon in farmlands is nevertheless being debated because of its likely impermanence.

The potential for aboveground carbon sequestration has been proven by several studies (Andrade et al. 2008, Rice 2008, Takimoto et al. 2008, Luedeling et al. 2012, Nguyen et al. 2012), evidencing agroforestry as a cost-effective and early-action response to climate change. Recent projection by Luedeling and Neufeldt (2012) showed that if mature parklands covered their maximum range, carbon stocks in Sahelian productive land would be augmented by 54%. Agroforestry can contribute to climate change mitigation in three ways: in carbon sequestration (above- and belowground C), in deforestation avoided (provision of ecosystem services that will be collected in the forest otherwise), and in the production of bioenergy (fuelwood).

There are currently high expectations that reforestation in developing countries can sequester large quantities of carbon. However, Vlek et al. (2004) demonstrated the challenge of utilizing non-cultivated lands for carbon projects in Africa, suggesting

that any program in Africa aiming to set aside land for the purpose of sequestering carbon will run into moral conflict with the need to increase food security. It appeared that the most investigated option to free up the necessary land for carbon sequestration would be the intensification of agricultural production, leading to lower emissions on a product base (although total emissions could rise).

Land-use change and soil degradation are not exclusively related to climate change. Many agroecosystems in Africa have been degraded as a result of past disturbances, including deforestation, poor land management, overgrazing, and over exploitation (Batjes 2003). Therefore, all strategies geared toward the global effort of mitigation and improving land health will need a combination of options or a more systematic approach at various scales to achieve significant change. Clear guidelines for AFOLU to manage multiple options (trade-offs) are missing in the current mitigation strategies (despite some attempts from Reyer et al. 2009).

Beside the need to promote carbon uptake initiatives there is a growing interest in forest preservation against the many deforestation drivers, such as extensive agriculture and forest extraction. The REDD+ program addresses the issue of avoiding deforestation as a supplementary effort to avoid emission in the tropics.

4.2 REDD+

Historically, REDD was set up after the acknowledgement that CDM may not meet the expected objectives for the first commitment period of the Kyoto Protocol. Figure 4.2 shows the recent history and trajectory of the UNFCCC negotiations. To reduce carbon emissions from land-use change, REDD+ initiatives are seen as being one of the areas where there were strong agreements in addressing emissions from deforestation and degradation (Mertz 2009). Improving forest management in tropical developing countries by protecting and

enhancing forest carbon stock is high on the international agenda. Many global organizations and international initiatives² support the REDD+ program because of the important potential of reducing GHG emissions from forest degradation. The debate on REDD+ is now in the spotlight of the so-called “green economy” and has produced a large body of knowledge and political mobilization because of the important expectations and the many concerns related to its implementation in poor countries—in particular, how REDD+ could deliver significant climate change mitigation benefits and provide co-benefits.

For the time being, there are some interesting pilot projects across the continent carried out in the framework of the Congo Basin Forest Fund (CBFF). The test sites are located mostly in Cameroon and the DRC,

which are receiving many grants for avoiding deforestation and for AFOLU, either through foundations, NGOs, UN organizations, and bilateral grants through DFID, NORAD, USAID, and AFD. Scaling up from these projects requires a clear assessment of the challenges related to safeguarding, prior and informed consent, incentive sharing, institutional frameworks, readiness, technical capacity, enabling policies, etc. (Mbow et al. 2012). Any incentive system aimed at reducing emissions from deforestation and forest degradation (REDD+) will have to address these issues if mitigation activities are to have social and development co-benefits. The number of REDD+ projects are increasing globally, but they have a greater momentum in Asia and Latin America than in the African countries due to their greater techni-

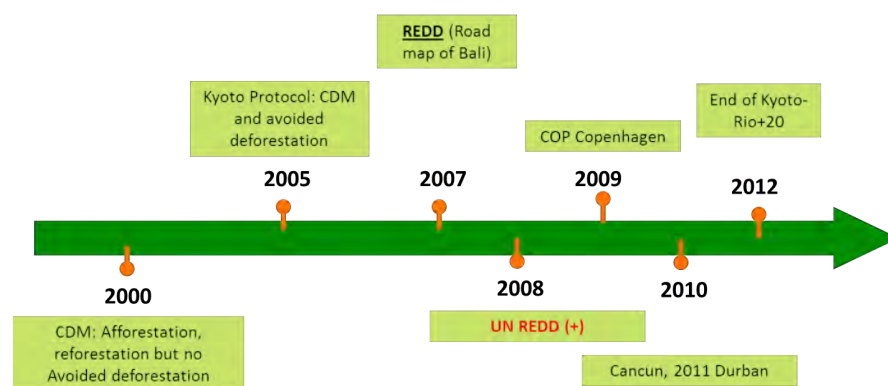


Figure 4.2 Milestones in climate change negotiations

² Focali - Forest, Climate and Livelihood research network is a Swedish knowledge-based network aiming to contribute to the provision of relevant knowledge to Sida and other Swedish authorities.

FCPF - The Forest Carbon Partnership Facility is a global partnership, housed within the World Bank's Carbon Finance Unit.

The UN-REDD Program is the United Nations collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD+) in developing countries.

FAO works actively with countries and forest-related organizations to identify and address information gaps for continuous improvement of knowledge about forests and forestry.

FIP - The Forest Initiative Partnership: Norway is prepared to allocate up to NOK three billion a year to efforts on reducing emissions from deforestation and forest degradation in developing countries (REDD+).

The CGIAR (Consultative Group on International Agricultural Research) has a Research Program on Climate Change, Agriculture and Food Security (CCAFS) and is associated with the Earth System Science Partnership (ESSP), led by the International Center for Tropical Agriculture (CIAT).

The Terrestrial Carbon Group is an international group of specialists from science, economics, and public policy with expertise in land management, climate change, and markets.

Global Research Alliance on Agricultural Greenhouse Gases was launched on 16 December 2009 in the margins of the UN climate change conference in Copenhagen.

COBAM - Climate Change and Forest in the Congo Basin.

cal, financial, and institutional capacities.

On the African continent, suitable implementation of REDD+ activities is complicated by the many human-induced drivers of deforestation that interact in a complex way and influence the land-use decisions and trends. The threats of leakages and the fear of non-permanence therefore require clever implementation, with a clear understanding of local livelihoods. As REDD+ is a performance-based mechanism, accurate monitoring, reporting, and verification (MRV) systems are required. Until recently, MRV posed considerable technical as well as financial challenges due to high uncertainties in monitoring and reporting carbon benefits and high costs. In recent years, new methods, based on increased remote-sensing capacities, have reduced costs while also being able to predict carbon stocks at larger scales and greater resolution (Milne et al. 2012). This poses the issue of MRV and the development of local capacity at various scales, the most sensitive of which being a community's ability to fulfill the technical requirement to implement REDD+ projects (see next section). Hence, REDD+ success will depend on many factors, ranging from social mobilization and improved organizational dynamics of target communities to strong technical capacities and new political frameworks for swift implementation.

The location of REDD+ in dense forest lands raises the issue of addressing deforestation in non-forested lands. Recent forest trends reported by FAO (2010) show clearly that deforestation is equally serious in other wooded lands, such as savanna or dry forest, where most of the pastoral and agricultural encroachments are taking place. Therefore, an improved reconceptualization of REDD, which takes into account the agricultural sector and non-forested ecosystems, is emerging in new climate change mitigation discussions (Mbow et al. 2012).



4.4 Requirement for adapted MRVs in African countries

The UN-REDD Program and other REDD related initiatives such as GEF recognize the importance of forest monitoring systems, which include MRV (Monitoring Reporting and Verification) of forest carbon and related mitigation activities. Developing MRV is one of the main thrusts of the Readiness Preparation Proposal/Plans being developed by selected UN-REDD countries. MRVs are the key guaranty of rigorous and consistent carbon monitoring across AFOLU activities and scales. There are many requirements, depending on the target sector, to the measurement schemes and to the precision and accuracy required. The debate is how to achieve a broad consensus on ways to measure mitigation activities, given that mitigation options change, depending on the site, type of activity, and scale. The question is what are the best tools and methods for an effective MRV system at various sectors and specifically suited to the ecology, geography, and conditions in Africa?

At the same time, the emerging sentiment related to MRVs is that they

should embrace a “broader-than-carbon-only” approach (environmental and socioeconomic outcomes) to monitoring REDD+ projects (Corbera and Schroeder 2011). An emphasis on carbon sequestration alone, without the environmental and social safeguards could present risks for preserving biodiversity; ensuring the ecological integrity of forests would require additional transaction costs for REDD. One reason for this is the view that any implementation of REDD+ will require a deep understanding and analyses of how REDD+ policies impact and are impacted by other management objectives (that is, the wider range of benefits and issues related to forest resources and land use) as well as governance safeguards, such as for biodiversity, livelihoods in local communities, indigenous people, and so forth.

In African countries, the big challenge for having actionable MRV will be on cost-effectiveness, if MRV is integrated with existing forest and natural resource management and monitoring systems prepared previously for other objectives and programs. The transaction costs related to MRVs and the level of effectiveness and capacities are in most case beyond the community scales in which



REDD+ projects are or will be implemented. The current under-capacity in most African REDD+ countries is acute and will require considerable investment to meet requirements of a future REDD+ mechanism.

The key technical and ecological challenges include ensuring the permanence and additionality of carbon stocks, preventing leakage, and setting an appropriate historical baseline or reference scenario for assessing reductions in deforestation and forest degradation. The establishment of effective national systems for MRV deforestation and degradation rates and carbon stock changes is technically possible, but will require some prerequisites in African countries. One of the requirements is the development of national forest inventory (NFI) systems, as well as the human resources needed for operationalizing an NFI strategy (Mbow et al. 2012).

In this context it is obvious that developing countries are starting from a difficult position. Central to this is the fact that their national inventory systems were never intended for the purpose of forest carbon accounting, and there is little evidence that the somewhat deep experience in forest inventory necessarily transfers to carbon (Mbow et al. 2012). Inversely, countries wherein REDD requires an initial—and new—sample, measure-

ment, and inventory system, may face the difficult choice of selecting an efficient, REDD-focused MRV system that will not completely fulfill the requirements of a national forest inventory for national resource assessment.

Full national participation in a global REDD+ system requires a far better MRV system than currently exists, and there is a huge capacity gap, according to Global Observations of Forest and Land Cover Dynamics (GOFC-GOLD 2011). The MRVs are so important that they should be linked to policy for a better understanding of the deforestation processes. They should be associated with current regulatory functions that link project activities with the regulatory entities responsible for overseeing domestic implementation.

4.5 Bioenergy

Bioenergy has a significant GHG mitigation potential, provided that the resources are developed sustainably and that efficient bioenergy systems are used (Chum et al. 2011). Biomass from cellulosic bioenergy crops is seen as a substantial part of future energy systems, especially in the framework of global climate policy that aims at stabilizing CO₂ concentration at low levels (Popp et al. 2011).

There are some popular options of bioenergy generation than can be applied in Africa, e.g., perennial cropping systems, use of biomass residues and wastes, and advanced conversion systems. Agricultural and forestry residues represent a potential low-cost, low-emission source for bioenergy and are of emerging interest for mitigation. At the same time, the existence of wood fuel markets in growing African cities is a basic argument to support sustainable land-use systems that integrate trees on arable or pasture land (agroforestry) for wood fuel supply.

Many wealthy nations are contemplating a shift towards biofuels, a trend that has as much to do with securing long-term supplies of fuel as it has to do with reducing GHG emissions (Mbow 2010). Biofuel can be produced from several plants, including maize and sugar cane (bio-ethanol), oil palm (*Elaeis guineensis*), and *Jatropha curcas* seeds (biodiesel). It is generally agreed that large areas of land will be required in order to satisfy the global biofuel demand and that the tropical regions are expected to bear the brunt of this emerging land need. The emerging wisdom of sustainable land use based on environmental integrity, human well-being, and social equity requires a close look at this emerging trend on biofuels, and in particular how biofuels affect land competition in Africa (Lambin and Meyfroid 2011).

Many studies show that the switch to biofuels over the coming century would entail major land-use and land-cover changes (Danielsen et al. 2008, Warren 2011). Much of the growth in land area under biofuel crops would come at the expense of forests and pasture. This means that not only is the fertile cropland or the so-called fallow land in Africa a potential target, but its forests may also face severe pressure in the future (Mbow 2010). This would significantly reduce its mitigation effect and may even turn the GHG balance from a sink into a source of emissions through clearing

of forests. The large-scale use of bioenergy is therefore very controversial in the African context because of its implication on land-use change and the threats to food security in Africa (Mbow 2010). Several studies on the process of land leasing underline the inconsistency between the need for bioenergy and the requirement for Africa to use its productive lands for sustainable food production (Cotula et al. 2009). According to the (FAO 2008), because of climate change, many of the traditional equilibria are changing, such as those between food crops and energy crops. Efficient biomass production for bioenergy requires a range of sustainability requirements to safeguard food production, biodiversity, and terrestrial carbon storage. For these reasons, Danielsen et al. (2008) described biofuel production as a “double jeopardy for biodiversity and climate” because of the risk of losing floristic richness and biomass stocks from converted forested or peat lands to oil palm plantations, for example.

On the other hand, Popp et al. (2011) demonstrate that N_2O emissions from agricultural soils may increase due to agricultural intensification for bioenergy production or as a result of avoiding deforestation (REDD+ model). When bioenergy products are acquired through land use conversion, it can lead to a loss of carbon stocks that neutralize the net positive GHG mitigation impacts (Chum et al. 2011).

4.6 Enabling conditions: Policy, institutions and governance

The success of REDD+ will depend largely on the management of social benefits, equity, and ethics. The safeguard of efficient REDD+ implementation is to promote a total participation approach from interest expression to implementation, ensuring a full compatibility with local livelihoods.

Participation requires consensus among the local social groups and a clear development agenda that will serve as framework to be used, as well as payments for ecosystem services (PES) credits expenditures, using transparent mechanisms and full accountability of local managers.

Policy instruments for climate change mitigation include emissions trading schemes, carbon taxes, and investment on improved energy technologies (Grafton et al. 2012). Cost effective GHG reduction requires a gradual and inclusive approach in order to promote productive systems and behavioral changes that are sustainable and climate friendly.

Land-use change to meet demands in agricultural productivity for food, fuel, and fiber will depend on many interactive factors, including policies at all scales for limiting anthropogenic climate change. Climate-change mitigation policies will alter the decision-making environment for land management at the local scale (Thomson et al. 2010) and will therefore prompt change in livelihoods and in the adoption of innovations in improved land management.

The reduction of GHG emissions requires a smarter participation scheme based on progressive cuts (Mattoo and Subramanian 2012) that

are based on clear assessments of historic emission levels, which have been quite diverse among African countries. As this approach is sometimes contested because of the overall low contribution of African countries to GHG, it is increasingly argued that the issue should be related to the promotion of sustainable energy in parallel with traditional energy systems. This will support the idea of improving equivalent per-capita emissions reduction based on sustainable approaches that keep development objectives intact. The need to preserve development opportunities requires a careful consideration of equity issues that necessarily impose large transaction costs in poor countries. This is the reason why green funds, including REDD+, should fulfill a number of requirements or preconditions related to the so-called readiness. These should encompass many important aspects, such as full participation, transparency, adequate forest policy that recognizes community rights, good technical skills, and appropriate methods for MRV.

Existing estimates of the cumulative GHG-offset potential of LULUCF activities are often driven by global institutions, and take a global or regional approach. In contrast, land-use decisions are usually made at the



local level and depend on many factors, including the productive capacity of the land, financial considerations of the landowner, and environmental concerns. Estimates of GHG-offset potential made at a local, or, at most, country level, that incorporate these factors, may be lower, as well as more useful for policy analyses, than are global or large regional estimates. While country-level estimates exist for forestry activities, similar estimates utilizing local information must be generated for agricultural activities and biofuels, as well as for the cumulative potential of all LULUCF activities in a particular location. Storing carbon on-site in forests or harvesting forests for a sustainable flow of forest products for local communities are not necessarily conflicting options, if operational policies recognize the relative merits of each in mitigating net emissions of carbon, and also depending on the site-specific factors, such as forest productivity and the efficiency with which harvested material is used (Marland and Schlamdinger 1997). These authors suggest that the relative merits of the different mitigation strategies must be considered because the land available for

reforestation or the development of forest plantations is limited.

4.7 Conclusion

Mitigation of climate change in Africa is all about the use of land and improved natural processes to capture some of the atmospheric carbon or avoid emissions related to land use. The land in Africa, as in any other part of the world, is a multilayered, multifunctional asset with resources that provide products and functions that are not always tradable, but contribute to human wellbeing in various respects. Addressing climate-change mitigation in societies that are closely dependent upon and connected to natural resources becomes a very sensitive issue that raises many questions over the ethical and fair use of land—and whether the first priority is the global commons or is local adaptation needs. This again raises the delicate question of how to combine climate mitigation objectives with local adaptation strategies in a way that meets the global needs of CO₂ reduction, poverty alleviation, and the preservation of environmental integrity. Assessing the benefits of mitigation

measures to local communities will require looking at the comparative advantages of investing time and resources on mitigation options versus rural development needs. In particular, the role of REDD as an effective mitigation option and a potential development opportunity for developing countries has been widely discussed. The concept of mitigation through land use has gained widespread acceptance, such that the question now is no longer whether, but how, it will be implemented and with which means.

On the other hand, it might be useful to conduct an ex-post evaluation of mitigation policies and institutional missions to set a new framework for improved mitigation strategies that harness adaptation and goals while promoting resilient ecosystems and sustainable land uses. Land use change, itself, must be analyzed against climate change processes, and this will require a better understanding of the interactions between land-use biogeochemical cycles, not only of GHG, but of other components, such as water. This will require efficient and effective actions and an integrated approach.



Chapter 5. Agroforestry and Climate Change

Dr. Henry Neufeldt, Dr. Ian K. Dawson, and Dr. Eike Luedeling

5.1 Biological vulnerability to climate change

Compared with simpler agricultural systems, very little research has been done on the impacts of climate change on agroforestry systems. Some experimental research has been conducted to investigate the possible consequences of climate change during the early stages of establishment of agroforestry systems. For many exotic agroforestry species (such as *Calliandra calothyrsus* and *Gliricidia sepium*), provenance trials have been conducted, but results have yet to be systematically evaluated with a view to climate change. For most tree species grown in agroforestry systems,

virtually no information on climate responses is available. The same is true for tree responses to elevated CO₂. Appropriate process-based models of agroforestry systems are yet to be developed.

Some information exists on system components. Esmail and Oelbermann (2011) analyzed the response of seedlings of the agroforestry species *Cedrela odorata* and *Gliricidia sepium* under controlled temperature and CO₂ conditions. The results imply that for the species analyzed and for Costa Rican climate conditions (as replicated in a growth chamber in Canada), climate change will likely accelerate growth, but change plant nutrient levels in ways that are likely unfavorable for the productivity of agroforestry systems.

Luedeling et al. (2011) projected climate change effects on winter chill, an agroclimatic factor that affects agroforestry systems that include temperate fruit trees. Winter chill is needed for allowing temperate fruit trees to overcome winter dormancy. Especially for warm growing regions, winter chill was projected to decline progressively throughout the late 20th and 21st centuries, casting doubt on the potential of subtropical and tropical growing regions of such fruits to maintain production of currently grown tree species and cultivars. Many production regions may become unsuitable for several currently grown tree species and cultivars.

In agroforestry systems, pollinators are instrumental in ensuring system functionality. Since many pollina-



tors of crops and trees are ectothermic organisms, they will likely be impacted by climate change, and if their rate of range shifts differs strongly from that of the plants that rely on them for pollination, ecosystem functions could be impaired. In a recent study focusing on historic shifts in North American plant and pollinator populations, Bartomeus et al. (2011) did not find evidence of such developments, but this may not be true for tropical contexts or for future climate changes. There is a big data gap on climate change effects on pollination in tropical agroforestry systems, and research is urgently needed, in particular for systems that rely on specialized pollinators.

Jaramillo et al. (2011) projected the likely impact of climate change on

the coffee berry borer (*Hypothenemus hampei*), a major pest of coffee agroforestry systems in East Africa. Using two future climate scenarios, they projected that pest pressure will increase substantially in Ethiopia, Uganda, Kenya, Burundi and Rwanda. In some growing regions, the number of possible generations of the coffee berry borer was projected to double. Such studies suffer from the constraint that the ecological interactions in complex ecosystems cannot reliably be modeled. Pest insects may be regulated by other biological processes, which may also be strengthened by climate change.

Besides process-based projections of climate change effects on components of agroforestry systems, we are not aware of process-based

attempts to model tree-based cropping systems. Yet some impact projection studies have used species distribution modeling to estimate future suitable ranges for systems; Luedeling and Neufeldt (2012) provide an example.

An indirect measure of the impacts of climate change on agroforestry systems can be derived by projected shifts in vegetation zones. The Vegetation and Climate Change in Eastern Africa (VECEA) project developed a high resolution map of potential natural vegetation for seven African countries (Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia), available in atlas and online formats (Lillesø et al. 2011, van Breugel et al. 2011). The VECEA map is likely the best possible tree seed

Table 5.1 The number of tree species mentioned in the Agroforestry Database (AFTD) as providing various functions in different regions of the tropics.

Function ¹	Origin	Region ²						Sum 6 regions
		Africa	Oceania	South America	South Central Asia	Southeast Asia	Western Asia and Middle East	
Apiculture	E	89	58	51	74	75	18	365
	I	88	26	32	34	46	16	242
	E + I	177	84	83	108	121	34	607
Erosion control	E	81	50	34	63	61	15	304
	I	94	20	23	57	56	17	267
	E + I	175	70	57	120	117	32	571
Fibre	E	85	58	40	73	82	14	352
	I	56	35	20	60	67	18	256
	E + I	141	93	60	133	149	32	608
Fodder	E	134	71	53	105	102	26	491
	I	161	30	43	112	89	35	470
	E + I	295	101	96	217	191	61	961
Food	E	137	81	68	113	115	28	542
	I	158	43	51	107	110	34	503
	E + I	295	124	119	220	225	62	1045
Fuel	E	167	96	73	133	133	27	629
	I	190	51	53	110	116	35	555
	E + I	357	147	126	243	249	62	1184
Medicine	E	167	101	86	149	158	30	691
	I	223	58	58	149	156	37	681
	E + I	390	159	144	298	314	67	1372
Shade/shelter	E	139	78	60	109	105	20	511
	I	142	53	44	84	97	26	446
	E + I	281	131	104	193	202	46	957
Soil improvement	E	95	56	40	83	84	14	372
	I	99	27	33	60	70	12	301
	E + I	194	83	73	143	154	26	673
Timber	E	199	119	91	160	172	34	775
	I	220	73	67	153	175	36	724
	E + I	419	192	158	313	347	70	1499
Sum 10 functions	E	1293	768	596	1062	1087	226	5032
	I	1431	416	424	926	982	266	4445
	E + I	2724	1184	1020	1988	2069	492	9477

¹ The AFTD contains data on a wide range of products and services provided by trees; a range of 10 of the most important functions is given here. Data are presented on the number of species given in the database as used for a particular purpose based on whether they are indigenous (I) or exotic (E) in origin to a particular geographic region. The database contains more species indigenous to Africa than to other geographic regions, which is a factor determining the greater number of total references to the African continent.

² The AFTD contains data on use across the globe; mentions of uses for a range of six important regions are given here. The regions of Africa, Oceania and South America were defined here according to the List of Sovereign States and Dependent Territories on Wikipedia.org. The regions of South Central Asia, South East Asia and Western Asia and Middle East were defined according to NationsOnline.org.



zonation map for the countries that it covers. By applying the precautionary principle that planting materials (such as seeds, seedlings or cuttings) of the same species should not be transferred across vegetation boundaries, failures of agroforestry or other tree planting projects due to a breakdown of genetic adaptation can possibly be reduced significantly. Another application domain of the VECEA map is to project the possible effects of climate change. Preliminary results from one study showed that the choice of IPCC scenario or choice of General Circulation Model resulted in clear changes in the distribution of vegetation types. However, for many places the same vegetation type was predicted to occur for all scenarios or models (van Breugel et al. 2011). Caution should be applied in interpreting the results from species distribution modeling studies: biotic factors affecting ecosystems, such as pest and disease organisms, pollinators and microsympionts, are assumed to migrate at rates corresponding to shift in vegetation types. It is also possible that new species assemblages will become established in novel climate regimes.

5.2 The importance of agroforestry for food and nutrition security

Local people in large parts of the tropics rely on a wide range of both indigenous and exotic tree species to meet their needs for various products and services (Table 5.1). Data on global export values for a range of 12 tree commodities that are grown primarily in the tropics are shown in Figure 5.1, amounting to more than \$ 66 billion based on figures for 2009. One notable feature is the rise in the value of palm oil exports, overtaking the value of green coffee exports in the last two decades. The actual value of other tree commodities may be considerably higher than shown because much of the crop is sold in local markets rather than exported, perishable fruit such as mango being a good example (Jain and Priyadarshan 2009). Nevertheless, export values provide an indication of the overall importance of a crop, with, on average, significant jumps in commodity prices, evident in recent years.

Smallholders account for considerable proportions of production. In

Indonesia, around 40% of palm oil production has been reported to come from smallholders (Indonesian Palm Oil Commission [IPOC] 2006), while some 30% of land planted to oil palm in Malaysia is reported to be under the management of small farmers (Basiron 2007). More than two-thirds of coffee production worldwide is on smallholdings (www.ico.org). With natural rubber, there has been a trend toward increased smallholder production, partly because estates have switched to less labor-intensive crops such as oil palm (see www.unctad.info/infocomm).

Many people in low-income nations are in danger from poor nutrition, with a lack of micronutrients, leading to poor health consequences for hundreds of millions. Solving malnutrition requires a range of interconnected approaches that include the bio-fortification of staple crops such as maize and rice, greater spending on food supplementation programmes, and the use of a wider range of edible plants for more diverse diets (United Nations Children's Fund [UNICEF] 2007, Negin et al. 2009). The further promotion of edible indigenous fruits, nuts, and vegetables, including those provided by trees, is an attractive option, as it allows consumers to take responsibility over their diets in culturally relevant ways (Keatinge et al. 2010). Furthermore, the biochemical profiles of these indigenous species, in supplying micronutrients, fat, fiber, and protein, are often better than staple crops (Leakey, 1999). The nutritional value of many forest foods, however, is unknown, including what genetic variation in nutritional quality is present within species, and further testing and compilation of the data are required (Colfer et al. 2006).

Communities in many parts of the tropics already incorporate many edible products harvested from forests into their diets as important components, and a few depend on them; it has been reported that these products are especially important for filling sea-

sonal and other cyclical food gaps (Arnold et al. 2011). In addition, forests provide woodfuel needed to cook food to make it safe for consumption and palatable, and income from the sale of other products that can then be used to purchase food.

The cultivation of trees for foods once obtained from forests has the potential to improve health and incomes through local consumption and sale. Special potential for cultivation lies in the great biological diversity of indigenous foods found growing in forests that are important locally but have, to date, been under-researched by the scientific community. At the same time as supporting livelihoods, the cultivation of these species in farmland also allows them to be conserved outside of threatened forests, helping to maintain resources for future use and further development as food crops.

5.3 Socioeconomic vulnerability of agroforestry to climate change

There are relatively few studies that clearly show how agroforestry systems contribute to managing climate risk. Trees on farms may mitigate direct climate impacts, e.g., providing erosion control (Ma et al. 2009; Mutegei et al. 2008) or reducing the loss of grain production in drought years (Sileshi et al. 2011). But most of the effects are indirect in the sense that agroforestry tends to improve livelihoods and wellbeing and thereby reduces vulnerability to climate impacts as much as development related factors (Neupane and Thapa 2001, Mithöfer and Waibel 2003, Garrity et al. 2010). For example, smallholder farmers in western Kenya plant trees mainly as a living “savings account” that allows them to pay for regular expenses (e.g., school fees) and emergencies (Neufeldt, unpublished).



For an example of direct effects, soil erosion is a serious problem in cultivated areas of the central highlands of Kenya, as there is a strong negative correlation to maize production (Mutegei et al. 2008). They estimated how crop yields might be affected by introducing different erosion control measures into the conventional maize monocropping system. Their results showed that napier grass (*Pennisetum purpureum*) alone had the highest erosion mitigating effects but that this was accompanied by a

loss in maize production, whereas a combination of napier grass with leguminous shrubs (*Leucena trichandra* or *Calliandra calothyrsus*) led to reduced erosion and an enhancement of maize production and soil fertility, particularly in the second year of establishment of the hedges.

Most effects of agroforestry are expected to be indirect in the sense that agroforestry increases farmers' food security, livelihoods, and income, and thereby reduces climate vulnerability and raises adaptive capacities.

Table 5.2. Proportion of farmers using coping strategies to deal with flood and drought in 2009-2010.

	Lower Nyando		Middle Nyando	
	Treated (%)	Control (%)	Treated (%)	Control (%)
Reduce quantity, quality, or number of meals	82	66	54	86
Help from government, NGO, church	40	47	11	25
Borrow money	31	40	29	46
Casual labor	24	40	32	18
Sell possessions or livestock	73	66	36	43
Consume seeds	67	80	50	71
Consume or sell fruit from trees	40	25	68	38
<i>N</i> =	45	15	28	28

There are few quantitative results so far that show how agroforestry reduces farmers' climate risk by increasing food security, livelihoods and income. Thorlakson and Neufeldt (in press) analyzed coping strategies in western Kenya during a drought in 2009 and flooding in 2010. Results showed that farm productivity dropped by 60% and 39% in the Lower and Middle Nyando catchment areas, respectively, which led to, on average, at least one month of food shortage in addition to the 4.5 and 2.3 hunger months experienced in normal years. During the hunger periods coping strategies consist of restriction of size, diversity and number of meals taken each day. The selling of livestock at

between 75% and 50% of market prices was also a typical measure. Farmers were also forced to use coping strategies that had detrimental effects in the long term such as selling oxen, which would not be available for plowing; consuming seeds reserved for planting; leasing land; and engaging in casual labor. Farmers practicing agroforestry typically used fewer of these detrimental coping strategies during hunger periods. Farmers with mature trees were able to sell seedlings, timber, and firewood, and consume fruit from their trees (Table 5.2). Farmers explained that the most effective way to reduce their vulnerability to the climate-related hazards was to diversify income, in-

cluding off-farm income activities. Higher farm productivity also contributed to reducing the overall climate risk. In order to overcome some of their vulnerabilities, poor farmers often rely on social safeguard systems, as opposed to financial safeguards. Chaudhury et al. (2011) described how social protection improves farmers' adaptive capacity and risk management in agroforestry contexts. Through case studies from Zambia and Honduras, their paper demonstrated that linkages between social protection and adaptive capacity reinforce each other, such that natural resource management through agroforestry leads to improved social protection and boosts adaptive capacity.



Chapter 6. Agroforestry in Kenya and Ethiopia

Dr. Jeremias Mowo, Dr. Badege Bishaw, and Dr. Abdu Abdelkadir

6.1 What existing agroforestry interventions are especially suitable for climate change adaptation?

Agroforestry, i.e., the growing of trees in agricultural landscapes, has the potential to achieve sustainable agriculture in smallholder farming in sub-Saharan Africa. Various agroforestry practices suitable for enhancing the adaptation of agroecosystems to climate change have been developed, tested, and popularized in Kenya and Ethiopia, although large-scale, landscape-level adoption is yet to be achieved. Most of these practices aim at preserving the natural dynamics of

ecosystems in order to achieve sustainable agroecosystem productivity, increase the resilience of agroecosystems to climate change, and promote biodiversity. Agroecosystem farming practices, as proposed by Schutter (2010), should mimic nature as much as possible through a range of simple techniques that increase crop yield by promoting naturally beneficial interactions among soil, nutrients, crops, pollinators, trees, and livestock. Agroforestry systems that achieve one or several of these interactions can contribute toward “climate-smart agriculture” that can increase sustainable productivity, strengthen the resilience of farmers’ livelihoods, and increase carbon sequestration. Below we discuss existing agroforestry practices that are

suitable for use in climate change adaptation strategies in Kenya and Ethiopia.

6.1.1 Improved fallow

Leaving land fallow is a means of resting depleted soil so that it can regain some of the fertility lost through continuous cropping with limited or no fertilizer application. We distinguish two types of fallow: natural and improved. Natural fallow consists of allowing land that is usually cultivated to remain uncultivated and instead using it for grazing or left to natural vegetation to restore soil fertility. Improved fallow consists of planting trees, mainly legume tree species, in order to enrich the soil within a shorter time period, compared with natural fallow (Bekele-Tesemma 2007). Im-



proved fallow is also used by farmers as a strategy for improving soil fertility as an alternative to inorganic fertilizers which are too expensive for many smallholder farmers.

Legume species improve the soil through biological nitrogen fixation whereby recycled nutrients are deposited through litter or when biomass is harvested at the end of the fallow period and is incorporated into the soil. Other fallow species include shrubs and herbaceous cover crops. Commonly used species for improved fallow include *Tephrosia vogelii*, *Sesbania sesban*, and *Calliandra grahamiana*. Large quantities of nitrogen (100–200 kg/ha) can be accumulated in situ by improved fallow and returned to the soil as leaf and root litter mainly by retrieving inorganic nitrogen from subsoil layers. Table 6.1 shows added nitrogen from improved fallow after four harvests (2000–2004) of different species in western Kenya, with the highest additions from *Calliandra calothyrsus*. Farmers in western Kenya have reported maize yield increases of up to 200 % from improved fallow. Kwesiga et al. (1999) reported a substantial increase in maize yield after two years of an improved fallow system in Malawi (Table 6.2), where maize grown after *Sesbania sesban*

fallow increased maize yields compared to plots fertilized with inorganic nitrogen.

6.1.2 Rotational woodlots

Woodlot refers to a segment of a woodland or forest capable of small-scale production of forest products such as wood fuel and timber. It can also be used for medicinal, food, grazing, and recreational purposes such as bird watching and bushwalking or hiking. Many woodlots occur as part of a farm or as buffers and undeveloped land between properties, such as housing subdivisions, industrial forests, or public properties (highways, parks, and watersheds). Rotational woodlot is an agroforestry option that attempts to simulate the traditional fallow system in shifting cultivation, where trees contribute to

Table 6.1 Nitrogen added into the soil through biomass incorporation by different fallow species in western Kenya.

Fallow species	Added nitrogen (kg/ha)
<i>Gliricidia sepium</i>	264
<i>Calliandra calothyrsus</i>	644
Non-coppicing	84
<i>Sesbania sesban</i>	305
<i>Tephrosia vogelii</i>	188

Source: Kiwira et al. (2009).

maintaining soil fertility through nutrient cycling during the fallow phase. Rotational woodlots combine the principles of crop production and forest management to provide multiple products. The technology involves growing trees and crops in three interrelated phases: (i) initial tree establishment, where trees are intercropped with crops; (ii) tree fallow; and (iii) cropping after tree harvests (Nyadzi et al. 2003).

6.1.3 Alley cropping

Alley farming or hedgerow intercropping, is the planting of trees or woody shrubs in two or more sets of single or multiple rows, with agronomic, horticultural, or forage crops cultivated in the alleys between the rows. This agroforestry practice is used to enhance or diversify farm products; reduce surface water runoff and erosion; improve utilization of nutrients; reduce water and wind erosion; modify the microclimate for improved crop production; improve wildlife habitat;

Table 6.2 Maize grain yield following two years of improved fallow system compared to inorganic fertilizers in Malawi.

Shrub	Grain yield (t/ha)
<i>Sesbania sesban</i>	5.4
<i>Tephrosia vogelii</i>	3.2
Fertilized maize (full dose)	4.0
Unfertilized maize	1.1

Source: Kwesiga et al. (1999)

and enhance the aesthetics of the area.

In alley cropping, trees or shrubs are generally planted in a single or multiple-rows. The spacing between rows is determined by the primary purpose of the alley cropping and the agronomic, horticultural, or forage crop grown. Leguminous species are selected for their potential in fixing biological nitrogen for the benefit of the accompanying crops. Fodder species are suitable when the primary target is to provide quality fodder to livestock. Woody plants are typically selected for their potential value for wood, nut, or fruit crops. All traditional crops can be grown with alley cropping. Trees or shrubs planted on the contour are selected for coppicing and multiple uses to reduce soil erosion and improve livelihoods. The primary factors determining which crops can be grown in a given alley cropping system are the density of the canopy and the sunlight requirements of the agronomic, horticultural, or forage crops.

6.1.4 Live fencing, hedges, animal pens, and boundary markers

Live fencing, hedges, and boundary markers can serve as productive and ecologically valuable components of agroforestry systems. Trees or shrubs can be used as living fence posts for barbed-wire fencing used to contain livestock or to exclude livestock from crops susceptible to damage and for boundary markers demarcating land parcels belonging to different land-holding groups or individuals. Living fences can serve as animal pens, either with or without wire; and as wind-breaks or barriers (see below).

6.1.5 Windbreaks

Windbreaks are strips of trees and/or shrubs planted and maintained to alter wind flow and improve microclimate, thereby protecting a specific area. They are planned and managed as part of a crop and/or livestock operation to enhance production, protect



livestock, and control soil erosion. Other benefits of windbreaks include the protection of farmsteads, reduction of dust, and provision of habitat for wildlife. Well-planned windbreaks can provide food (fruit trees), shelter, and travel corridors. Like other agroforestry practices, windbreaks store substantial amounts of carbon and can provide nitrogen for harvest and transport to crops or fodder for livestock.

6.1.6 Fodder species for soil conservation

Conserving soils, especially in the highlands, requires construction of soil conservation structures such as bench terraces, contour bunds, *fanya juu*¹ and *fanya chin*², which need to be stabilized to withstand the impacts of rainwater. Agroforestry practices such as the planting of fodder trees and shrubs, fruit trees, or timber trees

along the contours and edges of terraces will retain these soil protection structures. Fodder trees and shrubs supply much-needed fodder for livestock, especially during feed shortages. Well-fed livestock will provide not only milk and meat, but also significant amounts of manure that can go into improving soil fertility. This may be considered a good example of the type of linked technologies (interrelated technologies applied together to address multiple constraints) that fit well with smallholder production systems (Masuki et al. 2010; Mowo et al. 2010).

6.1.7 Home gardens

Home gardens are integrated tree-crop-animal production systems that are established on small parcels of land surrounding homesteads. This land-use system may have evolved from shifting-cultivation and bush-fallow systems in response to population growth. It comprises numerous woody species in close, multi-storied association with herbs, annual and perennial crops, and livestock—all managed in the same piece of land (Figure 6.1).

¹ *Fanya juu* is a Kiswahili word meaning “turn upwards” and in this context refers to terraces from which the dugout soil is heaped on the upper side of the terrace, leaving the ditch on the lower side to trap water.

² *Fanya chini* is similar to *fanya juu*, except that the soil is put on the lower side, rather than on the upper side.



Figure 6.1 The Chagga home garden in Kilimanjaro, Tanzania.

6.1.8 Fodder banks

Fodder banks are concentrated units of forage legumes established and managed by pastoralists near their homesteads as a means of providing additional protein for cattle during the dry season. Fodder banks can also play a crucial role in soil fertility improvement in cropping systems. Areas under fodder banks have been associated with increased floral and edaphic changes and increases in cereal yields when they are reverted to cropping.

6.1.9 Silvopasture

Silvopasture is an agroforestry practice that integrates livestock, forage production, and forestry on the same land-management unit. Silvopasture systems are deliberately designed and managed to produce a high-

value timber product in the long term, while providing a short-term annual economic benefit from a livestock component through the management of forage or from an annual crop component.

6.1.10 Riparian forest buffers

Riparian forest buffers are natural or re-established streamside forests made of tree, shrub, and grass plantings. They buffer non-point source pollution of waterways from adjacent land, reduce stream bank erosion, protect aquatic environments, and enhance wildlife.

6.1.11 Forest farming

In a forest-farming practice, high-value specialty trees and shrubs crops, e.g., coffee and tea, are grown

under the protection of a managed forest canopy that has been modified to provide the correct shade level. The practice also includes the production of non-timber forest products such as mushrooms, pine straw, wildflowers, and medicinal plants for specialty markets.

6.2 What additional research is required?

Additional research is required in the following areas:

- Better understanding of the contribution agroforestry practices to adapt to and mitigate climate change and how climate change affects agroforestry systems
- Adoption and adaptation of agroforestry practices by farmers
- Development of methods and approaches scaling agroforestry technologies to attain landscape level impacts
- Identification of agroforestry tree species for different agroecological and farming systems that meet both production and ecological objectives in general and for the domestication and promotion of trees species suitable for agroforestry in drylands
- Development of appropriate policies and institutional infrastructure to catalyze adoption of agroforestry.



Chapter 7. Case Studies Approach

Dr. Henry Neufeldt and Dr. Kathleen Guillozet

The following four case studies, two from Ethiopia and two from Kenya, provide some context regarding the social, economic, and environmental conditions relevant to climate change in particular locations. We use the sustainable livelihoods framework (World Commission on Environment and Development [WCED] 1987; Carney 1998; Bebbington 1999) to loosely organize information from the case studies. Because cases were gleaned from previous research and data was not collected in a uniform manner, we apply the sustainable livelihoods framework in order to identify points of consistency and distinction among the cases, but recognize that the data are incomplete. Summary tables should therefore be viewed as a preliminary starting point in organizing our understanding of the factors that can increase or limit farmer adaptive capacity to climate

change rather than as findings grounded in systematic research. In the paragraphs that follow, we provide a brief background on the sustainable livelihoods framework and a description of the capital asset tables used in Chapter 12.

The sustainable livelihoods framework integrates social, economic, and environmental dimensions, providing a means to evaluate different resource management approaches. The concept delineates five key capital asset categories—natural, financial, physical, human, and social—and is widely accepted, although others have argued for additional or different categories. Bossel (1998), for instance, has argued for organizational capital such as bylaws, cultural norms, and rules to be separated from social capital. Similarly, Jones et al. (2010) distinguish between the asset base on the one hand

and institutions and entitlements such as knowledge and information, innovation, and governance on the other. Although some of this capital can be commoditized, the concept provides a broader consideration of assets, some of which cannot be appropriately monetized or do not have markets; this concept therefore provides for a better reflection of environmental, social, and economic assets than does price as a one-dimensional market indicator.

Natural capital includes access to and quality of natural resources such as agricultural lands, grassland, forests, soils and water. Preserving these resources from overexploitation is necessary to guarantee that the natural capital continues to provide ecosystem services that sustain livelihoods.

Financial capital consists of direct income, savings, credits, and remit-

Table 7.1 Indicators for sustainable livelihoods assessment at different scales (adapted from Campbell, Sayer et al. 2001).

Principles for each capital asset	Potential indicators		
	Household level	Village level	District level
Natural capital	Soil fertility; erosion; water resources; above- and belowground carbon stocks; area of land available	Water resources; availability over time	Siltation levels; downstream water availability over time
Financial capital	Credit volume; savings; remittances	Community financial assets and credits	Financial programs; off-farm livelihood opportunities
Physical capital	Houses; mobile phones, etc.; livestock; woodlots; food storage facilities	Markets; access to inputs	Transportation and communications infrastructure; access to affordable inputs and improved seeds/livestock varieties
Human capital	Schooling rates; reading; special training; health; labor availability; traditional ecological knowledge	Schools; nurseries; traditional knowledge; religious institutions	Capacity raising programs; agriculture, natural resource and health extension services
Social capital	Intra-household equity in decision making	Local institutions; leadership roles; equitable institutions for dispute resolution	Gender awareness programs; transparent regulatory enforcement processes

tances. Net Present Value increase across these categories would be considered a positive change leading to greater adaptive capacity and resilience to climate impacts and other shocks.

Physical capital consists of a wide range of manufactured provisions that contribute to improving livelihoods in the smallholder farmer settings we are examining in the case studies. Along with infrastructure, such as roads to allow market access, and household assets, such as stables to keep livestock and machinery, physical capital consists of agricultural and other implements, such as fertilizers and pesticides. In this paper, physical capital also consists of the livestock, annual crops, and woodlot resources that farmers rely on for their livelihoods. Although it may be possible to categorize these assets under natural capital, they are essentially related to human activities and therefore fit better under physical capital. An increase in these assets, possibly expressed as commodities, indicates a positive development.

Human capital consists of skills and knowledge, obtained through

formal or informal training, as well as health and labor availability, all of which are indicators of the capacity to transform natural, physical, and financial assets into higher quality goods or services. Indicators that can show an increase in human capital could consist of an improvement in household educational status, HIV rates, or the relationship between demand and availability of labor.

Social capital can be described as a set of formal and informal rules, norms, and institutions that generate social cohesion and improve the ability of individuals and communities to live together in relative peace. The availability of platforms or institutions for discussing and mediating conflicts and that allow for the effective implementation of accepted sanctions could be considered an indicator of high social capital.

The five asset categories are strongly interlinked. For instance, natural assets can generate financial capital, which can be invested in physical or human capital, which may in turn affect natural capital; human and social capital can contribute to the management of natural, physical,

and financial capital. Through valuation of the different capital assets, the approach can therefore appropriately reflect important trade-offs and synergies across natural resource management options or over time. The indicators described in Table 7.1 are linked to case study descriptions in Chapter 12. Case study text was scanned for relevant information, which was then incorporated into a table of capital assets. For example, in the Gedeo homegarden case, the “maintenance of complex agroforest systems [which] reduces soil exposure to erosion and increases soil organic matter” was added to Table 12.1 as an example of natural capital. Because data collection involved different approaches and occurred over different time frames, we do not attempt to normalize these indicators across sites, but rather use them in order to flag strengths and weaknesses and identify areas for future research. A quantitative comparison is not possible, even when quantitative information is available from the case studies. Instead, we rely on qualitative comparisons across management systems within and between the case studies.



Chapter 8. Case Study – Gedeo: Highland Home Garden Agroforestry System

Dr. Abdu Abdelkadir and Mr. Tewodros Assefa

The agricultural systems most vulnerable to the effects of climate change are those already affected by population pressure, such as the Gedeo Zone in Ethiopia. In these areas, climate change combined with population pressure may result in unsustainable management of the farming system, resulting in land and resource degradation. It is important to note that these changes will also bring changes to terrestrial ecosystems, threatening biota and human livelihoods. Yet even as the climate changes, food and fiber production, envi-

ronmental services, and rural livelihoods must not only be maintained, but improved.

8.1 Gedeo Zone background information

With a total area of 1,347 km² and an altitude range of 1,350 to 3,000 MASL, the Gedeo Zone stretches along the main highway from Addis Ababa to Moyale. The mean annual temperature range is 12.6–22.4°C and the mean annual rainfall range

is 1,001–1,800 mm. The warm humid temperate climate makes the Gedeo Zone ideal for abundant plant growth (Ethiopian Mapping Agency [EMA] 1988).

Land use within the zone is divided into 80% cultivation and 19% grazing, with 1% considered forest and other uses. According to the estimated population and housing census of the Central Statistical Agency (CSA 2007), the total population of the Gedeo Zone was 843,928, making up about 5.5% of the population of the Southern Nations, Nationalities



and People's Regional State (SNNPR), one of the nine regions of Ethiopia. The Gedeo Zone population density, 626.5/km², and family size are significantly higher than the national average (United Nations Development Programme 1996). The population density of Wonago Wereda, one of the six Weredas (administrative districts) of the Gedeo Zone, is about 956.2/km², far greater than the SNNPR average of 122/km².

One of the impacts of population growth can be seen in the reduction in the size of farms. The regional food security assessment of SNNPR indicated that the largest landholding in Wonago Wereda was 1.5 ha; about 24,829 (65% of households) owned 0.5 ha or less. A study undertaken by Woldeamanuel (2009) indicated that the majority of the respondents owned less than 2 timad (<0.25 ha) of land, while only one individual had more than 1 ha. About 6.4% of the households lacked a home garden.

Educational attainment in the Gedeo Zone is poor, with only about 29.9% of the population considered literate (CSA 1994). This, in conjunction with a poor public healthcare system undoubtedly contributes to

farmers' incapability to create sustainable land resource management systems and thus ensure subsistence security for their families. According to Woldeamanuel (2009), economic problems constrain families from enrolling their children in school or allowing them to remain in school; many children drop out due to economic problems. Furthermore, only 10% of farmers benefit from credit services; 90% of farmers have little access to credit, which limits their ability to purchase seeds, fertilizers, and other productive assets.

According to the regional food security unit assessment in 2001/2002, the major problems affecting income generation and credit services are the lack of entrepreneurship and managerial skills and shortages of capital and skilled labor. The study also indicated that about 51% of the respondents have no access to savings, while 46% have developed traditional saving habits (although the actual amount of savings is very small, at only 60 USD per year per household).

In the Gedeo Zone, the introduction of cash crops has affected the production of food crops. Structural

service provision problems leave the zone at constant risk for lack of food availability each time the rains fail or the price of coffee declines. Increased cereal and enset prices combined with fluctuating coffee value and production have limited people's food purchase capabilities, pushing many into destitution. The coffee market, which is the major source of income and employment, has been seriously affected for many years, but has further declined during the last four or five years; as a result, once plentiful communities now face hunger and lack of resources. A few literate respondents have expressed regret at failing to acquire savings during previously abundant times (Woldeamanuel 2009).

8.2 The Gedeo agroforests

The Gedeo "home gardens" are traditional agroforests composed of an assemblage of diverse, closely growing trees, shrubs, and annuals that form a seemingly unbroken vegetation cover. These agroforestry systems stand in lush, beautiful contrast to the treeless farmlands of much of the Ethiopian agricultural landscape.

The Gedeo agroforests can be divided into three categories based on their altitudinal ranges (Negash 2007):

- Enset-tree based agroforests located at altitude above 2000 MASL (higher altitude agroforestry; accounting for 8% of the area)
- Enset-coffee-tree based agroforests located at altitude ranges of 1600 to 2000 MASL (accounts for 71%)
- Coffee-fruit crops-tree based agroforests located at altitude below 1600 MASL accounts for about 21%

Crops typically grown in Gedeo home gardens include coffee (*Coffea Arabica*), enset (*Ensete ventricosum*), godere, chat, sweet potato, pepper,

and numerous other kinds of vegetables. Fruit trees such as avocado, banana, and pineapple are also integral parts of the system, especially at lower elevations. Trees such as *Cordia africana*, *Millettia fruginea*, *Albizia gummifera*, *Ficus* spp., and *Acacia* spp. form the upper stories of home gardens. A recent study has shown that among the canopy species used in the heat- and drought-stressed lowland areas, some introduced tree species can reduce coffee yield by as much as 90%, while indigenous trees, such as *Millettia ferruginea*, can double coffee yield. This suggests that the selection of overstory species can significantly affect coffee production (Abebe 2009).

The Gedeo home-garden agroforests are among the most structurally complex and diverse forms of Ethiopian home gardens. There are home gardens in other parts of the country, such as the Gurage Zone enset farms, that have less complex forms consisting of one or two crop/tree mixtures. These demonstrate the evolution of agroforestry systems on different sites. According to Negash (2007), as many as 30 to 40 newly germinated seedlings of *Millettia* spp. were counted in a home garden plot of about 100 m² in the Gurage Zone, with up to 59 enset plants, 29 coffee plants, and 25 fruit crops per 100 m². A total of 50 crops with 35 plant families were also recorded in the system.

Gedeo farmers have gradually intensified their farming systems into agroforestry systems via increased architectural complexity with high plant diversity. In turn, this has helped to diversify land-use values and contribute to more sustainable use of natural resources. It should be noted that the introduction of enset and coffee into the farming system may have been the most important action in the intensification of the Gedeo agroforestry system. Currently, enset and coffee make up more than 50% of the total land area of a typical farm in the Wonago area of the Gedeo Zone (Sustainable Land Use Forum [SLUF]

2006). While enset remains the main staple food, coffee is the most dominant cash crop.

The home gardens' purpose is primarily to meet household needs, and they are solely managed by family labor (Kanshie 2002; SLUF 2006). They supply much of the basic needs of the local population, serve as a means of cash income, and help reduce environmental deterioration.

8.3 Climate change mitigation, biodiversity conservation, and livelihoods

8.3.1 Potential role in carbon sequestration

The carbon sequestered within agroforestry systems may have a positive impact on the global GHG balance (Harvey et al. 2010). Most tree species in the overstory of the Gedeo home gardens are slow growing and long lived. They can also form a large canopy volume with a high total carbon accumulation. An example is *Ficus*, one of the most prominent canopy species, which is a slow-growing tree that can attain a large size, has a higher carbon density, and

can be credited with sequestering a maximum total carbon.

Tree management in the Gedeo agroforestry system primarily consists of lopping and pollarding. The wood is used for fuel, construction, and/or farm implements. Whole tree harvest is uncommon in the management of this type of system; thus, the carbon sequestered stays there over a long period of time. If the aim is to maximize mitigation potential by maximizing the total amount of carbon sequestered (Harvey et al. 2010) in a system, then the use of such large-sized and long-lived canopy species within a Gedeo-type agroforestry system can play a critical role in climate change mitigation.

8.3.2 Potential role in biodiversity conservation

The Gedeo agroforests form a system of well-composed architectural complexity with high plant diversity. In a study conducted by Negash (2007), a total of 50 plant species with 35 plant families were recorded in a home garden plot of about 100 m². The Gedeo home gardens are small and are often managed around homesteads, but form a structural continuity over a wide range of the agricultural matrix. From a landscape-level





view, the fragmented gardens appear to form a continuous vegetation cover that looks almost like a closed forest. Kanshie (2002) equates the Gedeo farming system to natural forests in terms of their architectural complexity, composition, and arrangement, and because of the interactions among system components.

These floristically and structurally diverse agroforests provide a habitat and microclimate suitable to a variety of plant and animal species (Harvey et al. 2010). Both domesticated and wild plant and animal species take refuge in home gardens. As noted previously, management practices involve periodic lopping and pollarding of the overstory trees to regulate the microclimate, then using the produce for fuel wood and farm implements. Moreover, there is an absence or restricted use of chemicals including fertilizers and pesticides in this system.

8.3.3 Potential role in livelihood improvement

The Gedeo agroforests play a significant role in alleviating poverty and advancing sustainable development through the diversification of products and services. Their use improves food

security by diversifying food products and reducing the risk of crop failure. They also offer the means to increase farm income through the sale of wood and other products; coffee and chat (*Catha edulis*) are among the foremost sources of farm income from this agroforestry system. The addition of continuous organic material to the soil through litter provides a ground cover against erosion and improves soil fertility. Although much of the landscape of Gedeo is very steeply sloped, incidences of runoff and erosion are minimal because of the intact vegetation cover. This agroforestry system may be sustainable and may afford agricultural productivity, ultimately improving farmers' livelihoods long term.

8.4 Anticipated climate changes and impacts

Although the Gedeo agroforestry system appears to be a resilient and sustainable system, numerous pressures are already threatening its existence, including

- The region's high population density, which impacts the size

of each individual landholding and results in increased land fragmentation

- The lack of non-farm jobs and opportunities to increase household income
- The increasing prevalence of insects, diseases, and animal pests, which are causing unprecedented yield losses within the system, especially within critical crops such as coffee and enset
- Lack of alternative crop varieties, credit facilities, marketing, and technical support, leading to reduced system productivity

These problems have been exacerbated by the advent of climate anomalies occurring around the world. The following section touches on the topic of expected climatic anomalies and the anticipated impacts that may result from climate change in the area.

8.4.1 Anticipated climate changes in the Gedeo Zone

Although studies indicated that annual rainfall in Ethiopia would increase with climate change, an unpublished study undertaken by LEM, the Environment & Development Society of Ethiopia (November 2010) at Wenago Wereda showed that rainfall has been decreasing by 6 mm annually since the turn of the century. The standardized rainfall anomaly analysis also showed that the Belg (February to May rainy season) rainfall was susceptible to drought occurrences in the study area in 6 of 21 years.

The study undertaken by LEM Ethiopia (November 2010) showed an approximate annual increase of 3°C in Wenago Wereda over the past 100 years, an increase of about 0.6°C every 20 years. Moreover, the study indicated that the mean maximum temperature trend analysis showed an increase of 4.9°C in 100 years. In addition, the mean minimum temperature trend analysis for the study

area showed an increase of 1.06°C in 100 years.

The assessment of evapotranspiration at 10-year intervals in the study area, based on the maximum and minimum temperature trends, indicated a possible increase of about 4.3 mm/day.

8.4.2 Anticipated impacts of these changes

8.4.2.1 Water resources

The hydrological cycle is intimately linked with changes in atmospheric temperature and radiation balance. Increased temperatures in the study area may increase precipitation intensity and variability, which are projected to increase the risks of flooding and drought. According to IPCC (2008), the frequency of intense precipitation events (or the proportion of total rainfall from intense falls) will likely increase over most areas during the 21st century, resulting in the risk of floods. At the same time, the proportion of land surface in extreme drought is also projected to increase.

A decrease in annual rainfall results in lower soil moisture, which, combined with high evapotranspiration, promotes desertification due to reduction in vegetation cover. This leads to soil erosion and sediment discharge that may cause reservoir siltation. The biggest problem is that even if the total amount of precipitation for the year is sufficient, the distribution in many parts of Ethiopia may be uneven and unpredictable. Reduced runoff and, hence, water resources, will also have an impact on water supply for agriculture (particularly coffee washing), domestic uses, and many other purposes in the zone, especially during warm and dry periods.

8.4.2.3 Soils and carbon sequestration potential

Field experiments indicate that climate changes will impact soil carbon stocks differently depending on the soil and regional climate. The depletion



tion of soil carbon is accentuated by soil degradation and exacerbated by land misuse and soil mismanagement (Chigwada 2004). Furthermore, the unprecedented increase in population pressure in Gedeo will result in the destruction of existing agroforestry practices, negatively impacting the zone's soil resources. Extreme climatic conditions may also cause land degradation in the forms of soil erosion and the losses of organic carbon and other nutrients, thereby reducing the carbon sequestration potential of the system. The adoption of restorative land use and recommended management practices (RMPs) on agricultural soils such as the Gedeo agroforests can reduce the rate of the increase in atmospheric CO₂ while having positive impacts on food security, agro-industries, water quality, and the environment.

8.4.2.4 Agriculture

As results of extreme rainfall events and variability, floods (and then erosion) and droughts will affect agricultural production. It is anticipated that reduced precipitation and high temperatures and evapotranspiration during droughts will negatively impact staple food production in the zone.

The current level of preparedness of the population may make it difficult to cope with possible climate hazards. Moreover, the increase in evapotranspiration will pose a threat to crop diversity, striking a heavy blow to food self-sufficiency.

The Gedeo Zone is heavily dependent on rain-fed agroforestry and the agricultural sector is especially vulnerable to the adversities of weather and climate. Farmers in the zone are likely to bear the brunt of the negative impacts of climate change because they use relatively basic technologies on tiny plots of land. Thus, negative impacts from climate change will bring about increased poverty, water scarcity, and food insecurity.

8.4.2.5 Economic impacts

The Gedeo Zone is known for its coffee production and marketing. A study undertaken by Oxfam International (2005) revealed that climate change in the form of increasing temperature is threatening Ethiopian coffee growth due to an increase in disease and pests, such as the coffee berry borer (*Hypothenemus hampei*), which thrives in high temperatures. The higher temperatures in the coffee-



growing areas have aggravated the problem by creating an environment conducive to the rapid growth of the pest. Farmers in the study area reported that yields of coffee and other crops had fallen in the last four years, and they attributed this to a mix of factors including a loss of soil fertility, along with both drought and unusually high rainfall at the wrong time. Furthermore, the study noted that a slight increase in annual maximum and minimum temperatures was recorded in recent years, which has

aggravated the problem of coffee berry disease during long dry seasons. Finally, the study reported that over 30% of households suffered financial losses ranging from 500-3000 birr because of the long dry seasons.

8.4.2.6 Gender and climate change

In Ethiopia, women and girls tend to be disproportionately impacted by climate variability. In times of crisis, women tend to stay home with their children while men move away from

their homes to look for alternative means of survival. Women also have fewer options in terms of finding alternative ways to earn a living, especially since their literacy rate is not even half of that of men. Women are also not involved in household decisions and are frequently without cash savings or assets to sell in order to buy food and other basic items.

8.5 Conclusions

Anticipated climate change together with population pressure and poor management may result in the degradation of the biophysical resources as well as negatively impact socio-economic conditions of the Gedeo Zone. In order to adapt to the adverse impacts of these changes, sustaining and improving the current home garden agroforestry system is thus of paramount importance. Overall, the literature synthesis on the Gedeo home garden agroforestry system indicates that adaptation to climate change will largely depend on the increased resilience of both these agroforestry systems and of local management capacity. Local biophysical conditions and socioeconomic factors must also be assessed and considered along with agroforestry practices in order to effectively reduce the vulnerability of these communities to climate change.



Chapter 9. Case Study – Afar: Arid Pastoral Agroforestry System

Dr. Gemedo Dalle and Dr. Abdu Abdelkadir

Changes occurring in the rural landscape of Afar region, particularly in land-use and farming systems, reflect the physical, ecological, and social features of the region. For example, the conflict between agriculture and forestry and the resultant pressure on natural resources are the major land-use problems of the region.

Information for this chapter was collected from interviews of individual clan members, clan leaders, extension agents, and professional foresters from local woredas and the zonal and regional Agricultural Bureau. Whenever available, information was included from reports of the Regional Agricultural Bureau and literature. This chapter describes agrosilvopastoral systems and presents multidis-

ciplinary, multi-agency programs designed to improve agroforestry through improvements to ecosystem services, biodiversity, and mitigation of climate change.

9.1 The Afar Regional State

The Afar National Regional State is located in northeastern Ethiopia and consists of 5 zonal and 28 woreda administrative units. The regional capital is Semera, situated approximately 700 km northeast of Addis Ababa. The Afar region is located between 8°45' to 14°45' N latitude and 39°35' to 42°45' E longitude and covers approximately 10,086,000 ha. It is bordered by the Amhara and Tigray

regions in the west, Oromia in the south and southwest, Eritrea in the north and east, and Djibouti in the east (Figure 9.1).

9.1.1 Physiographic and agroecological features

The physiographic and agroecological features of the Afar region vary from extremely hot lowland plains in the east and northeast to a mild climate at higher elevations in the west bordering the central highlands. The region has one of the driest climates in the Ethiopian Rift Valley and is prone to recurrent droughts and famine. The topography of the region varies from flat or gently sloping to undulating landscapes interspersed with rugged hills. The elevation rang-

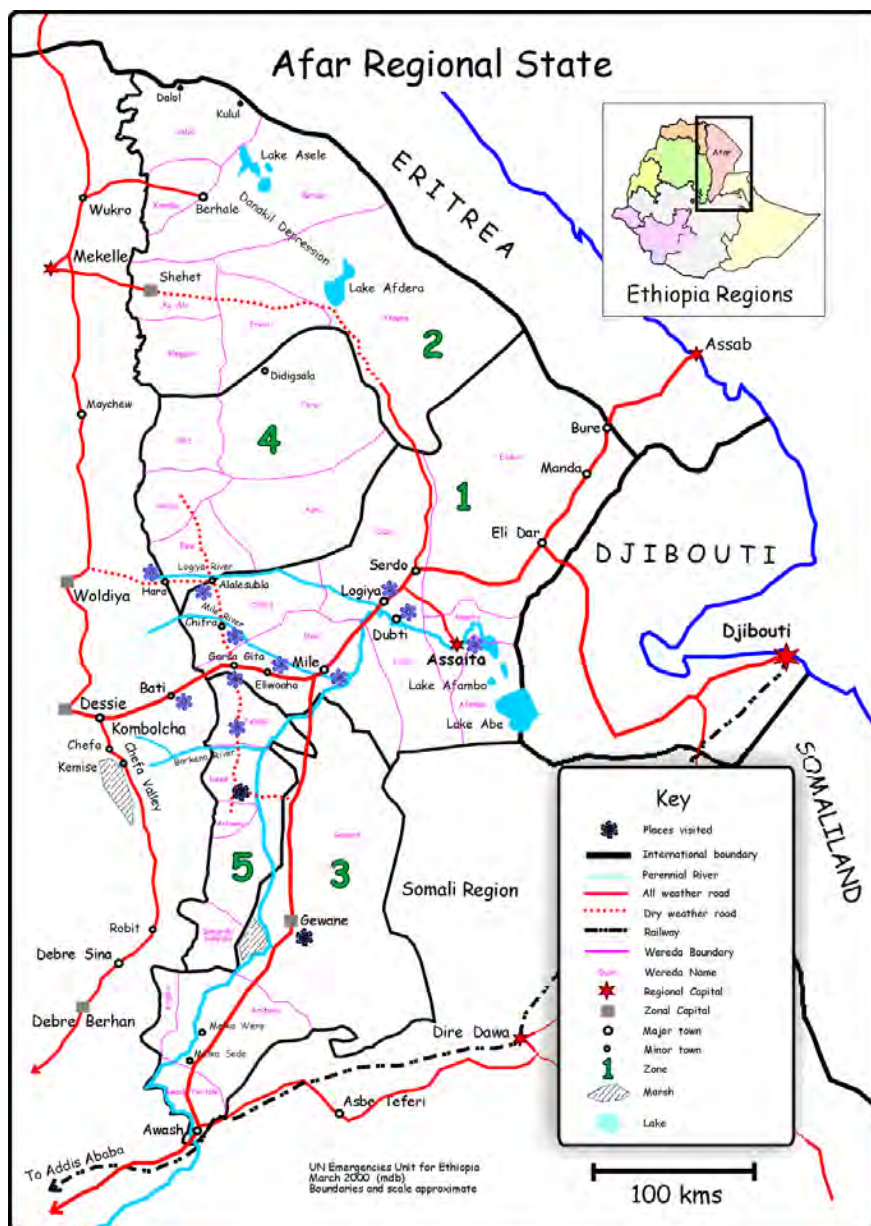


Figure 8.1 Map of Ethiopia and Afar Regional State with revised Ethiopian agroecological zones (source: ReliefWeb 2012).

es from 100 m below sea level to more than 1000 MASL. About 80% of the land area has an elevation of less than 500 MASL and is considered hot-arid; the remaining 20% is semi-arid with an elevation of 500-1500 MASL.

The revised agroecological zones of Ethiopia divide this region into three sub-zones as follows (Ministry of Agriculture [MoA] 1998):

1. Hot, arid plains in the east, with a mean annual rainfall

ranging between 100-700 mm and evapotranspiration at 1700–3000 mm. Vegetation includes drought-tolerant bushes, scant grasses, and bare areas. Livestock rearing is the major occupation, with limited crop production along major rivers.

2. Hot, warm valleys in the arid plains, with evapotranspiration rates of 2000–2600 mm. These valleys are covered by

wooded grasslands and are conducive to cultivation; maize and sorghum are the two primary crops grown in these areas.

3. Hot, warm valleys and escarpments in the southwest at an elevation of 500–1200 MASL, with an annual rainfall of 100–600 mm and evapotranspiration rates of 1400–2200 mm. Vegetation is composed of bush and shrub lands, as well as both annual and perennial crops.

9.1.2 Climate

In western Afar, rainfall is seasonal with distinct wet and dry seasons. The main rainy season is from June to September, preceded by a short rainy season from April to May, locally known as “belg.” Generally, annual rainfall increases with an increase in elevation; in this region, it ranges from 80 mm in the lowlands to about 700 mm in the highest areas.

Temperature is also a function of elevation. Probably the least variable component for plant growth is the average temperature, which ranges between 16.3°C and 36°C. Day length and radiation remain conducive to plant growth throughout the year. Generally, the hottest months are March through June and the coldest are October – December with some daily temperature variations exceeding typical seasonal temperatures.

9.1.3 Soils

Deep alluvial soils are located in riverine areas, while eroded sites are characterized by shallow, sandy soils that are low in organic matter, total nitrogen, available phosphorous, and cation exchange capacity. Parent materials, including the conglomerate sand, clay, and reef limestone, are the youngest sediments of the quaternary volcanic period from the Cenozoic age. Dominant soil types include gleyic and orthic Solonchaks; Lithosols; calcaric and eutric Fluvisols; and calcaric and eutric Regosols

and Xerosols. Saline soils dominate the region. Wind and water erosion are the major causes for the shallow and unproductive soils.

9.1.4 Population

Population estimates include a total of 1,098,184 million people, with 1,012,305 residing in rural areas and 85,879 in urban areas. The annual rate of growth is 2.1% and 4% in rural and urban areas, respectively. Most people are pastoralists and agro-pastoralists. The harsh environment and prevalence of diseases like malaria discourage people from living in the hot lowlands. Generally, the population density in Afar increases from the extreme northeastern and eastern areas to the western areas where the environment is more conducive for life.

Under low populations, a sort of equilibrium existed between utilization and conservation of the natural resources; however, recent increases in human and livestock populations both in urban and rural areas have created severe land utilization concerns, including degradation of woodland and shrub land vegetation. This, in turn, has resulted in wind erosion and serious environmental degradation.

9.1.5 Natural vegetation

Vegetation varies from the relatively unbroken *Acacia* woodlands in riparian areas and highlands of the west to areas of bush and scrub in the hot lowlands. There are vast areas of land devoid of vegetation. The vegetation comprises the three classifications below, categorized according to the distribution and structure or diversity of species.

9.1.5.1 Riparian zone vegetation

Numerous perennial and intermittent rivers support large numbers of species in relatively dense vegetation, giving a seemingly unbroken canopy cover. One example is the vegetation along the Awash and EWA waterways, with the most prevalent



species being *Acacia tortilis*, *A. nilotica*, *Balanites aegyptica*, *Tamarindus indica*, *Tamarix* spp., and *Ziziphus* spp. This vegetation is an important source of fodder for livestock during the dry season and a source of food, medicinal plants, fuelwood, and wood for utensils for humans. It is also home to many bird species and other wild animals. The Afar pastoralists have high reverence for these woodlands. The estimated area covered by riparian woodlands is 153,463 ha. A substantial part of these woodlands is located in Chifra, Mille, Gewane, Awra, Ewa, Fursi, Semuna Robi, with a small portion in Dewe and Artuma woredas (Land Use Planning and Rural Development [LUPRD] 1998).

9.1.5.2 Highland vegetation

Increased rainfall in the highlands of western Afar supports a fairly intact shrub vegetation. The vegetation in these areas is less complex and diverse both in terms of composition and structure than in areas with riparian vegetation. Vegetation on these shrub lands consists of *Acacia senegal*, *A. seyal*, *A. etbaica*, *A. mellifera*, *A. oerfota*, and several other species. The continuous uses of these species for fodder, fuelwood, and charcoal

are incompatible with tree regeneration and growth, and thereby degrade the original vegetation. This results in the local concentration of less useful species such as *A. mellifera* and *A. oerfota*. These open and dense shrub lands cover a total of 1,522,367 ha and are located in at least 20 woredas including Chifra, Mille, Gewane, Buremudaitu, Dulecha, Amibara, Awash Fentale, Yellow, Golina, Awra, Ewa Talalah, Dewe, Semuna Robi and others (LUPRD 1998).

9.1.5.3 Lowland vegetation

The low altitude areas in eastern Afar are severely degraded *Acacia* bush lands, comprising scrub and grass vegetation on highly eroded lands with rock outcrops. Many parts of Gewane, Aysaita, Afambo, and other woredas are devoid of vegetation. The most common tree/shrub species are *A. senegal*, *A. oerfota*, *A. mellifera*, *Combretum* spp., *A. tortilis* and other species. Most natural vegetation in these lowlands has been destroyed by overgrazing, fuelwood gathering, charcoal, and recurrent droughts. In eastern Gewane, *A. senegal* has been selectively cut for charcoal and overgrazed, thereby shifting the climax vegetation to stands of less palatable



species such as *A. oerfota* and *A. mellifera*. The capacity of these areas to rehabilitate, under present circumstances and with continued human interference, is extremely limited. These areas are ecologically fragile and require serious attention in resource management and conservation.

Besides the general vegetation classes mentioned above, a newly introduced species, *Prosopis juliflora*, is encroaching rapidly, colonizing vast areas of the fertile agricultural lands in the Awash River Valley. As a result, large areas of fertile farmlands have been abandoned in the Amibara and Gewane woredas. *Prosopis* produces wind-blown seeds that spread and colonize the area. The species may also reproduce vegetatively.

Wetlands formed by flooding, in particular those near the Awash River, also form an important part of the landscape of the region. Wetland vegetation has great economic and ecological value as a home for wetland animals and birds and is home to many important plant species of local economic significance, such as *Arundinaria* spp. Wetlands are fragile ecosystems that require careful management and conservation, which should be done by local agencies and people.

9.1.6 Land use and farming systems

Major uses of land resources within the Awash and other major river basins include livestock rearing, crop production, and forestry, combined with the harvesting of wood, fruit, and medicinal products. Though livestock rearing continues to dominate as the foremost agricultural enterprise, the exploratory survey across the Afar area suggests an expansion of agricultural enterprises, especially commercial farming. Grasslands are slowly being converted to agricultural lands. Agroforestry practices are major features of land-use in the drylands of eastern and central Africa, and trees are used for a variety of purposes in both cropland and livestock grazing systems.

9.1.6.1 Livestock

Livestock rearing is the most important occupation of the Afar pastoralists. Sheep, goats, camels, and sometimes donkeys thrive throughout the region. Cattle are less resistant to dehydration; therefore, they are kept in the milder western escarpments during the hottest months where the environment is more suitable.

A rational utilization of resources in marginal lands requires mobility in order to have a minimal impact on

natural resources. Pastoralists move to reduce risks from disease epidemics and to improve livestock feed quality. The Afar pastoralists are traditional conservationists; they move to take advantage of ephemeral rainy-season grasslands while staying within reach of water sources like the Awash River. However, the recent explosion of human and livestock population has resulted in massive degradation of the natural and silvo-pastoral environments.

9.1.6.2 Crop production

Settled, mixed-farming systems producing both crops and livestock on the same management unit are common in the western parts of the region. These areas have better environmental conditions to support crop production than the areas in northeastern and eastern Afar. According to LUPRD (1998), estimated total cultivated land in the region is 161,059 ha. State farms cover around 50,210 ha and are concentrated in Amibara, Aysaita, Awash Fentale, Dubti, Dulecha, Gewane, Mille, and Yallo woredas. About 77,347 ha are cultivated, with about half of that area cultivated intensively. Major crops include maize, sorghum and cotton, which are grown mainly on state farms. A variety of fruit crops such as orange, banana, and mango are also grown. Land under cultivation is limited compared to arable land where numerous rivers, including the Awash, Golina, Mille, and Alawaha, offer irrigation potential.

Overall, crop and livestock productivity is low (LUPRD 1998). Causes include erratic rainfall, poor land management, diseases and parasites, low yielding crop varieties, poor extension services and institutional support, shortages of animal feeds, and the complex socio-cultural pressures of the pastoralists in the region.

9.2 Agroforestry systems in Afar

The agro-silvo-pastoral system is defined as all practices that involve a

close association of trees and shrubs with crops and/or animals. This association has both ecological and economic importance. Agroforestry practices contribute a wide range of goods and services to the rural community. Trees and shrubs provide food, fodder, shelter, energy, medicine, raw materials for crafts, and cash income. They also improve soil fertility, improve microclimate, and protect fragile environments such as riparian areas, hill slopes, and rangelands from wind and water erosion (Rocheleau et al. 1988).

9.2.1 The agro-silvo-pastoral system

The vast grass and tree-steppes across the Afar region have been home to the mobile and semi-mobile pastoralists since time immemorial. The people have adapted to the difficult ecological circumstances of the environment by managing migration routes and grazing times based on available water and fodder resources. The Afar pastoralists move their cattle away from rivers to take advantage of ephemeral rainy-season grasslands, returning to water sources such as the Awash River. According to local information, this movement allows livestock to take advantage of quality and quantity forage while breaking disease and parasite cycles through avoidance. These people gather dead firewood, protect useful trees and fodder species, and express hostility toward intruders who cut and degrade these resources.

Food: Trees/shrubs are used as supplemental food, especially riverine species such as *Balanites aegyptica*, *Ziziphus* spp., and *Gassera* (local name). These are valued and protected by Afar pastoralists because of their fruit.

Fodder: In Afar, leaves, pods, and fruits of many tree and shrub species are good sources of fodder during the dry season due to their high content of protein and minerals. Species such as *A. tortilis*, *A. nilotica*, *A. seyal*, *A. senegal*, and *Balanites aegyptic*

are important browse and fodder species. Due to the highly irregular rainfall and virtual disappearance of nutritious grasses during the dry seasons, trees and shrubs are essential sources of fodder in Afar.

Fuelwood: Normally, Afar pastoralists gather dead branches and sticks for fuel wood. Only rarely do they selectively cut older trees for fuel wood, while leaving young, pod-bearing trees to produce dry season fodder. However, shrub lands are also extensively exploited for charcoal by people from outside the region.

Habitat for wildlife: The riparian vegetation supports numerous bird species and other wild animals, particularly in the wetlands.

Minor forest products and traditional medicines: Forests provide honey, rope, water purification, and sticks for cleaning teeth. The Afar people share medicinal plant knowledge for both human and animal diseases only among family members.

Construction materials: Afar shelters (tukuls) are usually made with wood collected locally rather than wood cut from live trees.

Shade for humans and livestock: Trees provide shade against the scorching heat; communal gatherings are often held under tree shade.

Soil and water conservation: Trees/shrubs also help maintain the stability and fertility of the grazing lands, improve soil moisture, maintain diversity of species, and reverse trends of land degradation and desertification.

9.2.2 Degradation of the agro-silvo-pastoral areas: causes and consequences

Under the agro-silvo-pastoral system, natural vegetation has virtually disappeared, leaving only a few scattered and irregularly spaced trees and shrubs, and vast areas of land devoid of vegetation. Local communities attribute causes of exploitation and land degradation to excessive grazing, charcoal manufacture, firewood cutting, recurrent droughts, and the expansion of agricultural land beginning in the 1960s. While the population was low, the land and resources were utilized in a reasonably optimum manner. With increased human and livestock population, however, overgrazing has severely impacted the landscape.

9.3 Impacts of climate change on dryland biodiversity

The Afar arid pastoral systems are classified as dryland agroecology





characterized by rich biodiversity. The impacts of climate change on biodiversity include distribution, abundance, behavior, phenology (the timing of events such as migration or breeding), morphology (size and shape) and genetic composition of the vegetation and associated wildlife. The following are direct impacts of climate change on biodiversity (Smithers et al. 2008): (1) changes in phenology which may lead to loss of synchrony between species, (2) changes in species abundance and distribution (including arrival and loss of species), (3) changes in community composition, (4) changes in ecosystem processes, and (5) loss of space due to sea level rise.

Climate change modifies biodiversity because as the temperature increases, many local species have to shift habitat ranges to areas better suited to their needs. For example, warming causes some species to shift their ranges upwards along altitudinal gradients, potentially replacing existing species in those areas. Changing temperatures will also influence species' reproductive cycles and their growth patterns; range shifts also affect interactions between species (Local Governments for Sustainabil-

ity [ICLEI] 2008). If rapid and irreversible change in biodiversity is to be avoided, conservation strategies need to focus more on supporting species' natural capacity to adapt to change. Helping species to adapt may also help avoid the loss of important ecosystem services and the degradation of cultural and economic values attached to particular species. Degradation of ecosystem services often causes significant damage to human quality of life and contributes to the loss of natural assets or wealth of a country. Unless addressed, these impacts will also substantially diminish the benefits that future generations obtain from ecosystems.

9.4 Adaptation to and mitigation of climate change

The Secretary of the Convention on Biological Diversity (SCBD) (2007) stated that maintaining and improving biodiversity must be the priority as people adapt to climate change. Adaptation is a process through which societies cope with an uncertain future (IPCC 2007c). Adapting to climate change must focus on reducing negative effects as well as enhancing

positive steps by making appropriate adjustments and changes.

Biodiversity contributes to the mitigation and adaptation to climate change (Djoghla 2007) by (1) reducing emissions from deforestation and other forms of habitat destruction, (2) providing a 'safety net' of genetic resources for adaptation, (3) providing protection (bioshields) against flooding, coastal erosion, and other natural disasters, and (4) ensuring livelihoods by providing goods and services (clean water, energy, food, etc).

Biodiversity ensures that as plants, fungi and soil bacteria interact, carbon dioxide is sequestered, thereby reducing the amount of GHG, which contributes to global warming. Carbon dioxide released through deforestation and land use accounts for as much as 16% to 20% of total human-induced GHG emissions. Maintaining local biodiversity and increasing urban green space, particularly in forested areas, are significant and effective contributions towards protecting the global climate.

Investing in global climate protection will improve the quality of life in cities and towns while maintaining diverse resources for pastoralists (ICLEI 2008). Increasing tree cover and green space in urban areas will reduce temperatures and create more livable microclimates. Protecting and restoring riverine or coastal vegetation will reduce the risks of flooding as a result of extreme weather events. Rehabilitating and diversifying municipal forests and wetlands will contribute to more evenly distributed water flow in watersheds. Avoiding habitat fragmentation will improve landscape ecosystems. Preventing conversion of plantations to single species maintains biodiversity, and practicing low-intensity forestry enhances the ecosystem. According to the SCBD (2007), adaptation options in drylands include more sustainable and efficient management of water resources and the restoration of degraded lands.

9.5 Potential agroforestry trees and shrubs in arid and semi-arid ecosystems

In arid and semi-arid ecosystems, trees and shrubs are valuable sources of fuelwood, shelter, timber, herbal medicines and food for people, and they also help to maintain soil fertility and ecosystem resilience. Furthermore, as these dry areas are commonly occupied by pastoralists, trees and shrubs are important sources of protein-rich fodder for livestock.

9.5.1 *Acacia tortilis*

Acacia tortilis is a drought- and salinity-resistant tree. Its long taproot and numerous lateral roots enable it to utilize the limited soil moisture. According to a research report from the Borana lowlands, *Acacia tortilis* has seven different uses, which include forage, medicine, and shade (Gemedo-Dalle et al. 2005). Products of *Acacia tortilis* include the following (World Agroforestry Center):

Food: In Kenya, the Turkana make porridge from the pods after extracting the seed; the Maasai eat the immature seeds.

Fodder: *Acacia tortilis* is an important source of fodder for cattle in India, West Africa, Somalia, and Ethiopia. Animals browse both foliage and fruit; and the leaves are fed dried as well as green. A 10-year-old *A. tortilis* yields about 4-6 kg dry leaf and 10-12 kg pods per year. Fruits are preferred for stall-fed animals and should be ground to improve nutrient absorption.

Fuel: *A. tortilis* starts producing fuelwood at the age of 8-18 years, at the rate of 50 kg/tree. Its fast growth and good coppicing, coupled with the high caloric value of its wood (4400 kcal/kg), make it suitable for firewood and charcoal.

Timber: The timber is used for planking, boxes, poles, moisture proof plywood, gun and rifle parts, furniture,



house construction and farm implements.¹

Tannin or dyestuff: The bark is reported to be a rich source of tannin.

Medicine: The dried, powdered bark is used as a disinfectant in healing wounds.

9.5.2 *Acacia senegal*

Acacia senegal is a multipurpose tree, highly valued for centuries for gum arabic production. It is grown primarily for gum but plays a secondary role in agricultural systems in restoring soil fertility and providing fuel and fodder. *A. senegal* is drought resistant, growing well in areas with annual rainfall between 100-950 mm, and 5-11 month dry periods. It tolerates high daily temperatures of 45°C or more, dry winds, and sandstorms.

9.5.3 *Tamarindus indica*

Tamarindus indica is a widely adapted, multipurpose fruit tree. Its uses include food, medicine, wood, and construction products. The species is drought resistant and hardy; it also

performs well as a windbreak and provides protection for people, crops, and animals against harsh winds and prevents soil erosion. The brown, sticky, sour-sweet pulp of the fruit is used widely as a flavoring in a variety of dishes and drinks.

9.6 Adapting to climate change: Agroforestry and institutional strategies

Recent surveys conducted in the Afar region have focused on peoples' priorities as well as the need to understand local resource conditions. Knowing the reasons that local people will accept or suggest improvements in each agroforestry practice will facilitate the adaptive research and extension process and enhance long-term success associated with mitigating climate change. The following agroforestry practices were either found to demonstrate merit or were considered to be feasible options worth testing by local people.

9.6.1 Proposed agroforestry packages

The design and implementation of agroforestry packages must be a col-

¹ This species has been used for wood products since ancient times; some traditions believe that Noah of the Old Testament made his ark from the wood of *Acacia tortilis*.

laborative process between local people sharing their needs and professionals who can suggest improvements for critical review and possible implementation. Perhaps the first step requires the definition of goals at multiple levels, including infrastructure improvements as well as what local people expect to achieve by planting trees or shrubs. Next, local people and professionals can present options and probable consequences so that relevant components may be assembled into systems that meet multiple objectives such as supporting livelihoods while contributing to climate change mitigation. Plans, timelines, and responsibilities need to be defined including the division of responsibility for the provision of required inputs, infrastructure, and monitoring. The following describes agroforestry practices and associated requirements deemed appropriate by local people and professionals within an integrated regional framework:

- Promote natural regeneration of desirable species as an affordable and easily managed option for the conservation and increase of beneficial trees and shrubs. Desirable

species may require protection by building exclosures to prevent livestock browsing or cutting by humans. A Self Help Development (SHDI) project in West Arsi of the Rift Valley regenerated preferred species that were guarded by local people.

- Enrich fodder reserves by planting trees such as *Balanites aegyptica*, *ziziphus species*, *Tamarindus indica*, *A. tortilis* in woodlands, pastures, and waterways adds diversity and valued products that pastoral people depend upon.
- Plant trees along roadsides, urban areas, and ornamental sites to offer shade, improve micro-climate, and provide wood, fruit, gum, honey, animal fodder, and other products. Woodlots can be managed for fuel, fodder, or construction materials depending on species selected by land managers.
- Plant fruit trees in settlements around homestead, water points, and areas with irriga-

tion for the generation of income. In Afambo woreda, date palm can add 20–30 kg of fruit from a single tree at a value of 3-6 birr/kg. In Kerensa Gara, pastoralists stayed longer or women stayed to manage fruit trees at water points.

- Install windbreaks to conserve soil and moisture while improving the micro-climate. When planted in rows of different species, wind-blown sand and erosion is reduced and harvestable products are increased.

9.6.2 Cultural barriers

Traditionally, the pastoralists' life of moving with their herds and focusing on the immediate needs of forage and survival discourages them from planting, protecting, and managing trees and forests or the associated biodiversity thereof. Successful tree planting and growth requires protection from grazing. Sharing the use of communal lands reduces personal "ownership" of the resource, thereby creating a "tragedy of the commons" where everyone utilizes, but few conserve or manage the resource. Surveys of pastoralists suggest that individuals do understand the management of these fragile resources. Thus, the next step requires pastoralists to envision how they might contribute to successful management of the resource across the landscape. Agriculturists and urban dwellers, as well as institutional representatives responsible for managing this resource across the entire region, must do likewise.

9.6.3 Water and tree protection

Water is the most important limiting factor for the production and survival of trees and animals in these arid and semi-arid areas. Thus, water-harvesting systems will have a tremendous value for increasing the survival of newly planted trees and helping agro-





forestry programs succeed. Rainwater can be harvested in inexpensive and easily constructed micro-catchments consisting of v-shaped or semi-circular depressions. Local people often know how to protect trees using thorny branches or structures built with local materials. Agencies can contribute by developing water points by managing ponds, drilling wells, or building small reservoirs to enhance the ecosystem and conserve its natural resources.

9.6.4 Ownership rights and land tenure

Long term investment in planting trees and developing conservation practices requires local people to consider strategies for managing resources within communities. Urban dwellers and hired farmers may also consider strategies for planting and managing trees on land considered to be for communal forage. As people move from one area to another, they

need to be informed and invited to contribute and help manage the planting of trees within the region, which benefits both people and the ecosystem.

9.6.5 Developing infrastructure

Infrastructural improvements such as roads, water catchments, and markets must coincide with expectations that local people manage their agroforestry and biodiversity. Partnerships between agencies and local people must form social infrastructures that contribute to the success of landscape-based projects that include planting and protecting trees.

9.6.6 Developing incentives to plant trees

Everyone must learn to value natural resources such as trees, water, soil, and biodiversity as assets that require conservation because they are critical for human survival. Agency personnel

must inquire and help individuals develop social capital to manage these resources within clans, urban areas, and watersheds where cattle roam broadly. They must also develop economic capital that recognizes the intrinsic value of resources that sequester carbon, enhance biodiversity, and may ameliorate climate change, as well as simply the products from those resources. Presently, most woredas may have sufficient tree and shrub cover, but local people and agencies must understand that this renewable resource nevertheless requires decades to mature.

9.6.7 Markets for tree products

Developing markets for products made, used, and harvested from renewable resources helps people survive while maintaining trees, shrubs, and ecosystem services. One example of infrastructure adaptation and livelihood improvement within the Afar



region must be the development of roads that will facilitate the transportation of rural inhabitants to city markets.

9.6.8 Research that encourages action

Interdisciplinary research on socioeconomic needs of the people and agencies is essential for the improvement of livestock and agroforestry practices. Adaptive research integrates results from other regions with creative local ideas and allows people to test and adapt these strategies to their needs. Action research encourages the multiple stakeholders managing Afar's natural resources to be involved in the research and extension of proposed practices and gauge their success.

9.6.9 Developing adaptable extension and institutional support

Successful implementation of agro-silva-pastoral practices across the Afar region requires an integrated

extension and research program. All agencies that build roads, develop water points, encourage markets, grow tree seedlings, and manage regional infrastructure must also unite to integrate program awareness, delivery, knowledge, and interventions. Agencies must first listen to and understand the views and experiences of pastoralists, agriculturists, and urban dwellers. Building local knowledge and values associated with resource management into regional management and agroecological strategies may be one avenue for greater success. Because climate change and regional resource management require both a personal and a public knowledge and responsibility, it is imperative that everyone think globally while acting locally.

Adapting an integrated, multi-disciplinary, and multi-agency approach means partnering to achieve regional success. For example, both pastoralists and agencies might be expected to develop catchment basins

to conserve water for individual trees while larger-scale catchments would increase regional water resources. Planting and protecting trees might be expected of agriculturists; planting trees in public places such as along roads or riparian areas may be delegated to agencies. Critical to success is having everyone share in the process of managing ecosystems over large landscapes and time periods. This will require an extensive remodeling of how people and agencies collaborate for the good of the entire ecosystem.

Extension education and agricultural research perform crucial functions in promoting agroforestry practices, expected benefits, and improved natural management. Multi-disciplinary teams comprising forestry, crop, livestock, and socio-economists can meet with clan leaders, local community members including women, and agency personnel to create awareness. Continuing socioeconomic research and surveys will help formulate and implement relevant programs that honor traditional values while expanding the use of multi-purpose trees and conservation practices, with the goals being to enhance the provision of ecosystem services while also adapting to climate change. Extension should include dynamic educational activities such as audiovisuals, demonstrations, and collaborative evaluation to determine needed improvements and ensure success. The aim is to develop dynamic programs in which everyone participates and that integrate current disciplines into productive agroforestry ecosystems that produce multiple services for human use, while mitigating climate change both within the Afar region and globally.



Chapter 10. Case study – Evergreen Agriculture Project: Meru (highlands)

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10.1 Introduction

This case study draws the bulk of its data from the results of a survey conducted in December 2010 as a baseline study for implementing the Evergreen Agriculture project in Meru (Muriuki et al., in review), as well as additional literature. Evergreen agriculture is a concept that implies the deliberate integration of particular tree species into annual cropping systems to improve system productivity. Ideally, it aims to combine principles of conservation agriculture¹ and agroforestry to reduce or reverse soil fertility depletion through the use of “fertilizer” trees, improve carbon and moisture retention in the soil, and provide shade and tree cover on cul-

tivated fields, in addition to the provision of tree products such as fodder, firewood, and fruits. The target site for this project is Meru Central District (Figure 10.1). The area is part of the 16% of high potential agricultural land in Kenya. In the survey, 512 households were interviewed from three locations representing different altitudinal zones in the district: high (above 1500 MASL), mid (1000–1500 MASL) and low (below 1000 MASL). Although only about one-third of the district is considered to have medium to high potential for agriculture, the output from that area is one of the highest in the nation.

Meru Central District lies to the east of Mount Kenya, a peak that cuts through the southwest border of the

district and straddles the equator, lying within latitude 0°3'45" N and 0°2'30"E. The district covers a total area of 2,982 km², of which Mount Kenya and the Imenti forests cover 1,030 km², leaving only 1,952 km² for human settlement. The wide range of altitude in the area (300 to 5,199 MASL) creates a variety of ecological zones ranging from extremely fertile, well-watered agricultural areas to low-lying semi-arid lands. The district is

¹ Conservation agriculture aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It is based on three principles: minimum soil disturbance, adequate soil cover especially through leaving crop residue in the field and crop rotations (FAO 2001).



characterized by valleys, hills, and plains with 10 major rivers emanating from Mount Kenya. The rainfall pattern is bimodal, with long periods of rain occurring from mid-March to May and short periods occurring from October to December. The mean annual rainfall is about 1,300 mm, ranging from 380 mm in lowland areas to 2,500 mm on the slopes of Mount Kenya. As evidence of the variation on the climate, the area is experiencing extreme weather conditions and the disappearance of glaciers, leading to intermittent river flows and the drying up of about 26 rivers and streams within the entire Mount Kenya area (which consists of Meru and four other districts). Famine Early Warning Systems Network (FEWS-Net) analysis (Funk 2010) shows that the precipitation in the “long rains” season in this area has declined by more than 100 mm since the mid-1970s and that the decline appears to be linked to warming in the Indian Ocean. It is also likely to continue. A warming of more than 1°C is also predicted for the Meru area, which may exacerbate the impact of drying.

10.2 Population and household assets

According to the 2009 Population and Housing Census in Kenya, Meru Central District has a population of 498,880, which is growing at 1.48 percent per annum. Youth (0-14 years) account for about 44% of the total population, while the aged (60 and older) account for 6% of the total population. Together, they total 50% of the population, giving a dependency ratio of 100:103. The large number of dependents results in low savings accumulation and can diminish households’ resilience to shocks, in addition to straining the existing health and education facilities. The economically active population (15–64 years old) constitutes about 57% of the population, of which 50.5% are women. The district is generally highly populated, which increases the pressure on the arable land. Most (90%) of the respondents to the Evergreen Agriculture Baseline Survey had lived at their current farm location for as long as they could recall, while a minority (10%) said that they had

migrated into the area. Nearly one-third (30%) of the immigrants could not specify their year of migration, while half had migrated between 1990 and 2010, mainly in search of better farming land. Additional studies indicate that most of the resettlement in the area had occurred in the 1950s as part of colonial government land consolidation plans², with further resettlement in the 1960s onto approximately 2000 ha of excised forests (Barr and McGrew 2004).

Most community members own land on a freehold basis, with an average ownership of about 1 ha, although landholdings decrease as elevation (and associated agricultural potential) increases. The Meru community is, on average, wealthier than the average Kenyan community, and the most common housing (about three-quarters of the community) is composed of wooden walls and corrugated iron sheet roofs. Markets selling agricultural products, as well as shops for agricultural inputs, are common and are within 5 km of at least 75% of the households. Machetes and hoes are the most common farming implements, but farmers have scant information on conservation agriculture and its associated tools. At least 25% of the adult population has access to mobile phones and radio, while fewer households possess assets such as water tanks, televisions, bicycles, cars, ox-carts, and motorcycles. The prevalence of communications technology implies that community members can easily be reached with information regarding climate change adaptation and mitigation.

The top two energy sources for cooking, as reported by respondents, were firewood (94%) and crop residues (35%), while 66% used kerosene. The majority of the respondents (70%) had access to piped water, which they mainly used for drinking (82%), livestock (83%), and domestic

² Following what has been referred to as the “Swynnerton Plan.”

uses (82%). Agriculture is mainly rain-fed; only 40% of the respondents used small-scale irrigation (overhead and watering cans) on their farms. It is significant to note that a third of the sampled households relied on crop residues as their second source of cooking energy; this has implications for the adoption of climate-smart agriculture. When farmers have diminished access to fuelwood, they tend to use crop residues or animal dung as energy. Conservation agriculture technologies are based on the principle of leaving crop residues in the field to ensure adequate soil cover. Conversely, planting more appropriately selected tree species will ensure more green cover on farms, while providing fuel wood for domestic use.

Slightly over half of the community (56%) can produce enough food to feed their families throughout the year. The rest of the community experiences food deficits for three to four months per year due to limited

land and lack of funds to buy agricultural inputs. This percentage of the community must either purchase food from markets or make dietary adaptations. About 10% of the population struggles to meet its food needs, and this number will increase if food production is reduced by climate change, as predicted.

10.3 Healthcare, education and agricultural extension

The Meru Central District has just over 160 health facilities spread throughout the district. The average distance to the nearest health facility is 7 km and the doctor to patient ratio is 1:33,259, suggesting that most healthcare facilities in the district are staffed by healthcare workers rather than doctors. The most prevalent diseases in the district are malaria, respiratory ailments, and intestinal worms (although the prevalence of

STIs, including HIV/AIDS, is also significant; Muriuki 2011). Climate change in the form of warmer conditions and increased frequency of extreme weather events is expected to increase the prevalence of these diseases. Primary health care programs (PHC) that address these medical problems must be implemented; such programs should also include education about and preventative strategies for managing the spread of STI/STDs including HIV/AIDS.

The district has a total of 367 primary schools with school enrollment at 48% for boys and 52% for girls. The district had 72 secondary schools, with school enrollment at 46.2% for boys and 53.8% for girls. Generally, most farmers have only attained a basic education; only 8% of the farm household heads in the Evergreen Survey reported the attainment of any form of college education. Slightly over half (55%) of farmers had reached the primary level, while one-

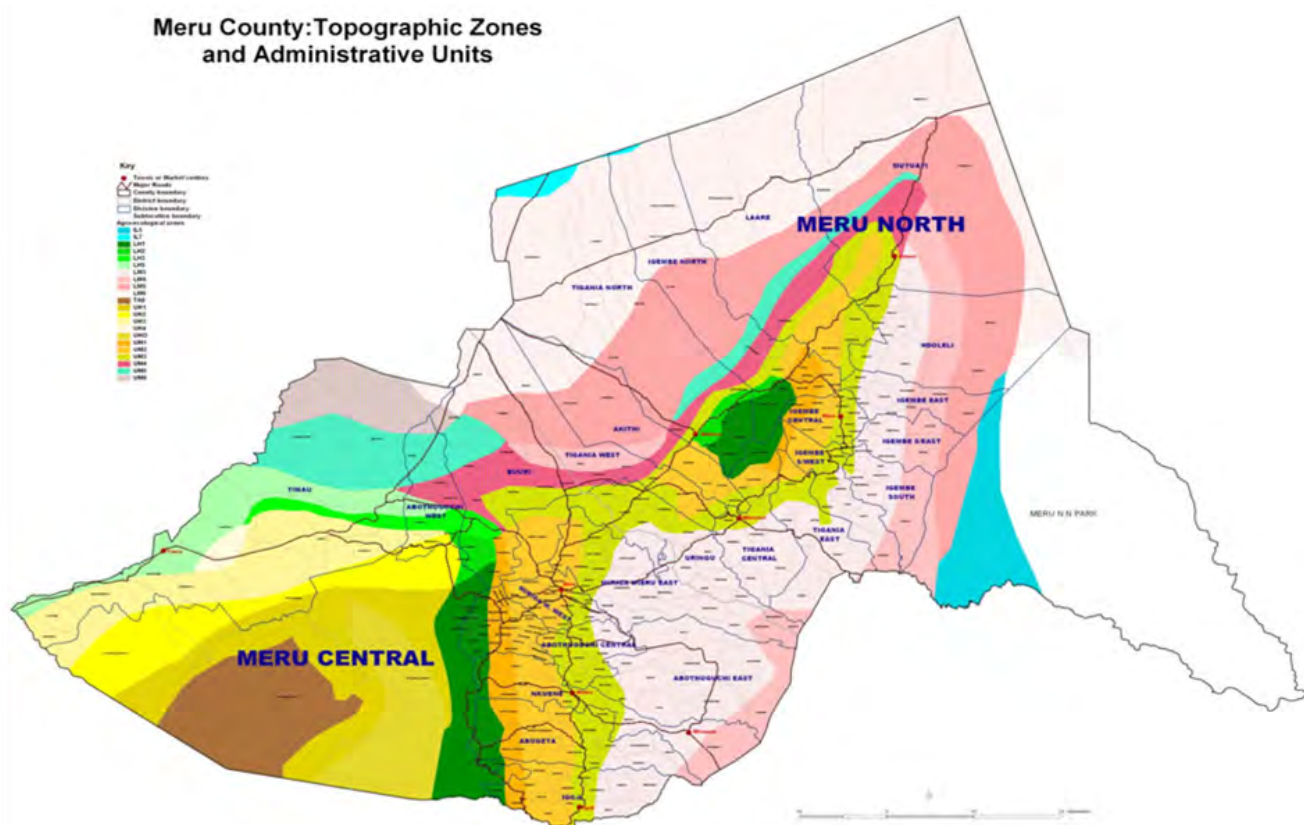


Figure 10.1 Agroecological map of Meru County showing administrative units and topographic zones.



quarter had completed their schooling to the secondary level.

Capacity building among farmers is mainly led by government extension services (especially the Ministry of Agriculture frontline workers) even though the private sector, NGOs, and community-based organizations also offer extension services (Muyanga and Jayne 2006). Extension means advisory and other services that help farmers to make the best use of their productive resources, including providing farmers with important information on agronomic practices, agricultural markets and other trends which can incorporate climate related information and coping strategies (Business and Industry Advisory Committee [BIAC] 2009). Farmer training is an important approach in extension through seminars, farmer field schools, and other methods. Training opportunities are not common for farmers in Meru, however; two-thirds of respondents to the Evergreen Survey had not attended training oppor-

farmers as their main sources of information on new agricultural technologies. Radio and television were the leading source of information on forest and/or watershed management and played a major role in the spread of information about markets and new seed varieties. These channels are therefore useful for conveying information on climate change adaptation and mitigation to farmers in this district.

Farmers are now organized into many collective action groups through which the extension service can reach them together, instead of earlier approaches where extension agents approached farmers individually (Muyanga and Jayne 2006). According to 512 respondents in the Evergreen Survey, there are nearly 100 evergreen groups, indicating that social capital is high in the community; Barr and McGrew (2004) had similar observations. Groups are formed to achieve many objectives: groups led by men often involve in-

tunities in the three years before they were interviewed. For those who had attended training sessions, climate change-related information was not reported in the content. It is positive to note that farmers did not perceive any discrimination based on gender or wealth from the organizations that offered these training opportunities, and that all farmers reported equal opportunities to participate.

Farmers cited personal experience and networking with other

infrastructural projects such as the provision of water and electricity, whereas those led by women often involve revolving funds for the purchase of household items. The groups also serve as a significant source of credit for farmers who have long been excluded from major credit institutions. Many respondents to the Evergreen Survey reported a phobia of bank credit, despite improvements in small-scale loan conditions for farmers. Farmers instead are choosing to rely on evergreen groups and relatives, using them as their main sources of credit.

This social capital has evidently played an important role in the conservation of natural resources and will support the adoption of climate-smart farming approaches that require a new set of tools, such as conservation agriculture, as argued by Pretty (2003). Community groups have already been involved in many activities aimed at climate change mitigation, such as tree planting and energy efficiency projects (Small Grants Programme [SGP] 2004, Barr and McGrew 2004). The Greenbelt Movement mobilized several women's groups in the district to raise indigenous trees and plant them in degraded community lands. The NGO has also raised awareness of the important role that native tree species play in the resilience of farming systems; several farmers subsequently planted some native tree seedlings in their farms (Barr and McGrew 2004).

10.4 Agricultural practices

Meru people predominantly practice mixed farming consisting of crop cultivation and animal husbandry. In Meru District there are approximately 100 large-scale farms (each over 20 ha) and 90,000 small-scale farms. Cash crops include coffee, tea, tobacco, cotton, khat (*Catha edulis*), and macadamia nuts. Commonly grown staple crops include maize, beans, potatoes, sorghum, pigeon

peas, cassava, yams, and arrowroot. Oil crops such as sunflower, groundnuts, cotton, and soybeans are produced in the marginal coffee zone (Jaetzold et al. 2006). A variety of horticultural crops such as cabbages, tomatoes, kales and onions are also produced in the coffee zone (UM 2). There are two cropping seasons: the first, or “long rains” (April to May), support the annual crops and are also vital in supporting perennial crops such as bananas, mountain pawpaw, avocados, passionfruit, and mangoes (Jaetzold et al. 2006). Predictions by FEWS-Net (Funk 2010) indicate that these long rains have been generally decreasing and that the “short rains” (October to January) are becoming more reliable for cropping. Because of this, there is a possibility that future rainfall patterns may support only one cropping season.

Three-quarters of the farmers consider their land to be fertile, while one-fifth no longer consider their land to be fertile. Over half of the farmers reported that the fertility of their land had decreased over time. Interestingly, nearly one-quarter (24%) observed some improvement in fertility. Two-thirds of the farms are on lands that slope to some degree, making the land vulnerable to varying degrees of soil erosion when rains fall. Climate change predictions indicate that rains will intensify in the region. Without more sustainable soil-management practices, both erosion rates and the frequency of landslides could increase. Landslides have already been reported in parts of the district (Ngechu and Mathu 1999).

The majority of respondents (over 90%) already apply some soil conservation measures, such as planting soil cover crops and terracing their farms, to reduce the severity of soil erosion. Lack of relevant skills as well as labor constraints are factors hindering farmers who do not apply soil conservation measures. Labor constraints are common during the preparation of land for a cropping season, as well as during planting, weeding,



and harvest. The application of conservation agriculture approaches and agroforestry technologies has the potential to reduce labor constraints in the long run (especially conservation agriculture; FAO 2001) and increase the resilience of farms to intense erosion.

Tea and coffee have traditionally been a major source of income for farmers but are very vulnerable to climate change. Farmers traditionally relied on the two crops for income and grew only two or three food crops (usually maize and beans) for subsistence. However, rising temperatures and less reliable rainfall have caused reductions in both cash crops. Climate change is predicted to shift suitable growth areas for the two crops upward on the altitudinal gradient, making current growing areas less suitable in the future (Eitzinger et al. 2011). This does not necessarily mean that farmers will be able to move upward as well, however. To stop the expansion of the agricultural frontier, the tea-growing areas close to gazetted forest boundaries and Nyayo Tea Zones Corporation established parastatal tea plantations along the forest boundary. Thus, farmers in the future will therefore be forced to stop grow-

ing these two crops and turn to other crops instead.

Climate-change coping strategies for farmers in these areas include growing crops such as maize, pigeon peas, cabbages, bananas, and passionfruit and the adaptation of agro-economic management practices for coffee that consider shade, varieties, irrigation, etc. (Eitzinger et al. 2011). Farmers have already been coping by diversifying their crops and growing roots and tubers such as potatoes and cassava. Banana growing is especially common in Meru and is a response to variations in cropping seasons. Most of the yield supplies urban centers outside of the region, especially the city of Nairobi. Farmers are also abandoning mono-cropping practices. The Evergreen Survey found that intercropping of up to four species on the same plot was becoming the norm. Pulses, especially French beans (*Phaseolus vulgaris*), have also become an important export crop where irrigated farming is possible.

Dairy production in the coffee zone is by what is called a “zero grazing system,” in which two to three animals are stall-fed (via a “carry and feed” method). Dairy farming is an

important economic activity in Meru, especially with the decline of the coffee industry due to declining yields and unreliable returns. The dairy industry has traditionally been cattle based, but dairy goats are becoming more common due to scarcity of feeds (Ahuya et al. 2006). Fodder is grown on the farms, and animals are rarely allowed to roam freely because there are often other farm enterprises in operation that are not compatible with a free-range system. In the marginal coffee zone, farmers can either freely graze cattle or paddock-feed cattle. Other livestock in the area include sheep, pigs, rabbits, and chickens; some farmers also keep bees. Just under one-third of the households sampled in the Evergreen Survey reported having more than three animals of any kind (excluding poultry). This indicates that farmers are reducing herd sizes as feed stocks become scarce because of competing land uses and climate change. An increase in the husbandry of the smaller animals was also reported by Macharia et al. (2010) as a measure for adaptation to increasingly scarce animal fodder by farmers on the leeward side of Mount Kenya.

10.5 Agroforestry practices and forestry

The integration of agroforestry practices remains an inherent part of crop and animal production in these systems. Agroforestry is practiced as part of the community culture (Castro 1991) and plays a major role in climate change mitigation by farmers in the area. Agroforestry practices include planting trees as woodlots along internal and external hedges as well as scattered in croplands.

As the dairy industry has become more important, farmers have also increased the incorporation of fodder shrubs along internal farm hedges and terrace bunds. Two major tree species in the farming landscape, especially in the middle and upper zones, are the Australian tree species *Grevillea robusta* or southern silky

oak and *Eucalyptus* spp. *Grevillea* was promoted for intercropping with coffee for many years, but later became popular with all farmers due to its fast growth rate, compatibility with crops, and potential for the production of timber and firewood. Other introduced species include *Cassia* and *Leuceana* species, especially in the lower zones, although the proportion of indigenous tree species in farms increases as altitude decreases.

Lengkeek et al. (2005) encountered a total of 297 tree species in 64 families in a sample of 35 farms (totaling 60 ha) in Meru. Similarly, Ogino-sako et al. (2006), found 459 tree species in 265 half-hectare plots sampled in the five districts surrounding Mount Kenya. However, most of the trees in the farms belong to a few species, as revealed by rank abundance curves plotted in several studies (Lengkeek et al. 2005, Ogino-sako et al. 2006, Muriuki 2011). Although up to 90 tree species may be encountered on a given farm, most of the species are represented by only one individual in approximately 4 ha, and the 200 to 400 trees present in a single hectare may be dominated by only two or three species. Farms can therefore appear to be like plantations of *Grevillea robusta* interspersed with *Eucalyptus* spp, and this can have negative repercussions on resilience in the face of climate change because indigenous species are under-represented and may not have proper pollen corridors for sustainable reproduction.

Increasing the number of trees in farms is not a very viable option in most parts of the district, especially at the higher elevations, given the high number of trees in the farms (Lengkeek et al. 2005). Instead, diversifying landscapes through increasing the proportion of indigenous tree species and shrubs is recommended as an adaptation measure against climate change. Since the tea industry was recently blocked from accessing forest plantations for fuelwood to use in curing tea leaves, there has been an increased demand for

farm timber trees (Barr and McGrew 2004). The factories turned to farms as a source of fuelwood, and the number of *Grevillea* trees on farms was substantially reduced. Formerly closed-canopy farms were opened for a period, due to this demand. This situation is changing, however, as the number of timber tree saplings in farms increases. The planting of the ecologically inefficient *Eucalyptus* spp. is increasing and small-scale commercial tree nurseries in the area cannot meet the demand (Muriuki 2011). At the same time, however, the proportion of indigenous species seedlings in the nurseries is low (Ogino-sako et al. 2006; Muriuki 2011), which can easily be attributed to the low demand; this implies that the proportion of indigenous species on farms could further decrease if the trend continues.

Campaigns to raise awareness on the role of indigenous species in climate change adaptation and the linkage of these particular species to payment for environmental services (PES) schemes may be necessary. Additionally, public funds must be invested in research on germplasm management and distribution mechanisms for these species. On a positive note, farmers in the area acknowledge that having many tree species in their farms rather than a few is preferable for system resilience (Barr and McGrew 2004). Communities have a wealth of indigenous knowledge associated with such species, especially about their medicinal value, which could be very useful as climatic regimes change, but that knowledge is slowly eroding as the species disappear from the landscape (Muriuki 2011). While indigenous species are maintained on farms (mainly via natural regeneration) for cultural reasons, farmers also reported ecological reasons for maintaining these species, which can be interpreted as adaptation (or mitigation) to harsh climatic conditions. Such reasons include the provision of shade for crops and to cover soils to minimize



Figure 10.2: A typical smallhold farm in Meru showing a complex agroecosystem of trees and both perennial and annual crops (Photo: Jonathan Muriuki)

drying, increased rainfall (soil water conservation), and increased soil fertility. They also acknowledge that indigenous species provide these services better than the exotic species do.

The district also has 86,000 ha of gazetted forest, a part of the Mount Kenya forest block, which is one of Kenya's five water sources. Meru Forest has plantation blocks that are highly characterized by exotic tree species such as cypress, pines, and eucalyptus, and native forest areas consisting of indigenous tree species such as the Meru oak (*Vitex keniensis*), *Juniperus procera*, *Olea* spp., *Croton* spp., and *Prunus africana*. The forest was massively degraded in the 1990s (Gathaara 1999), which, in ad-

dition to climate change, exacerbated the drying of rivers emanating from the Mount Kenya ecosystem. Corruption was the primary cause of this deforestation, as timber merchants, aided by errant forestry officials, logged the forest beyond the allowable cuts, which resulting in the massive degradation of the drier part of the forest (Barr and McGrew 2004). Irregularities in the management of the shamba system³ also hampered forest regeneration and contributed to additional degradation of forest land through soil erosion.

³ The Shamba system is a forest plantation regeneration practice where forest managers allow farmers to grow crops in recently logged forest areas as they tend young tree seedlings until the sapling canopies start to close.

The Meru community, however, joined hands with the government's forest department to reverse the situation. Deforestation greatly impacts women, and several primarily female community groups came together to form a community-based organization called the Meru Forest Environmental Conservation and Protection (MEF-ECAP), which has spearheaded efforts to replant deforested areas. MEFECAP also engages with members of the forest-adjacent community to reduce forest destruction and promote agroforestry practices by supplying tree seedlings, and has initiated ecotourism activities for forest protection (Ongugo et al. 2008). Support of such local community organizations has been provided by the

government through the Kenya Forest Service and Kenya Wildlife Services, as well as from international organizations such as UNDP-COMPACT and locally based NGOs (SGP 2004). These restoration efforts in Mount Kenya forests have had greater success in comparison to efforts in other water towers in Kenya.

10.6 Conclusion

Meru is an area of high potential where the community is engaged in various agricultural enterprises that have yielded a good quality of life for many households, compared to other parts of the country. Climate change impacts are already being felt in the area, as rainfall becomes more irregular and temperatures rise. This, coupled with decreasing land sizes, has caused farmers to adopt different farming practices to improve productivity in a worsening atmosphere. Farmers are moving away from conventional farming practices that were

based on growing a single cash crop (coffee or tea) for income generation and two or three food crops (mainly maize and beans, usually grown as mono-crops) for household subsistence. Several crops, such as pulses, have been introduced as cash crops, and individual small-scale farms now grow many crops, including roots and tubers, and intercropping is common. Livestock numbers have decreased in farms and are mainly managed under zero-grazing systems, while small stock is becoming more common. Although farmers practice soil management technologies, they are barely aware of technologies such as conservation agriculture that may help mitigate the effects of climate change. Farmers are willing to adopt technologies that lead to a sustainable, climate-smart agriculture, however, and the institutional framework necessary to disseminate information regarding such technologies is already in place.

Agroforestry is widely practiced in the district and has great potential to mitigate climate change by absorbing GHG. Farms are dominated by a very few tree species that mainly provide timber and firewood, and the overall number of indigenous species is very low—although many different species are still present, albeit in low numbers. This lack of diversity weakens the resilience of farms; thus, agroforestry practices must diversify tree species by increasing the proportion of indigenous trees as an adaptation measure. The community is aware of the role trees play in climate change adaptation and mitigation and has begun to contribute toward forest protection and regeneration by planting indigenous tree species on community lands. The sharing of climate information and predicted trends with the farming community through various media has great potential to further contribute toward a climate-smart agriculture in Meru.



Chapter 11. Case Study – Agricultural Practices in Kibwezi District, Kenya, in the Context of Climate Change Adaptation and Mitigation

Dr. Jonathan Muriuki, Dr. Henry Neufeldt, Dr. Jeremias Mowo

11.1 Introduction and climatic conditions

Kibwezi District is part of the drylands of Kenya that occupy over 80% of the country and are characterized by low potential for rainfed agriculture. The district is part of Makueni County in the southeastern drylands of the country and is mainly occupied by agro-pastoralists. This case study relies on information drawn from various papers and statistics, rather than a field study. It focuses on studies specific to Kibwezi District, but also draws from countywide (Makue-

ni) studies where these are the most relevant.

Kibwezi District lies between latitudes 2°6'S and 3°S and longitudes 37°36'E and 38°30'E, occupying 3400 km² in land area and at elevations varying from 600 to 1100 MASL. The area lies in the agro-climatic and ecological zones III - VI of Kenya (Figure 11.1), but zones III and IV, which have some medium agricultural potential, constitute only 13% of the district (Gichuki 2000a). The area is characterized by low soil fertility as well as low, erratic and unreliable rainfall of about 600 mm per annum

(Mwang'ombe et al. 2011). The rainfall regime is bimodal and is associated with the north-south movement of the Intertropical Convergence Zone (ITCZ). Temperatures average 23°C and the potential evapotranspiration is up to 2000 mm, which implies that available moisture is lost quickly, making water the most limiting resource.

The short rains fall between November and December and the long rains between March and May. Both seasons used to be reliable for crop production, but farmers report that the long rain season has become unreliable since the 1980s and

Kibwezi District: Agro-Ecological Zones

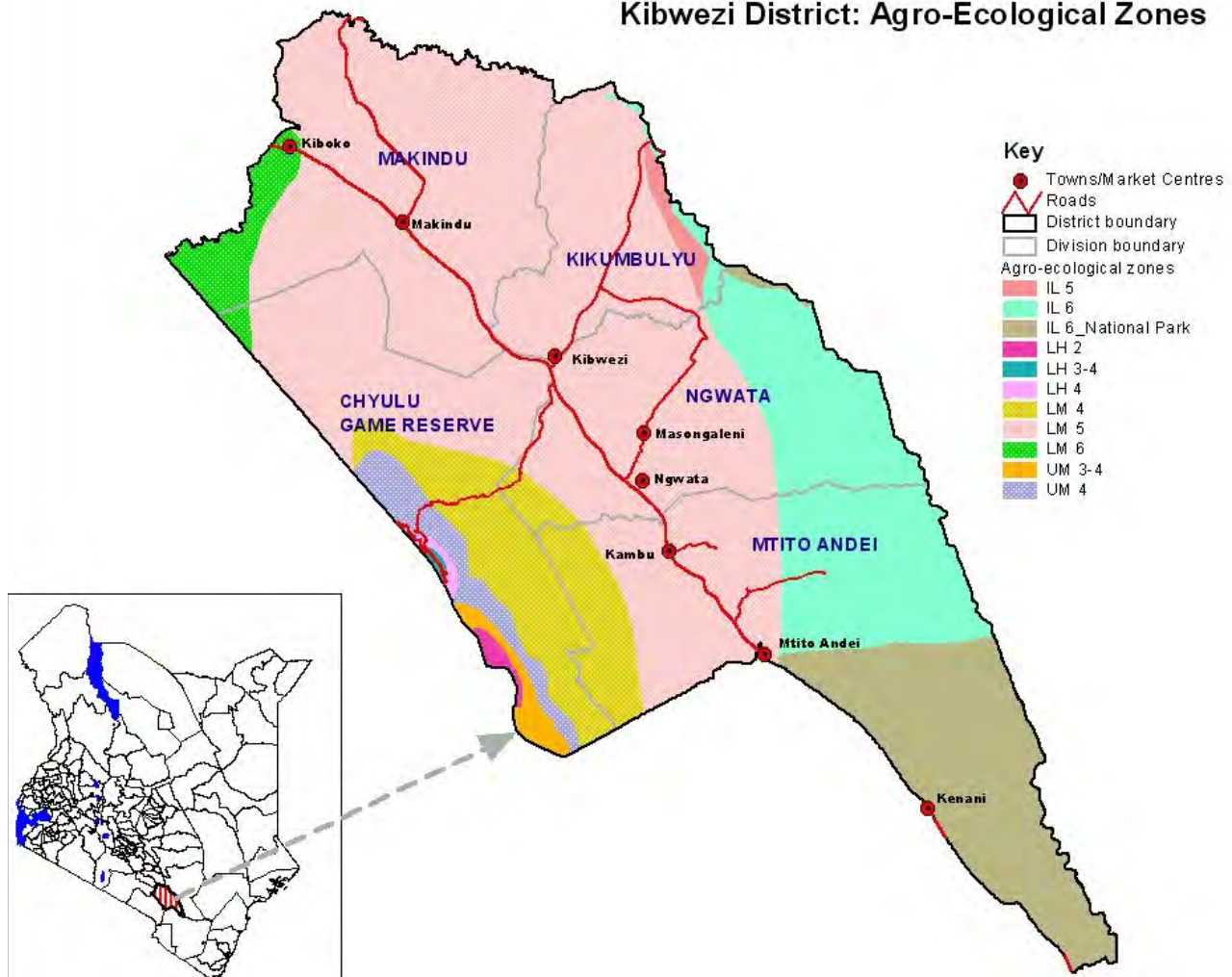


Figure 11.1: The agroecological zones of Kibwezi district, Kenya

droughts are more frequent (Awour 2009). Empirical studies conducted by Musembi and Griffiths (1986) supported the reliability of the short rain season compared to the long rains for crop production. Although rains have normally fallen 75% of the time (Lawrence and Mwanzia 2004), the district has experienced very severe droughts in the last six years, such that even when other parts of Kenya have moisture, crops fail in the district (Church World Service, undated).

Less reliable rainfall combined with rising temperatures has led to reduced crops and pasture growth, and is contributing to desertification and biodiversity loss, food insecurity, and livestock loss, and thus greater insecurity of livelihoods. Lack of feed for both human beings and livestock

is common and people have to cope by eating fewer meals in a day (Mwangombe et al. 2011). Lack of animal feeds leads to a vicious cycle, as members of the community have to cut tree branches to feed their livestock, which (depending on the tree species and whether it has positive effect on crop productivity) impacts food production negatively when the trees do not sufficiently regenerate. Also notable regionally are government efforts to protect major wildlife, with large territories attached to the Tsavo National Park removed from use by farmers, including the Chyulu Hills, the regional watershed. Sometimes livestock owners have to buy feed for their livestock, and grass bails (about 20kg each) can cost up to 3.5 USD. Families that usually have to

buy food and sometimes rely on government relief food cannot afford to buy livestock feeds; thus, stocks have reduced from an average of five or six cows before the drought cycles to little or no livestock holding for most families.

11.2 Demographic characteristics and household capital

Kibwezi District is predominantly occupied by the Akamba community, but a minority of Maasai, Taita, Swahili, Luhya, and other communities also reside in Kibwezi town. The district has a population of 248,704 persons in 53,000 households and a density of 73 persons per square kilometer. Women constitute 50.5 of



the population (Mars Group 2011). Half of the population is younger than 16 years; this creates a dependence ratio of about 124:100. Most of the population arrived after 1960, following land consolidation and overpopulation in the areas of higher agricultural potential north of the district (notably Machakos County), and progressively settled in the district up to the 1990s (Lawrence and Mwanzia 2004, Speranza 2010).

Two thirds of the community live in brick-walled houses with corrugated iron sheet roofs (84%), but a substantial number live in mud-walled houses (29%), often with grass thatched roofs (13%), indicating a generally poor community (Mars Group 2011). The mean monthly income for the entire Makueni County is Ksh 5,506 (USD 60), highly skewed towards the rich few (FAO Kenya 2007). Job opportunities are rare, with less than 15% of the population en-

gaged in salaried employment and about half in daily wage labor. Other occupations for heads of household include their own farm labor, livestock herding, petty trading, and charcoal burning (ACF International 2011). Kerosene is the most common lighting energy and is used in lanterns and tin lamps by 57% and 34% of the households, respectively, while cooking and heating is almost entirely based on wood energy. Only 7% of the population has access to electricity by main grid supply (4%) or by solar powered batteries (3%).

Hygiene and health conditions are severely compromised due to lack of running water or adequate sanitation. Poor access to water of good quality increases the incidences of waterborne diseases to both human beings and livestock.

Kibwezi and indeed the whole Makueni County is one of the underserved areas in Kenya in terms of

health services. There are 6 hospitals, 14 health centers, 59 dispensaries, and 59 nursing homes in the whole of Makueni County (Kibua et al. 2009). The doctor-patient ratio is 1:119,879, indicating a higher workload for medical staff and therefore inadequate access to health care services for a large proportion of the population. HIV/AIDS prevalence is between 10% and 30%, with rates increasing with proximity to the Nairobi-Mombasa highway, where the incidence is 30%. AMREF's presence in Kibwezi for over 30 years could have improved the state of health in the district to levels higher than the national average in many aspects, especially by making the community more involved in community health projects; however, the state of health is generally low in the district (ibid).

Statistics by Mars Group Kenya (2011) indicate that 45% of the households in Kibwezi have some access



to piped water, but only 4% have piped dwellings in the rural areas. Profiles from FAO Kenya (2007) indicate that only one-fifth of the households in the entire Makueni County have access to clean and safe water sources within a 5 km distance, and conditions are worse in drier divisions such as Kibwezi. One fifth of the population in Kibwezi can only access water from ephemeral streams and a quarter of the households rely on springs, wells, or boreholes, most of them seasonal. Sand harvesting in the rivers reduces the length of time the ephemeral rivers can store water for human and/or livestock consumption. The district has only four permanent rivers, Kamibu, Kibwezi, Kiboko, and Mtito Andei—all tributaries of Athi River—but only one, Kibwezi, is not saline. A private farm estate dammed the river in the 1960s, however, leaving poorer people downstream without reliable sources of water; their efforts to access water from the dam have been constantly blocked (Lawrence and Mwanzia 2004, ACF International 2011).

Lack of water not only induces stress in domestic operations, but

also in crop and livestock production. The community has responded to increasing water stress, exacerbated by climate variability, through various approaches, such as the construction of dams, digging of shallow wells, rainwater harvesting using roof catchments, directing runoffs into the farms, and buying water for domestic use (Lawrence and Mwanzia 2004). Farmers who adopted rainwater harvesting had better pastures and crops, making this approach the most successful drought mitigation measure and earning the farmers extra income through sale of grass for fodder (Lawrence and Mwanzia 2004).

Literacy levels are low in Kibwezi District, as two thirds of the population (both men and women) has only attained a primary-school level of education; only 14% of the men and 12% of the women have attained a secondary-school level. Just 2.5% of men and 1.7% of women have attained a tertiary or college-level education. Government and non-governmental organizations have been involved in capacity building activities to enhance community skills in public health (Kibua et al. 2009), soil conservation

(Gichuki 2000b), and agroforestry (Muriuki et al. 2006), however, through formal and informal training.

Lawrence and Mwanzia (2004) give a detailed chronology of Kibwezi as a community-in-formation, pointing to its recent settlement by various community groups and the battle for land rights by indigenous communities, that have settled (or squatted) on former colonial farm estates. The struggle for land rights has been characterized by frustrations and perceived betrayals that portray a weak social capital. This factor, coupled with unclear land tenure and weak political capital, weakens the resilience of the community in the wake of a changing climatic regime, and community organization for mitigation activities is seen as weak. There are, however, many farmers' groups in the district and they have been involved in activities that raise farm productivity and resilience; these activities include soil and water conservation, tree planting, and raising tree seedlings. The community groups may disband after achieving specific outcomes but new ones form when the community is faced with new challenges (Lawrence and Mwanzia 2004).

11.3 Agriculture, agroforestry, and forestry practices

The mean farm size in the 1990s ranged from 5 to 6 ha, with over 50% of the inhabitants holding between 1.2 and 4.0 ha (Nyariki and Musimba 1997); however, this has decreased to an average of 1.8 ha per household (Mbuvi 2009). Land tenure is mainly freehold, as most of the land belonged to the crown. A very few farmers hold large tracts of land, which they acquired over time through buying or simply staking claims on previous government lands. Many households live as squatters with insecure land tenure, however; the government's efforts to resolve the land crisis seem

to have been riddled with massive corruption that has left many households dissatisfied (Lawrence and Mwanzia 2004). The land is relatively flat, with an average slope of less than 5% (Gichuki 2000b), and soil erosion by water is not extensive. Nevertheless, many farmers undertake soil conservation measures such as *fanya juu* terraces, cut-off drains, grass strips, trash lines, and conservation tillage, with the main objective being to trap run-off water. Tillage practices such as ridging and hand-hoe digging are other measures to trap and retain moisture (Gichuki 2000b).

Mixed farming is the main agricultural activity in the higher potential (agro-pastoral) areas of the district, while livestock production is the main livelihood in the pastoral areas. Nyariki and Musimba (1997) reported higher resource-use efficiency by farmers who practiced mixed farming and especially for crops established in the short rain season of October to November. Farmers grow maize, green grams (mung beans), pigeon peas, and beans, in that order of abundance. Other crops grown include sorghum, millet, cow peas, and cassava. Lately, horticultural crops



for cash generation have also been introduced to farms that have access to irrigation facilities. Crop yields have dwindled in the last two to three years due to climatic variability. This has resulted in the increased frequency of droughts, and total crop failures are common: for example, most of the crops planted in the short rain season of 2010 failed, including drought-resistant cultivars (Figure 11.2). According to farmers' observa-

tions recorded by Mwangombe et al. (2011), other unusual climatic events include increased floods, strong winds, changes in rainfall patterns, and increased temperatures.

Cattle are the most important livestock, as they indicate a household's wealth status, followed by goats and sheep (Mwang'ombe et al. 2011). However in terms of animal abundance in the district, goats are the most common, followed by indigenous

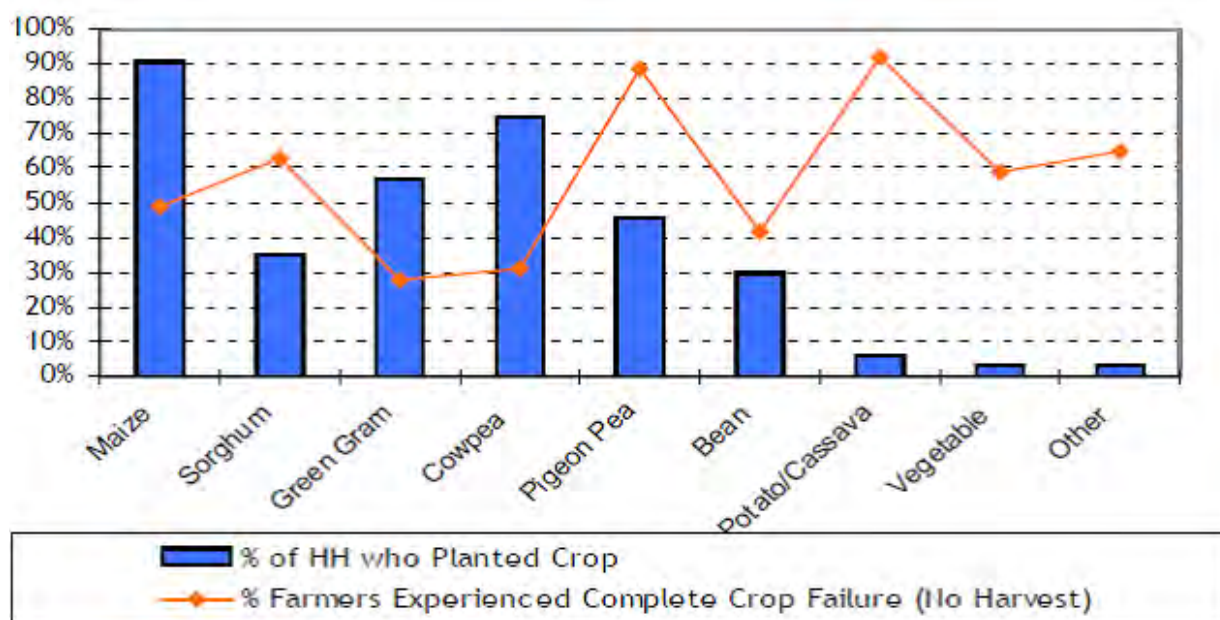


Figure 11.2 Crops planted and crop failure experienced in the 2010 short rain season in Makueni County, Kenya (ACF International 2011).



chicken and cattle at 44%, 31%, and 11%, respectively (Mars Group 2011). This indicates a shift towards small stock husbandry as feed resources become limiting. Other livestock kept in the district include sheep (5%), commercial chicken (2%), donkeys, pigs, and camels. A number of households also have beehives. Despite its low milk production, the local zebu is the main breed of cattle due to its ability to survive harsh semi-arid conditions.

Livestock serves mainly as disposable capital and insurance against loss of crop production by the agropastoralists. Large stock is sold to offset big problems, such as medical bills and school fees, while smaller stock such as goats are sold to take care of smaller needs, such as purchasing farm inputs and domestic items (Speranza 2010). Women have exclusive rights over sales of chicken to offset minor domestic needs, but may not sell bigger stock without express permission from their husbands. Households manage the risk of losses due to livestock diseases by owning different livestock types; those with bigger herds split them into subherds that graze in different areas (Speranza 2010). Droughts worsen the situation by exacerbating livestock diseases and exhausting pastures,

resulting in massive deaths. Farmers cope by preserving pastures and storing animal feeds, as well as by stocking drugs for treating animals.

Low rainfall and high potential evaporation has been a characteristic of Kibwezi and other arid lands. Forests are not common in these areas; the only natural forest in Kibwezi that provides indigenous timber for building, fuel, and woodworking is Kibwezi Forest. This forest covers a mere 5849 ha and is managed by the Kenya Forest Service (KFS), a government parastatal organ. Although other uncultivated woodlands exist, the unabated cutting of trees for these products, as well as for charcoal production for sale, has exposed huge tracts of land to soil erosion and degradation. However, farmers have learned to rely on trees planted in their farms to improve farm productivity and increase access to other tree products, such as firewood, fruits, and herbal medicine.

Gichuki (2000c), observed a gradual shift by farmers, beginning in the mid-1980s, from cutting trees to conserving and planting them both in their farms and grazing lands as a reaction to dwindling wood resources. Farmers also maintained scattered, naturally regenerating trees in croplands for (i) shade and micro-climat-

ic improvement, (ii) improved water efficiency, (iii) medicinal value, (iv) soil fertility enhancement (when trees drop their leaves, which later decompose, and by the droppings of browsing animals), and (v) livestock feed and stabilization of erodible soils. Water scarcity and termite attacks limited seedling survival rates, but farmers nevertheless continued to plant trees, especially fruit trees, live fences, mulberry, and neem trees, in croplands. Drought-tolerant fruit species such as *Mangifera indica* and *Carica papaya* were more commonly planted, while others such as *Musa* spp., *Citrus* spp., and guava are grown in areas with improved soil water regimes, either through runoff concentration or in large planting pits.

Many households manage more than one parcel of land and remote parcels are left as grazing lands. In these parcels, bush clearing is done gradually, leaving high-value tree species such as *Acacia* spp. (for browse) and *Terminalia brownii* (termite-resistant hardwood for the construction of houses, ox-yokes, and handles for farm tools). Other trees that have medicinal value to the community are also saved, but trees producing good-quality charcoal are likely to be cut. As these grazing lands are converted to cultivation, deforestation increases along with agroforestry practices. Indigenous trees are cut down to increase room for crop cultivation, but the young saplings of useful species are allowed to grow to maturity (Gichuki 2000c). Planting of exotic species is also undertaken, but the lack of seedlings of indigenous tree species and low survival rates of planted trees are major constraints to increasing the number of trees per hectare. While planting trees in big basins, as well as diverting run-off to tree planting holes, is reported for high-value exotics, it is not clearly done for indigenous species. The government has built the capacity of farmer groups to raise seedlings of various species, however, and is promoting

indigenous species to ensure their continued regeneration. Due to their adaptive capacity, increasing the numbers of indigenous tree species in farms is a good adaptation measure for farming systems in a changing climate.

Muriuki et al. (2006) reported that farmers in Makueni (including parts of Kibwezi) invested little in soil fertility management. Lack of disposable income was cited as the major constraint towards this kind of investment. Agroforestry was practiced mainly to produce fruit, fuel, and construction materials, but farmers were not aware of agroforestry as a measure of soil fertility improvement. However, the World Agroforestry Centre (ICRAF) has initiated activities with farmer

groups in Masongaleni Settlement Scheme in the district to promote the planting of trees that provide fertilizer. Dubbed “evergreen agriculture,” the project aims to identify specific tree species, both indigenous and exotic, that can be intercropped with annual crops in order to boost crop productivity (Figure 11.3). *Faidherbia albida* is one such species that has shown great potential in many parts of Africa (Garrity et al. 2010) and has been promoted in the area, while technologies such as improved fallows can help increase system resilience. Over 25 farmer groups, with a total of 777 farmers, have been trained on concepts of evergreen agriculture, such as tree establishment and management for soil fertility improvement.

The groups established demonstration plots that will also serve as learning sites for other farmers (Gachie 2010). Great improvements have already been observed in soil organic carbon and soil water content in these plots, leading to increased yields (Kalinda 2012).

The use of local genetic resources that are currently under-exploited is important in adaptation and, therefore, the current practices by farmers to save valuable indigenous tree species are useful for the success of the initiative. One such species is *Melia volkensii*, a species that grows well in the area and produces both timber and fodder for livestock. Verchot et al. (2007) reported on the potential of the species to improve the incomes



Figure 11.3 A farmer in an evergreen agriculture demonstration plot where *Gliricidia sepium* and *Faidherbia albida* are established to improve soil fertility and moisture retention for increased crop yields (Photo: Alex Aduor)

of farmers and compensate for lost crop productivity during drought years. The income raised from timber sales can be used to re-stock after livestock are lost or sold to avoid losses during drought periods and to avoid the cutting of other trees for charcoal. Fodder from the species can sustain livestock, especially goats, in periods of drought. Farmer-managed natural regeneration, as is already being practiced by farmers in Kibwezi, is a key component of the portfolio of useful technologies identified for scaling up evergreen agriculture; it is also essential increasing the number of indigenous trees (species and individuals) and improving system resilience.

The evergreen agriculture project also builds the capacity of farmers to harvest rainwater and use the water to raise tree seedlings, as well as improve the survival of planted tree seedlings. Gichuki, (2000b) observed

that farmers with soil (and water) conservation structures were growing fodder, which they would sell to other livestock keepers to raise extra income. In addition to the indigenous species already maintained on farms, trees that provide fodder and also improve soils, such as *Leucaena* spp., can be grown in these conservation structures to enable farmers to sustain a minimum number of livestock units that are useful for crop productivity.

11.4 Conclusion

Farmers in the semi-arid area of Kibwezi have observed climate variability and are particularly vulnerable to the effects of this change because of their poor asset disposal and technical capacity to adapt. Lack of water for both domestic and agricultural use is the major limiting factor and has contributed to increased food insecurity and livestock deaths, further in-

creasing the vulnerability of the communities. Assisted by various governmental and non-governmental organizations, farmers are investing in various practices that raise their adaptive capacity, such as water harvesting, soil conservation, and tree planting. Saving high-value indigenous tree species has also been practiced in grazing lands, while firewood is collected from dried sticks and prunings of trees to avoid unnecessarily felling the trees. Charcoal burning for income generation is a threat to these afforestation efforts, however. Investing in farmer-managed natural regeneration of trees, as well as water harvesting, is essential to increase farmers' adaptive capacity. Finally, the identification of trees that boost crop productivity and provide fodder for livestock when planted in crop fields will assist in improving the food insecurity that is rampant in the district.



Chapter 12. Lessons Learned

Dr. Kathleen Guillozet

Ethiopia and Kenya have unique social, cultural, institutional, economic, and ecological characteristics, and yet a review of four agroforestry adaptation sites reveals a number of common themes relating to farmer adaptation to climate change. Climate change is having real implications for livelihoods across diverse agroecological zones and requires investment at multiple levels. While this document focuses on interventions at household, village, and district levels, required funds and mandates will need to originate at national and international levels.

12.1 Capital asset indicators across the four cases

Tables 12.1 to 12.4 describe the capital assets noted in each of the four sites. Attention to livelihood diversification, increased access to extension and availability of new crop varieties and tree stock types will help build on existing farmer strengths and reduce vulnerability to climate change. All interventions should leverage local ecological knowledge and acknowledge cultural values.

Table 12.1 highlights some of the capital assets relevant to farmer adaptation to climate change in the Gedeo Zone Case. Much adaptive capacity in these highland home garden agroforest systems resides at the household level, and is embodied in traditional ecological knowledge and intensive farming practices. Targeted investments in activities at village and district levels that directly support farmers, including extension and farmer training on pest control and disease management, increased availability of alternative crop varieties, and enhanced access to financ-

Table 12.1 Capital asset indicators at different levels in Gedeo Zone, Ethiopia.

Level Capital	Household	Village	District
Natural	Maintenance of complex agroforestry systems reduces soil exposure to erosion and increases soil organic matter	Biodiversity	
Financial	Cultivation of high-value cash crops (coffee and chat)		Integrated markets for sale and transport of high-value cash crops
Physical	Well maintained terrace systems		
Human	High degree of farmer knowledge regarding agroforestry and intensive cropping systems		
Social			



ing and credit will bolster farmer capacity to further diversify cropping systems and develop more resilient livelihoods. Dynamics associated with intergenerational change, including increased interest among youth in off-farm livelihoods, mean that efforts to increase the status of farmers and to strengthen knowledge transfer among generations will also contribute to the development of future farmers with high adaptive capacities.

Table 12.2 highlights some of the capital assets relevant to farmer and pastoral peoples' adaptation to climate change in Ethiopia's Afar Region. Capital assets relevant to climate change adaptation are noted particularly at the household and village levels. In the Afar region, more

Table 12.2 Capital asset indicators at different levels in Afar, Ethiopia.

Level Capital	Household	Village	District
Natural	Diverse food sources	Biodiversity	
Financial	Livestock ownership as insurance		
Physical			
Human	Traditional ecological knowledge Knowledge regarding sustainable management of fragile resources		
Social		High cultural values regarding riparian woodland conservation High mobility of pastoral people and livestock with managed migration routes to reduce ecological impacts	

mobile pastoral people share the landscape with growing numbers of sedentary farmers. In some cases, increased conversion to farmland reduces available grazing land for livestock, creating the need for new livelihood models that rely upon more diversified income streams. In order for these to be successful, substantial investment in and coordination with different groups of people in the region is required. Many agroforestry-based adaptation measures have implications for the cultural integrity of pastoral people, and should be developed in coordination with local experts and negotiated in the context of local values and traditions.

Table 12.3 highlights some of the capital assets relevant to farmer adaptation to climate change in Meru, Kenya. Actions that build adaptive capacity among Meru farmers should build upon existing strengths, including strong social networks and relative wealth. Access to new forms of knowledge regarding conservation agriculture is limited, and investments in extension and diversified sources of tree seedlings will likely bring significant benefits to farmers. Coupling



these investments with payment for ecosystem service schemes may further incentivize beneficial practices and help offset the financial challenges associated with shrinking farm sizes.

Table 12.4 highlights some of the capital assets relevant to farmer and pastoral peoples' adaptation to climate change in Kenya's Kibwezi Dis-

trict. Investment in public health services, especially in water, sanitation, health, and education, will help alleviate acute stressors on farmers and pastoral people. Livestock insurance programs and investments in value-added and diversified income opportunities that help people transition away from livestock-intensive livelihoods will reduce vulnerability to cli-

Table 12.3 Capital asset indicators at different levels in Meru, Kenya.

Level Capital	Household	Village	District
Natural	Positive farmer perceptions regarding soil fertility	Community-level tree planting activities and promotion of energy efficient technologies and practices	
Financial	Cultivation of high-value cash crops (coffee and tea)	Above average wealth status compared to national figures	Integrated markets for sale and transport of high-value cash crops
Physical	High levels of land ownership on a freehold basis Most (3/4) households have metal roofs and wooden walls. Farm terracing	70% of community members have access to piped water	Good market access (agricultural products)
Human	Strong farmer knowledge regarding agroforestry and intensive cultivation		Over half (55%) of farmers completed primary school
Social		High levels of participation in farmer collectives and other groups in order to access services and credit	

Table 12.4 Capital asset indicators at different levels in Kibwezi District, Kenya.

Level Capital	Household	Village	District
Natural	High (75%) farmer perception of good soil fertility Predominantly flat agricultural fields	1/5 of population can access water through seasonal streams High levels of participation in groups that practice soil and water conservation techniques including tree planting and seedling propagation	
Financial	Livestock ownership as insurance	Above average wealth status compared to national figures	
Physical	Most (2/3) households have metal roofs Land ownership mainly freehold Terracing and other mechanisms for water capture	45% of community members have access to piped water Community has constructed dams, shallow wells, roof catchments, and irrigation ditches	
Human	High levels of farmer knowledge regarding mixed farming techniques	25 farmer groups are trained in concepts of Evergreen Agriculture	2/3 of men and women are literate
Social		High levels of membership in farmer collectives and other groups to gain access to services and credit	

mate change. Agroforestry practices that incorporate multiple-value trees such as *Leucaena* have potential to alleviate some climate-related stresses and mitigate future impacts. Innovation and extension relating to appropriate practices in water-scarce

environments is also a priority and should build upon local knowledge.

12.2 Next steps

Additional research is needed to further develop our ability to understand

and address equity considerations related to climate change among farmers and pastoral peoples in Ethiopia and Kenya. This review does not incorporate information on gender or marginalized social groups. Emerging tools such as IFPRI's Women's Empowerment in Agriculture Index can help researchers track women's engagement in the agricultural sector and identify priority areas for investment that will reduce climate-related vulnerabilities and promote social justice.

This document highlights capital assets relevant to adaptation from disparate case studies and is not intended to serve as a comprehensive review. A future study that applies a standard methodology to the measurement of capital asset indicators relevant to farming communities in Ethiopia and Kenya would allow for a more rigorous comparative analysis and could serve as a mechanism to track changes in climate-related adaptive capacity over time.





Chapter 13. Conclusions

Dr. Badege Bishaw

13.1 Climate change

Farmer adaptation to climate change in Ethiopia and Kenya can be significantly strengthened through investments in research, agricultural extension, and knowledge co-generation among local people and scientists. The questions of most interest to farmers concern what kinds of crops they should plant and livestock they should rear, and how they might access these resources. Climate change is likely to lead to increases in tem-

perature, changing patterns of rainfall, and more extreme droughts and floods. This, in turn, could lead to dramatic changes in patterns of land use. While some farmers are likely to benefit—for example, from longer growing seasons—there will be large numbers of losers as well. This document highlights the potential role of agroforestry in reducing farmer vulnerability to climate change. It describes the opportunities and constraints that farmers face in adapting to shifting climate conditions and

emphasizes interventions that governments, civil society, research organizations, and farmers can promote.

13.2 Opportunities for agroforestry development

There are many ways agroforestry can help in reducing poverty, improving food security, and addressing climate change in Ethiopia and Kenya. Agroforestry can be an important pathway to prosperity through the ad-



dition of trees to farming systems. There is a huge potential for agroforestry development in Ethiopia and Kenya; if properly practiced and managed, it can make significant contributions to food security, environmental rehabilitation, and climate change. The diversity in altitude, climate, soils, and other physical features have created a variety of agroecological zones that give rise to diverse forest flora and agricultural systems with opportunities for agroforestry in different settings.

Research by the World Agroforestry Centre has demonstrated that agroforestry can improve livelihoods,

restore degraded soils, and raise crop productivity. Conservation agriculture, a practice that advocates for minimal soil disturbance, high levels of organic matter, and crop rotation, has helped African farmers increase their crop yields and incomes. Agroforestry and conservation agriculture constitutes “evergreen agriculture”—a practice that could transform the fortunes of millions across sub-Saharan Africa.

Since Ethiopia's economy and the wellbeing of its people are closely linked to agriculture and the use of natural resources, the Ethiopian government has developed the “Climate

Resilient Green Economy” initiative, which promotes agroforestry among other environment conservation activities. The government of Ethiopia is engaged in the regeneration of tree cover on both communal and agricultural land on a large scale to improve food security and environmental resilience. At the Durban Climate Change Convention in December 2011, the Ethiopian government declared that it would implement a program that seeks to establish 100 million *Faidherbia albida* trees on smallholder cereal croplands across the country within the next three years to improve food production and the livelihoods of smallholder farmers. The government also has plans to reforest 15 ha of land, including the regeneration of tree cover on croplands. Recognizing the need for sustainable agricultural and national development, Ethiopia in 2011 launched its strategy to build a climate resilient green economy. This strategy focuses on the development of forestry and agroforestry and on improving agricultural productivity and energy efficiency.

Agriculture also remains central to the economy of Kenya and the growth of the sector is positively correlated to growth in the overall economy. The sector is also given priority under the Economic Pillar, one of the three growth pillars envisioned in Kenya Vision 2030 (Government of Kenya 2007). Some practices that farmers are adopting to cope with climate change include diversifying both their crops and farming practices through the adoption of fish farming, kitchen gardening, hay staking, and bio-intensive agriculture. Farmers are supported in these and other practices, such as tree planting in both communal and private landholdings, by government ministries, private sector initiatives, and many non-governmental organizations. At the policy level, the National Climate Change Response Strategy (NCCRS) recommends a number of interventions to help adapt to and mitigate the impacts of climate change (Government of

Kenya 2010b). Investment in early warning systems as well as in the construction of water harvesting dams and food storage facilities has been proposed. Agricultural practice options include the promotion of underutilized crops that are drought- and salt tolerant and pest- and disease resistant, such as millet and cassava, as well as the protection of the natural resource base through soil and water conservation efforts such as the promotion of conservation agriculture (Government of Kenya 2010a).

The World Agroforestry Centre (ICRAF), which deals with agroforestry research, extension and information exchange, is playing a leading role in improving land husbandry and agroforestry in Ethiopia and Kenya. Recently, the Australian International AID, in collaboration with the World Agroforestry Centre and the Ethiopian government, has launched the Trees for Food Security Project in Ethiopia. Promoting and scaling up evergreen agriculture, which is based on agroforestry and conservation farming, is a promising approach toward promoting sustainable land-use systems in Ethiopia and Kenya in order to address food security, environmental degradation, and climate change.

13.3 Recommendations

13.3.1 Agroforestry for biodiversity and climate change

Many trees and shrubs planted through agroforestry can increase plant and ecosystems biodiversity; trees are also helpful in ameliorating global climate change by sequestering vast amounts of carbon. The physical presence of trees on farm boundaries serve as living fences and protect home gardens from free grazing livestock.

13.3.2 Agroforestry and soil conservation

Agroforestry has the potential to mitigate land degradation by controlling



soil erosion (barrier approach) and maintaining soil organic matter through mulch and biomass transfers. The contour hedges created by multipurpose trees provide soil erosion control through the barrier approach mechanism.

13.3.3 Agroforestry and food security

Agroforestry can contribute to food security through the provision of edible products such as fruits, roots and seeds. Trees can also improve soil

fertility by fixing nitrogen from the air and recycling nutrients, thereby helping to increase crop yields. Trees provide valuable supplemental fodder for animals to enhance livestock production. Trees provide household energy for cooking, heating, and light.

13.3.4 Agroforestry and household income

Agroforestry provides farmers with products—many of them high in value—that can be sold in rural and urban markets. These include selling





timber, poles, charcoal, and honey. Many trees and shrubs have medicinal value that promotes health and generates additional income. Trees that bring benefits to farmers and that have characteristics more suited to changing climate conditions (such as drought tolerance) can serve as insurance mechanisms against crop failures.

13.3.5 Agroforestry and fodder trees

Agroforestry practices such as the planting of fodder trees and shrubs along farm borders and grazing lands can provide fodder for livestock. Fodder trees and shrubs supply much needed fodder for livestock, espe-

cially during feed shortages. Fodder banks are also a source of forage legumes, established and managed by pastoralists near their homesteads, as a means of providing additional protein for cattle during the dry season. Well-fed livestock will provide not only milk and meat, but also significant amounts of manure that can go into improving soil fertility.

In order to realize the full potential of agroforestry in Ethiopia and Kenya, it has to be supported by research results from the National Institute of Agricultural Research, regional research institutions, institutions of higher learning, the World Agroforestry Centre, CIFOR, and the International Livestock Research Institute. Such existing data can provide a good background for future research and development activities, including scaling up of successful experiences.

13.4 Suggested future research

Most agroforestry activities in Ethiopia and Kenya evolved over many decades, but economic and environmental impacts could be enhanced through improving the existing agroforestry management practices, and the processing, utilization, and marketing of products. Woody riparian buffers, the development of shelterbelts and windbreaks in drylands, alley cropping on hillside farming, short rotation woody crops (woodlots) in moist regions, and tree management in rangelands provide opportunities for further development of agroforestry in Ethiopia and Kenya, and should receive high priority. Exploiting these opportunities will increase the capacity of these countries to adapt to the changing climate and contribute significantly to GHG emission reductions, from which payment for environmental services (PES) could potentially accrue, in addition to products and services for local communities.

Ethiopia lags behind its potential for agroforestry development. Wood-



lots comprise the only successful agroforestry technology implemented on a large scale in rural Ethiopia, owing to their ability to generate highly needed cash for smallholder farmers. While backyard fruit orchards are expanding, agroforestry practices that are widely publicized (such as alley cropping and conservation agriculture with trees or CAWT) are not popular in Ethiopia. One lesson is that the conventional agroforestry approach, focusing on soil fertility management, does not seem to be appreciated by smallholder farmers, and thus, future interventions should also consider seriously the economic benefits of trees in agroforestry.

There are still technical knowledge gaps for several aspects of agroforestry practices. However, addressing the institutional, legal, and policy gaps (e.g., free grazing) will play a crucial role in promoting agroforestry in Ethiopia and Kenya, thereby transforming lives and environments. Another important factor that could contribute to agroforestry development is the strategic coordination of activities of several governmental and other development agencies involved in natural resource management.

In July 2012, a workshop was conducted in Ethiopia to revitalize agroforestry research and development for improved food security and environmental resilience; the goal was to bring different agricultural research and development organizations to mobilize and synergistically coordinate their knowledge and resources to promote agroforestry development in Ethiopia. It is also encouraging that the World Agroforestry Centre has been invited by the Ethiopian government to provide technical support toward the scaling up of tree planting on farms in order to improve food security and the livelihood of smallholder farmers.

Through its presence in both Ethiopia and Kenya, the World Agroforestry Centre can build close collaboration with government and non-governmental organizations and pro-



vide assistance in capacity building, as well as share research findings and advise policymakers to promote agroforestry development in these countries.

It is important that research attention is focused on the following areas:

- Enhancing the growers-consumers market link, value addition, processing of products from traditional agroforestry practices in cereal-based farming areas
- Improving nutrition and health of households through fruit-tree-based agroforestry practices in the cereal dominated production system
- Improving the production, processing, handling, and marketing of products from agroforests
- Introducing a new germplasm for agroforestry with a focus on economically useful trees (upgrading the genetic material for agroforestry development for typical agroecological zones of Ethiopia and Kenya)

- Optimizing and assessing the bio-carbon stock of the traditional multi-story home-garden of southern Ethiopia and developing market strategies
- Testing the reforestation payment program (RPP) for the conversion of sloping lands in selected mountainous areas: a win-win situation for poverty alleviation and climate change mitigation
- Enhancing the adaptive capacity of drylands farming to climate change through CAWT

Although science can improve agroforestry practices, an important aspect of the challenge for Ethiopia is to mobilize and implement what is already known. Kenya, on the other hand, has already taken advantage of the presence of many international and non-governmental organizations, and has involved them in agroforestry research and development. It is now generally accepted that the integration of trees into farming systems can provide many of the ecological, economic, and social benefits necessary for smallholder farmers to adapt to and mitigate climate change.

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