Sub-Saharan Africa
Managing Land in a Changing Climate
An Operational Perspective for Sub-Saharan Africa

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Sustainable Development Department
Africa Region
Vice President: Obiageli Katryn Ezekwesili
Sector Director: Inger Andersen
Sector Manager: Idah Z. Pswarayi-Riddihough
Task Manager: Taoufiq Bennouna
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<tr>
<td>AEZ</td>
<td>Agroecological Zones</td>
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<tr>
<td>AFTEN</td>
<td>Africa Environment and Natural Resources Unit</td>
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<td>AFTWR</td>
<td>Africa Water Resources Management Unit</td>
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<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
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<td>CRU</td>
<td>Climate Research Unit</td>
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<tr>
<td>CV</td>
<td>Coefficient of Variation</td>
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<td>ENSO</td>
<td>El Niño Southern Oscillation</td>
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<tr>
<td>ENV</td>
<td>Environment Unit</td>
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<td>ESW</td>
<td>Economic and Sector Work</td>
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<td>FAO</td>
<td>UN Food and Agriculture Organization</td>
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<td>FGD</td>
<td>Focus Group Discussion</td>
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<td>FMNR</td>
<td>Farmer-managed Natural Regeneration</td>
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<td>GCM</td>
<td>Global Circulation Models</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GEF</td>
<td>Global Environment Fund</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<td>GIS</td>
<td>Geographic Information System</td>
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<td>GLASOD</td>
<td>Global Assessment of Soil Degradation</td>
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<td>ICAF</td>
<td>International Center for Research in Agroforestry</td>
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<td>ICRISAT</td>
<td>International Crop Research Institute for the Semi-Arid Tropics</td>
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<td>IFAD</td>
<td>International Fund for Agricultural Development</td>
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<td>IFPRI</td>
<td>International Food Policy Research Institute</td>
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<td>IIEED</td>
<td>International Institute for Environment and Development</td>
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<td>ILRI</td>
<td>International Livestock Research Institute</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>IPPM</td>
<td>Integrated Pest and Production Management</td>
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<td>ITCZ</td>
<td>Intertropical Convergence Zone</td>
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<td>LADA</td>
<td>Land Degradation Assessment in Drylands</td>
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<td>LGA</td>
<td>Local Government Authority</td>
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<tr>
<td>MAAIF</td>
<td>Ministry of Agriculture, Animal Industry and Fisheries</td>
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<td>MDGs</td>
<td>Millennium Development Goals</td>
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<td>MWLE</td>
<td>Ministry of Water, Land and Environment</td>
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<td>Abbreviation</td>
<td>Full Form</td>
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<td>NAADS</td>
<td>National Agricultural Advisory Services</td>
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<td>NAP</td>
<td>National Action Plan</td>
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<td>NAPA</td>
<td>National Adaptation Programme of Action</td>
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<td>NASA</td>
<td>National Aerospace Agency</td>
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<td>NDVI</td>
<td>Normalized Difference Vegetation Index</td>
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<td>NEMA</td>
<td>National Environmental Management Authority</td>
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<td>NEPAD</td>
<td>New Partnership for Africa’s Development</td>
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<td>NGO</td>
<td>Nongovernmental Organization</td>
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<td>PAC</td>
<td>Community Action Program</td>
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<td>SDN</td>
<td>Sustainable Development Network</td>
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<td>SLM</td>
<td>Sustainable Land Management</td>
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<td>SLWM</td>
<td>Sustainable Land and Water Management</td>
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<td>SOC</td>
<td>Soil Organic Carbon</td>
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<td>SOM</td>
<td>Soil Organic Matter</td>
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<td>SSA</td>
<td>Sub-Saharan Africa</td>
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<td>UNCCD</td>
<td>United Nations Convention to Combat Desertification</td>
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<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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<td>UNFPA</td>
<td>United Nations Population Fund</td>
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<td>WBI</td>
<td>World Bank Institute</td>
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<td>WDI</td>
<td>World Development Index</td>
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<td>WDR</td>
<td>World Development Report</td>
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<td>WOCAT</td>
<td>World Overview of Conservation Approaches and Technologies</td>
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<td>WRI</td>
<td>World Resource Institute</td>
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- Pillar 1 Objective: Developing a Knowledge Baseline for the Land and Climate Nexus
- Pillar 1 Outputs: Developing a Knowledge Baseline for the Land and Climate Nexus
  - Data collection
  - Data analysis
  - Development of knowledge tools
- Pillar 1 Outline: Developing a Knowledge Baseline for the Land and Climate Nexus

## INTRODUCTION

Why an economic and sector work on the role of sustainable land and water management to mitigate and adapt to climate change in Sub-Saharan Africa?

What is Sustainable Land and Water Management?

What is the objective of this work?

How is this work organized?

What does this work encompass—and what does it not?

How can the outputs of this work best be used?

## Pillar 1: generating or consolidating the existing body of knowledge on the land and climate nexus in order to provide practical guidance

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The Approved Concept note of this ESW includes three pillars:

- **Pillar 1** focused on generating or consolidating the existing body of knowledge on the land and climate nexus in order to provide practical guidance to development practitioners;
- **Pillar 2** aimed at generating context-specific recommendations of sustainable land and water management (SLWM) practices best suited to improve food security while reducing climate-related risks; and
- **Pillar 3** aimed at sharing and disseminating knowledge on the land and climate nexus to improve on the ground resilience to climate change and variability impacts.

Under Pillar 1, a team of consultants was established to gather, consolidate, and generate information related to the land and climate nexus. Casey Brown and Richard Washington provided analytical guidance in terms of climate-change information. Christian Crepeau selected, gathered, processed, and analyzed online datasets that could be made available to meet the pillar’s objectives. Anne Woodfine developed specific guidance on the role of sustainable land management (SLM) for climate-change mitigation and adaptation. All of these inputs were further deeply analyzed by a group of experts that combined, collected, and generated information to develop a Land & Climate Hazard Exposure Map, a Best Management Practices Database, and the Africa Land & Climate Portal. The group was composed of Lakhdar Boukkerou, Michel Bouchard, Anne Woodfine, Ymene Fouli, and Philippe Rapaport, with support from Varuna Somaweera. In addition, a stocktaking exercise was carried out by Patrice Wadja and David Bonnardeaux. During this exercise, many researchers were contacted and provided inputs. They included Christian Valentin (IRD, France), Florent Maraux (CIRAD,
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Under Pillar 2, a team of researchers carried out case studies in four countries: Kenya, Niger, Nigeria, and Uganda. The team was led by the International Food Policy Research Institute (IFPRI) and was composed of John Pender, Ephraim Nkonya, and Claudia Ringler of IFPRI, Frank Place of the International Center for Research in Agroforestry (ICRAF), and Jupiter Ndjeunga and Pierre Sibiry Traoré of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). They were supported at the country level by national research teams.

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The Country Offices in Kenya, Niger, Nigeria, and Uganda provided support for the case studies and activities related to the short films developed under Pillar 3. The Country Office in Mali hosted the regional workshop on the roles of SLM and local institutions in climate-change adaptation held on March 11 and 12, 2010, in Bamako.

This ESW is part of the TerrAfrica Joint Work Program. The TerrAfrica Land and Climate Special Advisory Group, led by the World Bank and the New Partnership for African Development (NEPAD), provided substantive comments to various pieces of this ESW, especially the case studies. The TerrAfrica Land and Climate Special Advisory Group is composed of representatives of African governments, NEPAD, the Global Mechanism of the United Nations Convention to Combat Desertification (UNCCD), the Food and Agricultural Organization of the United Nations (FAO), the International Fund for Agricultural Development (IFAD), the Government of Norway, and Ecoagriculture Partners.

The team is also grateful to the national counterparts, community representatives, and rural household heads who participated in community and household surveys. Without them this task would not have been possible. This report is dedicated to them, to their fellow rural people in Kenya, Niger, Nigeria, and Uganda, and to their efforts to combat land degradation and the impacts of climate variability and change. We hope that the information in this report will contribute to broader and more effective efforts in Sub-Saharan Africa.
FOREWORD

Climate change is the central development challenge of the 21st century. Perhaps more than any other region, Africa cannot address one without addressing the other. In virtually every sector of the economy and society – agriculture, water resources, health, energy, transport, tourism – the impact of droughts, floods, erratic weather patterns, and other climate-related shocks threatens to undermine Africa’s hard-won development progress.

Although Africa contributes less than 4% of global CO₂ emissions, it is most vulnerable and least prepared to deal with the impacts of climate change. With heavy dependence on agriculture to drive economic growth and inadequate infrastructure, African economies and communities will be hurt through reductions in crop yields, falling livestock productivity, shortages of drinking water, reduced potential for hydro-generations of electricity, the spread of diseases such as malaria, potential migration and social strife, and increased cost of infrastructure maintenance. Already, Africa is facing the negative impacts of an annual loss of 1-2 % of GDP due to climate variability. Climate change threatens to exacerbate these impacts.

Sub-Saharan countries are taking significant steps to promote sustainable land and water management practices. There are lessons learned at the national and local levels that could be scaled up provided incentives, institutions, and information sharing improve. This study, “Managing land in a changing climate: an operational perspective for Sub-Saharan Africa” undertaken by the World Bank in close collaboration with TerrAfrica partners - the New Partnership for Africa's Development (NEPAD) Planning and Coordinating Agency (NPCA), the United Nations Convention to Combat Desertification (UNCCD) secretariat, and Kenya, Niger, Nigeria, and Uganda, provides a decision-making tool for practitioners and policymakers to advance climate-resilient rural development through better land management. The study demonstrates the intertwined benefits of sustainable land and water management to support rural communities in better adapting to climate variability and mitigating the effects of climate change, while also protecting soil fertility and agricultural production and productivity.

The practices best suited to address climate variability and land degradation are those that diversify and integrate production options. Cover crops, tree planting on pasture and cropland, small irrigation, no tillage, integrated livestock and crop systems, strategic use of both organic and inorganic fertilizers, and soil and water conservation structures are all being practiced at small scale in Africa and should be scaled up.

This study report complements, the World Bank Climate Change Strategy for Africa, the CAADP Agriculture-Climate Change Adaptation and Mitigation Framework, the UNCCD 10-year strategy and countries’ own land management investment frameworks in supporting the scaling up of land and water management based climate change adaptation and mitigation measures. Within the context of the TerrAfrica partnership framework, the World Bank, NPCA and UNCCD will continue to work together to promote sustainable land and water management for better climate resilience and food security in Sub-Saharan Africa.

Inger Andersen
Director, Sustainable Development Department, Africa Region, World Bank

Richard Mkandawire
Adviser for Agriculture and head of CAADP at the NPCA, NEPAD

Luc Gnacadja
Executive Secretary, UNCCD
GLOSSARY

About the glossary
There exist multiple definitions of climate change related-concepts and issues. For the purposes of this ESW, we have adopted definitions used by the World Bank Group and those used in the scientific and policy arenas (IPCC, UNDP, and so forth).¹

Adaptation
Adaptation is an activity that intends to reduce the vulnerability of human or natural systems to the impact of climate change and variability by maintaining or increasing adaptive capacity and resilience. Adaptation can be carried out in response to or in anticipation of changes in climatic conditions, and entails a process by which measures and behaviors to prevent, moderate, cope with, and take advantage of the consequences of climate events are planned, enhanced, developed, and implemented (adapted from UNDP 2005, UK CIP 2003, and IPCC TAR 2001). In other words, an adaptation measure is an activity that intends to reduce the vulnerability of human or natural systems to the impact of climate change and variability by maintaining or increasing adaptive capacity and resilience.

Note: Some development practitioners include under the term adaptation a wide range of activities (i.e., natural resources management, improved access to markets, land tenure, etc.) that, although disconnected from climate risk considerations, are considered to indirectly decrease vulnerability / increase adaptive capacity. For the purpose of this ESW, a measure is referred to as adaptation not only when it is an explicit response to climate risk considerations but also when it clearly increases resilience to climate variability and change even though it was primarily undertaken for other reasons (economic reasons, for instance).

The following types of adaptation have been defined by the Intergovernmental Panel on Climate Change (IPCC).²

- **Anticipatory or proactive adaptation**: Adaptation that takes place before impacts of climate change are observed.
- **Autonomous or spontaneous adaptation**: Adaptation that does not constitute a conscious response to climate change stimuli but is triggered by ecological changes in natural systems and by markets or welfare changes in human systems.
- **Planned adaptation**: Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Based on these types of adaptation, a continuum ranging from proactive or anticipatory adaptation to planned adaptation is described in figure G.1.

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¹ For more definitions, see www.eird.org/cd/on-better-terms/docs/Organisation-of-Economic-Co-operation-and-Development.pdf.
² IPCC Fourth Assessment Report, Appendix 1, Glossary.
Figure G.1: Range of Adaptation

<table>
<thead>
<tr>
<th>Proactive or anticipatory adaptation</th>
<th>Planned adaptation</th>
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<td>Addressing the drivers of vulnerability to climate variation and change</td>
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<tr>
<td>Activities to reduce poverty, including non-climatic related factors</td>
<td>Activities to address impacts exclusively linked to climate change</td>
</tr>
</tbody>
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Adaptation Deficit

Adaptation deficit refers to greater exposure to climate-related risks and vulnerability due to failure to fully adapt to climate change. Addressing the adaptation deficit is basically a matter of catching up with past neglect. The “ex post” responses to climate variability and change address this adaptation deficit. Some interventions that are undertaken to address the adaptation deficit can, if climate change impacts are taken into account, at the same time address the adaptation gap.

Adaptation Gap

Adaptation gap refers to the climate change challenges ahead. The “ex ante” responses to climate change address this gap. “Addressing the adaptation gap” refers to the use of special interventions required to address issues that have arisen as a consequence of climate-change, issues that are additional to overcoming the adaptation deficit.

Adaptation costs

Adaptation costs include planning, preparing for, facilitating, and implementing adaptation measures, including transition costs.

Adaptive capacity

Adaptive capacity is the ability of a human or natural system to adapt, that is, to adjust to climate change (including climate variability and extremes); to prevent or moderate potential damages; to take advantage of opportunities; or to cope with the consequences. The adaptive capacity inherent in a human system represents the set of resources available for adaptation (information, technology, economic resources, institutions, and so on), as well as the ability or capacity of that system to use these resources effectively in the pursuit of adaptation. (Adapted from UK CIP 2003 and UNDP 2005)
**Climate change**
Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may result from natural internal processes or external forcings as well as from persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that United Nations Framework Convention on Climate Change, in its Article 1, defines “climate change” as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” The UN framework thus makes a distinction between “climate change” attributable to human activities altering the atmospheric composition, and “climate variability” attributable to natural causes. (IPCC 2001)

**Climate risk management**
Climate risk management is an approach to climate-sensitive decision making that is increasingly seen as the way forward in dealing with climate variability and change. The approach seeks to promote sustainable development by reducing the vulnerability associated with climate risk. Climate risk management involves proactive “no regret” strategies aimed at maximizing positive and minimizing negative outcomes for communities and societies addressing climate-sensitive issues in such areas as agriculture, food security, water resources, and health. The “no regrets” aspect of climate risk management means taking climate-related decisions or action that make sense in development terms anyway, whether or not a specific climate threat actually materializes in the future. (IRI 2007, 10).

**Climate variability**
Climate variability denotes deviations of climate statistics over a given period of time (a month, season, year, and so on) from the long-term climate statistics relating to the corresponding calendar period. In this sense, climate variability is measured by those deviations, which are usually termed “anomalies.” As an effect of climate change, climate variability is expected to increase in most locations.

**Mitigation**
Mitigation refers to a human intervention to reduce the “sources” of greenhouse gasses (GHGs) or enhance the “sinks” that remove carbon dioxide from the atmosphere. (Adapted from IPCC 2001).

**Mitigation potential**
The concept of mitigation potential was developed to assess the scale of GHG reductions that could be made, relative to emission baselines, for a given level of carbon price (expressed in cost per unit of carbon dioxide equivalent emissions avoided or reduced). Mitigation potential is further differentiated in terms of “market potential” and “economic potential” (IPCC 2007).

**Mainstreaming adaptation**
Mainstreaming adaptation refers to the integration of adaptation objectives, strategies, policies, measures, or operations such that they became part of the national and regional development policies, processes, and budgets at all levels and stages (UNDP 2005).
Resilience to climate change
Resilience to climate change is the capacity of a system, community or society potentially exposed to climate vulnerability and changes to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past events for better future protection and to improve risk reduction measures. (Adapted from UN/ISDR 2004)

Note: According to the definition, the term “resilience” can refer to adaptation measures that increase the system’s resilience in a sense that no damage or very insignificant damage can occur; or it can refer to adaptation measures that increase the ability to recover from the damage. For the purpose of this ESW, in most cases the notion of “ability to recover from the damage” or changes will apply.

Sustainable land management and sustainable land and water management
Sustainable land management (SLM) is the adoption of land-use systems that, through appropriate management practices, enable land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources. There is a broad recognition that SLM is crucial for ensuring an adequate, long-term supply of food, water, raw materials, and other services provided by agricultural and natural resources. SLM involves both the long-term maintenance of the productive capacity of agricultural lands and the sustainable use of natural and seminatural ecosystems. (TerrAfrica Vision Paper (http://knowledgebase.terrafrica.org/ter-documents/ter-view-doc/en/?uid=44758))

More broadly, sustainable land and water management (SLWM) means management of the land in such a way as not to negatively affect production, climate, or water and other resource availability. Under this definition, SLWM covers a wide range of approaches and practices, such as conservation agriculture, tree planting, watershed management, integrated fertility soil management, improved grazing management, reduced or no tillage, small-scale irrigation, water harvesting, and others.

Note: This report refers to SLWM with the understanding that the report focuses on land management while another report from the AFTWR team focuses on water management aspects.

Vulnerability to climate change
Vulnerability to climate change is the degree to which human and natural systems are susceptible to harm as a consequence of climate change (including climate variability and extremes). Vulnerability is a function of the character, magnitude, and rate of climate variation to which the system is exposed, and the system’s adaptive capacity (adapted from IPCC TAR 2001). “Vulnerability” seems largely to imply an inability to cope and “resilience” seems to broadly imply an ability to cope. They may be viewed as two ends of a spectrum.
EXECUTIVE SUMMARY

Livelihoods, food security, and development processes in Sub-Saharan Africa are highly dependent on land management practices to generate natural ecosystem goods and services. Out of a total population of about 717 million people, almost 60 percent depend for their livelihood on agriculture, hunting, fishing, or forestry. However, unsustainable land management already is leading to large-scale land degradation trends, which pose a threat to food security and poverty alleviation in Sub-Saharan Africa.

Climate change threatens to exacerbate and add to the existing vulnerabilities. Evidence has shown that the number of people affected by climate variability, through floods and droughts, is already increasing. Much-needed increases in agricultural production have, as a result, been unrealized. These outcomes place smallholder farmers, who depend largely on rainfed agriculture, in highly vulnerable circumstances under climate-change predictions.

Development questions focus on how to enhance rural communities’—and especially land users’—capacity to be more resilient to climate variability and change and even undertake actions that may reduce their climate-related risks and vulnerability.

Vulnerability of communities and farmers to climate-related hazards requires a local approach managed by grassroots institutions in coordination with the national level. The adoption of sustainable strategies against climate change is only possible if, at local level, legitimate, effective and sustainable institutions are capable of fostering environmental governance and sustaining collective action against risks, and if, at national level, climate change is integrated into sectoral policies taking into account the linkages between different sectors and different levels of governance. Adaptation to climate variability and change includes measures such as diversification of livelihoods, permanent/temporal migration and household splitting, which together with SWLM can be used to promote sustainable livelihoods through increased resilience to climate change.

The objective of this work is to improve practical knowledge resources for Sub-Saharan African countries, regional institutions, and development practitioners at the World Bank and other partner institutions to help them make informed decisions about (i) the risks posed by climate variability and change to land-resource-dependent livelihoods in Sub-Saharan Africa and (ii) Sustainable Land and Water Management (SLWM) approaches and practices that are best suited for meeting development objectives while also addressing the challenge posed by climate-change adaptation and mitigation.

This work was initially divided into three pillars that complemented each other. Activities carried out under Pillar 1 focused on generating or consolidating the existing body of knowledge on the land and climate nexus, and on further combining these various knowledge inputs in order to generate practical guidance that could be made available to Bank task team leaders (TTLs) and client countries through specific tools. This practical guidance was further refined and tested under Pillar 2 through case studies in four countries. The case studies generated context-specific

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3 Food and Agriculture Organization of the United Nations, FAOSTAT, data reported for 2004.
recommendations for SLWM approaches and practices suited to improve food security and economic prospects while reducing climate-related risks and greenhouse gas (GHG) emissions. All findings, recommendations and tools from Pillar 1 and Pillar 2 have been and will continue to be disseminated broadly as part of Pillar 3.4

PILLAR 1: GENERATING OR CONSOLIDATING THE EXISTING BODY OF KNOWLEDGE ON THE LAND AND CLIMATE NEXUS IN ORDER TO PROVIDE PRACTICAL GUIDANCE

Pillar 1 of this analytical work consolidates and presents knowledge and technical information on the nexus of land management and climate change in Sub-Saharan Africa. The objective of Pillar 1 is to (i) collate scientific datasets on climate conditions, the physical environment, and socioeconomic characteristics of Sub-Saharan Africa; (ii) analyze data to identify areas at risk to climate change and land-degradation impact; and (iii) identify practical land- and water-management approaches to address the identified risks. Each of these three steps presents a building block for the broader knowledge resource on land and climate that was developed as part of this piece of analytical work.

Pillar 1 deconstructs the complex and multidirectional relationship of land degradation, sustainable land and water management, and climate variability and change. Pillar 1 summarizes and elaborates how the degree of land degradation in Sub-Saharan Africa exacerbates the climate-change vulnerability of productive and natural lands and of the people that depend on these lands for their livelihoods. Pillar 1 further examines the accelerating impact that climate variability and change can have on land degradation, and how succeeding land degradation, in turn, fuels increasing GHG emissions from agriculture, forestry, and land use, resulting in accelerated climate change. On the flipside, Pillar 1 also presents the critical role that SLWM has in halting the downward cycle of land degradation and climate impact. Since extensive literature is available on the role of SLWM as a response to the challenges of land degradation and declining agricultural productivity, Pillar 1 focuses specifically on the discussion of the co-benefits of SLWM to increase resilience to climate variability and mitigate the effects of climate change.

The key findings and recommendations that are elaborated in Pillar 1 include the following:

There is broad recognition of the important role of productive lands for economic growth in Sub-Saharan countries and the reliance of rural livelihoods on rainfed agriculture, and the consequential extreme climate vulnerability of Sub-Saharan livelihoods. Yet, efforts to tackle the development challenges associated with the need for increased agricultural productivity in a changing climate are complicated by the fact that the existing information basis on the underlying constraints continues to be incomplete or complicated with high degrees of uncertainties. For example, to date, no full picture exists of the spatial distribution and the respective degree of land degradation, or the relative change of land degradation over time. Further, with the exception of East Africa, climate projections for most of Sub-Saharan Africa have considerable uncertainties. In the case of West Africa, climate models do not even

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4 For the purpose of this report, information on knowledge dissemination has been made available in annex 12.
agree on the major direction of climate trends, i.e., whether the future will be characterized by dryer or wetter conditions. The key factor for the uncertainties in Sub-Saharan climate-projections is the high level of climate variability that often masks long-term climate-change trends and makes it difficult to identify climate-change signals in observational data sets over large parts of Africa. These constraints consequentially limit the effectiveness of targeting areas with the highest risk exposure to combined impact from land degradation and climate impact.

On the other hand, there is also general agreement that the immediate impact of climate variability is more significant than are gradual climate-change trends to productive and natural landscapes. Underscoring this is evidence that increases in the frequency of extreme climate events will pose the greatest challenge for African smallholder farmers in future climate scenarios. Accordingly, a risk-management approach that combines the strengthening of preparedness for extreme climate events combined with strategic use of seasonal forecasts will not only provide near-term benefits but also provide important lessons for climate-change adaptation over the medium and long term. All findings thus underscore the importance of better understanding existing climate variability and identifying means to improve resilience to current and increased future climate variability. As such, sustainable land management practices that help cope with increased climate variability will need to be at the core of near-term climate-change adaptation strategies.

Taking into consideration already stagnant and declining agricultural productivity in many Sub-Saharan African countries, the negative effect of climate change and variability on productive capacity of lands will need to be countered with land and water management practices that not only address the adaptation deficit (e.g., past neglect of agricultural improvement in dryland areas), but also close the adaptation gap (e.g., respond to the climate change challenges ahead). Many sustainable land and water management practices rise to this challenge as positive yield impacts of improved land management practices have shown to dwarf the predicted negative yield impact of climate change. Moreover, such productivity-enhancing SLWM practices not only contribute to climate-change adaptation but also help to depress the push factors, which have long induced rapid land conversion and consequently land degradation in Africa.

As sustainable land and water management practices are closely tied to increased carbon content of the soil, they have both, considerable mitigation and adaptation co-benefits. The increased rates of terrestrial carbon sequestration and reduced rates of GHG emissions achieved with SLWM thus present large opportunities related to potential carbon finance schemes.

While sustainable land and water management delivers important co-benefits for climate-resilience, it is important to maintain a more holistic view on the benefits of SLWM considering its important benefits for poverty reduction, food security, ecosystem services provision, and biodiversity conservation. A multifocal approach to SLWM that takes into account all ecosystem services, as well as benefits for human well-being, is more likely to succeed than an approach focused exclusively on climate-change mitigation and adaptation benefits. To make some of the above knowledge and information easily accessible to end-users, web-based tools, resource guides and other dissemination tools have been developed. The choice
of tools was guided by factors such as accessibility and ease of comprehension, as successful inclusion of scientific knowledge in decision-making has shown to depend on these factors.

The Africa Land & Climate Portal was developed to collate scientific datasets and make them accessible to end-users. The portal has a map interface and displays climate information (historic, current, and projected trends), physical environment information (both biophysical and human-induced), and socioeconomic information (historic and current population, administrative boundaries, and so forth). The Africa Land & Climate Portal is integrated into the existing World Bank Climate Data Portal and strengthens the corporate effort of providing a one-stop shop for climate-related data and tools.

The Africa Land & Climate Hazard Exposure Map was elaborated to point-up areas at risk for climate-change and land-degradation impact and thus helps guide development practitioners, project managers, and other decision makers in strategically focusing investments in vulnerable areas. The hazard exposure map is based on a combination of critical factors—such as land-use type, slope gradient, population density, precipitation, and evapotranspiration—to generate georeferenced risk assessments for current as well as predicted future rainfall conditions (for 2100).

The third tool that was developed as part of Pillar 1, the Best Management Practices (BMP) Database, is linked to the Africa climate portal and allows the identification of practical land- and water-management approaches that respond to both land degradation and climate risks. Thanks to various proposed search criteria, the database helps to easily identify SLWM practices that respond to specific considerations such as: targeted land-use type, opportunity costs, corresponding production benefits, and so forth. Detailed technical data sheets provide information and further references for each identified SLWM practices.

Pillar 1 sets the stage for the more in-depth analysis that is undertaken in Pillar 2. While Pillar 1 looks solely at the relationship of land degradation, SLWM, and climate change, Pillar 2 adds further factors into the analysis of this multidirectional relationship. Pillar 2 looks at context-specific aspects of SLWM in pilot sites in East and West Africa, while the analysis in Pillar 1 remains strictly at the level of the African continent.

**PILLAR 2: GENERATING CONTEXT-SPECIFIC RECOMMENDATIONS OF SLWM PRACTICES BEST SUITED TO IMPROVE FOOD SECURITY WHILE REDUCING CLIMATE-RELATED RISKS**

Building on the practical guidance generated under Pillar 1, the overall objective of Pillar 2 is to generate practical, local and context-specific recommendations of SLWM approaches and practices that are well suited to improve food security and economic prospects while reducing climate-related risks and greenhouse gas emissions. Pillar 2 offers case studies developed to answer questions such as the following:

- What types, modalities, and conditions of SLWM investments are the most relevant in terms of adaptation to current variability and future climate change?
• What context-specific actions can improve the contribution of SLWM investments to adaptation and mitigation, considering improved information, institutions, and policy, program, and regulatory instruments?

• What are the best synergies between water and land resource management to generate mitigation and adaptation benefits?

To answer these questions, many sites in four countries (Kenya and Uganda in East Africa and Niger and Nigeria in West Africa) were used as case studies. In each subregion, sites were selected according to similar agroclimatic zones. Paired sites sharing an international boundary were selected to capture the impacts of different policies on farmers’ responses to climate change and variability.

The key findings of the case studies respond to the aforementioned questions and provide a clear picture of the level of adoption of SLWM practices that have a strong potential for helping communities increase their resilience to current climate and future climate issues. The case studies document practices that are being the most used, the drivers that create a favorable environment for adopting SLMW practices, the multiple benefits of SLWM for agriculture productivity, carbon sequestration, climate mitigation and adaptation, as well as other pertinent information.

Key finding #1: Climate change is an important driver of change in all communities but not the only one. Population pressure and its effects on deforestation and degradation were also often mentioned. Communities reported a number of responses to climate change, including new institutions for managing grazing areas and governing the use of other natural resources. They also mentioned tree planting and protection of rivers and water sources. However, it was also apparent that some of these initiatives were new and in some cases not yet fully effective.

Key finding #2: Many SLWM practices have been adopted more for productive reasons than as a response to climate change, and the overall adoption rate of SLWM practices remains low. While there is awareness of climate change and land degradation, it is not clear to the rural communities that they interact and that adoption of SLWM practices is a response that has a double dividend, as it addresses both climate change and land degradation.

Key finding #3: Major factors that drive responses to climate change and adoption of SLWM practices include access to rural services, household-head gender, household level of education, and household capital endowment:

• Households who depend heavily on agriculture and ecosystem services are more likely to adopt adaptation strategies than those who have alternative livelihoods, such as nonfarm activities. Those who have higher education or are closer to markets where there are alternative livelihood options are more likely to adopt SLWM practices as a response to climate change. However, in a more specific finding, the research shows that farmers in remote areas are more likely to use organic soil fertility management practices than those closer to markets.

• Limited household capital and access to rural services lead to nonresponsiveness to climate change.
• Lack of agricultural inputs (e.g., improved seeds and fertilizer) and lack of information on appropriate adaptative methods were also mentioned as important reasons for not adopting SLWM practices. This highlights the weak agricultural input markets and the low capacity of the agricultural extension services to advise farmers on climate-change adaptation methods.

• Farmers with poor plots are less likely to use SLWM as coping strategies to climate change and variability; mixed crop-livestock production enhances the adoption of SLWM practices.

• Extension services are generally weak in providing advisory services on organic soil fertility management practices. Traditional agricultural extension services can be complemented by technical assistance provided in the context of SLWM projects. The results underscore the importance of multiple providers of extension services that have complementarity in provision of different types of technologies.

Key finding #4: The study has identified the following SLWM practices that efficiently increase the resilience of rural communities and ecosystems to adverse climate changes:

Diversified and integrated agriculture
1. Diversified agricultural systems
2. Mixed production of crop and livestock systems

Integrated SLWM
3. Integrated land and water management
4. Improved livestock feeding systems in the drylands
5. Irrigation and water-harvesting practices
6. Integrated soil fertility management practices
7. Protection and planting of multipurpose trees and other vegetation

Adaptive strategies to complement SLWM
8. Use of crop varieties and animal breeds well suited to climate change
9. Planting calendar updating at community level

A diversified and integrated agriculture is a practice that communities and farmers are already moving toward. There is evidence of diversification across crops, livestock, and trees and within crops (for example, introducing horticulture) and livestock (for example, introducing poultry) in all communities. The trend toward diversification is also a reaction to population growth and market opportunity growth, which together increase incentives to include higher value enterprises. Some farmers further diversify into value by adding activities—a key feature of this is a strong element of mixed crop and livestock systems. In addition to the obvious risk benefits of diversification, it creates synergies between the feeding of livestock from crop residues and the returning of manure to the soil.

Livelihood diversification will increase resilience to climate change. Households reported to engage in non-farm activities as a way of coping to climate related risks. Livelihood diversification beyond agriculture will help address the adaptation deficit—which is defined as greater exposure to climate-related risks and vulnerability due to failure to fully adapt to climate change. Livelihood diversification is especially crucial in the drylands where climate-related risks
are high. Thus the wider livelihood diversification needs to be taken into account in SLWM and other natural resource management programs.

**Integrated SLWM practices** are fundamental to increasing adaptive capacity of rural households. They also contribute significantly to mitigating climate change and its effects on soil and water for agriculture. The level of integrated SLWM in the case study sites is so far limited. However, there is evidence that individual or combinations of SLWM practices have favorable impacts on productivity and yield variability. These include a host of soil fertility practices such as mulching and manuring, soil conservation practices, and water harvesting. There is also evidence of benefits from the planting of nitrogen-fixing trees and from the improved management of rangelands and pastures in the drylands. The evidence is clear that the promotion of mineral fertilizers and seeds alone is insufficient to raise productivity and to enrich the agricultural resource base to withstand climate shocks. While integrated SLWM is important, it is also vital that further awareness and support for the individual practices also continue, as many have their own unique requirements for widespread scaling up (some require seed systems, some collective action, and so on).

**Even with efforts to promote SLWM, adaptive strategies to complement SLWM will still be needed.** Practices such as changing crop type and variety as well as planting dates are already widely used by farmers. Greater sharing of scientific and local knowledge of crop types, varieties, provenances, and landraces is also important so that communities facing climate variations can benefit from the experience of others who are already living in those types of climates. There is a further need to expand the crop and livestock choices available to farmers through improved breeding programs. Current practices will be challenged not only by potential rainfall changes but also by temperature changes and the consequent changes in pests and diseases. Planting at the right time is vitally important to crop yield, notably in the short to medium-length growing seasons. However, farmers rarely reported receiving seasonal forecast information. It will become more important to have such information if, as predicted for much of Africa, growing seasons shrink.

**Key finding #5: National policies play a critical role in scaling up SLWM practices that have a potential for increasing resilience to climate variability and change**, but only if they clearly highlight a long-term commitment to agriculture and natural resources management and if they can be supported by strong local institutions. A variety of strategies can be used to enhance adaptive capacity. These strategies can be effectively achieved if countries design specific policies and strategies for adaptation and mitigation (for example, National Adaptation Programmes of Action). Given the wide variety of implementing sectors, there is a need for such policies and strategies to be harmonized and well aligned with other development programs, and there is a need to ensure long-term commitment to avoid useless efforts.
The recommendations for advancing rural communities’ abilities to cope with climate variability and offset climate change effects can be classified into five main areas.

Recommendation #1: Promote the use of SLWM practices that have a strong potential to increase resilience to climate variability and mitigate the effects of climate change.5 Promotion of SLWM practices will require concerted efforts among ministries of agriculture, livestock, water, forestry, environment, and natural resources. There is a need to align programs that seek complementarity and synergy between the sectors rather than competition. The ministries of agriculture will be critical to implementation as they house the main extension programs and the bulk of field staff. There is further need to strengthen collaborations with and among the often numerous projects implemented by NGOs. This is especially important for supporting broader efforts to capture adaptation and mitigation co-benefits within the SLWM framework, which requires further action research and focus on coordinated policy interventions. All of these are necessary to achieve impact at scale, which is critical. However, this is not to advocate for top-down approaches. Indeed, SLWM is highly context specific and requires skillful mechanisms to support community-driven plans. There is no way around the fundamental need to develop capacity in SLWM at local levels, so that communities are able to support the development and dissemination of relatively knowledge-intensive innovations.

Recommendation #2: Strengthen and disseminate technical knowledge. Technical knowledge needs in this arena are many, but in relation to climate-change adaptation and mitigation in rural communities, the study has identified the importance of information dissemination and extension—and its current weak state. Extension systems have to play an important role as the key interface with communities. Furthermore, there needs to be better articulation and integration between local traditional knowledge and professional knowledge systems, as well as focus on the SWLM as part of wider livelihood context. For this to happen, however, there needs to be much greater integration of climate-change-related research and experiences from learning by doing into national research and policy agendas able to produce nationally and locally relevant results. This will require more formal linkages between meteorological departments with agricultural research systems as well as wider platform for exchange and sharing of information and knowledge between different levels of institutions and among communities. The strengthening of linkages among research, extension, and policy is also essential.

Recommendation #3: Improve access to markets through better marketing of rural products and services. Scaling up SLWM investments requires that rural markets function well. Chief among these are input markets for items such as fertilizer, crops, trees, and equipment for irrigation. Since the retail-input sector consists largely of diversified small businesses, this effort will likely involve capacity building of existing rural businesses to understand the potential of different products. On the demand side, there is a need to improve credit and other financing systems for agricultural inputs, which remain poorly supported by formal and informal institutions or programs. Initiatives to insure loans taken by farmers in case of poor weather

5 Such practices include diversified agricultural systems, mixed production of crop and livestock systems, integrated land and water management, improved livestock feeding systems in the drylands, irrigation and water-harvesting practices, integrated soil fertility-management practices, protection and planting of multipurpose trees and other vegetation, use of crop varieties and animal breeds well suited to climate change, and an updated planting calendar at the community level.
should also be tested where potential impact is large. In addition, because SLWM has been shown to deliver environmental services for society, chief among them carbon sequestration and watershed protection, several projects in Africa are pursuing the opportunities for communities to be compensated for these services in informal markets. These initiatives need wider testing, which requires support from national governments. In the case of carbon sequestration, for example, if successful models for rural carbon storage and measurement can be developed, it is more likely they will be recognized in formal carbon-financing protocols.

**Recommendation #4: Strengthen local natural resource management institutions.** The strengthening of local institutions, both formal and informal, is vital to sustainable success in SLWM. The role of informal institutions and social networks is essential for local ownership and implementing best local environmental practices. There are some encouraging examples of new bylaws protecting local resources. In order to strengthen these institutions, actions are needed to devolve or delegate responsibility, build capacity, and develop the ability to generate finances. Capacity-building is a long-term effort that requires commitment, adequately designed measures (workshops, publications, radio) and resources. Besides community resources, landscape resource management requires urgent attention, as competition over resources continues to be a key cause of conflict and violence in rural Africa. This poses new challenges as well as opportunities for the climate change agenda. Governance systems at the landscape level thus also need to be developed and strengthened to better manage landscape resources such as rangelands, woodlands, and water.

**Recommendation #5: Build strong national policies that support the scaling up of SLWM in Sub-Saharan Africa.** None of the recommendations above can be implemented without serious policy reforms at the national level. The first shift needs to be a long-term commitment to agriculture and rural communities. Although governments had pledged that 10 percent of their budgets would be devoted to agriculture, few have met their pledges. Second, there is urgent need to formulate policies and strategies on adaptation to and mitigation of climate change and to commit resources to implement such policies and strategies on a long-term basis. Climate Change requires appropriate political and strategic response that goes beyond environmental degradation and loss of agricultural productivity and current knowledge on the scope of climate change should be integrated into a whole range of initiatives from national to local levels. There is also an urgent need to solve problems of climate change, natural resource management, and agriculture in a more coordinated and collaborative manner. Intersectoral dialogues are often held, but there is a lack of empowerment of such processes, and the bulk of planning is still done at sectoral level. Decentralization can help, but it can also lead to the marginalization of longer term SLWM over urgent needs in social services. There are many justifiable reasons for supporting SLWM, such as the environmental services they produce or the stewardship of resources for future generations. There is need for more vertical integration between facilitating policies and public programs, and local-level initiatives, with a view to creating a favorable environment for the spread of local initiatives. Funds are now also becoming increasingly available. But governments must lead and indicate a strong demand for this to happen. This is much more than approval of projects; it is a long-term commitment to programs that will have impact at scale. The New Partnership for Africa’s Development (NEPAD) Planning and Coordinating Agency and the regional economic communities have been building their capacity in both climate change and SLWM and would be expected to play key roles in supporting national government planning processes and in securing financing the resulting programs.
**PILLAR 3: SHARING AND DISSEMINATING KNOWLEDGE ON THE LAND AND CLIMATE NEXUS TO IMPROVE ON THE GROUND RESILIENCE TO THE IMPACTS OF CLIMATE CHANGE AND VARIABILITY**

The primary audience includes the Bank’s task team leaders and other development practitioners, including in African institutions—at either the regional level, such as NEPAD, or at the country level, such as policy makers or government officials. The TerrAfrica\(^7\) platform, which gathers partners around the objective of scaling-up SLWM in Sub-Saharan countries, will also provide a way of reaching an ideal target audience.

The dissemination activities carried out as part of this work are critical to ensuring that the findings inform new policies and investments and have an impact on taking SLWM to a larger scale in Sub-Saharan Africa. The knowledge products and web-based tools generated through this work aim to inform policy and strategy formulation, provide operational guidance, and catalyze national and regional actions in SLM. The main outputs of this analytical work are synthesized in annex 1.

The ultimate objective of this work is to provide sufficient guidance to development practitioners and policy makers to make a difference on the ground and scale up SLWM in Sub-Saharan Africa for climate- and environment-smart development. Dissemination activities should be continued and expanded to make knowledge and information available to policy makers at the country level.

Even though a lot has been achieved, it is clear that this ESW and its related outputs should be considered as a first attempt to fill the practical knowledge gap rather than seen as an exhaustive and comprehensive piece of work that is sufficient in itself. As environment and climatic data are growing and improving, and as researchers further explore the linkages among land degradation, climate change, and SLWM, additional relevant knowledge should be gathered and made available to development practitioners and policy makers so that they can respond to development challenges faced by Africa in the context of a changing climate.

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6 Considered as Pillar 3 in the Concept Note, the detailed write-up related to knowledge dissemination is available in annex 12.

7 Available at www.terrafrica.org/.
Box 1:…What you should remember about this work

It is recognized and demonstrated by several studies that climate variability and change exacerbates and will continue to exacerbate the existing vulnerabilities of African countries that already face poverty, food insecurity and land degradation. This study highlighted that:

- **SLWM plays a critical role in halting the downward cycle of land degradation and climate impact. SWLM practices, and especially combined ones such as integrated land and water management practices, have been shown as key to increase resilience of rural communities to climate variability and to mitigate the effects of change through increasing agriculture productivity, building soil carbon stocks, being more profitable than as-usual land management practices, conserving biodiversity, etc.**

- **National policies, relayed by local institutions, play a critical role in scaling up SLWM practices that have a potential for increasing resilience to climate variability and change.**

It is therefore important and essential that all stakeholders join their efforts to promote and scale up these practices. To do so, we should reconsider the way we are doing things. The following 3 key behaviors regroup the recommendations proposed in this study. Most of the things that should be “done differently” or “more” fill the adaptation deficit while the “new things” mainly respond to the adaptation gap:

- **Doing the same things differently:** decentralization is an ongoing process in several countries, we should (i) strengthen differently the local institutions to give them necessary power to better manage natural resources, (ii) promote long-term and greater investment in agricultural development and natural resources management, (iii) encourage diversification of rural livelihoods.

- **Doing more of the same things:** some policies implemented by the local or national institutions, as well as some practices applied by farmers, are already increasing their resilience to climate variability and change and should be carried on, such as (i) develop and promote improved livestock feeding systems in the drylands, (ii) invest in irrigation and water-harvesting practices, (iii) invest and promote community-driven development small-scale and medium-scale irrigation, (iv) develop and promote multipurpose trees, (v) promote pluralistic agricultural extension services, (vi) improve input marketing system, (vii) formulate policies and strategies specific on adaptation to and mitigation of climate change, and (viii) programs for enhancing adaptation to climate change should target women and the poor.

- **Do new things:** either across countries or in some specific countries, and in addition to what is already being done, some practices and policies should be implemented as part of the adaptation strategies (i) promote mixed production of crop and livestock systems, (ii) develop and promote integrated land and water management practices and integrated soil fertility management practices, (iii) revise and widely promote planting calendars, (iv) develop and promote use of crop varieties and animal breeds well suited to climate change, (v) strengthen capacity of agricultural extension services to provide climate-change-smart SLWM practices, (vi) harmonize and integrate adaptation to and mitigation of climate change policies and investments with other rural development programs, (vii) long-term and greater investment in agricultural development and natural resource management.
INTRODUCTION

WHY AN ECONOMIC AND SECTOR WORK ON THE ROLE OF SUSTAINABLE LAND AND WATER MANAGEMENT TO MITIGATE AND ADAPT TO CLIMATE CHANGE IN SUB-SAHARAN AFRICA?

Livelihoods, food security, and development processes in Sub-Saharan Africa are highly dependent on land management practices to generate natural ecosystem goods and services. Out of a total population of about 717 million people almost, 60 percent depend for their livelihood on agriculture, hunting, fishing or forestry.8

However, unsustainable land management already leads to large-scale land degradation trends, which pose a threat to food security and poverty alleviation in Sub-Saharan Africa. Water and wind erosion affect 46 and 38 percent of the total land area, respectively. Nutrient loss and decline in soil fertility are widespread problems across the continent. Estimates suggest that a total of 485 million people (65 percent of the entire African population) and 67 percent of African land are already affected by land degradation.9

Climate change threatens to exacerbate and add to the existing vulnerabilities, unless prevention and remedial measures are taken. On average, the African continent has warmed by 0.5°C over the last century, and the median temperature is projected to increase another 3º to 4ºC by the end of this century.10

Coping with climate variability and change is a major challenge for the people of Sub-Saharan Africa. The high dependence of the economies and rural people of Sub-Saharan Africa upon rainfed agriculture, the prevalence of poverty and food insecurity, and limited development of institutional and infrastructural capacities in this region make coping with natural climate variability a perennial challenge. This is magnified by global climate change. Over several decades, the number of extreme weather events and the number of people affected by droughts and floods have grown dramatically. Many climate models predict negative impacts of climate change on agricultural production and food security in large parts of Sub-Saharan Africa. These changes are predicted to reduce the area of land suitable for rainfed agriculture by 6 percent (averaged across several projections) and reduce total agricultural gross domestic product (GDP) in Africa by 2 to 9 percent.11

Despite the close linkage between land degradation processes and vulnerability to climate variability and change, the World Bank operations in Africa, which explicitly address

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8 Food and Agriculture Organization (FAO) of the United Nations, FAOSTAT, data reported for 2004.  
10 IPCC 2007, WG I.  
11 Pender, J. et al. (2009), The role of sustainable land management for climate change adaptation and mitigation in Sub-Saharan Africa.” TerrAfrica, Washington DC.
climate risks, have been limited to date. While the need for “climate-resilient development” is increasingly recognized by the Bank and its client countries, one constraining factor is the lack of practical information and knowledge. There is a need for information focused on providing sector- and region-specific operational guidance on addressing climate risks, vulnerabilities, mitigation and adaptation options, and the opportunities for synergies among them.

All the aforementioned factors explain the need to undertake this analytical work, which will help clarify the linkages between climate change and land management and highlight the role of sustainable land and water management to improve resilience to climate variability and mitigate the effects of climate change in Sub-Saharan Africa.

WHAT IS SUSTAINABLE LAND AND WATER MANAGEMENT?

Sustainable land management (SLM) is the adoption of land-use systems that, through appropriate management practices, enable land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources.12 There is a broad recognition that SLWM is crucial for ensuring an adequate, long-term supply of food, water, raw materials, and other services provided by agricultural and natural resources. SLWM involves both the long-term maintenance of the productive capacity of agricultural lands and the sustainable use of natural and seminatural ecosystems.

More broadly, sustainable land and water management (SLWM) means management of the land in such a way as not to negatively affect production, climate, or water and other resource availability. Under this definition, SLWM covers a wide range of approaches and practices, such as conservation agriculture, tree planting, watershed management, integrated fertility soil management, improved grazing management, reduced or no tillage, small-scale irrigation, water harvesting, and others.

While this report focuses more on the land dimension of SLWM, another report13 led by the Bank’s Africa Water Resources Management Unit (AFTWR) focuses on the water dimension. These two analytical pieces are complementary and some activities have been carried out jointly to ensure better coordination—especially the climate-change baseline.

WHAT IS THE OBJECTIVE OF THIS WORK?

The objective of this work is to improve and increase practical knowledge resources available to Sub-Saharan African countries, regional institutions, the World Bank and other partners to help make informed decisions about (i) the risks posed by climate variability and change to land-resource-dependent livelihoods in Sub-Saharan Africa, and (ii) the SLWM approaches and practices best suited for meeting development objectives while also addressing the challenge posed by adaptation to and mitigation of climate change.

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13 “Climate Change and Africa’s Water: What Are the Operational Implications?” led by Nagaraja Rao Harshadeep and Amal Talbi (P108455)
HOW IS THIS WORK ORGANIZED?

This report is divided into two Pillars that complement each other in achieving the objective of the report.

Activities carried out under Pillar 1 focused on generating or consolidating the existing body of knowledge on the land and climate nexus, both in terms of scientific data (climate, land and development data) and technical operational information related to SLWM practices. The objective of Pillar 1 is to further combine these various knowledge inputs and to analyze them in order to develop practical guidance that could be made available to Bank TTLs and client countries through specific tools.

This practical guidance was further refined and tested under Pillar 2 through case studies in four countries. These generated context-specific recommendations of SLWM approaches and practices well suited to improve food security and economic prospects while reducing climate-related risks and greenhouse gas emissions. The case studies demonstrate the relevance of operational guidance generated under Pillar 1 for addressing key vulnerabilities and the role of SLWM practices in increasing adaptive capacity of rural communities.

All findings, recommendations, and tools from Pillar 1 and Pillar 2 have been and will continue to be disseminated broadly. Since the lack of practical information and knowledge was the major driver for undertaking this work, dissemination activities are considered critical to promote the scaling-up of SLWM in Sub-Saharan Africa; they are detailed in annex 12.

WHAT DOES THIS WORK ENCOMPASS—AND WHAT DOES IT NOT?

SLWM forms an essential part of a wider livelihood context to cope with climate change and variability. While promoting the use of SWLM measures to adapt to climate variability, it is important to mainstream adaptation strategies in a broader socioeconomic context of local development. Adaptation to climate variability includes measures such as diversification of livelihoods, permanent/temporal migration and household splitting, which together with SWLM can be used to promote sustainable livelihoods through increased resilience to climate change. Within this perspective, it will also be necessary to better integrate knowledge and best local environmental practices in devising adaptation strategies. Among other things, this relates to a better integration among planning mechanisms and empowerment of stakeholders (according to the principle of subsidiarity) and also to a better mobilization of all the national institutions in charge of local development planning on the theme of the fight against climate change. Therefore, if this report focuses on the role of SLWM to increase the resilience capacity of rural livelihoods in Sub-Saharan Africa, it is clear that SLWM should be considered as part of a broader package of measures that support adaptation to climate change and variability.
This work does not pretend to be exhaustive in terms of data and information collected under Pillar 1. A choice was made to investigate free and available on-line datasets focusing on climate, land, and development characteristics. Data has been combined, analyzed, and made available through the Africa Land & Climate Portal. This tool was developed to initiate the process and should be updated and improved on a regular basis.

The report is not designed as a toolkit, but it does provide significant operational guidance on climate risks and induced vulnerabilities of rural livelihoods, and on SLWM practices best suited to mitigate the effects of climate change and improve resilience to climate variability while improving agriculture productivity and preserving ecosystems services. This guidance is provided through practical tools that TTLs and client countries can use to advance the SLWM agenda in Sub-Saharan Africa and include in climate-resilient land-management approaches and techniques in their projects.

**HOW CAN THE OUTPUTS OF THIS WORK BEST BE USED?**

Since the focus of this work was to provide practical and operational guidance to Bank TTLs and other development practitioners in client countries in terms of climate risks, related vulnerabilities, and SLWM practices, a series of tools has been developed, such as the stocktaking matrix of land and climate publications, the Africa Land & Climate Portal, the database of SLWM Best Management Practices, and a library of short films. These can be used in policy making, dissemination efforts, project planning, etc.

The report also refers to a series of stand-alone reports that are considered annexes to this report. These include the country case studies reports, the Resource Guide “Using Sustainable Land Management Practices to Adapt to and Mitigate Climate Change in Sub-Saharan Africa,” regional climate profiles titled “Climate Profiling Sub-Saharan Africa under Current and Future Conditions: Making Development Climate Resilient,” and a discussion paper titled “The Role of Sustainable Land Management for Climate Change Adaptation and Mitigation in Sub-Saharan Africa.” These reports are available on the CD that accompanies this report.
PILLAR 1: GENERATING OR CONSOLIDATING THE EXISTING BODY OF KNOWLEDGE ON THE LAND AND CLIMATE NEXUS IN ORDER TO PROVIDE PRACTICAL GUIDANCE

INTRODUCTION

Pillar 1 Objective: Developing a Knowledge Baseline for the Land and Climate Nexus

The objective of Pillar 1 of the analytical work Managing Land in a Changing Climate: An Operational Perspective for Sub-Saharan Africa is to consolidate and group in a similar and common data base knowledge and technical information on the nexus of land management and climate change. The following activities have been carried out to achieve this objective:

1. **Data collection:** Baseline data and information on historical, current, and future climate conditions and key biophysical, environment, and socioeconomic characteristics across Sub-Saharan Africa have been consolidated.

2. **Data analysis:** Baseline data have further been analyzed to determine areas with high risk exposure to land degradation and climate risk impact. Further, a body of analytical work was carried out to feed into this report and to substantiate the knowledge and findings presented.

3. **Development of knowledge tools:** An Africa Land & Climate Portal, which includes a set of web-accessible tools, has been set up and provides easy access to land and climate data as well as practical guidance on SLWM practices that respond to climate-induced land degradation risks.

Pillar 1 first discusses land degradation and climate-change risks based on the technical data, information, and evidence that was collected, consolidated, and analyzed. Pillar 1 then elaborates how SLWM practices can provide opportunities to adapt to and mitigate climate change. It focuses on the co-benefits of SLWM practices in terms of (i) building resilience to climate variability and change and (ii) supporting climate-change mitigation through increased carbon sequestration and reduced greenhouse gas (GHG) emissions.

Pillar 1 Outputs: Developing a Knowledge Baseline for the Land and Climate Nexus

**Data collection**

Data and information on land, climate, and development was collated, processed and synthesized. The main elaborated products are the following:

- a database of observed, historical climate data for the Africa Region for the time period of 1901–2000;
• a review of methodologies to downscale climate projections of global circulation models (GCMs) to the finer resolutions used in hydrological models and applications;

• a database of key georeferenced land and development data and information covering the entire Africa Region; and

• an annotated database with over 200 of the most relevant publications and knowledge resources on the land and climate nexus.

Data analysis

Collected and processed data served as a base for further analysis and interpretation. Based on combination of biophysical, socioeconomic, and climate information, areas in Sub-Saharan Africa with high-risk exposure to land degradation under present and expected future climate conditions have been identified. Further, an analysis of a wide variety of information and knowledge sources was carried out. As a result, a body of analytical work was developed that includes background reports, scientific and technical studies, discussion papers, expert reviews, and inputs from many contributors. Some pieces of analytical work are also published as self-standing reports. The following analytical products were developed:

• climate profiles for the five climate subregions of Sub-Saharan Africa;

• a Technical Discussion Paper on the role of sustainable land management (SLM) for climate-change adaptation and mitigation in Sub-Saharan Africa;

• the Resource Guide on Best Management Practices: Using SLM Practices to Adapt to and Mitigate Climate Change in Sub-Saharan Africa; and

• the Africa Land & Climate Hazard Exposure Map, which provides a spatial projection of land vulnerability to land degradation and climate-change risk.

The self-standing pieces of analytical work present important outputs of Pillar 1 and form part of the broader body of knowledge resources developed as part of this work. A reference table with all work carried out within the context of this report is provided in annex 1.

Development of knowledge tools

Based on the knowledge and data collected, interpreted, and processed for this work, three interlinked, user-friendly, and Web-accessible tools have been designed to allow TTLs, development practitioners and other users to easily access land and climate information and seek guidance on best-suited SLWM practices. A strong emphasis is placed on the use of a geographic interface to allow users to visualize and compare temporal and spatial scales of data on the land and climate nexus. These knowledge tools present important outputs of Pillar 1 and will serve as the basis for a series of knowledge-sharing and dissemination activities that will be carried out. These are dynamic tools that are expected to be updated and improved on a regular basis.
These tools can be accessed at http://sdwebx.worldbank.org/climateportal/?page=africamap and consist of the following:

- **The Africa Land & Climate Portal** is a Web-accessible platform with a geographical interface (Google Maps) that includes several layers of climate, socioeconomic, land, and environmental data organized against spatial and temporal scales. The Africa Land & Climate Portal is fully integrated into the corporate World Bank Climate Data Portal by adding and populating additional datasets.

- **The Land & Climate Hazard Exposure Map** is a georeferenced map of Africa, obtained by combining several data bases, that identifies areas exposed to high risk for land degradation and climate-change impact. It provides users with spatially projected information on the various factors that influence land degradation in current and future climate conditions and thereby guides decision making on SLWM options.

- **The Best Management Practices Database** is a searchable database of a variety of SLWM practices that respond to land-degradation threats and provide additional cobenefits for climate-change adaptation and mitigation. The database draws information mainly from the *Resource Guide: Using Sustainable Land Management Practices to Adapt and Mitigate Climate Change in Sub-Saharan Africa* that was prepared in support of this work. It is complemented with additional information from the World Overview of Conservation Approaches and Technologies (WOCAT) and the UN’s Food and Agriculture Organization (FAO).

This report is not designed as a tool kit, yet the value-added of the knowledge tools lies in their applicability in the web-based medium. Therefore, only reference is made to the knowledge tools throughout Pillar 1, but more detailed guidance on their application is provided in a separate user guide. More details on the Africa Land & Climate Portal and related knowledge tools are provided in annexes 2 and 3.

**Pillar 1 Outline: Developing a Knowledge Baseline for the Land and Climate Nexus**

Pillar 1 consolidates and presents knowledge and technical information on the nexus of land and climate in Sub-Saharan Africa by drawing on the information and knowledge developed in the analytical work presented further above. Pillar 1 begins by introducing the reader to the land dimension of the complex relationship of land degradation and climate change. Pillar 1 then examines the climate dimension with an overview of current climate characteristics and projected climate change and variability for Sub-Saharan Africa. The further discussion of the multidirectional relationship of land degradation and climate change then forms the basis for the presentation of the Africa Land & Climate Hazard Exposure Map.

While the first part of Pillar 1 maps out land and climate interactions and the associated risks for land productivity, food security, and sustainability of ecosystem services, the second part of Pillar 1 provides guidance on the multiple benefits that SLWM can offer. These benefits address not only land degradation threats but also adaptation to and mitigation of climate-change impacts. The discussion first centers on how SLWM practices can provide cobenefits by strengthening resilience to climatic variability and change (a local good) and promoting climate-change mitigation efforts (a global good).
LAND AND CLIMATE INTERACTIONS IN SUB-SAHARAN AFRICA

Land Degradation and Climate-change Vulnerability\(^{14}\)

The relationship between land and climate is complex and multidirectional. This section aims to set the context for the further discussion of this relationship throughout this study. More specifically, this section elaborates the land dimension of the land and climate nexus and presents land degradation as one of the key underlying factors for climate-change vulnerability of Sub-Saharan economies and rural land users. The text explores the following questions:

- What is the status of land degradation in Sub-Saharan Africa?
- How does land degradation affect the productive qualities of the land?
- How well can we quantify the extent and degree of land degradation in Sub-Saharan Africa?
- What are the main underlying causes of land degradation in Sub-Saharan Africa?
- Why does land degradation exacerbate climate-change vulnerability in Sub-Saharan Africa?

Sub-Saharan African countries are overwhelmingly dependent on productive lands and natural resources for their wealth and livelihoods, as roughly one-third of the region’s economic growth and the majority of its livelihoods rely on the production of food, fuel, fiber, and medicines. About 70 percent of the population in Sub-Saharan Africa is reliant on rainfed agricultural for employment and livelihood, yet only 14 percent of the region is estimated to be relatively free of moisture stress (Eswaran et al. 1997). With two-thirds of Sub-Saharan Africa’s surface areas being desert or dry land, the land that forms the safety net and basis of many of Africa’s livelihoods is highly vulnerable to desertification, land degradation, and drought. Fifty-five percent of the land in Africa is unsuitable for any kind of cultivated agriculture, with only parts of this land suitable nomadic grazing. Yet, about 30 percent of the population (or about 250 million people) live in or depend on deserts (including salt flats, dunes, and rock lands as well as steep to very steep lands) for survival. Of Africa’s poor, 70 percent live on these marginal lands.

These figures show how the majority of the population in Sub-Saharan Africa is extremely vulnerable to climate variability and change—and this vulnerability is further exacerbated by land degradation. Severe land degradation on the African continent generally corresponds with either high population densities or the presence of human population on marginal lands, or the combination of both. Widespread land degradation is evident in the underperformance of productive lands, such as cropland, rangeland, and forests. Estimates suggest that 65 percent of the entire African population (486 million people) is already affected by land degradation in Africa (Eswaran et al. 1997).

\(^{14}\) This section is based on J. Pender et al., The role of sustainable land management for climate change adaptation and mitigation in Sub-Saharan Africa (Washington, DC: World Bank/TerrAfrica/IFPRI/ICRAF, 2009).
Among the regions of the world, Sub-Saharan Africa has the highest rate of land degradation (World Meteorological Organization, 2005). Water and wind erosion affect 46 and 38 percent of the total land area, respectively. Figures from the first attempt to quantify the extent and severity of land degradation in Africa, the widely cited GLASOD project, reveal that by 1990 some 20 percent of the region was affected by slight to extreme land degradation, with 7 percent degraded to such an extent as to directly affect its productive potential. Newer figures reveal that in Africa land degradation affects 67 percent of total land, with 25 percent characterized as severe or very severely degraded and 4 to 7 percent as nonreclaimable.

A more recent assessment of human-induced land degradation (Vlek et al. 2008) analyzed changes in the Normalized Difference Vegetative Index between 1981 and 2003. The study found that overall in Sub-Saharan Africa about 10 percent of the land showed clear declines in NDVI that were unrelated to rainfall decline and were thus classified as degraded areas. Experts assume, though, that the total degraded area in Sub-Saharan Africa should include another 10 percent of land identified as severely degraded by GLASOD, because that land would not have shown further decline in NDVI. These areas are home to about 60 million people, and a large proportion can be found in the semi-arid Sahelian belt south of the Sahara and extending eastward into Sudan and Ethiopia.

Depending on the data, the method of assessment used, and the time frame taken into consideration, the resulting estimated extent and severity of land degradation varies considerably. Thus far, there is no global map that fully integrates all dimensions of land degradation. Using deviation of the NDVI against a norm and adjusting data by rain-use efficiency is considered the best proxy for assessing land degradation based on the decline of productivity and ecosystem function. When land degradation is expressed in terms of net primary productivity, an economic appraisal of the degree of degradation can be undertaken.

Severe land degradation is caused mainly by the conversion of forests, woodlands, and bush lands to agriculture; the overgrazing of rangelands; unsustainable agricultural practices on croplands; and excessive exploitation of natural habitats, with the most severe impacts in drylands and forest margins. With agricultural productivity stagnant on most of the continent, agricultural production gains have been made predominantly by bringing new land under cultivation, while crop yields per area remain flat.

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15 The first attempt to was to quantify the extent and severity of land degradation in Africa from a “convergence of evidence” and expert consensus through the Global Assessment of Soil Degradation (GLASOD) project (Oldeman 1994). That effort generated data revealing that all land uses are associated with significant degraded areas, with agriculture and rangeland estimated to have the greatest proportion.

16 The NDVI is a measure of “greenness” of vegetation based on analyses of satellite images. Changes in the NDVI over time are correlated to both the changes in rainfall and the changes in management/exploitation by humans and animals. The study found that in more than 50 percent of the sites analyzed there was an increase in NDVI, or a greening phenomenon. For the most part, these areas correspond to increases in annual rainfall amounts, often starting from historically low levels in the early 1980s. In these areas, it is not possible to determine whether land management is improving or worsening and therefore whether land degradation is occurring. It is possible that the increased rainfall is off-setting negative effects of exploitation in terms of overall vegetation estimates.
Unsustainable agricultural practices on croplands have increased production temporarily, but the cost has been soil degradation, as soils are mined for their nutrients. According to Nellemann et al. (2009), past soil erosion in Africa might have generated yield reductions from 2 to 40 percent, compared to a global average of 1 to 8 percent. Few African countries are self-sufficient in food production, resulting in the need for massive annual food imports. If nutrient depletion continues in Sub-Saharan Africa, about 950,000 km² of land is threatened by irreversible degradation. Annual rates of soil nutrient depletion of agricultural land in Sub-Saharan Africa is estimated at 22kg N/ha, 2.5kg P/ha, and 15kg K/ha for a total of about 40 kg/ha per year. Studies from Henao and Banaante (2006) agree with this and estimate that 85 percent of African farmland has nutrient-mining rates of more than 30 kg/ha of nutrients annually, and 40 percent of land has mining rates of over 60 kg/ha per year. If these figures are extrapolated to the roughly 190 million hectares of cultivated land in Africa, this would translate into a fertilizer replacement cost of well over $500 million in 2006 and even more in 2008, considering soaring fertilizer prices.

As a result of nutrient depletion, smallholder farmers are forced to extend agricultural practices to new land and thus into forest margins. Consequently, expansion of extensive smallholder agriculture is one of the key drivers of deforestation in Africa, with 89 percent of deforestation estimated to be attributable to clearing for agriculture. The rate of deforestation of 0.6 percent per year for the past 15 years is among the highest globally. Further accelerating the deforestation trend is the need for biofuel. Up to 70 percent (in many countries) of energy comes from fuelwood and charcoal, and newer technologies using cellulosic sources of biofuels will result in even greater demand on woody resources. Deforestation is also causing increased surface runoff and consequently decreasing groundwater recharge, resulting in lowered water tables, reduced and intermittent flow of formerly perennial rivers and springs, and dried up wells and boreholes, thus exacerbating land degradation impact.

Overgrazing has been estimated to account for half of the land degradation. However, there is much unsettled debate about how much of the observed degradation (for example, vegetation loss) is due to management and how much is attributable to climate changes. They are clearly related, as climate-change shocks, for example a prolonged drought, will lead to reduced vegetation, to which herd size cannot be easily adjusted in the short term. Also, persistent drought in West Africa is well documented, yet still very little is known about the length, severity, and origin of drought before the 20th century. Evidence suggests that the West African monsoon is closely linked to changing Atlantic sea surface temperatures and intervals of severe drought lasting for periods ranging from decades to centuries are characteristic of the monsoon. Consequently, the severe drought in the Sahel of recent decades is not anomalous in the context of the past three millennia, indicating that the monsoon is capable of longer and more severe future droughts (Shanahan, T.M., et al. 2009). These extended drought periods in the Sahel have a big impact on available grazing land and the carrying capacity for livestock.

Land-use changes in Africa are not only exacerbating vulnerabilities of the development process but are also the single biggest source of GHG emissions in Africa. 30 to 50 percent of savannah is burnt annually in Africa, accelerating the release of GHGs and the loss of soil organic matter

17 Of the 89 percent, 54 percent are attributed to subsistence agriculture and the other 35 percent to intensive agriculture.
Increased demand for productive land is further leading to conflicts—especially between settled farmers and herders—over access to land resources as households and communities search for land and water for their crops or livestock.

**Land degradation increases the vulnerability of people to climate variability and change by restricting the range of viable rural enterprises; reducing average agricultural productivity and incomes; increasing production vulnerability** (for example, by reducing the soil’s water-holding capacity and organic-matter content); and reducing local resource asset levels, such as forest resources, water resources, and so forth. All of this undermines people’s ability to adapt to climate change (for example, by a reduced ability to collect forest products or produce livestock in response to shortfalls in crop production due to climate variation). Coping with natural climate variability is a perennial challenge for the rural people in Sub-Saharan Africa who are reliant upon rainfed agriculture, face the prevalence of poverty and food insecurity, and can expect limited support from weak institutional and infrastructural capacities.

**As much as 25 percent of land productivity has been lost to degradation in the second half of the 20th century in Africa** (Oldeman 1998). **Because of the importance of agriculture to African economies, this has cost between 1 percent and 9 percent of gross domestic product (GDP), depending on the country** (Dregne and Kassas 1991). Since the majority of the rural poor in Africa are engaged in agriculture, the status of the agricultural sector has a more significant impact on them than does any other sector. In the absence of growth in employment opportunities in urban areas, the rural population continues to grow rapidly in Sub-Saharan Africa (at about 2.3 percent per year), fueling the quest for new agricultural land. To ensure food security over the long term, land-use patterns will need to shift, and farmers will need to move from low-yielding, extensive land-use practices to more intensive, higher yielding practices, with increased use of improved seeds, fertilizers, and irrigation. Yet farmers face a variety of constraints to increasing productivity across the continent, including limited access to new and sustainable agricultural technologies and weak markets.

**Main Findings:** This section of Pillar 1 summarizes the status of knowledge available on the land dimension of the complex relationship of the land and climate nexus. The climate dimension of this relationship is elaborated in the following section.

This section emphasizes the important role of productive lands for economic growth in Sub-Saharan countries and the reliance of rural livelihoods on rainfed agriculture, and—in this context—discusses the extreme climate vulnerability to which Sub-Saharan livelihoods are exposed. The literature shows that the underlying causes of land degradation are clear. Progress has also been made to estimate the impact of land degradation on economic growth and on the provision on ecosystem services. The use of satellite images has improved the mapping of the extent and severity of land degradation around the globe. However, remote sensing data and derived information remain used mainly by researchers and scientists and not used in operational way by technicians and deciders, there is for example no global map on Africa that fully integrates all dimensions of land degradation. Consequently, it remains a challenge to provide a full picture of the spatial distribution, the respective degree of land degradation, and relative change of land degradation over time.
Climate Change and Variability

This section discusses the climate dimension of the land and climate nexus and presents general climate characteristics of Sub-Saharan Africa. Climate-change projections and inherent uncertainties of climate simulation models are also discussed. A more detailed presentation of climate characteristics specific to each subregion is summarized in annex 4 complementing this section.

This section points toward the high level of climate variability in Sub-Saharan Africa over time, which constrains the ability to identify climate-change signals in observational data sets over some parts of Africa. As a result, gradual changes in rainfall patterns and changes in other climate parameters resulting from climate change may not be adequately detected. This is particularly true for countries in predominantly arid and semi-arid areas, which are already facing great planning uncertainties associated with climate variability. These constraints also underscore the importance of better understanding existing climate variability. This section argues that a risk-management approach that combines the strengthening of preparedness for extreme climate events combined with strategic use of seasonal forecasts will not only provide near-term benefits but also provide important lessons for climate-change adaptation over the medium and long term.

More specifically, the text will elaborate the following questions:

- What are the main climate characteristics of Sub-Saharan Africa?
- What are projected climate-change trends for the different subregions?
- How confident are climate-change projections for Sub-Saharan Africa?
- What are the key factors that influence climate characteristics in Sub-Saharan Africa?

Main characteristics of Africa’s climate

Africa’s climate is characterized by steep precipitation gradients. It is the only continent that resides largely within tropical latitudes. Moving from the equator either northward or southward, one can observe a steep decline in average annual precipitation accompanied by an increase in climate variability (figure 1.1). Moving further northwards or southwards towards more temperate climates, the trend is again reversed. This general picture is somewhat modified by the influence of larger-scale atmospheric circulation and topography. For example, the western equatorial regions are wetter than the eastern equatorial regions, and the Ethiopian highlands experience a cooler and wetter climate than the surrounding lowlands.

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18 This section is based on R. Washington, Climate Profiling Sub-Saharan Africa under Current and Future Conditions; Making Development Climate Resilient: A Strategy for Sub-Saharan Africa (Oxford, UK: Oxford University Centre for the Environment, 2008).
The seasonality of rainfall characteristics over most parts of the continent is influenced by the annual movement of the Intertropical Convergence Zone (ITCZ). The ITCZ is where warm, moist air parcels rise upward, leading to rainfall events. The equatorial regions that are consistently under the influence of the ITCZ exhibit a fairly consistent climate with a daily cycle of rainfall. Regions north and south of the equator experience seasonal cycles as they move in and out of the influence of the ITCZ. Variations in the northward and southward movement of ITCZ influenced by the larger scale atmospheric variations are associated with higher or lower than normal rainfall conditions. Interannual variability in temperature and precipitation patterns is often also driven by teleconnections—larger-scale variations in ocean-atmosphere conditions such as the El Niño Southern Oscillation (ENSO).

Most regions of Sub-Saharan Africa experience high levels of climate variability. Interannual climate variability tends to be most pronounced in regions with marginal average rainfall totals (figure 1.1). The planning uncertainties associated with climate variability that countries in predominantly arid and semi-arid areas are already facing are usually much greater than the near- and medium-term climate changes. In fact, large-scale natural climate fluctuations observed in several African countries may even mask the signal and trend of climate change.

**Figure 1.1: African Rainfall and Rainfall Variation**

The figure depicts (a), on the left, average annual precipitation (mm) and (b), on the right, the coefficient of variation (percent) over Africa, based on the Climatic Research Unit–University of East Anglia’s monthly time series from 1951 to 2000.

*Source*: A. Lotsch, World Bank.

Five main climate subregions can be distinguished in Sub-Saharan Africa, when taking into consideration (i) average annual precipitation, (ii) seasonality of rainfall, and (iii) the influence of teleconnections, such as ENSO, on interannual variability. The main climate subregions are West Africa, the Horn of Africa, East Africa, Central Africa, and Southern Africa. All subregions, with the exception of Central Africa, include large areas with low annual rainfall totals and pronounced interannual climate variability. Table 1.1 provides a summary of the main climate characteristics by subregions. A more detailed overview on current, observed, and future trends specific for the five subregions is provided in annex 4.
Table 1.1: Regional Climate Characteristics, Sub-Saharan Africa

<table>
<thead>
<tr>
<th>Region</th>
<th>Current Characteristics</th>
<th>Projected Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sahel</td>
<td>• Rainy Season Jul-Sept</td>
<td>• Higher temperatures</td>
</tr>
<tr>
<td></td>
<td>• Low seasonal rainfall: 100-400 mm</td>
<td>• Highly uncertain precipitation changes (particularly for Sahel: wetter and drier scenarios possible)</td>
</tr>
<tr>
<td></td>
<td>• Long-term drying trend</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High inter-annual variability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• As above but higher seasonal rainfall 400-1200 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Rainy Season May-Oct</td>
<td>• Higher temperatures</td>
</tr>
<tr>
<td></td>
<td>• Seasonal rainfall &gt;1200 mm</td>
<td>• Decrease for large parts of West Coast</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sea level rise</td>
</tr>
<tr>
<td>Sudan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guinea Coast</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horn of Africa</td>
<td>• Rainy Season: July-Sept</td>
<td>• Higher temperatures, exposure to heat waves</td>
</tr>
<tr>
<td></td>
<td>• Seasonal rainfall 200-1200</td>
<td>• Precipitation gains may be offset by offset by rising temperatures</td>
</tr>
<tr>
<td></td>
<td>• High temporal and spatial variability</td>
<td></td>
</tr>
<tr>
<td>East Africa</td>
<td>• Two rainy seasons: Mar-May (Long Rains), Oct-Dec (Short Rains)</td>
<td>• Higher temperatures</td>
</tr>
<tr>
<td></td>
<td>• Seasonal Rainfall 500-1200 mm</td>
<td>• Increase in precipitation</td>
</tr>
<tr>
<td></td>
<td>• High temporal and spatial variability</td>
<td>• More intense precipitation</td>
</tr>
<tr>
<td></td>
<td>• Strong ENSO influence: El Nino (wet)/ La Nina (dry)</td>
<td>• Strong model agreement on precipitation changes, particular for northern parts of region</td>
</tr>
<tr>
<td>Central Africa</td>
<td>• Two peak rainy seasons, generally wet</td>
<td>• Higher temperatures</td>
</tr>
<tr>
<td></td>
<td>• Rainfall: &gt;1300 mm</td>
<td>• Increase in precipitation for some areas</td>
</tr>
<tr>
<td></td>
<td>• Lowest inter-annual variability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No known ENSO influence</td>
<td></td>
</tr>
<tr>
<td>Southern Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western part</td>
<td>• Rainy Season: Jan-Mar</td>
<td>• Drying trend over large parts</td>
</tr>
<tr>
<td></td>
<td>• High inter-annual variability</td>
<td>• Possible intensification of cyclones (more destructive) and southward expansion of risk zones (large uncertainties)</td>
</tr>
<tr>
<td>Central and Eastern Part</td>
<td>• Rainy Season: Dec-Feb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Seasonal Rainfall: 450- &gt;1500 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Spatial heterogeneity in rainfall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ENSO influence: El Nino (dry), La Nina (wet)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• (usually opposite signal to E-Africa)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cyclones (mainly Madagascar, Mozambique)</td>
<td></td>
</tr>
</tbody>
</table>

Given that rainfall amounts are already unevenly distributed across the continent and that many countries in arid and semi-arid regions depend on runoff fueled by rain elsewhere, it is important to understand the impact of climate change on rainfall and runoff in transboundary river basins. The impacts of climate change on water conditions in river basins can be considerable and can have profound transboundary implications for water-management requirements and land-management options. They may require a rethinking of approaches to water and land management within and beyond the watershed. Complementary to this report, analytical
work is being carried out on the implications of climate change for water management. This includes assessments of runoff and precipitation changes over Africa’s river basins.

Climate projections and uncertainties in climate simulations

Current projections of the direction of climate change are significantly robust only for East Africa, pointing to increased rainfall. Despite more rain, however, the length of growing seasons may be shortened as precipitation gains could be offset by higher temperatures (Thornton et al. 2006). Countries in East Africa will also need to be prepared for more intense precipitation events, while the exposure to dry spells and prolonged drought conditions will continue. For Southern Africa, climate projections agree on a uniform warming trend, which is most pronounced over the western part of Southern Africa. Considerable uncertainties remain related to rainfall predictions. Most models suggest drier conditions in the western parts and wetter conditions in eastern parts of Southern Africa. However, regional downscaling efforts, which take into consideration local climate factors, suggest increases in precipitation over central and western parts of Southern Africa. Due to the strong influence of teleconnections on climate variability in East and Southern Africa, relatively good forecasting capabilities exist and thus reduce the planning risks associated with climate variability. Due to the distinct topography of the Horn of Africa, climate predictions for this region would benefit from downscaled climate information. Generally, predictions of slightly wetter conditions for the Horn of Africa are largely offset by increased temperatures through all seasons, resulting in greater frequency of heat waves with increased evaporation rates. Climate projections for Central Africa suggest increases in annual rainfall amounts. However, the validation of climate simulations is constrained by the lack of observational data and limited understanding of climate mechanisms in the subregion. Sahelian countries face the greatest uncertainty with respect to future climate change. Both, wetter and drier conditions are within the realm of possibility depending on the climate simulation model applied. On average, simulations predict wetter conditions, but the there is a strong systematic bias in coupled atmosphere-ocean general circulation models for this subregion. In contrast, those models that best simulate the historically observed climate over West Africa suggest a trend toward drier conditions. In either case, high variability is expected to persist.

While a warming trend is evident across the entire continent, a detailed spatial understanding of changes in precipitation is still fraught with uncertainty. The agreement among model projections, as well as their ability to reproduce current average climate conditions, varies considerably among the African climate subregions. Many global climate models also do not yet consider the effects of El Niño events on climate variability or the effects of changes in land covers, vegetation feedbacks, and feedbacks from dust aerosol production in Africa and other regions (Hulme et al. 2001; Christensen et al. 2007). It is generally accepted that vegetation patterns influence the different climate regions of Africa, and changes in land cover and vegetation are thus expected to alter local climate conditions. Consequently, available climate models might underestimate the impacts of global warming in regions facing land degradation and reduction in the vegetation cover.
The presentation of current and future climate conditions allows for basic comparison at the aggregate level, but it masks spatial variability within a country. Hence, data has to be treated with caution when considering subnational or local conditions. This applies particularly to countries with steep topographic gradients or diverse ecosystems, where broad statistics may be of limited value. Given the lifetime and impact horizon of most operational activities, a sound understanding of current climate variability and observed climate changes is often more meaningful and applicable than long-term gradual climate projections. Current and observed historical climate data are available with more accurate detail than future predictions and are thus more specific to local conditions. Medium- to long-term climate-change projections do provide additional information, however, and may offer strategic guidance.

**Main Findings:** The findings of this section were based on climate profiles for Sub-Saharan Africa under current and future conditions that were developed by Richard Washington of Oxford University for the purpose of informing the World Bank’s regional climate-change strategy and to guide strategic planning under the TerrAfrica platform. In addition, historically observed climate data for the Africa Region was compiled by the IRI group of Columbia University under the lead of Casey Brown. This baseline data on observed climate conditions for the period 1901 to 2000 has been made available through the Web-accessible Africa Land & Climate Portal (annex 2).

To better understand the capability of methodologies to downscale climate predictions to finer geographical resolution, a methodology review of in the context of African climate data was also carried out by IRI group. The report (available on the CD ROM accompanying this report) presents background on the skillfulness of global climate models (GCMs) to simulate different climate variables and their ability to generate reliable projections at different spatial resolution and at different temporal scales. The background report further discusses added value as well as constraints of downscaling methods, specifically dynamical and statistical downscaling.

There is a general agreement that the immediate impact of climate variability is more significant than are gradual climate-change trends to productive and natural landscapes. Similarly, historical and current observational data on climate variability are more relevant to near-term sustainable land-management planning and natural-resource management than future climate-change predictions. **Climate variability often masks long-term climate-change trends, adding to the considerable uncertainties that still remain for climate-projections for most of Sub-Saharan Africa—with the exception of East Africa.** Furthermore, uncertainties and constraints in GCMs, such as the lack of ability to predict near-term climate change (decadal time scale) or constraints in predicting higher order statistics such as future variability, cannot be removed by downscaling data to finer geographical resolution, as downscaling techniques do not add simulation skill to GCMs. In contrast, observational data on climate variability is available in comparatively high resolution and provide important guidance for near-term planning efforts. Efforts to better understand existing climate variability will be key to reducing uncertainties in climate-change projections. An integral part of climate-smart development in Africa should thus include efforts to improve climate data generation. The low density of observational climate data and declining number of meteorological stations in some parts of Africa present a major constraint for validating future projections of climate models.
A sensible way forward is to adopt a holistic approach to managing both climate change and variability—especially in countries and subregions for which the agreement among climate models and their forecasting capacity still vary considerably.

Impact of Climate Variability and Change on Productive Landscapes

This section substantiates the findings from the previous two sections and elaborates climate-induced impact on productive lands and food security in more detail. Potential reductions in agricultural production and in land suitable to agriculture are quantified where data are available. More specifically, the text elaborates the following questions:

- What is the projected impact of climate change on agricultural production and food security?
- How will agroecological conditions change?
- What are the consequences of increased climate variability?

Many climate models predict negative impacts of projected climate variability and change on agricultural productivity and food security in large parts of Sub-Saharan Africa. Higher temperatures throughout Sub-Saharan Africa will cause shorter growing periods, drying of the soil, increase in pest and disease pressure, and shifts in suitable areas for growing crops and livestock. Already the average temperature over the African continent has increased by 0.5°C in the past century.

This warming trend is becoming more pronounced. The Intergovernmental Panel on Climate Change’s (IPCC’s) Fourth Assessment Report (AR4) predicts that temperature increases will exceed the expected global mean increase of 2.5°C in all regions of Sub-Saharan Africa (Christensen et al. 2007). Cline (2007) projects mean temperature increases of 3–4°C by the end of the 21st century for most countries in the region. Warming is expected to be more intense in the interior, semi-arid tropical margins of the Sahara and Central Southern Africa (Hulme et al. 2001). Some of these temperatures may well exceed the optimal temperature for agriculture with some key food crops in the region. With rises in temperature, evapotranspiration rates will also increase, and the growing season for crops may shrink by more than 20 percent in several countries on the African continent. Crop yields may decline by 50 percent in some countries by 2020 (Boko et al. 2007).

The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) estimates that with a 2°C increase in temperature coupled with a 10 percent decline in rainfall, 1.6 million km² of subhumid areas in Africa will become semi-arid, and 1.1 million km² of semi-arid areas will become arid (Cooper et al. 2009). Climate change is expected to increase the area of drylands in Sub-Saharan Africa and hence reduce the area suited to intensive agriculture. Generally, the projected changes in rainfall may exacerbate the already existing differences in water

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20 This section is based on Pender et al. 2009.
availability across the continent, meaning that already dry areas will receive even less precipitation. Considering that some 86 percent of African soils are already under soil-moisture stress, these figures demonstrate the scale of the challenges to come (Ryden 2008).
All regions of Africa are likely to experience increases in severe environmental constraints for rainfed crop production according to projections for 2080 as per climate simulation model used by the Hadley Centre.\textsuperscript{21} North, South,\textsuperscript{22} and West Africa already contain most of the continent’s land that is too dry for rainfed production. It is predicted that these regions will face increases in their areas of land too dry for rainfed cultivation, from 88 percent, 59 percent, and 51 percent during 1961–1992 to 95 percent, 79 percent, and 54 percent by 2080, respectively. These scenarios are further exacerbated by widespread land degradation in Sub-Saharan Africa, which in turn accelerates global and local climate changes.

The impact of climate variability has also increased in Sub-Saharan Africa in recent decades and is expected to continue a result of climate change. Extreme rainfall events and consequent flood events are expected to intensify and become more frequent as a warmer atmosphere can hold and ultimately release more moisture.\textsuperscript{21} Easterling et al. (2007) cite several recent studies that project increased frequency of extreme weather events such as droughts and floods, which will actually have more serious consequences for food production and food security for Sub-Saharan Africa than projected changes in mean climate temperature and precipitation, given the high dependence of the region on rainfed agriculture. Climate variability, particularly severe droughts, has been directly linked to declines in economic activity (measured by GDP), whereas a gradual increase in mean temperature has not yet been linked to changes in GDP (Brown et al. 2008). Adapting to more frequent extreme climate events will thus likely be the larger challenge for African farmers.

Without specific adaptation measures, climate variability and change will contribute to greater land degradation by exposing unprotected soil to more extreme conditions and straining the capacity of existing land management practices to maintain resource quality, contributing to devegetation, soil erosion, depletion of organic matter, and other forms of degradation. These changes can cause land management practices that were sustainable under other climate conditions to become unsustainable and induce more rapid conversion of forest or rangeland to unsustainable agricultural uses.

While much of Sub-Saharan Africa is expected to face harsher agroclimatic conditions, there are also some areas where climate conditions are predicted to improve. For example, under certain climate-change scenarios through 2050, large areas of Ethiopia, Kenya, Mozambique, Nigeria, Uganda, and Zimbabwe are predicted to experience an increase in the length of growing periods (Thornton et al. 2006), leading to potentially higher agricultural productivity in such areas. This in turn may offer greater incentives for investment in agriculture and land management. Looking from another angle, increased carbon dioxide levels resulting from climate change are also expected to have a positive fertilization effect on plant growth for many C3 plants such as rice, wheat, soybeans, legumes, and most trees (Cline 2007). However, it is generally accepted, that the negative impact of climate change will greatly outweigh localized opportunities that may emerge from changing climate conditions.

\textsuperscript{21} Hadley Centre Coupled Model Version 3 (HadCM3-A1F1). This model was improved over earlier versions. Among other things it includes a new land surface scheme that includes a better representation of evaporation, freezing, and melting of soil moisture.
\textsuperscript{22} South Africa should be understood here as Southern Africa, not the country South Africa.
Main Findings: Providing more detailed facts and figures, this section illustrates how climate-change impact will reduce the land area suitable to agricultural production and will thus undermine food security for a rapidly growing population in Sub-Saharan Africa. Further, evidence is presented that increases in the frequency of extreme climate events will pose the greatest challenge for African smallholder farmers. Consequently, land-management measures to cope with increased climate variability will need to be at the core of near-term climate-change adaptation strategies. Agroclimatic conditions are not expected to degrade uniformly across Sub-Saharan Africa, and some areas will actually experience net benefits from climate change. To strategically focus adaptation efforts, it is thus important to identify those areas most exposed and most vulnerable to land degradation and climate-change impact. In response to this challenge, the Africa Land & Climate Hazard Exposure Map was developed.

Visualizing Land and Climate Hazard Exposure in Africa

The Africa Land & Climate Hazard Exposure Map was elaborated to identify areas exposed to combined land-degradation and climate risk impact and is also accessible (and scalable) online via the Africa Land & Climate Portal, http://sdwebx.worldbank.org/climateportal/?page=africamap. This map is based on the combination of critical land, climate, and population factors to create a georeferenced risk assessment for current as well as predicted future rainfall conditions (for 2100). The map depicts the high- versus low-risk areas on the African continent. It provides an easy and practical tool to guide development practitioners, project managers, and other decision makers to strategically focus investments in sustainable land management on locations with the highest risk exposure.

Objective of the Land & Climate Hazard Exposure Map

Climate is not the only factor that influences land and natural resources. Other environmental conditions, as well as socioeconomic factors, are of importance and play a comparable or greater role in defining vulnerabilities in some areas. The Land & Climate Hazard Exposure Map provides land users, development practitioners, project managers, and other decision makers with spatially projected information on areas exposed to land degradation and climate-risk impact. The degree of risk exposure was determined by a combination of several weighted factors, including land-use type, slope gradient, population density, precipitation, and evapotranspiration. Georeferenced data for these weighted factors were combined with climate information to define the degree of risk exposure for any given point on the African continent.

Combined land and climate hazard exposure can be displayed against current or projected rainfall conditions for 2100 to help decision makers identify areas of immediate versus future risk exposure (figure 1.2). This enables them to make land-management decisions and formulate appropriate policies while taking climate trends into consideration. The Land & Climate Hazard Exposure Map displays the degree of risk exposure on a color-coded 10-point scale. Low levels of risk exposures are displayed in blue shades, and high levels in red shades. High-risk exposure can be attributed to a single dominating factor or to a combination of medium to high factors (for example, a combination of drought risk, high population density, and steep slope).
Map interpretation: Areas of high risk Exposure

The Land & Climate Hazard Exposure Map identifies six areas across the continent as exposed to high risk from combined land degradation and climate impact:

- **Coastal West Africa** is considered at risk with a key factor being high population densities.
- **Central Sudan** is considered at risk with key factors being low rainfall combined with high population density relative to production capacity (although moderate population density in absolute terms).
- **Western Mali** and **south-central Niger** are considered at risk with key factors being very low rainfall combined with high population density relative to production capacity (although moderate population density in absolute terms).
- **Western central Ethiopia** is considered at risk with a key factor being steep slopes.
- **Somalia and northern Kenya** are considered at risk with a key factor being predicted changes in rainfall.
- **Rwanda and Burundi** are considered at risk due to the combined factors of high population density and steep land gradients.
The Land & Climate Hazard Exposure Map is considered a work in progress. There is scope to continuously improve and fine-tune information by adding additional layers of relevant land and climate information or by adjusting the relative weights of the different layers. Future refinement of the map will need to focus on further integration of climate factors, such as map data on changes in growing periods, predictions on reliable crop growing days, and so on over the period of the current century. A more detailed discussion of the strengths and the limitations of the map as well as recommendations for further improvement of the map are presented in annex 3.

Proofing results with other comparable assessments

To validate findings, the Land & Climate Hazard Exposure Map has been compared to other maps based on comparable vulnerability assessments, more specifically, maps defining the change in probabilities of failed growing seasons. In their analysis, Thornton and Jones (2009) identify land-use systems in Sub-Saharan Africa that are particularly vulnerable to the impact of predicted climate change. They focus on the arid/semi-arid livestock and arid/semi-arid mixed farming systems. Based on their findings, Thornton and Jones demonstrate that many places will see a variety of changes in agricultural systems.

- **Moderate crop and livestock production losses** are predicted and could be addressed with improved efforts in breeding, agronomy, and land management.
- **Major production losses** will be experienced in large areas and may be addressed with new crops, improved production systems, and new livelihood options.
- **Some areas will experience production benefits**, presenting new opportunities for smallholders.

Comparing the outputs of the Land & Climate Hazard Exposure Map with the map of areas predicted by Thornton and Jones to have changes in the length of growing period for the years 2000 to 2090 results in the following high-risk areas:

- the band extending west from Senegal through southern Mali, central Burkina Faso, northern Nigeria, southern Chad, parts of southern Sudan, and scattered areas of Ethiopia; and
- large areas in Southern Africa.

However, the two maps disagree on the extent of the risk areas in Southern Africa. While the Land & Climate Hazard Exposure Map assesses only parts of Namibia and western South Africa as being at particular risk, the map by Thornton and Jones highlights an extensive area across the whole of Southern Africa as being at risk. These differences are attributed to the fact that the study by Thornton and Jones is based on predictions of much lower rainfall across Southern Africa as a result of climate change. While the Land & Climate Hazard Exposure Map integrates multiple risk factors, climate-change data was considered only to a limited extent, more specifically, with a view only to precipitation changes.
**Main Findings:** The Africa Land & Climate Hazard Exposure Map identifies areas exposed to risk from combined land degradation and climate-change impact. While there is scope to further improve and fine-tune the risk interpretation of the map, a comparison to similar vulnerability assessments has demonstrated robust results. The Africa Land & Climate Hazard Exposure Map is available in an online version, which allows users to zoom in and out of the map for better resolution of risk exposure at local, national, subregional, or continent-wide scale. This easily accessible web-based tool allows for intuitive interpretation by end users and contributes to strategic decision making to curb land degradation in changing climate conditions. The Africa Land & Climate Hazard Exposure Map is complemented by other online tools that are accessible through the same website (see annex 2): The Africa Land & Climate Portal provides the underlying point-specific land, climate, and population data. The Best Management Practices (BMP) Database helps users to make well-informed choices by identifying practical land and water management practices that respond to the specific conditions of an identified location or larger land area.

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**SUSTAINABLE LAND AND WATER MANAGEMENT: MULTIPLE BENEFITS FOR LAND AND CLIMATE**

The following subsections elaborate not only the more commonly known role of SLWM as an effective response to land degradation, but also highlight the important cobenefits it provides in terms of climate-change adaptation and mitigation. Part of this section emphasizes the role of SLWM in reducing the vulnerability of managed land resources to the negative impact of climate change. Another part of this section emphasizes the important contribution of SLWM to climate-change mitigation through carbon sequestration. More specifically the text elaborates the following questions:

- Why is SLWM an effective response to land degradation?
- How does SLWM contribute to maintaining ecosystem services of productive lands?
- How much of the total cropland in Sub-Saharan Africa is under SLWM?
- What are the constraints to greater uptake of SLWM?
- What are the adaptation benefits that SLWM provides?
- What are the off-site benefits of SLWM?
- What is the role of SLWM in climate-change mitigation?
- What is the carbon sequestration potential of improved SLWM practices in Sub-Saharan Africa?
- What are the constraints to carbon sequestration and carbon accounting in agricultural lands?
Sustainable Land and Water Management in the Climate-change Context

In the previous section, the complex and multidirectional relationship between land degradation and climate risks was presented. Land degradation can be exacerbated by climate variability and climate change, as current land management practices become unsustainable and as climate change drives more rapid conversion of land into unsustainable land-use practices. As land degradation increases the release of GHG emissions from soil and vegetation, it accelerates climate change. Land degradation further increases the vulnerability of agricultural production systems to climate variability and change. It restricts the range of viable rural enterprises, reducing average agricultural productivity and income, increasing production vulnerability, and reducing local resource asset levels, thus undermining people’s ability to adapt to climate variability and change. These accelerating cross-effects can lead to a destructive downward spiral with mutually reinforcing effects. However, on the flipside, climate change may also offer new opportunities for sustainable land and water management by enhancing rainfall or growing periods in some places or through creating markets that might pay farmers for improved SLWM practices. Experts agree, though, that negative climate-change effects will dominate in Africa.

There is broad recognition that SLWM is an effective response to the challenges of land degradation and land-related climate impact. As will be presented in the following pages, SLWM can break the downward cycle by reducing vulnerability to climate change and increasing people’s ability to become more resilient—and in many cases contribute—to the mitigation of climate change through improved carbon sequestration and reduced GHG emissions.

SLWM further helps to maintain the long-term supply of productive resources and services of agricultural and natural lands (such as food, water, raw materials, and other ecological services). This is particularly important in Africa, where land is a key asset of the rural poor and often the only safety net supporting rural livelihoods. As areas at risk for land degradation expand with increased climate-change impact, population growth, and other underlying factors, it is critical to scale up the adoption of SLWM practices.

However, it is estimated that less than 3 percent of total cropland in Sub-Saharan Africa—191 million hectares in 2005 (FAOSTAT 2008)—are under SLWM using low-cost, productivity-enhancing land management practices. This corresponds to only about 6 million smallholder farmers in Sub-Saharan Africa on at least 5 million hectares of land (Pender 2008). These figures show that the land area under SLWM is alarmingly low and that there is insufficient knowledge and understanding on the benefits of SLWM. Thus far there have been only a few land management practices for which adoption rates have expanded noticeably: for example, the expansion of the zai pit system in Burkina Faso and Niger that has been well documented (see, for example, Shapiro and Sanders 2002). Further, stone terracing was found to be practiced by almost half of farmers in Tigray (Kruseman et al. 2006), and Deininger et al. (2003) estimated that 47 percent of all Ethiopian farmers had built or maintained terraces between 1999 and 2001. Rainwater harvesting is another practices that has found wide adoption, for instance, in semi-arid Tanzania (Hatibu et al. 2001).
On the following pages, this report presents the multiple benefits that SLWM provides. The discussion focuses particularly on benefits related to addressing the risks of climate variability and change, both in terms of climate-change adaptation and mitigation. This report further looks at additional cobenefits of the public goods that SLWM can provide. However, the analysis does not review in depth the potential of SLWM to enhance productivity and economic returns, as these aspects are discussed in detail in other papers in progress under the TerrAfrica umbrella.

Knowledge and awareness gaps are not the only constraints that prevent smallholder farmers, who cultivate the majority of land in Sub-Saharan Africa, from applying SLWM technologies. A number of underlying constraints, such as land tenure insecurity and lack of economic incentives (insufficient market access), and thus the lack of strong profit opportunities, serve as disincentives to invest in agriculture. As a consequence, inappropriate land management practices are applied that lead to land degradation and desertification and fuel the expansion of extensive agriculture into the forest margin.

Available information and evidence on the cost and benefits of the different SLWM practices and their competitiveness compared to other agricultural production practices are highly variable and cannot be usefully generalized across the Sub-Saharan region. The profitability and competitiveness of SLWM practices is specific to the local economic, environmental, and policy context. More specifically, the success of SLWM practices is influenced by market factors (i.e., market access, labor costs), agricultural input (i.e., fertilizer affordability, farm assets), existing agricultural policies, and various geophysical and environmental factors (i.e., site conditions, soil types, topography, vegetation) and consequently varies significantly across different agroecological zones.

Analytical work is currently underway in various countries in Sub-Saharan Africa (e.g., Nigeria, Mali, Ghana, Ethiopia) to generate more information on the costs and benefits of SLWM practices, including up-front investment cost, long-term maintenance cost, the timeframe for returns and the overall competitiveness of SLWM practices to other agricultural production practices. Since land degradation and investment and returns to SLWM can be long-term processes, time series data are required to effectively conduct cost-benefit analyses of SLWM. Additionally, there are both on-farm and off-farm costs of land degradation and benefits of SLWM. Assessment of the off-farm costs and benefits is complicated and difficult to measure.

Preliminary results from an ongoing cost-benefit-analysis in Nigeria suggest that land management practices that combine organic and inorganic fertilizers and crop residues have a higher benefit-cost ratio than those, which use either one of them alone. Early findings from the study show that a combination of crop residues, soil organic matter (manure and compost) and inorganic fertilizer has the largest yield and average net benefit for rice and maize, and highest carbon sequestration. Results further show that sustainable land management practices provide more average returns to labor day than minimum rural wage rates and thus suggest that they are competitive in the rural labor market.23

23 See pages 82 and 83 for more details.
These results are consistent with other socioeconomic studies which have shown that land management practices that strategically integrate organic and inorganic soil fertility management practices are more profitable than practices using either mineral fertilizer or organic soil fertility management practice alone (e.g., Doraiswamy et al. 2007, Sauer and Tchale et al. 2007, Mekuria and Waddington 2001).

To support up-scaling of promising SLWM practices, it is important to increase the reliability and availability of information on the returns from different land management practices taking into consideration both biophysical characteristics and economic factors, and to compare them to competing agricultural production practices.

It is further important to acknowledge that the full range of benefits from SLWM investments is often not evident in strict economic cost and benefit estimations. Analytical work on the impact of sustainable land management programs in Niger has shown that the actual value of community-based land management investments is likely to be greater than the actual estimated economic value. In Niger, the full range of reported benefits from SLWM investments included: increased vegetation, reduced erosion, rehabilitation and increased use of degraded land, increased agricultural yields, more fodder for livestock, improved water availability, improved food security, improved welfare of vulnerable groups, and reduce poverty, among others. Some of these benefits are difficult to capture in terms of economic cost and benefits.

Smallholder farmers must be given more support to apply SLWM practices with a view to achieve to whole range of tangible and intangible benefits, including increased income, improved food security, and enhanced vital ecosystem services.

Local and national governments will further need to prioritize regional planning at the watershed or micro-watershed level, as SLWM is often beyond the means, responsibility, and decision-making power of individual land users, in particular when off-site and downstream interactions need to taken into consideration. At the landscape level, simulations of on- and off-site cost of land degradation and potential returns from scaled-up SLWM approaches at the farm level and in terms of downstream ecosystem services can help to scale the size of investments in SLWM and prioritize the use of these investments to areas with highest expected returns to society.

SLWM’s Potential for Climate-change Adaptation and Mitigation

SLWM to increase resilience of rural livelihoods to climate variability and change

Many SLWM practices exist that contribute to making farming systems in Sub-Saharan Africa more resilient to the adverse impacts of climate change. The negative effect of climate change and variability on already stagnant and declining agricultural productivity will need to be countered with SLWM practices that not only address the adaptation deficit (e.g., past neglect of agricultural improvement in dryland areas), but also close the adaptation gap (e.g., respond to the climate change challenges ahead). Climate-smart development will have to focus on sustainably intensifying agricultural systems by restoring soil carbon to reverse

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24 This section is based on Pender et al. 2009.
declining soil fertility and to tap into existing and emerging financial opportunities for climate-change mitigation in the agricultural sector.

Generally, SLWM technologies can serve to increase average productivity (for example, improved agronomic practices, nutrient management, enriched pastures, and water management). Some can also serve to reduce variability of production (for example, irrigation and integrated pest management), and yet others may serve to diversity agricultural portfolios (for example, agroforestry systems and crop rotations).

Implementing SLWM practices, which increase carbon sequestration in soils, will be key to achieve more productive agricultural systems, thus contributing to climate-change adaptation. Maintaining and improving soil organic carbon (SOC) has multiple benefits, including (i) improving soil quality, (ii) enhancing soil fertility, (iii) increasing rainfall infiltration rates, (iv) increasing water retention capacity, and (v) improving food production and, eventually, food security. A number of SLWM techniques, such as crop rotation, reduced tillage, agroforestry, mulching, and manure management, are already in use, have been time-tested, and are optimized by farmers to fit local conditions.

More specifically, agroforestry activities can increase farmers’ agricultural productivity and income security by improving soil fertility, reducing vulnerability to drought, and helping to diversify income sources while also sequestering carbon. Water harvesting, soil and water conservation measures, conservation agriculture, organic soil fertility management, and other sustainable land and water management practices can have similar income- and resilience-enhancing impacts and also increase carbon sequestration and thus reduce GHG concentration in the atmosphere.

A large selection of SLWM technologies is available to help farmers adapt to the challenges posed by climate change. In some cases, production challenges posed by climate-change risk can even be overcome with the adoption of SLWM technologies. For example, it was found that predicted negative yield impacts of climate change could often be dwarfed by proven positive yield impacts of improved land management practices (Cooper et al. 2009).

Such productivity-enhancing SLWM practices not only contribute to climate-change adaptation but also help to depress the push factors, which have long induced rapid land conversion in Africa. This is important considering that 89 percent of deforestation in Africa is driven by rapidly expanding agriculture. In addition to reducing pressure on natural resources, such as native forests, sustainable intensification of production will also drive economic growth.

Overall, SLWM contributes to optimized water, nutrient/carbon, and biomass cycles, all of which are prerequisites for agricultural productivity. SLWM also protects the regulating and supporting services that ecosystems provide, such as soil development and nutrient cycling. As such, SLWM helps to increase soil moisture, improves soil structure, enhances primary production, and supports nutrient cycling, thus increasing the resilience of the land.
In this context, it is of interest to consider the important on-site and off-site land-use interactions that lead not only to local but also to regional and global benefits. For example, local adoption of SLWM practices can prevent dust storms that have potential impacts thousands of kilometers away. These practices prevent downstream floods caused by improper upstream land management and safeguard water flows to densely populated lowlands through proper land-use management in highland areas. Taking into account predicted drying trends for large parts of the African continent, off-site benefits related to water regulation are critically important for climate-change adaptation. If coordinated at catchment or watershed scales, improved water infiltration (and thus reduced runoff) resulting from SLWM can have important off-site impacts on hydrological flows, flooding risk, and hydroelectric generation, all of which are expected to be affected by climate change. At the regional level this will further lead to improved water quality and aquifer recharge. Meanwhile, on-site water benefits of SLWM include reduced evaporation loss from the soil surface due to improved vegetation cover.

Almost all of the National Adaptation Programmes of Action (NAPAs) adopted in the region recognize the important potential of SLWM practices and their role in maintaining ecosystem service as well as helping rural people adapt to climate variability and change. Most African countries have developed NAPAs, but implementation has been limited by funding and other constraints. Although several adaptation funds have been established or are planned, the access to these funds has been limited in Sub-Saharan Africa thus far. Climate-change adaptation and mitigation financing related to agricultural adaptation efforts and emission reductions may help to overcome barriers and constraints that are currently hindering the uptake of more sustainable and productivity-enhancing practices and technologies, some of which have initial high investment costs or do not offer immediate financial rewards.

Successful efforts to enhance the adaptive capacity of rural land users will further require increasing environmental awareness and knowledge. Continuous efforts are needed to help people understand the short-, medium-, and long-term implications of climate change and variability and how agricultural practices can be altered to be more resilient. Such efforts should include and appreciate the opportunities of traditional knowledge, but they should also encourage land users to embrace new SLWM technologies when traditional practices cannot overcome existing challenges.

The application of SLWM is not limited to smallholder farmers. On the contrary, many SLWM practices can also contribute to making large-scale commercial farming systems in Sub-Saharan Africa more sustainable and resilient to climate variability and change. This necessitates working with private sector suppliers to make available adapted equipment and inputs such as direct seeding equipment and drip irrigation technologies instead of ploughs and sprinkler-and-furrow irrigation systems. Further, access to seeds and germplasm of drought-resilient crop varieties and cover crops will need to be enhanced. Lastly, cost-benefit analyses may help to encourage large-scale farmers to shift to improved practices—inter alia, conservation agriculture, reduced traffic, precision agriculture, and organic agriculture.
SLWM to mitigate the effects of climate change

**Generalities**

Most SLWM practices have both mitigation and adaptation benefits, as both are closely tied to the carbon content of the soil. Yet large economic potential lies with the opportunities that exist to help mitigate climate change through activities related to agriculture, forestry, and land use (AFOLU), such as (i) aforestation and reforestation, (ii) the avoidance of deforestation and forest degradation, (iii) soil and biomass carbon sequestration through improved cropland and rangeland management and restoration of degraded lands, and (iv) reduced GHG emissions through improved management of livestock and manure, paddy production, and nitrogenous fertilizer.

Conversion of natural systems to cultivated agriculture has already resulted in losses of between 20 and 50 percent of preculture soil organic carbon (SOC) stocks from the surface meter to the atmosphere. The SOC stocks have been further reduced by soil degradation and through inappropriate practices: for example, burning rangeland and crop residues, repetitive tillage, and use of fertilizers without restoring soil organic matter. Adding to the carbon loss from the soil are GHG emissions from mechanized agricultural practices, many of which use significant quantities of fossil fuels as a source of energy for on-farm activities—and even more in food processing, packaging, and transportation. Lastly, the production of inorganic fertilizer is very energy-intensive and further contributing to GHG emissions.

In Africa, land-use change and deforestation account for the overwhelming amount of GHG emissions. With 64 percent, this is a much greater share of GHG emissions than elsewhere in the world. Furthermore, agricultural emissions in Africa have the highest projected growth resulting from expected population growth and changing food consumption habits (for example, higher meat consumption).

Sustainable land and water management can play a significant role in climate-change mitigation by reducing emissions of GHGs and sequestering carbon in vegetation, litter, and soils. The adoption of SLWM practices to restore land can increase the sequestration of carbon and reduce the rate of enrichment of atmospheric CO₂ and other GHGs. The global potential of SOC sequestration through adoption of SLWM practices is 0.9±0.3 Pg C/year, which would offset one-quarter to one-third of the annual increase in atmospheric CO₂ due to human activities, estimated at 3.3 Pg C/yr.

The UNFCCC (2008) estimates that 924 megatons (Mt) of additional CO₂ could be stored in Africa with the adoption of improved agricultural practices, with most (89 percent) sequestered as soil carbon. Although less carbon can be stored in soils compared with vegetation above ground, the total land areas and total volume of soil is high.
In comparison, the IPCC estimates that improved agricultural and land management practices in Sub-Saharan Africa, including improved cropland and grazing land management, restoration of peaty soils, restoration of degraded land and other practices, could reduce GHG emissions by 265 Mt CO\textsubscript{2} per year by 2030 (at opportunity costs of up to $20 per tCO\textsubscript{2}e). Aorestation in Africa could sequester 665 Mt CO\textsubscript{2} per year, while reduced deforestation and forest degradation in Africa could reduce emissions by 1,260 Mt CO\textsubscript{2}e in 2030 (at opportunity costs of up to $100 per tCO\textsubscript{2}) (Pender and al. 2009). These potential emission reductions in Africa represent about 6.5 percent of global GHG emissions in 2000, which is a substantial potential impact even if it would not solve the climate problem by itself.

As discussed, building up soil carbon presents a win-win outcome, as increased SOC contributes to agricultural productivity (Swift and Shepherd 2007). Generally, humid areas have a higher potential for increased soil carbon sequestration compared to dry areas. With the majority of Africa’s land area being dry lands, it is important to understand the potential of dryland to store carbon. While plant biomass per unit areas of drylands is low compared with many other terrestrial ecosystems, the large surface of drylands gives them a global significance for carbon sequestration. Altogether, total dryland soil organic and inorganic carbon reserves make up, respectively, 27 percent and 97 percent of the global soil organic and soil inorganic global carbon reserves (Millennium Assessment 2005b). The soils of drylands have lost a significant amount of carbon due to degradation and desertification and are far from saturation. Rehabilitating degraded dryland soils thus offers significant sequestration potential. Degraded soils in drylands often have less than 1 percent of soil organic carbon, which can be significantly increased (2–3 percent) through sustainable land and water management (UNCCD 2009). Taking into account all the cobenefits of SOC restoration, carbon sequestration in drylands may be particularly attractive.

**Constraints and obstacles for soil carbon projects**

There are various constraints to soil carbon projects related to biophysical, technical, economic, and political factors. The particularly contentious issues are leakage, permanence, and verifying and monitoring.

From a biophysical perspective, soils and terrestrial biomass have a maximum capacity for carbon sequestration, which is often reached after 15 to 60 years, depending on the type of ecosystem and the respective management practices. Further, there is a risk of nonpermanence (reversibility), due to the fact that a change in land management could reverse the gains. For example, a single tilling can release 60 to 80 percent of stored carbon. This is why the formulation of soil carbon sequestration projects is still facing considerable challenges. It also demonstrates the difficulty of managing and verifying carbon sequestration as part of a carbon finance agreement.
From a technical perspective, there exists a challenge in first establishing an appropriate baseline, and subsequently assessing management-induced GHG net emission reductions compared to the baseline. Measuring and validating estimates of soil carbon over any considerable area is an incredibly complex modeling work due to the high degree of spatial variation in soil characteristics and the relatively small changes in carbon content that will be seen on an annual basis. Further, modeling is not yet advanced enough to replace field surveys, because the models are too dependent on the parameters that determine them. There is also an uncertainty related to measurements. Agricultural systems show substantial variability between seasons and locations, creating high variability in offset quantities at the farm level. Increasing the geographic extent and the duration of the accounting unit can reduce this variability, but these steps may again present additional coordination and oversight challenges. Also, soils tend to have complex decomposition processes because organic matter consists of innumerable chemical compounds. Although some soil-carbon modeling methods exist, they still need to be calibrated to the large variety of African soils and the respective local climate condition. And finally, the applicability of the model outputs to large-scale areas has yet to be verified.

These technical constraints shed light on the high transaction cost that small-scale farming systems in developing countries face in order to access carbon markets. That means that it would be more conducive to cover large land areas and bundle projects together for the purpose of carbon accounting, as the effort for a small, single unit of land would mostly outweigh the mitigation and thus the carbon-finance potential. The question remains whether potential carbon revenue can reduce opportunity cost in favor of sustainable agricultural practices.

Consequently, the issue of transaction cost also raises the question, are large-scale agricultural systems the more likely partners for carbon finance benefits? In West Africa, the important, export-driven and large-scale cocoa production systems and similarly, in East Africa, the coffee plantations, may provide attractive soil-carbon sequestration opportunities, e.g., if soil enhancing techniques are applied. Further, agroforestry practices could be used to mix cocoa trees with other tropical trees. Agroforestry practices are already approved by the UNFCCC for aforestation and reforestation projects. Further, quantifying and monitoring would be relatively easy in cocoa or coffee plantations, as they are usually large connected and homogenous areas. Commercials-scale production system may also more easily attract project developers and private carbon finance.

Nevertheless, in Kenya, two pilot agricultural land management projects, the Western Kenya Smallholder Agricultural Carbon Project and the Kenya Smallholder Coffee Carbon Project, are set up to generate benefits from agricultural carbon assets especially for smallholder farmers. The two World Bank supported projects are intended to bridge the cash-flow gap between the adoption of sustainable agricultural management practices and the resulting improved crop production and intended carbon finance payments. As sustainable production practices are adopted by smallholder farmers, they will help to restore soil health, thereby not only increasing production, but also resilience to climate risks. The two pilot projects are aiming to demonstrate that carbon finance may provide the necessary additional financing to incentivize primarily small-scale, resource-poor farmers in uncertain and risk-prone environments to shift to more sustainable and more productive agriculture that is desperately needed in Sub-Saharan Africa to enhance livelihoods.
It should not go unmentioned that a range of challenges also exist from a social perspective, related to property rights, carbon ownership rights, landholdings, and shared community land ownership, all of which result in implementation challenges. However, this topic demands a detailed and substantial discussion that goes beyond the scope of this report.

Despite the above challenges that still need to be addressed, land use and land-use change in Africa have huge climate-change mitigation potential, and carbon finance may offer new possibilities to a continent that has been largely absent from the global carbon market map. Yet the operational potential of mitigation measures is still low, and until now only initiatives like the World Bank’s BioCarbon Fund and the voluntary carbon market include soil carbon sequestration in their portfolios.

Other benefits from SLWM

While sustainable land and water management delivers important benefits for mitigating climate-change effects and increasing resilience to climate variability, it also plays a considerable role for other issues of local and global importance, such as poverty reduction, food security, ecosystem services provision, and biodiversity conservation. Other indirect benefits include increased energy security, employment, and income generation. All these potential SLWM benefits can be pursued synergistically, and scaling up SLWM in Sub-Saharan Africa should be seen as a holistic approach to reduce land degradation, mitigate and adapt to climate change, conserve biodiversity, and reduce poverty and food insecurity. A multifocal approach to SLWM that takes into account all ecosystem services, as well as benefits for human well-being, is more likely to succeed than an approach focused exclusively on climate-change mitigation and adaptation benefits. This is particularly true as carbon sequestration per se is not a priority of poor communities or countries, while the associated benefits related to productivity and ecosystem functions are. A multifocal approach may also overcome constraints and barriers that carbon finance approaches still face by providing opportunities for other financing streams.
BOX 2  PILLAR 1 KEY FINDINGS

The negative effect of climate change and variability on already stagnant and declining agricultural productivity will need to be countered with land and water management practices that not only address the adaptation deficit (e.g., past neglect of agricultural improvement in dryland areas), but also close the adaptation gap (e.g., respond to the climate change challenges ahead). Many SLWM practices rise to this challenge as positive yield impacts of improved land management practices have shown to dwarf the predicted negative yield impact of climate change. Such productivity-enhancing SLWM practices not only contribute to reducing adverse climate change but also help to depress the push factors, which have long induced rapid land conversion and consequently land degradation in Africa. Most SLWM practices have both mitigation and adaptation benefits, as both are closely tied to the carbon content of the soil. As such, the increased rates of terrestrial carbon sequestration achieved with SLWM also present large opportunities related to potential carbon finance schemes.

While sustainable land and water management delivers important benefits for climate-change adaptation and mitigation, it is important to maintain a more holistic view on the benefits of SLWM considering its important benefits for poverty reduction, food security, ecosystem services provision, and biodiversity conservation. A multifocal approach to SLWM that takes into account all ecosystem services, as well as benefits for human well-being, is more likely to succeed than an approach focused exclusively on climate-change mitigation and adaptation benefits.

In summary, Pillar 1 comprises the consolidation and analysis of scientific baseline data on the land and climate nexus. Baseline data and knowledge is presented in the context of a broader theoretical discussion of the multidirectional relationship of land degradation, sustainable land management and climate change at the level of the African region.

As such, Pillar 1 sets the stage for Pillar 2 aimed at country-specific application of the knowledge and information generated under Pillar 1. Under Pillar 2, country-specific case studies were carried out to generate specific recommendations on additional factors that have an impact on the multidirectional relationship between land degradation and climate change and influence the adoption of sustainable land and water management practices in specific local conditions.

Accordingly, Pillar 2 deepens the analysis from the regional to the local level, yet broadens it from the strictly theoretical analysis to also include a review of the political economy of the selected countries and to examine how context-specific conditions influence the adoption and success of SLWM practices. More specifically, Pillar 2 looks at the institutional, policy, and regulatory context, as well as the broader enabling environment at local as well as national level to identify how they influence the adoption of SLWM practices. Pillar 2 further examines specific local conditions under which selected SLWM practices deliver climate-change adaptation and mitigation benefits most effectively.
PILLAR 2: OPERATIONAL GUIDANCE FOR CLIMATE-RISK MANAGEMENT THROUGH SUSTAINABLE LAND AND WATER MANAGEMENT: CASE STUDIES IN KENYA, NIGER, NIGERIA, AND UGANDA

INTRODUCTION: OBJECTIVES AND METHODOLOGY

Climate change and variability pose a great threat to natural resources and livelihoods of rural African people. Evidence has shown that the number of people affected by floods and droughts has already been increasing. In addition, there is strong evidence showing a degradation of forest and soil resources. The needed increases in agricultural production have therefore been unrealized. These outcomes have placed smallholder farmers, who depend largely on rainfed agriculture, in highly vulnerable circumstances under challenging climate-change predictions.

Important development questions are currently being raised on how to enhance ecosystems and land users’ adaptive capacities and even undertake actions that may mitigate climate change or its effects, thus reducing their climate-related risks and vulnerability. Building on the guidance generated under Pillar 1, the following case studies were conducted to provide empirical evidence that can help answer these questions, with a focus on the role of SLWM practices.

Objectives of the Case Studies

The overall objective of Pillar 2 is to generate practical, context-specific recommendations for SLWM approaches and practices that are suited to improve food security and economic prospects while reducing climate-related risks and greenhouse gas emissions.

The case studies were developed to answer specific questions such as, but not limited to, the following:

- What types, modalities, and conditions of SLWM investments are the most relevant in terms of adaptation to current variability and future climate change?
- What context-specific actions can improve the contribution of SLWM investments to adaptation and mitigation, considering improved information and institutions as well as policy, program, and regulatory instruments?
- What are the best synergies between water and land resource management to generate mitigation and adaptation benefits?

In mid-2009, further discussions were held with TerrAfrica partners and the research team to explore whether some progress could be made into another challenging area: how to develop cost-effective measures for measuring carbon sequestration/storage in soils and in vegetation. Therefore, the case studies also aimed to address the following additional questions:
• What are the carbon stock patterns in the sites and how have they changed over time as a result of land-use change?
• Is there a relationship between carbon stocks and SLWM practices within the agricultural land-use classification?
• Is it possible to predict soil carbon using adoption of SLWM as a proxy?
• Is it possible to extrapolate carbon stock measures across wider landscapes, in order to make assessments of change over time, and how can that best be done?

Methodology

To answer the aforementioned questions, four sites (Kenya and Uganda in East Africa and Niger and Nigeria in West Africa) were selected as case studies. (See figures 2.1 and 2.2.) Within the Kenya and Uganda, sites are matched according to agroclimatic zone: humid (Bungoma and Kapchorwa), subhumid (Bondo and Kamuli), and semi-arid (Samburu and Moroto). In Nigeria and Niger, all sites chosen were in the semi-arid zone.

Some sites were paired with others with whom they share an international boundary, in order to capture the impact of policies on farmers’ responses to climate variability and change. The study used a variety of data sources, including satellite imagery data, focus group discussion, and household and plot level survey data to determine (i) how land users have responded to climate variability and change, (ii) the impacts of their responses on agricultural productivity, ecosystems services, and climate-related risks. The study also analyzed the

Figure 2.1: Case Study Sites in East Africa

25 The detailed methodology is provided in annex 6.
drivers of farmers’ responses to climate variability and change, the constraints they face, what SLWM practices are best suited in each specific context, and related policy implications.

Site selection methods

The steps used for the site selection are as follows:

- Using monthly rainfall data from CRU (1981 to 2001) and NASA (2002 to 2007) for the four countries, the mean and standard error of annual rainfall and the year trend and year squared trend coefficients for each pixel (0.5 degree pixel for CRU data and 1 degree pixel for NASA) were computed.

- Using the nearest neighbor matching procedure (Abadie and Imbens 2007), matching pixels in Niger and Nigeria in West Africa and Kenya and Uganda in East Africa that were from areas having common support in terms of mean annual rainfall were selected based on the mean and standard error of annual rainfall, the rainfall trend coefficient, and standard error of the coefficient. The matches with minimum percentage difference in these statistics between the matching pixels were kept.

- In the case of East Africa, elevation was also included in the matching characteristics to take into account the large differences in terrain.

- To determine the impact of access to market and technical support on farmer response to climate change, the matching pairs were further grouped according to market access and the presence of an SLWM project.

- The selected pixels were overlaid on boundaries of administrative units (districts in Kenya and Uganda, communes in Niger, local government authorities in Nigeria), and the pixel that represented the best the administrative division was selected.

In East Africa, three different agroecological zones (AEZs) were selected:

- The semi-arid zone is where pastoral communities predominate. This zone represents 18 percent of the land area in Sub-Saharan Africa. The matching sites selected were in Samburu District in Kenya and Moroto District in Uganda. In both districts, rainfall and population density are low and the major livelihood is
transhumant even though crop production is an emerging livelihood undertaken as a diversification strategy to adapt to climate change.

- The second AEZ was the subhumid zone, receiving rainfall above 800 millimeters per year. In Kenya, Bondo District in Nyanza province bordering Lake Victoria was chosen. The district is affected heavily by malaria, a disease aggravated by climate change. The sites matching Bondo in Uganda are located in Kamuli District. The subhumid zone represent about a fifth of Sub-Saharan Africa’s land area.

- The third AEZ was the highlands, which account for 4.4 percent of Sub-Saharan Africa’s land area. Though small in area, the highlands are important in East Africa in terms of population and agricultural production and the fact that land management in the highlands has important effects on lowlands. Sites selected in Kenya were located in the Bungoma District, and in Uganda they were in Kapchorwa District.

In each of the three zones, two villages with high market access—one with an SLWM project and another without an SLWM project—were selected. Similarly, two villages in low market-access areas—one with and another without an SLWM project—were selected.

A similar approach was used to select case study villages in West Africa. Eight villages were selected in Tahoua region in Niger and four matching villages were selected in Sokoto state in Nigeria. An additional four villages were selected from Niger state in Nigeria.

Data collection methods

This study used five major sources of data, each for a specific purpose of the study. Detailed discussion of data collection methods are given in the individual country reports. Here a brief description of the data collected is presented:

- Satellite and field data were used to determine changes in land use and land cover and the carbon density of the different types of use or cover.

- Community resource mapping was used to determine biophysical changes and used also for ground truthing and updating the satellite imagery data.

- Focus group discussion was used to obtain community perceptions on biophysical and socioeconomic changes, the timeline of their occurrence, and their drivers and impacts.

- Household-level data were collected and analyzed to understand the determinants of adaptation to climate variability and change and the impacts of SLWM practices on agricultural productivity.

- Crop simulation models were used in the Nigerian sites, which coincided with another ongoing study focusing on the costs and benefits of SLWM options, to analyze returns of SLWM practices.

Analytical methods

The qualitative information and data collected from the focus group discussions were compiled and summarized in tabular and graphical format to capture commonalities and divergence of responses across different sites. The household surveys also provided significant quantitative
analysis related to the key questions. Descriptive analysis was made on household perceptions of (i) climate shocks and longer term changes, (ii) the effects of the shocks and changes, (iii) responses implemented to address those shocks and changes, (iv) the impacts of those responses, (v) the identification of additional desired adaptation measures, and (vi) the constraints in implementing them. Descriptive analysis was also conducted on household capital endowment and the prevalence of household land and water management practices.

A second set of analyses involved econometric methods, including the following:

- Awareness of climate change = f (social capital, human capital, physical capital, access to services, meso level factors…)
- Responses to climate shocks and change (drought, longer term change) = f (social capital, human capital, physical capital, access to services, meso level factors same…)

Both models were estimated at the household level. At plot level, the following models were estimated:

- Adoption of SLWM = f (social capital, human capital, physical capital, access to services, meso level factors, land tenure, other plot level characteristics…)
- Impacts of different SLWM practices on plot productivity, risk of production, and soil carbon.

Methodology for the soil carbon work

Both above and below ground carbon was measured at the plot level from each of the sampled households in Kenya and Uganda. For the aboveground carbon, only perennial vegetation was measured by estimating the type and number of trees and allometric measures. The above ground carbon of annual vegetation was not considered given that it changes significantly depending on the season—hence unreliable. The below ground carbon was measured by taking composite soil samples from the topsoil (which responds faster than subsoils to management practices) was taken from each type of land use. Two additional samples were taken, one from a well-managed plot and another from a plot with poor land management practices. This approach was used to determine the impact of different land management practices on carbon sequestration and the capacity of farmers to assess agricultural carbon potential impact of SLWM practices on carbon.

**BACKGROUND ON THE CASE STUDY COUNTRIES**

Climate conditions, agroecological zones characteristics, and socioeconomic background may be different in the four countries selected. Both their similarities and their differences will provide information to later understand the most favorable conditions to scale up SLWM practices and the drivers of SLWM adoption that have a potential for climate change adaptation and mitigation. In this section, the text will elaborate the following questions:

- What are the major climate characteristics in the selected sites?
- What policies have been put in place in each country to address negative effects of climate change and variability, and how are they implemented at the local level?
What is the socioeconomic background for the four countries—to help better understand their vulnerabilities to climate variability and change and their potential adaptive capacity?

The case studies cover four countries: Kenya and Uganda in East Africa and Niger and Nigeria in West Africa. In each country, sites were selected to represent areas with different major agroecological zones, farming systems, and vulnerability to climate variability and change. Understanding the differing climate-change patterns and the different agroecological and socioeconomic environments in the two subregions will help current efforts to enhance adaptation and mitigation of climate change in the Sub-Saharan Africa region.26

The West African Sudan-Sahelian region and East Africa are priority regions for studying climate change and SLWM linkages because they are characterized by high levels of current climate variability and severe levels of land degradation. The risks of climate change differ between these regions. East Africa is strongly influenced by the El Niño Southern Oscillation (ENSO), and most global circulation models (GCMs) predict that the climate in this region will become wetter, with increased risks of erosion and flooding (table 2.1).

Table 2.1: Changes in Rainfall from Their Levels in 1980–90 to 2080–90 (%)

<table>
<thead>
<tr>
<th>Region</th>
<th>Season</th>
<th>DJF</th>
<th>MAM</th>
<th>JJA</th>
<th>SON</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Africa</td>
<td>DJF</td>
<td>13</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>West Africa</td>
<td>MAM</td>
<td>13</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>JJA</td>
<td>6</td>
<td>-3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sahara</td>
<td>SON</td>
<td>0</td>
<td>0</td>
<td>-23</td>
<td>-13</td>
<td>-4</td>
</tr>
<tr>
<td>East Africa</td>
<td>Annual</td>
<td>-18</td>
<td>-18</td>
<td>-4</td>
<td>6</td>
<td>-6</td>
</tr>
</tbody>
</table>

DJF = December, January, February; MAM = March, April, May; JJA = June, July, August; SON = September, October, November
Source: Christensen 2007.

By contrast, the Sudan-Sahelian climate of West Africa is less predictable, both interannually and in the long term, with some models predicting a wetter climate and some predicting a drier climate. In general, a more variable climate is expected. However, it is fairly certain that temperatures will increase throughout the region, and the likelihood of extreme weather events leading to droughts and flooding is predicted to increase (Boko et al. 2007).

Current National Efforts to Address Negative Effects of Climate Change and Variability27

26 More details on the climate characteristics of the selected sites are available in annex 7.
27 More information is available in annex 8.
Each of the four case study countries have grappled with climatic shocks and long-term climate change and have designed various strategies to cope and adapt to climate change. However, only Niger and Uganda have prepared National Adaptation Programmes of Action (NAPAs).

Different policies and adaptation programs have been set up in all four case study countries and have shown considerable impacts. The strong research and development program and open market policies in Kenya have offered strong incentives to farmers to invest in improved production technologies, including organic soil fertility management practices and irrigation. Even though such efforts were not implemented as part of adaptation to climate change, they have enhanced farmer adaptation to such change and have therefore addressed the adaptation deficit. Similarly, Nigeria had invested in the development and promotion of irrigation long before climate change became a major problem. Niger’s and Uganda’s NAPAs are steps that have created awareness of climate change and the need for designing policies and strategies for adaptation and mitigation. Uganda is among the few African countries with an elaborate decentralization structure and a land tenure policy that provides full ownership of land, including land under customary tenure. Similarly, Niger has enacted the Rural Code, which integrates the customary institutions and recognizes the customary land tenure. The country has also implemented an exemplary tree planting and protection program, which has contributed to the regreening of the Sahel.

Despite these significant achievements in each country, major weaknesses exist. The major weaknesses of the NAPAs in Niger and Uganda and National Action Plans (NAPs) in all four countries are their short-term project orientation, which puts their sustainability into question. Both programs remain largely donor-funded with limited political commitment to finance their activities during and beyond the project period. Additionally, both programs are poorly integrated into all ministries and departments responsible for effective and efficient implementation. For example, despite the importance of local institutions and civil societies in managing natural resources, which both NAP and NAPA recognize, their role in implementing both programs is sketchy and abstract (Pearce 2006; Mutunga and Hardee 2009).

In all countries, different ministries that affect land and water resources formulate policies and regulations with poor coordination. For example, it is only in Nigeria where the offices of livestock, agriculture, and water resources are in one ministry. In the other three countries, each is in a different ministry, posing a daunting challenge to coordinating the implementation of climate-change adaptation strategies. For example, in Niger the Rural Code gives pastoralists community-level ownership of water resources in a defined area. Other pastoral communities outside the area of jurisdiction require a permit to access water. On the other hand, the Water Code states that water is a common resource available to anyone (Cotula 2006). Such conflicts pose a challenge that need to be addressed as the country strives to improve local government and decentralization.
The central government climate change-related regulations have not been effective at community level; only Niger and Uganda have designed a NAPA and their implementation has been weak due to the small budgets allocated and the short-term nature of the proposed activities. According to the focus group discussions, the local governments have played a leading role in enacting regulations in response to climate change and other major changes in the past 30 years.

In Kenya, the ongoing decentralization policy reforms are likely to have far reaching implications on natural resource management such as enacting of SLWM regulations. Key institutional changes reported during the community focus groups are related to the use of resources, such as water, trees, riverine areas, fish, and rangelands. Indeed, Kenya did implement a logging ban. However, there was much confusion about the coverage of this regulation among community members and some forest officers misapplied the rule to include trees grown on farms. In late 2009, the government has clarified their intention to regulate cutting of trees in natural habitats and not on farms by proclaiming that all farmers should grow trees on at least 10 percent of their farm area. Regulation of water use was mentioned by focus groups in the highlands district of Bungoma. However, this regulation has not yet been enforced in rural areas. In semi-arid district of Samburu, there was both a government restriction on animal movement in one location and local byelaws on rotational grazing to reduce the spread of disease in the first case and to regenerate degraded grazing areas in the second. In the sub-humid district of Bondo, regulations on fishing in Lake Victoria appear to have emerged from a concern with overexploitation and desire to regenerate resource stocks.

In Niger, the important part of decentralization that affects significantly SLWM is the Rural Code that has been one of the policies that enhanced regreening of the Sahel. The Rural Code seeks to provide tenure security and participatory land management of land owned under customary land tenure systems. As part of the case studies, villages were asked to state the steps they have taken to collectively enhance adaptation to climate change. There were few local adaptation strategies initiated at the local level by local actors. The major regulation was establishment of livestock corridors. This was set to reduce conflicts between sedentary farmers and pastoralists, which have been increasing due to dwindling pasture and water resources. In Niger, byelaws requiring community members not to cut trees or to cut trees with authorization of forestry agents on community forests or woodlots were enacted by local governments in all the 8 villages. As seen above, the Rural Code and other institutional reforms contributed to the regreening of the Sahel in Niger. However, compliance and enforcement to regulations is difficult but there is evidence that the institutional structure that gives the local communities the right to own trees has enhanced tree planting and has contributed to regreening of the Sahel in Niger (Reij et al. 2009).

Nigeria is administratively very much decentralized. Local government authorities can enact byelaws but only if such laws should be consistent with the state and Federal laws which weakens the autonomy of local governments. The most common climate change-related regulations enacted in Niger state were on prohibition of bush burning and requirement to protect and plant trees. Three of the four villages enacted regulation prohibiting bush burning. The bush-burning ban contributed to reduction of the burnt area and underscores the importance of local institutions in enhancing adaptation to and mitigation of climate change. Given that the local governments in all communities did not enact similar byelaws, these findings demonstrate the synergistic characteristics of the different local institutions in enhancing
adaptation to climate change. For example in this case, conflicts over natural resources are likely to increase due to climate variability (Barnett and Adger 2007) and customary institutions seem to have taken steps to address this problem. Where there is an absence of local byelaws and regulations, this could be due to weakness and ignorance of the community about their rights to enact byelaws. This is underscores the weaknesses of the local institutions, which is a common problem in Sub-Saharan Africa (Smoke 2003).

In Uganda, decentralization devolves most political, legislative and executive powers to local governments. Both the National Environment Action Plan (NEAP) and the National Environmental Management Authority (NEMA) have taken advantage of decentralization and the development of local institutions to manage local natural resources and the environment. There is higher compliance with regulations enacted by local governments than those enacted by higher administrative level. Byelaws requiring community members not to cut trees were enacted by local governments in all but one of the 12 villages included in this study. Interestingly, even the customary institutions in three villages enacted regulations prohibiting tree cutting. Payment of water user fees was enacted in three of the four communities in the semi-arid zone. Controlled grazing was enacted by two of the four communities in the semi-arid zone. The enactment of controlled grazing and access to water resources in the pastoral communities in the semi-arid zone is interesting and sets a trend that overcomes challenges that past efforts to enforce controlled grazing among pastoral communities have failed to achieve (Mwangi and Ostrom 2009; Nori et al. 2008). Analysis of the potential impact of presence of SLWM projects on capacity of local governments to enact byelaws showed that villages with SLWM projects enacted more byelaws than those without. This shows the importance of projects and programs in enhancing the capacity of village institutions to enact SLWM byelaws.

**Socioeconomic Background**

The four case study countries have experienced economic development, which will help policy makers and administrators better understand the programs being implemented. In East Africa, the Kenyan and Ugandan economies have been growing fast: about 4 percent in Kenya and 7 percent in Uganda from 1990 to 2007 (table 2.2). The growth rate of Nigeria in West Africa has also been about 7 percent during the same period, while the growth rate in Niger has been low and in some years negative. This is largely due to the political instability and droughts that affected economic growth. Expenditures in Niger and Nigeria on agricultural research and development (R&D) as share of the agricultural gross domestic product (agGDP) are comparable even though Nigeria’s R&D is among the best in Sub-Saharan Africa (Beintema and Stads 2006).

The policies and political history of Kenya and Uganda also present interesting comparison. While Kenya has enjoyed a relatively stable political environment and a more open economy that have allowed significant development of the private sector, Uganda is emerging from political crises, although it has been implementing ambitious policy reforms that have led to rapid economic growth. Kenya has also invested significantly in the agricultural sector.
Table 2.2: Economic Development and Major Policies of the Case Study Countries

<table>
<thead>
<tr>
<th></th>
<th>Kenya</th>
<th>Uganda</th>
<th>Niger</th>
<th>Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (millions)²</td>
<td>35</td>
<td>32</td>
<td>14</td>
<td>147</td>
</tr>
<tr>
<td>Per capita income (2008 US$)¹</td>
<td>838</td>
<td>454</td>
<td>391</td>
<td>1401</td>
</tr>
<tr>
<td>GDP (US$ billions)³</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>8.6</td>
<td>4.3</td>
<td>2.5</td>
<td>28.5</td>
</tr>
<tr>
<td>2000</td>
<td>12.7</td>
<td>6.2</td>
<td>1.8</td>
<td>46.0</td>
</tr>
<tr>
<td>2007</td>
<td>24.2</td>
<td>11.8</td>
<td>4.2</td>
<td>165.5</td>
</tr>
<tr>
<td>Growth GDP (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>4.20</td>
<td>6.50</td>
<td>-1.30</td>
<td>8.20</td>
</tr>
<tr>
<td>2000</td>
<td>0.60</td>
<td>5.60</td>
<td>-1.40</td>
<td>5.40</td>
</tr>
<tr>
<td>2007</td>
<td>7.00</td>
<td>7.90</td>
<td>3.20</td>
<td>5.90</td>
</tr>
<tr>
<td>Average growth</td>
<td>3.93</td>
<td>6.67</td>
<td>0.17</td>
<td>6.50</td>
</tr>
<tr>
<td>Agriculture value added as % of GDP</td>
<td>26.00</td>
<td>24.00</td>
<td>38.00</td>
<td>33.00</td>
</tr>
<tr>
<td>Contribution of livestock to GDP (%)⁴</td>
<td>11.00</td>
<td>8.00</td>
<td>15.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Contribution of forestry to GDP (2006) (%)⁵</td>
<td>1.70</td>
<td>4.00</td>
<td>3.30</td>
<td>1.40</td>
</tr>
<tr>
<td>% of public research and development expenditure as % of AgGDP³</td>
<td>2.68</td>
<td>0.50</td>
<td>0.28</td>
<td>0.38</td>
</tr>
<tr>
<td>% below the poverty line</td>
<td>22.8</td>
<td>31.1</td>
<td>60</td>
<td>70.8</td>
</tr>
</tbody>
</table>


In all four countries, agriculture accounts for 24 percent or more of the GDP. The sector accounts for 38 percent of the Nigerien GDP, the largest share among the four. Considering that most farming in Africa is rainfed agriculture, the impacts of climate change and variability on national GDP could become a serious issue in these countries.
The livestock sector is important in each country. The sector is especially important in the dry areas in each. It contributes 15 percent of the Nigerien GDP—the largest contribution among the four. The livestock sector in Niger is largely pastoral with low productivity due to the low rainfall levels, poor rangeland management, and livestock breeds. The dry arid and semi-arid areas make the livestock sector suited to the agroclimatic environment of the country. The country recognizes the importance of the livestock sector, and the sector receives significant attention in the NAPA. The livestock sector in Nigeria accounts for the smallest share of the GDP (5 percent) among the four countries even though demand for livestock products is increasing rapidly with increasing urbanization and income (Ogunyika and Marsh 2006). The most climatically harsh and economically poor areas are located in northern states where livestock is the major sector. This suggests that improvement of the livestock sector will reduce poverty significantly. Livestock in Kenya accounts for 11 percent of the GDP and is the major livelihood for rural communities in semi-arid northern areas and the Maasai communities in southern Kenya. A study in western Kenya showed that livestock was the third most important pathway out of poverty—after crops and nonfarm activities—and that about 42 percent of all households that escaped from poverty in 1980–2004 diversified into livestock (Kristjanson et al. 2004). Livestock in Uganda is concentrated along the cattle corridor area, which runs from northeastern areas to the southwestern regions and accounts for 55 percent of the cattle population in Uganda (NEPAD and FAO 2004). Livestock accounts for 8 percent of the GDP but has a potential to contribute much more given the increasing demand and the low productivity.

The forest sectors in all four countries do not contribute significantly to the GDP. The small contribution could be due to the nontimber forest products that are not recorded yet contribute significantly. Weak development and promotion of forest management and degradation (deforestation) also contribute to the small contribution of the sector to the economy. The forest contribution to GDP ranged from 1.4 percent in Nigeria to 4 percent in Uganda (table 2.2). The sector presents a large potential for poverty reduction and climate-change mitigation. Expansion could be achieved if effective policies and institutions for developing and managing the forest sector are put in place and considerable resources are provided to implement such policies.

28 The Sahara Desert covers 77 percent of the country, and the Sahel and Sahara region covers 12 percent (Republic of Niger 2006).
Box 3: SYNTHESIS OF CASE STUDY SITES CHARACTERISTICS

Overall, rainfall variability is increasing; dry sites will become dryer while subhumid zones will tend to become wetter. Rainfall in the dry sites (Samburu in Kenya, Moroto in Uganda, Sokoto in Nigeria and Tahoua in Niger) show a declining trend with increasing variability. This is consistent with the community perception and with the GCM models predictions. In the wetter sites, rainfall has shown a steady pattern and in some cases increasing trend (e.g., Bondo in Kenya and Minna in Niger state, Nigeria) with an increasing overall variability.

Implementation of climate-related national policies at the local level is not considered successful because of lack of funding, short-term vision, lack of coordination among authorities. Different policies and adaptation programs have been set up in all four case study countries and have shown considerable impacts. Despite these significant achievements in each country, major weaknesses exist. The major weaknesses of the NAPAs in all four countries are their short-term project orientation, which puts their sustainability into question. Both programs remain largely donor-funded with limited political commitment to finance its activities during and beyond the project period. Additionally, both programs are poorly integrated into all ministries and departments responsible for effective and efficient implementation. Last but not least, in all countries, different ministries that affect land and water resources formulate policies and regulations with poor coordination. Such conflicts pose a challenge that need to be addressed as the country strives to improve local government and decentralization.

Local policies are more successful (better compliance from communities) but local institutions are weak and sometimes can’t enforce local regulations as necessary. Local institutions and communities have been taking collective action to address resource changes precipitated by climate variability and change and other biophysical and socioeconomic changes. These initiatives provide an opportunity for the NAPA to take advantage of the community awareness of climate change and the need to collectively and individually take action to address land and water resources. However, the major weakness of these actions is the weak capacity of the local institutions to enact and enforce these regulations.

The four case study countries have experienced economic development but are highly dependent on rainfed agriculture and therefore vulnerable to climate impacts. Agriculture is a key economic sector in all four countries since it accounts for 24 percent or more of the GDP. Livestock also play an important role in the economic development of these countries while forest management is still under developed. The dependence of national economies on rainfed agriculture explains the high vulnerability of these countries to current climate variability and the role SLWM can play to increase the resilience of rural livelihoods.

This section provided information on the overall and specific objectives of the case studies, the methodology applied and some background information both in terms of site specific climate and socioeconomic characteristics. This is the basis on which the data analysis and the discussion on results are being undertaken in the next section.
DATA ANALYSIS AND RESULTS DISCUSSION

Based on the presentation of the case studies (objectives, methodology and background), this section presents and discusses the data analysis and its results. More specifically, this section will respond to questions such as:

- How rural communities have responded to climate variability and change and what are the drivers of responses?
- What drives the adoption of SLWM practices?
- What are the benefits of SLWM for agriculture productivity and mitigation of climate-related production risks?

Detailed results are available in the country reports, as well as in a synthesis report that gathers inputs from the four countries. All reports are available on the CD that accompanies the present document.

Communities were asked to discuss how they have responded to climate variability and change. Responses differed significantly—largely depending on the type of livelihoods. Rural communities develop a broad range of responses in order to increase their resilience to climate variability and change; SLWM is only one of these responses. As per the objective of this study, the discussion focuses here on SLWM practices only.

How Have Rural Communities and Households Responded to Climate Variability and Change and What are the Drivers for such Responses?

Rural communities have used many SLWM practices that increase their resilience to current climate variability and projected changes. However, their intake remains low in comparison with other land management practices and the research shows that such practices were not always used as a response to the perceived climate variability but for other reasons.

What are the most commonly used land and water management practices mentioned by rural communities and households in response to climate variability and change?

The most commonly used land and water management practices reported by the communities living in the sites selected for the case studies are the following:

- Protection and planting of trees
- Livestock and rangeland management
- Irrigation and water harvesting
- Early maturing varieties
- Mulching
- Fertilizer and manure application
- Horticultural crops
- Livelihood diversification and new crops

29 For more information, see annex 9.
• Changing of planting date
The selected communities considered such practices as being adaptation strategies adopted in response to observed changes in climate conditions. As discussed in the next section, some are clearly climate-smart while others have a smaller potential for increasing resilience to climate variability and change.

In summary, some existing activities have been modified to better cope with the observed climate changes and new activities were also adopted by almost all communities in response to climate variability and change. Pastoral communities in East and West Africa have increased controlled grazing and in some cases controlled access to water, both of which have not been common in the transhumant livelihoods. Protection and planting of trees has been a particularly common practice across all countries and agroecological zones. Of concern is the limited use of irrigation as an adaptation strategy in the dry areas. This is a major problem that increases risks toward crop production in dry areas. New varieties and agronomic practices were used—particularly in Kenya and Nigeria. Overall, the community-level discussions show a variety of strategies that have a potential to increase resilience to climate variability and change, which shows the capacity of communities to cope with changing climate conditions, albeit within a host of constraints that limit the level of adaptation.

In addition to gathering information from communities, many households were asked similar questions. Farmers reported a large number of adaptation practices, but some of the practices were reported by only a small number of respondents. Table 2.3 summarizes the responses to climate variability and change obtained at the household level.30

Changing crop varieties and crop type were the most common adaptation strategies across all countries and AEZs. In Kenya, farmers shifted away from maize and into other crops such as cassava, millet, beans, and vegetables. In Nigeria, the new crops were wheat, hungry rice, garden eggs, tomatoes, groundnuts, maize, cashew nuts, and soybean. In Niger, farmers reported switching from cotton and fruit trees to onion and vegetables, sweet potato, cassava, beans, onion, and beans. Some of these crop types are more drought tolerant than the crop replaced, while some, notably vegetables, require more water and irrigation. The switch to vegetables presents an interesting case, contrary to expectation of switching from less drought-tolerant to more drought-tolerant crops. In all cases, farmers switching to vegetables had some form of irrigation. The trend is a reflection of the impact of market access and tendency to move to high-value crops as a strategy to intensify and maximize returns to the increasingly scarce water and land resources.

Change of planting date was the third most common adaptation strategy, which was adopted to address the perception of late onset of rainfall. However, the largest share of households reporting change in planting date was from subhumid areas and highlands in Kenya and Nigeria and not from the semi-arid areas of Uganda and Niger, where rainfall variability has increased. Farmers in semi-arid regions may feel that planting dates are less flexible due to the limited length of growing period.

30 It focuses on the top five adaptation practices reported in each country. In East Africa, SLWM practices are reported across AEZs.
Of major interest are the SLWM practices. In Kenya, only one household undertook field-level conservation practices, two households started water harvesting in the highlands, and two changed fertilizer application regimes. In the subhumid zone, a relatively larger share of households (19 percent) reported having made soil- and water-management adaptations and developed a water harvesting scheme, or planted trees. In neighboring Uganda, the adoption rate of SLWM was highest in the subhumid area (18 percent) and lowest in the semi-arid zone (7 percent). About 17 percent of households in Niger reported having used SLWM practices to cope with climate variability, but none in Nigeria reported to have used SLWM. As the case in the semi-arid zone of Uganda, however, farmers in Nigeria also reported using SLWM to address short-term climatic shocks. Many farmers in Nigeria and in the other countries also reported having already adopted a range of SLWM practices before this became a major problem.

Table 2.3: The Five Most-used Climate-change Adaptation Strategies in East and West Africa (%)

<table>
<thead>
<tr>
<th>AEZ/country</th>
<th>No change</th>
<th>Change crop variety</th>
<th>Change crop type</th>
<th>Change planting dates</th>
<th>SLWM practices</th>
<th>Change field location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highlands (Bungoma)</td>
<td>24.2</td>
<td>35.5</td>
<td>32.3</td>
<td>27.4</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>Subhumid (Bondo)</td>
<td>19.3</td>
<td>35.1</td>
<td>28.1</td>
<td>19.3</td>
<td>19.4</td>
<td></td>
</tr>
<tr>
<td>Uganda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subhumid (Kamuli)</td>
<td>17.5</td>
<td>7.0</td>
<td>22.8</td>
<td>5.3</td>
<td>17.6</td>
<td>10.5</td>
</tr>
<tr>
<td>Highlands (Kapchorwa)</td>
<td>49.8</td>
<td>18.6</td>
<td>18.6</td>
<td>0</td>
<td>11.9</td>
<td>0</td>
</tr>
<tr>
<td>Semi-arid (Moroto)</td>
<td>65.0</td>
<td>11.7</td>
<td>10.0</td>
<td>0</td>
<td>6.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Nigeria</td>
<td>71.0</td>
<td>8.1</td>
<td>54.0</td>
<td>35.1</td>
<td>-</td>
<td>2.7</td>
</tr>
<tr>
<td>Niger</td>
<td>2.4</td>
<td>47.0</td>
<td>20.0</td>
<td>4.1</td>
<td>17.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

1 Includes soil and water conservation structures, water harvesting, tree planting, manure application, and fertilizer.

Table 2.3 shows that SLWM practices clearly do not represent the most used adaptation strategy in the selected sites. SLWM practices address the adaptation deficit by addressing the drivers of the vulnerability to climate variability and change, while the crop related strategies address the adaptation gap which consists in directly managing climate variability. Both types of adaptation strategies are complementary and can show interesting results when combined.

Which land management practices are climate-change-smart and which ones were adopted?

The climate-change-smart land management practices for crop production are those that integrate land and water, enhance soil carbon, and use crop varieties adapted in the dry areas that address climatic variations. Additionally, a combination of organic and inorganic soil fertility management practices enhances resilience to climate change and increases crop productivity.
Integrated land and water management practices have been shown as key to effective adaptation to climate variability and change in dry areas (Pandey et al. 2003; Bationo 2001). Among land management practices, those that increase soil carbon also enhance moisture-holding capacity, improve biological activities, and provide other benefits (Lal 2004), and they consequently reduce climate-induced production risks. For example, a study in semi-arid areas in Kenya showed that mulching could increase the length of growing period from 110 to 113 days (Cooper et al. 2009). Empirical evidence has also shown a synergistic relationship among SLWM practices: holding all else constant, a household that uses more than one SLWM practice is likely to better cope with climate variability than a household using only one. For example, Bationo (2001) observed that water and nutrient management increased water use efficiency and yield response to fertilizer when land- and water-management were combined. On a long-term soil fertility experiment in Kenya, Nandwa and Bekunda (1998) observed that plots receiving crop residues, fertilizer, and manure registered the highest maize yield many years after the start of the experiment compared to plots receiving the recommended or higher fertilizer doses. Other studies have also shown similar results (Titonell et al. 2008; Vanlauwe and Giller 2006).

Adoption of early maturing or drought resistant crop varieties also enhances resilience to climate variability (Lobell et al. 2008; Anderson et al. 2004). New efforts to develop high-temperature-tolerant crop varieties are currently under way (Anderson et al. 2004). Likewise, crop varieties that are resistant to climate-induced pest and diseases will also enhance adaptation to climate change. Agronomic management practices, such as changing the time of the planting season to reflect the new climatic patterns, and other improved technologies will generally improve resilience to climate variability.

Climate-change-smart livestock management practices are also related to the land management practices for crops. Likewise, livestock breeds for the dry areas should tolerate the expected higher temperatures and reduced water availability. Pasture and rangeland management fall into the category of crop management practices, and what has been discussed above also applies to pasture management. Grazing regimes should ensure enhanced productivity of livestock. For example, rotational grazing has been shown to increase cattle live weight by up to 63 percent (Walton 1981).

The land management practices adopted in response to climate variability and change show limited integrated land and water management (table 2.4). For the top five SLWM practices used to adapt to climate change (table 2.3), only a small share of farmers reported having used SWLM, including some water management practices. These results are consistent with Yesuf et al. (2008), Benhin (2006), and Kabubo-Mariara and Karanja (2006), who found limited use of SLWM practices as adaptation strategies. Water management is particularly limited in Uganda and Niger. A good example of the effect of the partial adaptation to climate change is the case of semi-arid zone of Uganda. Farmers reported having started using mulching and manure but did not use irrigation. Consequently, they experienced 100 percent crop failure two years in a row (2007/08 and 2008/09). Contrary to this, farmers in Nigeria reported increased use of irrigation and improved crop varieties and fertilizer. Community focus discussions found that crop yields have doubled from their level in 1980, and this was largely due to adoption of both land and water management practices.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Kenya</th>
<th>Uganda</th>
<th>Niger</th>
<th>Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>3.4</td>
<td>1.8</td>
<td>4.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Alley cropping</td>
<td>13.3</td>
<td>15.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer &amp; organic soil fertility</td>
<td>33.0</td>
<td>2.0</td>
<td>0.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Animal manure</td>
<td>68.0</td>
<td>11.9</td>
<td>1.0</td>
<td>12.1</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>36.4</td>
<td>6.1</td>
<td>0.1</td>
<td>45.3</td>
</tr>
<tr>
<td>Bench terraces</td>
<td>11.6</td>
<td>3.0</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Composting</td>
<td>28.8</td>
<td>1.0</td>
<td></td>
<td>6.8</td>
</tr>
<tr>
<td>Crop rotation</td>
<td>39.1</td>
<td>43.0</td>
<td>0.4</td>
<td>59.3</td>
</tr>
<tr>
<td>Deep tilling</td>
<td>2.45</td>
<td>30.8</td>
<td>0.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Vegetative strips</td>
<td>15.6</td>
<td>12.6</td>
<td>1.2</td>
<td>1.9</td>
</tr>
<tr>
<td>Fanya chini&lt;sup&gt;31&lt;/sup&gt;</td>
<td>11.5</td>
<td>6.5</td>
<td>17.7</td>
<td></td>
</tr>
<tr>
<td>Fanya juu&lt;sup&gt;32&lt;/sup&gt;</td>
<td>10.0</td>
<td>2.4</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Green manure application</td>
<td>10.6</td>
<td>1.0</td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>Improved fallow</td>
<td>4.9</td>
<td>1.9</td>
<td>0.6</td>
<td>5.9</td>
</tr>
<tr>
<td>Crop residue incorporation</td>
<td>34.4</td>
<td>31.8</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Mulching</td>
<td>35.2</td>
<td>22.2</td>
<td>6.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Trash lines</td>
<td>4.1</td>
<td>8.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree planting</td>
<td>37.6</td>
<td>19.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero tillage</td>
<td>0.8</td>
<td>4.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zai pits</td>
<td>0.9</td>
<td></td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Rotational grazing</td>
<td>7.5</td>
<td>1.8</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Restricted grazing</td>
<td>7.4</td>
<td>1.8</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Resting of grazing land</td>
<td>5.0</td>
<td>2.6</td>
<td>2.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Weeding of pastures</td>
<td>14.9</td>
<td>0.6</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Infiltration ditch</td>
<td>3.3</td>
<td>3.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Water harvesting</td>
<td>17.2</td>
<td>0.5</td>
<td>0.4</td>
<td>0.6</td>
</tr>
</tbody>
</table>

<sup>31</sup> *Fanya chini* is a trench with a soil bund on the lower side.

<sup>32</sup> *Fanya juu* is a trench with a soil bund on the upper side.
Regarding integrated soil fertility-management, even practices that have been adopted regardless of use (i.e., not because of climate change) show limited adoption of such practices. It is only in Kenya where practices are significantly integrated. About a third of farmers reported having adopted fertilizer in combination with organic soil fertility-management practices, which include manure, mulch, crop residues, and tree planting, and other organic land management practices. For the rest of the countries, the adoption of fertilizer in combination with organic soil fertility-management practice is either very low or zero. This suggests the need to promote integrated land management practices that can effectively enhance resilience to climate variability and change.

In summary, if communities and households have reported using some SLWM practices that improve their resilience to climate variability and change, the intake remains low compared to the adaptation potential of such practices. Looking at the drivers of response to climate change will provide some inputs to better understand the conditions under which to scale-up SLWM practices in Sub-Saharan Africa.

What are the main drivers of response to climate change?

Farmers were asked to state reasons for their lack of response or lack of additional desired responses to climate change. The major reason given for not responding or not more effectively responding was lack of money (table 2.5). In all countries, lack of money was the major reason cited for failing to pursue adaptive strategies to climate change or not responding more effectively. This confirms the vulnerability of the poor and the high cost of some of the adaptation strategies used by farmers. Lack of access to agricultural inputs was the second most important reason for not taking any particular action in the face of climate variability. This suggests greater vulnerability for farmers in remote areas where access to agricultural inputs, such as early maturing crop varieties, is lower. Lack of information on appropriate adaptation strategies was the third most important reason for not responding to climate change. This is to be expected given the level of uncertainty in predicted and perceived climate change and the lack of a coordinated and operational strategy on climate-change adaptation in agriculture. This also underlines the weak agricultural extension services to provide advisory services on adaptation to climate change, a problem that is common in Sub-Saharan Africa, where agricultural advisory services are still focused on crop production.

### Table 2.5: Reasons for Not Responding to Climate Change (%)

<table>
<thead>
<tr>
<th>Reason</th>
<th>Kenya¹</th>
<th>Uganda²</th>
<th>Niger²</th>
<th>Nigeria²</th>
<th>All countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>No money</td>
<td>100.0</td>
<td>42.0</td>
<td>53.5</td>
<td>44.6</td>
<td>60.0</td>
</tr>
<tr>
<td>No inputs</td>
<td>46.0</td>
<td>12.2</td>
<td>21.3</td>
<td>6.9</td>
<td>21.6</td>
</tr>
<tr>
<td>No information on appropriate interventions</td>
<td>22.0</td>
<td>33.0</td>
<td>2.1</td>
<td>15.0</td>
<td>18.0</td>
</tr>
<tr>
<td>No access to credit</td>
<td>14.0</td>
<td>3.5</td>
<td>17.5</td>
<td>26.7</td>
<td>15.4</td>
</tr>
<tr>
<td>No access to land</td>
<td>13.0</td>
<td>8.3</td>
<td>2.1</td>
<td>6.9</td>
<td>7.6</td>
</tr>
<tr>
<td>Shortage of labor</td>
<td>23.0</td>
<td>3.5</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No water</td>
<td>58.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Includes households that reported having used an adaptation strategy and wanted to use other adaptation methods but were unable to do so. ² Includes only those who failed to adapt to climate change.
Other reasons for not responding to climate variability and change include lack of access to credit, land, and labor. Below are detailed the determinants of response to any type of the long-term climate modifications.

**Head of household**

Table 2.6 shows that female-headed households in Niger were less likely to respond to climate variability and change than male-headed households. The results underscore the vulnerability of female-headed households: even though they are aware of the climatic changes, they are unable to respond to short-term shocks. In Kenya, Uganda, and Nigeria, however, the gender of household headship does not have a significant impact on responding to climate variations. Primary and secondary education do not have a significant impact on responses to climate change in all countries. In all countries, having nonfarm activities reduces the likelihood of a household responding to climate variability and change, probably because households with significant nonfarm livelihoods may prefer to respond to additional agricultural risks of climate variability by emphasizing responses in nonagricultural areas. In Kenya, the ability to respond to climate variability and change was more likely among households who have been farming for long durations. This makes sense given that experienced farmers may be both more aware of the climate variations and impacts and knowledgeable about how to respond based on their long experience.

**Access to markets**

Distance to market in all countries is positively related to responses to climate variability and change, suggesting that those in remote areas are more likely to respond to climate variability and change than those near markets. These results are plausible for households in areas remote from markets in that they have fewer nonagricultural options and therefore take more action in agriculture. This is consistent with the negative association of nonfarm activities with response to climate change discussed above.

**Access to information**

Access to climate-related information is negatively associated with response to climate variability and change. The major type of climate-related information farmers received was current weather information, which may not be helpful in deciding on the response to long-term climate change. Analysis of the determinants of response to climatic shocks showed that access to climate-related information increases the likelihood of responding to drought shocks in Niger state. This is consistent with literature showing that response to climatic shocks is enhanced by access to climate-related information (Adger et al. 2005). Drought shocks are important in dry areas like the Niger state, and it is likely that farmers make efforts to get climate-related information and use it to plan their production strategies. For other shocks—erratic rainfall, too much rainfall, and all other climate-change variables considered—access to climate-related information is negatively associated with response to such shocks and changes in Niger state and in Tahoua region in Niger. This could be due to the fact that farmers may seek climate-related information after experiencing climatic shocks.

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33 Female-headed households in Uganda were also less likely, but the results were not significant at $p = 0.10$. 
Access to extension services

Access to agricultural extension services did not have a significant impact on responses to climate variability and change. This is a reflection of the weak capacity of extension services in offering advisory services related to climate issues. Advisory services on climate are currently not embedded in the agricultural advisory services and are used in isolation of the agricultural extension messages (Vogel and O’Brien 2006). This suggests the need to integrate climate-change messages in the existing extension services.

Physical capital endowment

Contrary to expectations and results implied in the descriptive statistics showing that lack of money was the major reason for failing to respond to climate variability and change, physical capital endowment, namely land area and livestock assets, did not have a significant effect on the likelihood of adopting adaptation strategies. The weak impact of the physical assets could be due to the small sample. As expected, access to irrigation in Uganda increases the likelihood of responding to climate variations.

Table 2.6: Determinants of Response to Climate Change

<table>
<thead>
<tr>
<th>Variable</th>
<th>Kenya</th>
<th>Uganda</th>
<th>Niger</th>
<th>Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability to respond&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Household capital endowment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Human capital</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(household size)</td>
<td>-</td>
<td>-0.149</td>
<td>-0.125</td>
<td>0.574</td>
</tr>
<tr>
<td>Female household head</td>
<td>0.590</td>
<td>-0.098</td>
<td>-0.078*</td>
<td>0.209</td>
</tr>
<tr>
<td>Log (male household members)</td>
<td>-0.061</td>
<td>0.146</td>
<td>-0.044</td>
<td>-0.402</td>
</tr>
<tr>
<td>Log (female household members)</td>
<td>-0.037</td>
<td>0.22</td>
<td>0.067</td>
<td>-0.123</td>
</tr>
<tr>
<td><em>Education/agriculture knowledge of household head (cf no formal education)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>0.479</td>
<td>0.033</td>
<td>0.344</td>
<td>-0.05</td>
</tr>
<tr>
<td>Secondary</td>
<td>0.776</td>
<td>-0.033</td>
<td>-0.012</td>
<td>0.081</td>
</tr>
<tr>
<td>Postsecondary</td>
<td>-</td>
<td>0.431***</td>
<td>-</td>
<td>-0.424***</td>
</tr>
<tr>
<td>Years of farming</td>
<td>0.039**</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nonfarm (cf crops)</td>
<td>-0.719**</td>
<td>-0.175*</td>
<td>-0.044</td>
<td>-0.420***</td>
</tr>
<tr>
<td>Livestock</td>
<td></td>
<td>0.528***</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Physical capital</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(farm area, ha)</td>
<td>0.024</td>
<td>0.088**</td>
<td>0.009</td>
<td>0.129</td>
</tr>
<tr>
<td>Log(value of farm equipment)</td>
<td>-</td>
<td>0.013</td>
<td>0.049***</td>
<td>-0.109**</td>
</tr>
<tr>
<td>Log(value of livestock)</td>
<td>-</td>
<td>-0.005</td>
<td>-0.006</td>
<td>0.01</td>
</tr>
<tr>
<td>Irrigation</td>
<td>-</td>
<td>0.247**</td>
<td>-0.068*</td>
<td>-0.278*</td>
</tr>
<tr>
<td><strong>Access to rural services</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>
Note: *, **, *** mean significant at p = 0.10, 0.05, and 0.01, respectively. Fixed-effects coefficients for each country are not reported. In Kenya and Uganda, unobserved location effects are also captured by district level dummy variables and in Niger and Nigeria by village level dummy variables. For presentation purposes, these are not shown in the table.

1 Marginal effects of Probit model

What Drives the Adoption of SLWM Practices?

The analysis above showed the drivers of response to climate variability change, regardless of the type of response. Below, the discussion focuses on the determinants of adoption of SLWM practices, which as mentioned before increases the resilience of rural livelihoods to climate variability and change. The main determinants are: physical capital, land tenure, human capital endowment and access to rural services. To better understand why farmers choose when and/or where they use a given land-management practice, the influence of plot level characteristics on adoption of SLWM is first examined. The discussion then focuses on policy-relevant drivers.34

Plot characteristics

Plot characteristics were the most important factor influencing the use of land-management practices in all four countries. The full description and analysis is available in the synthesis report of the case studies. To summarize, plots with sandy soils or poor soil fertility are more likely to either receive organic land management practices alone or nothing. More fertile plots or those with finer soil texture are more likely to receive fertilizer in countries where fertilizer application level is high (Kenya and Nigeria). These results are consistent with other studies and suggest that farmers with less fertile plots are less likely to adapt to climate variability and change through adoption of SLWM practices.

Physical capital

Physical capital endowment generally had a favorable influence on adoption of SLWM practices. The value of farm equipment increased significantly the probability that a farmer would adopt the use of fertilizer, but it reduced the probability that the farmer would use compost and irrigation in Nigeria and fanya juu35 and irrigation in Niger. In Uganda, owning livestock

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34 Econometric results tables are not presented here, but they are available from authors upon request.
35 Again, fanya juu is a trench with a soil bund on the upper side.
increased the likelihood of using manure, mulch, and tree planting. Likewise, livestock endowment showed a significant positive impact on adoption of fertilizer, irrigation, compost, manure, improved fallow, and a combination of fertilizer and manure or compost in Nigeria. These favorable results of livestock in Nigeria and Uganda underscore the positive crop-livestock interaction observed in other studies and the potential for sustainable land- and water-management for households with both crop and livestock production. Farm size seems to be positively associated with some SLWM practices but this is not consistent across countries.

Overall, the results suggest that having livestock enhances the adoption of both organic and inorganic fertilizer. This suggests that there is a need to promote mixed crop-livestock production, since they can have a synergistic relationship. The results also show that irrigation is more available to larger farmers, which implies a high vulnerability of small farmers to climate variability and change.

Land tenure

Overall, SLWM practices are used either on plots held under customary tenure or on plots under leasehold or freehold according to the type of practices and the country. This suggests that farmers holding land under customary tenure perceive their security to invest as more or just as secure as those farmers holding land under leasehold or freehold (in Uganda) with official certificates. For instance, plots held under customary tenure were more likely to receive mulch and crop residues and to have crop rotation in Uganda than were plots held under freehold tenure. Likewise, plots under customary tenure are more likely to receive fertilizer and manure than those held under leasehold tenure in Nigeria. Plots under customary land tenure in Niger were more likely to be irrigated than plots under leasehold. The results are consistent with studies in Sub-Saharan Africa (Toulmin and Quan 2000; Platteau 1996; and Deininger 2003) and depict a high security perception that farmers attach to plots held under customary tenure. However, in Niger, fanya juu is more likely to be practiced on plots held under leasehold than those held under customary tenure. Crop rotation in Nigeria is more likely to be practiced on plots held under leasehold than on plot held under customary land tenure. The use of manure and crop residues was more likely on plots held under leasehold than those held under customary tenue in Uganda. Land tenure did not have significant influence on the use of other land management practices in the case study countries.

Human capital endowment

The data analysis shows that the adoption of some SLWM practices seems to be gender specific. With the exception of fertilizer in Kenya, the results show that female-headed households are more likely to use organic soil fertility management practices than male-headed households. The organic soil fertility management practices of female-headed households could be due to their failure to buy fertilizer. However, results in Niger show that female-headed households are less likely to use fanya juu and irrigation, suggesting their limited access to water, which is key to adaptation to climate change. In Kenya, the opposing results observed on men and women suggest

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36 Note that all lands in Bondo and Bungoma (Kenya) were formerly registered, and thus the distinction between customary and formal tenure is not relevant. Similarly, there were only a couple of rented plots in the sample, so almost all plots were acquired by inheritance or purchase.
that there may be diverging gender interests in tree planting and crop residue incorporation, with men favoring tree planting and women favoring crop residue incorporation. In Uganda, however, female and male household members tend to move in the same direction. They are both positively associated with mulching but negatively associated with deep tillage and tree planting.

Overall, the results confirm the high labor intensity of SLWM practices, and the weak labor market that makes family labor key to the adoption of labor intensive land management practices. The low adoption of the labor intensive SLWM practices also reflect the tendency of households to use its own labor instead of paying to hire farm equipment or labor to make long-term land investments. Results also show diverging interests or responsibilities for doing some practices in the households, with women more likely to participate in mulching while men are responsible for tree planting and for tending plots that receive fertilizer.

The impact of education on adoption of SLWM practices differ across the four countries, although it appears that more educated farmers in East Africa tend to use fertilizer and, in all countries, not to adopt labor intensive practices such as manure. In Kenya, more educated household heads are found to be more likely to have adopted mulching, crop residue management, fertilizer, and conservation structures. Similarly, postsecondary education in Uganda is associated with a higher likelihood of using crop rotation, mulching, crop residue, and tree planting, while secondary education is associated with fertilizer and deep tillage. On the contrary, the household head’s level of education generally has a negative or insignificant association with land management practices in Niger and Nigeria. This is due to the high opportunity cost of highly educated labor, which makes it more costly to adopt labor intensive land management practices.

Regarding nonfarm activities, the results show complementarity and trade-offs that farmers have to take when they engage in nonfarm activities. Nonfarm activities certainly help farmers increase their resilience to climate variability and change, since they diversify livelihoods and reduce the heavy dependence on agriculture, which is heavily influenced by climatic shocks and long-term climate change.

There is an overall positive impact of membership in production groups and credit and savings associations on the adoption of SLWM practices. Membership in credit and savings association increases the probability of adopting SLWM practices such as mulching, crop residue management, and manure and soil conservation. It is possible that access to credit increases the liquidity and helps farmers to hire labor or farm equipment for transportation of manure. As observed in other studies (Pender et al. 2004), membership in savings and credit groups is negatively associated with fertilizer use in Kenya and Uganda, suggesting that money borrowed is used for consumption purposes or nonfarm activities with higher returns.

Collective action through group membership has often a positive impact on SLWM adoption through providing farmers with greater access to information, whether through extension, NGOs, projects, or other farmers. This appears to be the case given the range of SLWM practices that have been catalyzed by group participation. The results also underscore the potential synergies of different groups and the importance of promoting different groups to provide different services required by farmers. Sometimes, the weak or negative impact of some of the groups on adoption of SLWM could be due to their weaknesses on providing support to
farmers. This suggests the need to enhance their capacity through rural development programs—such as community driven development. For example, the demand-driven agricultural extension services offered by the Fadama II project in Nigeria and by the National Agricultural Advisory Services (NAADS) in Uganda offered limited advisory services on sustainable land and water management practices (Nkonya et al. 2010; Benin et al. 2009). These groups should promote advisory services on land management practices.

Access to rural services

The **significantly greater likelihood of farmers using fertilizer when they are closer to agricultural markets** is consistent with expectations and reflects high transaction costs for farmers away from the markets. The results also suggest that farmers in remote areas are more likely to use organic soil fertility management practices than those in areas closer to markets.

Access to extension services increases the probability of adopting some SLWM practices and reduces the probability of adopting others. These results suggest that extension services are weak in providing advisory services on organic soil fertility management practices, as observed by Nkonya et al. (2010) and Banful et al. (2009) in Nigeria and Benin et al. (2009) in Uganda.

As expected, the presence of SLWM projects in a village increased the probability that farmers would adopt SLWM practices. The different influence of the traditional agricultural extension services and the SLWM projects shows their potential complementarity, also observed by Nkonya et al. (2004) in Uganda. In this case, the traditional extension agents have a significant impact on the adoption of fertilizer and irrigation, while SLWM projects have a significant impact on the adoption of organic soil fertility management practices. The results underscore the importance of multiple providers of extension services that have potential complementarity in their provision of different types of technologies. Current efforts to diversify extension services through Fadama III in Nigeria and NAADS in Uganda provide the opportunity to involve NGOs and other service providers who will address the weaknesses of the traditional agricultural extension services.

**What Are the Benefits of SLWM for Agriculture Productivity, Carbon Sequestration, and Mitigation of Climate-related Production Risks?**

In Pillar 1, the cobenefits of SLWM have already been discussed from a theoretical perspective. The findings of Pillar 1 are being comforted by the experimental research done for the case studies: SLWM practices have a positive impact on agriculture productivity, carbon sequestration, soil fertility and also help mitigate climate-related production risks.

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37 Fertilizer, irrigation, and crop rotation in Nigeria; irrigation in Niger; and tree planting in Uganda.
38 Manure in Nigeria; mineral fertilizer in Kenya; crop rotation in Uganda; and alley cropping, mulching, and *fanya chini* in Niger.
39 See pages 44-52.
Impact of SLWM practices on agricultural productivity

According to the type of practices and how they are applied, SLWM practices can actually have positive and negative influence on agricultural productivity. Table 2.7 shows the impact of SLWM practices on the value of crop per hectare.

Table 2.7: The Impact of SLWM on the Value of Crop Produced per Hectare

<table>
<thead>
<tr>
<th></th>
<th>Kenya</th>
<th>Uganda</th>
<th>Niger</th>
<th>Niger state, Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Log (value produced per ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer</td>
<td>0.094**</td>
<td>-</td>
<td>2.763***</td>
<td></td>
</tr>
<tr>
<td>Improved fallow</td>
<td>2.258***</td>
<td></td>
<td>2.810*</td>
<td></td>
</tr>
<tr>
<td>Agroforestry</td>
<td>-0.796**</td>
<td>0.600*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water harvesting</td>
<td>-0.516</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulch &amp; crop residues</td>
<td>-1.572**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulch &amp; manure</td>
<td>-1.849*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>-4.209**</td>
<td>0.886**</td>
<td>1.441</td>
<td></td>
</tr>
<tr>
<td>Log(carbon)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(carbon squared)</td>
<td>2.512***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compost</td>
<td>0.303</td>
<td>-0.244**</td>
<td>5.849***</td>
<td></td>
</tr>
<tr>
<td>Crop rotation</td>
<td>-0.299</td>
<td>0.403</td>
<td>0.354</td>
<td></td>
</tr>
<tr>
<td>Manure</td>
<td>0.099**</td>
<td>0.512</td>
<td>-2.526*</td>
<td></td>
</tr>
<tr>
<td>Soil erosion control</td>
<td>0.342</td>
<td>-0.283</td>
<td>-0.023</td>
<td></td>
</tr>
<tr>
<td>Incorporation of crop residues</td>
<td>-0.915**</td>
<td>-0.216</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer &amp; compost</td>
<td></td>
<td></td>
<td></td>
<td>-4.341*</td>
</tr>
</tbody>
</table>

Notes: For brevity, non-land-management practices are not reported and only land management practices that were significant at least at p = 0.10 in one country are reported. Blank means the corresponding land-management practice was not reported in corresponding country. Irrigation and water harvesting were combined in Kenya. *, **, *** mean significant at p = 0.10, 0.05 & 0.01 respectively.

Fertilizer application has a positive and significant impact on agricultural productivity in Nigeria and Kenya but a negative impact in Uganda. The varying associations of mineral fertilizer application and crop productivity across countries could be due to the fertility status of the plots receiving fertilizer. Farmers in Nigeria and Kenya apply fertilizer on better plots, such as fine-textured and fertile soils, while farmers in Uganda are more likely to apply fertilizer on plots with moderate or severe soil erosion than on plots without soil erosion. Hence, the negative association between fertilizer application and agricultural productivity in Uganda is due to the poor fertility of the plot rather than use of fertilizer.40 This shows the potential losses that farmers are likely to experience when they use fertilizer on plots with poor soil fertility.

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40 The experience controlled for plot quality using qualitative indicators, which may not fully capture the soil quality attributes.
Specific SLWM practices have been observed to have a positive impact on agriculture productivity in some of the selected sites. Irrigation has a large and positive influence on crop productivity in Niger. This is expected and confirms the importance of land and water management practices in enhancing productivity in dry areas. Improved fallow has a positive influence on agricultural productivity in Uganda and Nigeria. Likewise, the following SLWM practices have positive influence on agricultural productivity, with the corresponding country in brackets: agroforestry (Uganda), compost (Nigeria), and soil erosion control (Kenya). Past studies in Eastern and Southern Africa have also shown the favorable impact of agroforestry on crop productivity (Sanchez et al. 1997). The other land management practices either do not have significant impact or have negative impact on agricultural productivity. The negative association of organic soil fertility management practices on agricultural productivity is due to the tendency to use them to rehabilitate degraded plots or plots with sandy soils.

For the case of Uganda, the influence of soil carbon stock on crop productivity was examined. A U-shaped relationship between crop productivity and carbon stock can be observed in figure 2.3. These results are consistent with Marenya and Barrett (2009), who found similar relationship in Kenya. The results suggest that carbon stock has a threshold that has to be attained before it increases crop yield. This also helps explain some of the negative association of crop productivity and organic soil fertility management practices observed in Uganda and other countries. It is possible that the quantities of carbon stored in the soil when using such practices have not reached the threshold required for increasing crop productivity. The results suggest that SLWM practices that sequester a large quantity of soil carbon will simultaneously increases crop productivity and contribute to climate-change mitigation. As it will be seen below, greater carbon stock also helps reduce climate-change-related production risks.

Figure 2.3: Relationship between Soil Carbon Stock and Crop Mean Yield and Variance in Uganda
The impact of SLWM practices on soil carbon

Some SLWM practices clearly contribute to increasing soil carbon. Table 2.8 shows that agroforestry, irrigation, and mineral fertilizer contribute significantly to soil carbon. As expected, agroforestry increases soil carbon by 15 percent and mineral fertilizer by 22 percent. Likewise, irrigation increases soil carbon by 35 percent. The impacts of the increase is significant at least at p = 0.05. These results are consistent with others showing that agroforestry and fertilizer use increases soil carbon (Vlek et al. 2004; Sanchez et al. 1997). The impact of irrigation on soil carbon could be due to its effect on plant growth. This is especially critical in the dry areas, where moisture is limiting. The share of plots irrigated in each zone in Uganda was 2 percent in the semi-arid zone, 13 percent in the highlands, and 6 percent in the subhumid zone.

Table 2.8: Impact of SLWM Practices on Soil Carbon

<table>
<thead>
<tr>
<th>Land-management practice</th>
<th>Regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulch &amp; manure</td>
<td>-0.260*</td>
</tr>
<tr>
<td>Mulch &amp; crop residues</td>
<td>-0.188*</td>
</tr>
<tr>
<td>Agroforestry</td>
<td>0.148***</td>
</tr>
<tr>
<td>Irrigation</td>
<td>0.345***</td>
</tr>
<tr>
<td>Mineral fertilizer</td>
<td>0.218**</td>
</tr>
</tbody>
</table>

Note: Results on double log robust regression model. For brevity, nonsignificant coefficients and nonland-management practice coefficients are not reported. *, **, *** mean significant at p = 0.10, 0.05, and 0.01, respectively.

There is a positive relationship between the rate of use of manure, tree planting, irrigation, and fertilizer and carbon storage rate. A nonparametric regression was done to determine the relationship between use of organic soil fertility management practices and soil carbon. Consistent with Cole et al. (1993), who showed a linear and positive relationship between the addition of organic matter and soil carbon, the results show a positive relationship between the rate of use of manure, tree planting, irrigation, and fertilizer (figure 2.4) and soil carbon. This highlights their carbon sequestration potential. The results also show the rate of carbon storage under different land management practices. As shown in the multivariate regression analysis, tree planting and irrigation builds soil carbon monotonically and at a faster rate right from the beginning. The carbon sequestration from fertilizer application is weak at the beginning, but the rate of soil carbon increases at higher rate with higher fertilizer rates. The results suggest the importance of soil organic management practices in building carbon stock. This is especially the case for smallholder farmers who apply small doses of fertilizer. The results further highlight the importance of integrated soil fertility management (ISFM): small farmers applying small doses of fertilizer should not depend on fertilizer to increase carbon stock.
A combination of mulch with manure or compost has a negative association with carbon stock. However, the association is only significant at $p = 0.10$. The negative association is due to the tendency to use mulch on plots with poor soil fertility and with sandy texture and not due to use of the land management practices. Overall, the results show that agroforestry, fertilizer application and irrigation or other types of land management practices are key to increasing soil carbon and therefore to being part of climate change mitigation strategies.

Returns of SLWM practices

**Methodology**

In order to fully understand incentives for the adoption of SLWM practices, crop simulation was used to determine the impacts of SLWM practices on crop yield. Then, these results were used to determine returns to SLWM practices. Results from Nigeria only are used, where crop simulation was done for an ongoing cost-benefit analysis of SLWM options (Nkonya et al. 2010). Since soil carbon is a key component for agriculture productivity and mitigation of climate change, the change in carbon was also analyzed, as different levels of land management practices are used. The yield and soil carbon stock response to a combination of the following land management
practices were analyzed: fertilizer, manure, and crop residue. The analysis was performed using a baseline treatment to determine the change in yield and carbon stock when a farmer switches from the baseline land-management practice to another practice. The common baseline land-management practice used was applying no form of organic or inorganic fertilizer but leaving 100 percent of crop residues in the field. The following crops were used in the analysis: rice, maize, cowpea, cassava, and millet, all of which are important crops in the study countries.

**Results**

Integrated soil fertility management practices are competitive on the rural labor market and are the most profitable. Maize and rice results reflect a clear pattern of the returns to SLWM practices. Figure 2.5 shows that a combination of crop residues, manure, and mineral fertilizer has the highest net benefit for rice and maize. Additionally, the average returns to a labor-day for all practices were higher than ₦300, which is the rural daily wage rate in Nigeria (figure 2.6). This suggests that land management practices included in the simulation are competitive in the rural labor market. The cost-benefit ratio was highest for land management practices that combine manure, crop residues, and mineral fertilizer. This is consistent with other socioeconomic studies, which have shown that integrated soil fertility management—land management practices that strategically integrate organic and inorganic soil fertility management practices (Vanlauwe and Giller 2006; Tittonell 2008)—are more profitable than practices using either fertilizer or organic soil fertility-management practice alone (Doraiswamy et al. 2007; Tschakert 2004; Sauer and Tchale 2007; Mekuria and Waddington, 2001).

**Figure 2.5: Net Benefit of Land Management Practices for Maize and Rice, Niger State, Nigeria**

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41 Details of the cost-benefit analysis are available upon request from authors.
However, even if they are competitive and profitable, the adoption rate of integrated soil fertility management (ISFM) practices remains low. The adoption rate of the ISFM practices is low in Nigeria, Uganda, and Niger and relatively high in Kenya only. Only 7.5 percent of plots sampled in Nigeria and 2 percent of plots in Uganda received fertilizer and manure or compost. No plot sampled in Niger received a combination of fertilizer and manure or compost. The adoption rate of ISFM was highest in Kenya, where a third of the plots received fertilizer and manure or compost. The constraints leading to the low adoption of the ISFM—despite high returns—include lack of livestock, which produces and transports manure; high labor intensity; poverty; and low capacity of extension services to promote ISFM (Benin et al. 2009, Banful et al. 2009).

Using a baseline incorporation of 100 percent of crop residue as a benchmark, the Net Present Value (NPV) was computed in order to determine the long-term returns to land management practices of each land management practice. Carbon sequestered for all management practices that incorporate crop residues, compost, or manure is high, highlighting the importance of organic soil fertility management practices in carbon sequestration. Overall, our results show that farmers using ISFM practices will realize higher profits and carbon sequestration than those using fertilizer alone or those not using fertilizer or organic matter.

In other words, among all land management practices, ISFM ones provide multiple benefits since they are more profitable, they are competitive on the labor market, they increase land productivity and soil carbon stocks—therefore improving resilience to climate variability mitigating climate change effects.

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42 For the 100 percent crop residue management practices, the benchmark treatment was 100 percent of crop residues being harvested.
Overall, SLWM practices reduce climate-related risks that lead to yield variability. Of the coefficients that were significant across all four countries, only three were positive, indicating that they increase yield variance—hence production risks (table 2.9). The other coefficients were negative, suggesting that they reduce yield variance. The results are consistent with biophysical studies showing that organic soil fertility management practices increase moisture storage capacity, which in turn addresses yield variability due to drought and other climate related changes (Bationo et al. 2007; Bationo et al. 2001).

Table 2.9: Effect of SLWM on Crop Yield Risks (deviation from conditional mean yield)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Kenya</th>
<th>Uganda</th>
<th>Niger</th>
<th>Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log (variance of value of crop productivity/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulch &amp; manure</td>
<td>-2.390</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulch &amp; crop residues</td>
<td>-3.385***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer &amp; manure</td>
<td></td>
<td>1.740</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer &amp; compost</td>
<td></td>
<td>37.850**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alley cropping</td>
<td></td>
<td>-0.132***</td>
<td>-0.078</td>
<td></td>
</tr>
<tr>
<td>Improved mulching</td>
<td>-0.015</td>
<td>3.597***</td>
<td>-0.782</td>
<td>-0.078</td>
</tr>
<tr>
<td>Improved crop rotation</td>
<td>0.444</td>
<td>-0.901*</td>
<td>-8.410**</td>
<td></td>
</tr>
<tr>
<td>Improved crop residue</td>
<td>0.714**</td>
<td>-1.167**</td>
<td></td>
<td>-33.45***</td>
</tr>
<tr>
<td>Compost</td>
<td>0.432</td>
<td>0.048</td>
<td>0.890</td>
<td></td>
</tr>
<tr>
<td>Inorganic fertility</td>
<td>-0.738**</td>
<td>-0.313</td>
<td>0.890</td>
<td></td>
</tr>
<tr>
<td>Improved fallow</td>
<td>-2.168*</td>
<td>14.950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm manure</td>
<td>0.473**</td>
<td>0.449</td>
<td>-2.100</td>
<td></td>
</tr>
<tr>
<td>Water harvesting</td>
<td>-0.264</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
<td>0.394</td>
<td>-0.011</td>
<td>-32.23***</td>
</tr>
<tr>
<td>Tree planting</td>
<td>-0.097</td>
<td>0.076</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fanya chini/soil conservation</td>
<td>0.083</td>
<td>-4.024***</td>
<td>-0.043</td>
<td></td>
</tr>
<tr>
<td>Deep tillage</td>
<td></td>
<td>0.109</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fallow strips</td>
<td></td>
<td>0.392</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trash lines</td>
<td></td>
<td>1.443**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil carbon</td>
<td></td>
<td>4.174</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil carbon squared</td>
<td></td>
<td>-0.569*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: *, **, *** mean significant at p = 0.10, 0.05, and 0.01 respectively. We controlled for other variables but only report land management practices. Results of other variables included in the model are available upon request from authors.

As discussed before, the study in Uganda also included soil carbon in the model, which shows an inverted U-shaped relationship with crop productivity. The yield variance—soil carbon is also U-shaped—suggests that lower soil carbon increases yield variability. After attaining a certain threshold, soil carbon reduces yield variability. The results suggest that carbon stocks increase yield and also reduce yield variability as shown in figure 2.1.
This section provided information on the results extracted from the data analysis. Qualitative information was analyzed vis-à-vis quantitative and econometric data to ensure strong analytical results. Information was made available through detailed description of what was observed at the site and country level; the description was strengthened by an analytical discussion on the results.

In order to ensure that key messages and findings are captured and made useful for development practitioners and policy makers, the following section focuses on key messages and their policy implications, on the basis of the data analysis done in this section.

**Main Findings from the Case Studies and Their Policy Implications**

After having discussed the results of the case studies in the previous section, this section aims at organizing the results into main findings and related policy implications from the four country case studies, looking at context-specific results but also trying to identify findings that could be expanded to other areas in Sub-Saharan Africa. Therefore, the text will respond to questions such as:

- To what extend have local farmers adopted SLWM practices that have a potential to mitigate climate-change effects and increase resilience to climate variability?
- What SLWM practices have been adopted? Why those? What are the constraints to scaling up their adoption?
- What are the drivers and conditions of adoption of SLWM practices?
- Do farmers and extension services have a clear understanding of the linkages between land management and climate change?
- Can it be proven that SLWM practices have a potential for sequestrating carbon, therefore increasing soil fertility and further mitigating climate-change effects?
- What is the role of local and national institutions in scaling up SLWM practices to improve climate-resilient development and mitigate climate-related risks?

At the end of this section, a table summarizes the main findings according to the specific objectives defined for the case studies in the “Objectives” section (pages 54–55).

**Finding #1: Impact of climate change is most evident in the semi-arid zones.**

Rainfall in the dry sites showed a declining trend, mainly with increasing variability. This is consistent with community perceptions and with the global circulation model predictions. In the wetter sites, rainfall has shown a steady pattern and in some cases an increasing trend, but it also comes with increasing overall variability.

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43 Detailed discussion for each country is presented in annex 7.
Policy implications: There is a need to develop new crop calendars and disseminate them widely in the dry areas. Current information available to farmers is still largely on short-term weather information. There is a need to develop simple extension messages on climate variability and change in each agroecological zone. This will especially help farmers to better cope with current climate variability.

Finding #2: Many SLWM practices have been adopted more for productive reasons than as a response to climate change, and the overall adoption rate of SLWM practices remains low

Although many land and water management practices are adopted for productive reasons—and not necessarily as a response to climate change, some were undertaken specifically to effectively address climate-change-related risks.45 Major strategies that farmers have been using to adapt to climate change include controlled grazing and water management, new crop varieties, change of planting dates, and to a limited extent, SLWM practices. These strategies have been shown to be effective, especially when used in combination. It is worth noting that while there is a high level of awareness of climate change and a reasonable awareness and adoption of SLWM, the actual use of SLWM for climate-change adaptation and mitigation is so far very limited.

Policy implications: Reinforcing the connection between SLWM and climate change would be an obvious and needed step to enhance the adoption of these practices, which only increase in importance under the threat of climate variability and change. While there is awareness of climate change and what is required to effectively adapt to it, it is important to bear in mind that farmer management practices are driven by incentives and the prevailing biophysical and socioeconomic conditions that are highly linked. Steps for achieving such reinforcement are to be discussed in the coming pages.

Finding #3: Major factors that drive responses to climate change and/or adoption of SLWM practices include access to rural services, gender of household head, level of household education, physical capital, land tenure, and household capital endowment

Major reasons that limited response to climate variability and change include lack of access to knowledge on the effective adaptive methods and efficient agricultural extension services. Agricultural extension services do not have a significant influence on farmers’ response to climate change because they have limited capacity to provide advisory services related to climate change issues. The assumption is that for the extension services to support farmers in adapting to climate change, they must first improve their own knowledge on climate changes issues. The major

45 The study shows that SLWM practices can have both positive and negative influence on agricultural productivity according to the context and the type of practices. A detailed explanation is provided on pages 77–78.
advisory services offered relate to improved varieties and fertilizer. Furthermore, knowledge about technologies that support climate change adaptation and mitigation in different agroecological zones is still evolving and has not yet been disseminated to advisory service providers.

**In all countries, communities reported a lack of funds** as the leading cause of non-response to climate change or of responses that do not fully address climate-change effects. In Niger, female-headed households with limited household capital endowment and those with no access to informal credit sources are least likely to respond to climate change. These results confirm the vulnerability of poor households and those with limited access to rural services.

**Households that depend heavily on agriculture are more likely to respond to climate change than those who have alternative livelihoods** (such as nonfarm activities), have higher education, or are closer to markets where there are alternative livelihood options. However, limited household capital endowment and access to rural services leads to non-response or to the limited effectiveness of responses to climate change.

**Physical capital endowment generally has a favorable influence on adoption of SLWM practices.** Overall, the results suggest that having livestock enhances the adoption of both organic and inorganic fertilizer. This suggests that there is a need to promote mixed crop and livestock production, since they can have a synergistic relationship. The results also show that irrigation is more available to larger scale farmers, which implies a high vulnerability of small farmers to climate change.

**Policy implications:** There is need to enhance the capacity of agricultural extension services to provide advisory services related to climate issues and to understand how to effectively respond to its negative effects and take advantage of its positive impacts. Supporting pluralistic extension services will also create synergies to overcome the deficiencies of public extension service providers who don’t provide adequate information about organic soil fertility management practices (Snapp et al. 2003) or climate change. The limited capacity of agricultural extension service providers to deliver advisory services on SLWM could be addressed by using pluralistic agricultural extension services, including providers with the capacity to offer advisory services on organic soil fertility management practices. Long-term training will require revisions of the college curriculum to include subjects on SLWM, integrated land and water management, and adaptation strategies to climate change. Specific extension messages on these technologies should also be developed and provided to extension service providers and to other outlets used to communicate extension messages to farmers. There is also a need to facilitate efficient agricultural inputs markets. This will require supporting private input traders in agricultural input marketing participation. Such efforts should be directed to remote areas, where both extension services and access to agricultural inputs are limited. Strengthening rural extension services is not a climate change specific recommendation but, in this context where the weaknesses of rural extension services have been highlighted vis-à-vis climate issues, this could be a win-win action that support capacity building of rural extension services for climate issues, SLWM and other issues at the same time.
One should also bear in mind that adoption SLWM practices as a way to cope with climate variability and change is only one solution among others that rural communities can consider. Hence, the level of adoption of SLWM practices should be considered in a broader context where communities can equally well adopt strategies of livelihood diversification; household splitting and circular or permanent migration in search of employment outside the local area, with remittances back home contributing to resilience, etc.

**Finding #4: Integrated land and water management practices are climate-change-smart and more profitable but their uptake is low**

The **climate-change-smart land management practices for crop production are those that integrate land and water, enhance soil carbon, and use crop varieties adapted** in the dry areas that address climatic variations. Additionally, a combination of organic and inorganic soil fertility management practices enhances resilience to climate change and increases crop productivity.

The **land management practices adopted in response to climate change show limited integrated land and water management**. There is limited of irrigation and water-harvesting practices as adaptation practices in the dry areas of Kenya, Uganda, and Niger. As a result of this weakness, communities in the semi-arid zone reported crop failure for two consecutive years even though they had adopted a number of land management practices, including mulching, tree planting, and so forth. It appears that what was lacking in the adaptation strategy was irrigation, rainwater harvesting, and other land management practices, which could have helped to offset rainfall variability, prolonged droughts, and related climatic shocks. In Nigeria however, communities have adopted the use of small-scale irrigation in the flood plains as well as early maturing crop varieties and fertilizer use. As a result, farmers reported an increase of 100 percent of irrigated crops compared to their yields in 1980. This shows that it is possible for smallholder farmers to effectively adapt to climate change when they use both land and water management practices.

In the case of poor farmers with few or no livestock, other methods of restoring and enhancing soil fertility could include the promotion of agroforestry practices. Planting leguminous trees has been shown to enhance soil fertility and increase crop yields significantly in East and Southern Africa (Sileshi et al. 2009; Sanchez et al. 1989). Unfortunately, the adoption of agroforestry practices is limited needs to be enhanced in all countries.

**Policy implications**: There is a need to address the constraints that limit the use of climate-change-smart SLWM practices. One such constraint is the low capacity of extension services to provide SLWM and climate-change advisory services. Poor resource endowment—especially livestock ownership—and poor access to rural services are the major constraints. Results also suggest that SLWM and climate-change programs specifically targeting women, the poor, and those in remote areas will have a much larger impact than generic programs. For example, the Fadama II and III programs in Nigeria, which promote small irrigation projects, have targeted women and the poor. However, there is no significant targeting of those communities in remote or dry areas, such as the pastoral communities, that are more vulnerable. Communities in remote areas have a higher carbon density, suggesting that they provide greater ecological services than communities in high market-access areas—hence the need to explore opportunities to reward them.
Finding #5: Improved crop varieties, animal breeds, and agronomic management practices are required to address climate change

Protection and planting of trees was the most frequently mentioned adaptation strategy in Kenya, Uganda, and Niger across all agroecological zones. In addition to the multiple uses of trees that help reduce vulnerability, household level data show that planting trees on crop plots increases soil carbon which effect is to simultaneously increase crop productivity and reduce climate-related production risks after attaining a certain threshold. Empirical results also show that trees are planted in plots with soil erosion in Kenya and Uganda and on sandy soils in Uganda. This suggests an additional role that trees play—prevention of soil erosion and rehabilitation of eroded soils. Of course, not all trees are the same, and in Kenya, where many of the planted trees were timber trees (for example, in woodlots), there is then a tradeoff of tree production with crop production.

Tree planting faces a number of problems—especially in the dry areas, where they are most needed. Female-headed households in Kenya were less likely to plant trees, as were households with small farms. These demonstrate two problems, one being competition for space with crops (which is also more severe for female-headed households) and the fact that women across Africa are yet to enjoy the rights to plant and manage a variety of trees. Several different systems have been developed that not only reduce competition between trees and crops but increase crop production (Sileshi et al. 2008). Moreover, trees and shrubs grown mainly for soils and fodders have found wide uptake by women, as these are seen more as “inputs” than trees by community institutions. We also find that access to extension services in Uganda is critical in enhancing tree planting. Unfortunately, advisory services on agroforestry and forestry are weak in Sub-Saharan Africa. Acquiring agroforestry planting materials also remains a challenge and will require targeted efforts to develop community-driven or private nurseries and to ensure that farmers directly benefit from planting trees.

Policy implications: Current reforestation efforts, such as the Great Green Wall and the green belt programs—both of which aimed to stop the southward spread of the Sahara Desert in West Africa—could be designed to ensure that communities directly benefit from the trees they plant. Bylaws reported in most of the communities covered in this study require only that communities plant trees and protect standing trees. The bylaws or other strategies say little about direct benefits and do not give guidance on sustainable harvesting of trees. Given the high average returns to community tree plantations and protected areas, the revision of policies and statutes to strengthen local institutions and to design incentive strategies for land users who plant trees is required.

Finding #6: Controlled grazing and water management for livestock in pastoral communities is imperative

Through new regulations, pastoral communities in East and West Africa have increased controlled grazing and in some cases, controlled access to water, both of which have not been common in the transhumant livelihoods. To ensure effective controlled grazing and access to water, pastoral communities in the semi-arid zones of the selected countries have enacted regulations. This has been done in response to the decreasing pasture and water resources, which have contributed to loss of livestock. Past top-down efforts by central governments to restrict mobility of transhumant communities were not effective (Mwangi and Ostrom 2009), but these community-based institutions offer more optimistic possibilities for effective grazing land and water management in the pastoral communities.
**Policy implications:** Controlled grazing in pastoral areas is required to address declining water and rangeland productivity. Due to the communal ownership of rangelands, communities need to have strong local institutions for the collective management of natural resources. Policy implications on strategies for enhancing local governments and local institutions are discussed in Finding #9, page 93.

**Finding #7: Improved crop varieties, animal breeds, and agronomic management practices are required to address climate change**

The use of new crop varieties is one of the most common adaptation strategies reported by communities and households. Efforts to develop crop varieties and animal breeds that could adapt to the changing biophysical environment are required. For example, the breeding programs for maize in Kenya supported by extension services and high market demand led to an 87 percent adoption rate of improved varieties (Smale et al. 2009) and high returns to research investments. Agronomic practices such as time of planting were also reported as adaptation strategies; they represent a good example of practices that respond to the adaptation gap.

**Policy implications:** Enhancing adoption of improved varieties will require increasing agricultural research investment, which is currently quite low in most Sub-Sahara African countries. Investment in research will help increase availability of crop varieties and animal breeds well-suited to the new climate patterns. Hence, it is important to make use of the existing crop varieties and animal breeds to the greatest extent possible. Under current climate change and variability, some countries experiences climatic conditions similar to those now existing in other regions or countries (climate condition in Ghana are expected to become more like those of Burkina Faso), this suggests the need to design better policies that encourage technical transfer across countries. Given the linkages among several technologies required to address climate change, it is important to use agricultural systems approach, where research on many technologies is done in an integrated way. This approach will also help to exploit the synergies among the technologies. Agricultural extension efforts (discussed above) and improved access to agricultural markets (discussed below) will also be required to improve incentives to farmers to use improved production technologies.

**Finding #8: SLWM practices are proven to have a potential for sequestrating carbon, therefore increasing soil fertility and further mitigating climate-change effects**

Organic soil fertility management practices greatly increase soil carbon, thus contributing to carbon sequestration. Results from Uganda show that farmers have significant knowledge of land management practices that increase carbon. The farmers were also able to qualitatively assess the plots with higher and lower carbon stock. Many organic soil fertility management practices significantly increase soil carbon and could be used to determine the payment in the carbon market. For example, tree planting and manure application greatly increase soil carbon. Designing monitoring and evaluation approaches that can be inexpensively applied to the assessment of trends in carbon sequestration in agricultural landscapes would therefore be the next challenge.

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46 See annex 10 for more detailed results.
The influence of soil carbon stock on crop productivity was analyzed. The results suggest that carbon stock has a threshold that has to be attained before it increases crop yield. The results suggest that SLWM practices that sequester a large quantity of soil carbon will simultaneously increase crop productivity and contribute to climate-change mitigation.

The assessment of land-use changes and their effect on carbon stock showed that there has been significant increase in cropland and a corresponding reduction of forests, bushlands, and woodlands in all countries. Such changes have led to a reduction in the soil carbon stock ranging from as low as 3 percent in the Guinea-Savannah zone in Nigeria to as high as 47 percent in the semi-arid zone of Uganda. Carbon losses were higher in the drier areas than in the humid areas, suggesting that vulnerability to climate change (and other stresses like population growth) increases even faster in the drier areas than in the more humid zones. However, it has been proved that degraded drylands have a much better capacity to bounce back than degraded humid areas, which should be taken into account while developing policies and projects.

With the exception of Niger, carbon stock losses were greater in areas with high market access than those with low market access. In order to address the unsustainable land conversion in areas with high market access, there is need to strengthen the capacity of the local communities to enact and enforce tree cutting and bush burning regulations. For example, the prohibition of bush burning in the Nigerian village of Emigginda led to a 53 percent reduction of the burnt bush in 2005 from its level in 2000. The Niger reforestation program that contributed to the lower decrease of carbon stock in high market-access areas than in low market areas also demonstrates that it is possible to reduce and reverse the faster decline of forest resources in the high market areas if reforestation programs are supported by conducive policy, as well as institutions that provide incentives for the planting and protecting of trees and the involvement of civil societies.

**Policy implications:** Forest and other natural resource policies and statutes should be revised to create incentives for local communities to sustainably manage and protect natural resources. This can be achieved if the local communities benefit directly from the natural resources. For example, deforestation could be prevented more effectively if local communities are given a role in the management and protection of forests and are made to understand the way in which these forests can benefit them. While current statutes in almost all Sub-Sahara African countries prohibit tree cutting and bush burning, they say little about the benefits that communities gain through the protection of forests, woodlands, and other natural resources. Current efforts to promote the carbon trade is one strategy that individual governments and the international community alike could use to demonstrate to communities the direct benefits of forests and, in turn, spur communities’ interest in the management and protection of forests, the planting of trees, and the increase in agricultural carbon.

Developing alternative energy sources and energy-efficient stoves are additional strategies that could be used to alleviate declining carbon stock. The NAPs and NAPAs in most countries mention this objective, but it remains one of the most poorly articulated strategies. Global fuelwood consumption has declined due to the increasing use of alternative energy sources (Arnold et al. 2003), but such reduction has been minimal in Sub-Saharan Africa. Increasing fuelwood scarcity has increased the incentive to promote social forests (Cooke et al. 2008). This provides an opportunity for the NAP and other government programs to promote tree planting—
especially in deforested areas in high market-access areas. The promotion of tree planting should also be aimed at addressing other key issues such as increasing soil erosion problems.

The promotion of nonfarm activities that do not involve tree cutting could reduce pressure on land. This is especially critical in areas with high market access and high population density where pressure on land is high. Investment in rural credit services, formal education, rural electrification, and the improvement of rural roads and other forms of communication infrastructure and institutions have been shown to promote non-farm activities (Haggblade et al. 2007). Rural vocation training will also enhance nonfarm activities. This should be targeted to the youth so that they can develop vocational skills. The targeting of such vocational training to the agricultural sector would greatly strengthen the linkage between agriculture and nonfarm activities.

Finding #9: Strong local institutions and farmer groups are required to collectively manage natural resources and effectively respond to climate change

Communities take collective action in order to address resource changes generated by climate change and other biophysical and socioeconomic changes. These initiatives provide an opportunity for the NAPAs to take advantage of community awareness to address the issues related to natural resources affected by climate change. Communities realize the weaknesses of local institutions to enact and enforce compliance with natural resources management rules. As pointed out in the adaptation literature, community-level actions are required to enhance collective adaptation (Aalst et al. 2008; Ayers and Forsyth 2009; Huq and Reid 2007).

This study observed the average number of SLWM byelaws enacted per community in each country strongly reflects the performance of decentralization (figure 2.7) and underscores the impact of national level statutes and policies on decentralization on community level capacity to manage natural resources.

Figure 2.7: Number of SLWM Bylaws Enacted in Response to Climate Change and Other Changes in the Past 30 Years

![Bar chart showing the number of SLWM bylaws enacted in response to climate change and other changes in the past 30 years.](image)

Source: Overall decentralization (Ndegwa and Levy 2004); # of SLWM byelaws/community (Focus group discussion of this study). Overall decentralization includes 12 performance and structural indicators of decentralization (Ndegwa and Levy, 2004. The larger the index, the greater the performance of decentralization.
Increasing the capacity of local communities to collectively manage rangelands and water resources will require the involvement of civil society organizations with a focus on natural resources management. These have been shown to increase the capacity of local institutions to enact bylaws (Berkes 2004; Nkonya et al. 2008; Lind and Cappon 2001). In Niger and Uganda, which have prepared their NAPAs, increasing the capacity of local communities to better address climate change challenges is not a strong component. Even though NAPAs in both countries mention the need to strengthen the capacity of local institutions to enhance adaptation to climate change, there is little resource allocation in this area in both Niger and Uganda. This is one of the policy weaknesses that require significant attention in policy formulation and resource allocation.

In Kenya, current efforts to strengthen local governments should pay particular attention to community-level natural resource management. The large presence of civil society organizations in Kenya provides ample opportunity to strengthen local communities to better manage natural resources. The decentralization structure in Uganda and Nigeria provide significant empowerment of local governments to enact bylaws and regulations for natural resource management, but their capacity remains low, a problem that is prevalent in most countries in Sub-Saharan Africa. The capacity of local governments to manage natural resources is especially low in both countries. Even though Niger provides one of the shining examples of local community tree planting and protection programs in Sub-Saharan Africa, its decentralization structure is one of the weakest in Sub-Saharan Africa (Ndegwa and Levy 2004).

Collective action through group membership has often been found to provide farmers greater access to information, whether through extension, NGOs, projects, or other farmers. This appears to be the case given the range of SLWM practices that have been catalyzed by group participation. We find that membership in production groups has a favorable impact on the adoption of a number of SLWM practices, while membership in marketing groups had a more mixed effect, depending on the country. The results highlight the focus of the different groups and the need to foster different groups in order to provide a variety of services that farmers need in their economic activities. The results also highlight the weakness of the groups to provide support to their members to increase their resilience capacity.

Policy implications: In countries with weak decentralization (for example, Kenya and Niger), there is a need to revise the statutes such that the local governments and communities have the legal right to pass local natural resources management bylaws. Experience in Sub-Saharan Africa and elsewhere has highlighted the weak capacity of local communities to collectively manage natural resources and, in turn, the extent to which NGOs and other civil societies with a focus on agricultural and environment enhance such capacity. This suggests the need to give civil societies a greater role in enhancing adaptation to climate change. For example, building partnerships with civil societies to implement NAPAs would be critical. Strengthening farmer groups will also enhance the collective management of natural resources. As is the case for local institutions, NGOs and other civil society efforts are required to support the development of farmer groups.
Also, the results show that some statutes for natural resources management are formed across sectors, eventually creating conflicting rules that create implementation challenges. This calls for the coordination of different ministries and departments within the government system, in addition to coordination with other programs that support the development and management of natural resources and the environment.

**Finding #10: National policies and strategies play a critical role in the level of the adoption of SLWM practices**

The four case study countries each offer success stories of policies that enhance adaptation strategies and underscore the impact of policies on adoption of SLWM. While Kenya shows policies that have strongly supported agricultural research and development and an agricultural market environment that has successfully offered incentives to farmers to adopt SLWM, neighboring Uganda has implemented a local government decentralization and land tenure system that has been one key to the development of stronger local institutions that offer opportunities for improved community-based resources management. In Kenya, the adoption of management practices that combine both fertilizer and organic soil fertility management practices was highest, highlighting the impact of the strong support for agricultural research and development, strong agricultural markets and the active participation of NGOs supporting agriculture. Underscoring the impact of highly decentralized government, Uganda communities reported the largest number of byelaws enacted in response to climate change. The high adoption rates of SLWM in Kenya—despite its weak decentralization—reflect the importance of multi-faceted approaches to enhancing adaptation to climate change. In West Africa, Nigeria has long supported irrigation development and recently focused on small-scale irrigation that has increased agricultural production and reduced production risks in the drier northern states. Even though such irrigation schemes were not implemented as part of adaptation to climate change, they have helped farmers to adapt well to such change. Growth of irrigation in Nigeria in the past 10 years has been among the fastest in Africa and reflects the outcomes of the long-term policy on irrigation. Niger also offers a good example of tree planting and protection, which was successful due to the Rural Code that gave land users the right to own benefits from trees on their farms. The farmer-managed natural regeneration (FMNR) tree planting and protection program in Niger was implemented following the prolonged droughts in the 1970s and 1980s (Reij et al. 2009). The Rural Code and other institutional reforms allowed communities to own and benefit from trees by harvesting fuelwood, fodder and nontimber tree products. Such efforts have been successful in Niger thanks to a strong collaboration between government and civil societies that provided significant technical support and policies that promoted both the planting of trees and the direct benefits created by the planting of those trees. The weak tree planting and protection in neighboring northern Nigeria and the successful tree program in Niger further underscores the influence of policies and how the implementation of each policy influenced the adoption of SLWM practices and the response to climate change challenges in general. The successful policies and programs observed in this study should be implemented and scaled up in each country.
For each of the previous key findings, there is variety of policy implications. Also, these policies are implemented across several ministries and sectors. A variety of strategies can be used to enhance and increase resilience to climate variability. These strategies can be effectively achieved if countries design and implement specific policies and strategies (for example, NAPAs). Given the wide variety of implementing sectors, there is a need for such policies and strategies to be harmonized and well-aligned with the other development programs. Intersectoral dialogues are often held, but these processes are rarely empowering and the bulk of planning is still done at the sectoral level.

There is also a need to align such policies and strategies with long-term public investment. Currently, public expenditure on agriculture and natural resources in Sub-Saharan Africa is low, raising concerns about the governments’ commitment to agriculture and natural resources, upon which the livelihoods of the rural poor heavily depend. Although Sub-Saharan Africa’s governments had pledged that 10 percent of their budgets would be devoted to agriculture, only eight countries (Burkina Faso, Ethiopia, Mali, Malawi, Ghana, Niger, Senegal and Zimbabwe) have achieved or surpassed this target (Fan, et al., 2009).

As demonstrated in the case of fertilizer use in Africa, incentives for investment in smallholder agriculture are so low that significant support in credit and/or cost sharing is required for any short-term impact. There are many justifiable reasons for supporting SLWM, such as the environmental services they produce or the stewardship of resources for future generations they elicit. Additionally, funds are becoming increasingly available. But governments must lead and indicate a strong demand for this to happen. This calls for much more than the approval of projects—for a long-term commitment to programs that will have impact at scale. One such program already at work in the countries studied here is Nigeria’s FADAMA program. The NEPAD Planning and Coordinating Agency and the regional economic communities have been building their capacity in both climate change and SLWM and would be expected to play key roles in supporting national government planning processes and in securing financing the resulting programs.

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**Box 4: Highlights on Livestock-related Policies**

The current low productivity of livestock in Sub-Saharan Africa—despite the increasing demand for livestock products and their role in achieving SLM practices and food security—requires concerted efforts to give the sector more attention as countries design policies and strategies for the adaptation to and mitigation of climate change. This is especially important given that the livestock sector offers a resilient option in the adaptation to climate change in the semi-arid zones of all four countries and also increases the adoption of organic soil fertility-management practices. Hence, promotion of mixed crop-livestock systems is required to achieve cost-effective SLWM. For this to be a reality among the pastoral communities, extension services are required to support crop production, since the pastoralists have limited experience in crop production. Likewise, crop farmers with no livestock will require support of livestock management.
Finding #11: The main conditions for scaling up SLWM practices that have cobenefits for climate resilience are the long-term commitment to building strong pluralistic agricultural and environmental advisory services, credit services, and efficient rural markets

Critical SLWM practices in all countries are being adopted at a slow pace. Thus, there is a need for public investment to support awareness creation and the technological support required for these often knowledge-intensive practices. The relative success of Kenya in promoting soil conservation and fertility measures suggests that large-scale extension programs can be effective, but that they require long-term commitment, something that is absent in the common practice of project funding. The long-term extension project in Kenya was also supported by a large number of NGOs active in land management. These organizations not only complement an extension program but inject a degree of innovation that can lead to the generation of improved SLWM practices. (Push-pull, mbili- mbili, fertilizer microdosing and packaging, biomass transfer, and manure management are all examples of recent innovations in Kenya crop and soil management.) Facilitating the linkages among all development organizations, and with research organizations, would serve to enhance the scaling up process.

Some SLWM practices may require special attention. The lack of irrigation has been highlighted in all the countries. Irrigation is touted as an essential ingredient for increased productivity and for climate-change adaptation in Africa by numerous organizations, including NEPAD Planning and Coordinating Agency. Irrigation faces many of the same challenges as other SLWM techniques but also brings in the element of the need for capital investment (for example, in water storage or distribution). Efforts to increase credit for irrigation investment are of high priority. The payoffs to irrigation would be large. Not only would irrigation enhance productivity and reduce yield variation on its own, but experiences in other regions show that it induces further investment by farmers, whether in high-value crops, in improved seed, in fertilizer, or in other SLWM practices. A good example is the community-driven development program in the lowland plains (Fadama) in Nigeria, which promoted small-scale irrigation and other rural development activities. The Fadama II project had a large impact on household income and agricultural productivity in the pilot states and has been scaled up to all states in Nigeria. Unfortunately, there are no good examples of major scaling up of efforts in Kenya, Uganda, and Niger. The Nigerian focus on promoting small-scale irrigation serves as a good example of successful programs that could help address climate-change risks and ensure food security to rural communities. This is especially true of the communities in the semi-arid areas, where the impact of climate change is most severe.
<table>
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<tr>
<th>Findings</th>
<th>Policy implications</th>
<th>Address Question #1</th>
<th>Address Question #2</th>
<th>Address Question #3</th>
<th>Address Question #4</th>
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<tbody>
<tr>
<td>Impact of climate change is most evident in the semi-arid zones.</td>
<td>• Develop new crop calendars and disseminate them widely in the dry areas • Develop simple extension messages on climate variability and change for each agroecological zone</td>
<td>✓</td>
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<td>Many SLWM practices have been adopted more for productive reasons than as a response to climate change, and the overall adoption rate of SLWM practices remains low.</td>
<td>• Reinforcing the connection between SLWM and climate change through capacity building and knowledge dissemination</td>
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<tr>
<td>Major factors that drive responses to climate change and/or adoption of SLWM practices include access to rural services, gender of household head, level of household education, physical capital, land tenure, and household capital endowment.</td>
<td>• Enhance the capacity of agricultural extension services • Supporting pluralistic extension services • Long-term training will require revisions of the college curriculum • Facilitate efficient agricultural inputs markets</td>
<td></td>
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<tr>
<td>Integrated land and water management practices are climate-change-smart and more profitable but their uptake is low.</td>
<td>• Address the constraints that limit the use of climate-change-smart SLWM practices • SLWM and climate-change programs specifically targeting women, the poor, and those in remote areas will have a much larger impact</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Tree planting is a win-win-win strategy: it increases crop productivity, reduces climate-related production risks, and sequesters carbon.</td>
<td>• Current reforestation efforts, such as the Great Green Wall and the green belt programs could be designed to ensure that communities directly benefit from the trees they plant • Revise policies and statutes to strengthen local institutions and design incentive strategies for land users to plant trees and/or avoid deforestation</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>Controlled grazing and water management for livestock in pastoral communities is imperative.</td>
<td>• Due to the communal ownership of rangelands, communities need to have strong local institutions for the collective management of natural resources.</td>
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<tr>
<td>Improved crop varieties, animal breeds, and agronomic management practices are required to address climate change challenges.</td>
<td>• Increase agricultural research investment • Use agricultural systems approach, where research on many technologies is done in an integrated way.</td>
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<td>Findings</td>
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| SLWM practices are proven to have a potential for sequestering carbon, therefore increasing soil fertility and further mitigating climate-change effects. | • Forest and other natural resource policies and statutes should be revised to create incentives for local communities to sustainably manage and protect natural resources.  
• Developing alternative energy sources and energy-efficient stoves are additional strategies that could be used to alleviate declining carbon stock.                                      |                      |                      |                      | ✓                    |
| Strong local institutions and farmer groups are required to collectively manage natural resources and effectively respond to climate change. | • In countries with weak decentralization, revise the statutes such that the local governments and communities have the legal right to pass local natural resource management bylaws.  
• Give civil societies a greater role to increase rural livelihoods’ resilience to climate variability  
• Strengthen farmer groups to enhance the collective management of natural resources  
• Ensure coordination of different ministries and departments within the government system |                      |                      |                      | ✓                    |
| National policies and strategies play a critical role in the level of the adoption of SLWM practices. | N/A                                                                                                                                                                                                                 |                      |                      |                      | ✓                    |
| The main conditions for scaling up SLWM for climate-change adaptation and mitigation are the long-term commitment to building strong pluralistic agricultural and environmental advisory services, credit services, and efficient rural markets | • Large-scale extension programs can be effective, but they require long-term commitment  
• Efforts to increase credit for irrigation investment are of high priority.                                                                                           |                      |                      |                      | ✓                    |

- Question #1 raised in the “Objectives” section: What types, modalities, and conditions of SLWM investments are the most relevant in terms of adaptation to current variability and future climate change?
- Question #2 raised in the “Objectives” section: What context-specific actions can improve the contribution of SLWM investments to adaptation and mitigation, considering improved information and institutions as well as policy, program, and regulatory instruments?
- Question #3 raised in the “Objectives” section: What are the best synergies between water and land resource management to generate mitigation and adaptation benefits?
- Question #4 raised in the “Objectives” section: Questions related to the soil carbon work which aims to explore how to develop cost-effective measures for measuring carbon sequestration/storage in soils and in vegetation.
MAIN RECOMMENDATIONS

Based on the results, findings, and policy implications summarized in the previous sections, some recommendations can be provided for Bank TTLs, development practitioners and policy makers to take into account while designing new projects or policies related to the land and climate nexus. The proposed recommendations focus on providing answers to the following questions:

- What SLWM practices should we promote to scale-up climate resilient development in the four selected countries?
- How can we strengthen technical knowledge and local capacities, especially for extension services?
- What activities should we undertake to better allow farmers to access market and rural services?
- How do we strengthen natural resources management capacity of local institutions so they will be able to implement SLWM climate-resilient activities?
- What national policies and strategies need to be either strengthened or developed to support the scaling up of SLWM practices and investments at the country level?

Recommendation #1: Promote the use of SLWM practices that have a strong potential both to increase resilience to climate variability and mitigate the effects of climate change.\(^{47}\)

Promotion of SLWM practices that increase carbon requires efforts to design low-cost methods of measuring, reporting and verification (MRV) of carbon stock in order to reward carbon sequestering land users. However, integrated monitoring approach is required to ensure that other outcomes (e.g., water use; productivity, household income, etc) are taken into account. To lower MRV costs, some action research is required to determine how local actors could be involved in the MRV. Such efforts will make current initiatives of agricultural carbon marketing feasible.

Promotion of SLWM practices will also require concerted efforts among ministries of agriculture, livestock, water, forestry, environment, and natural resources. There is need for alignment of programs that seek complementarity and synergy among the sectors rather than competition. The ministries of agriculture will be critical in implementation, as they house the main extension programs and the bulk of field staff. There is further need to strengthen collaborations with and among the often numerous projects implemented by NGOs. This is especially important for supporting broader efforts to capture adaptation and mitigation co-benefits within the SLWM framework, which requires further action research and focuses on coordinated policy

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\(^{47}\) Such practices include diversified agricultural systems, mixed production of crop and livestock systems, integrated land and water management, improved livestock feeding systems in the drylands, irrigation and water harvesting practices, integrated soil fertility-management practices, protection and planting of multipurpose trees and other vegetation, use of crop varieties and animal breeds well suited to climate change, and updating planting calendars at the community level.
interventions. This is all necessary to achieve impact at scale, which must happen. However, this is not to advocate for top-down approaches. Indeed, SLWM is highly context specific and requires skillful mechanisms to support community-driven plans. There is no way around the development of capacity in SLWM at local levels in order to support the development and dissemination of these relatively knowledge intensive innovations.

As already noted, SLWM may be adopted by rural communities for other reasons than related to climate change. Therefore, those who are responsible for the design and support of interventions at country level should understand that awareness of climate change in itself may be an insufficient motivator for adoption of SLWM by community level actors; there is a necessity to stress the multiple benefits of SLWM for scaling-up such practices at the local level.

**Recommendation #2: Strengthen and disseminate technical knowledge.**

Technical knowledge needs are many, but in relation to climate-change adaptation and mitigation in rural communities, this study has identified the importance of information dissemination and extension, as well its current weak state. Extension systems will have to play an important role as the key interface with communities. Furthermore, there needs to be better articulation and integration between local traditional knowledge and professional knowledge systems, as well as focus on the SWLM as part of wider livelihood context. For this to happen, however, there needs to be much greater integration of climate-change-related research and experiences from learning by doing into national research and policy agendas in order to produce nationally and locally relevant results. This will require more formal linkages between meteorological departments with agricultural research systems as well as wider platform for exchange and sharing of information and knowledge between different levels of institutions and among communities. Finally, the strengthening of linkages among research, extension, and policy is essential.

**Recommendation #3: Improve access to market through better marketing of rural products and services.**

Scaling up SLWM investments requires that rural markets function well. Chief among these are input markets for items such as fertilizer, crops and trees, or equipment for irrigation. Since the retail input sector consists largely of diversified small businesses, scaling-up is likely to involve building the capacity of existing rural businesses to understand the potential of different products. On the demand side, there is need to improve credit and other financing systems for agricultural inputs. Such systems are poorly supported by both formal and informal institutions and programs. Programs to insure loans taken by farmers in case of poor weather should also be tested where potential impact is large. In addition, SLWM has been shown to deliver environmental services for society, chief among them carbon sequestration and watershed protection, and this should provide additional economic potential. Several projects in Africa are pursuing the opportunities for communities to be compensated for these services in informal markets. These initiatives need wider testing, which requires support from national governments. In the case of carbon sequestration, for example, if successful models for rural carbon storage and measurement can be developed, it is more likely this will be recognized in formal carbon financing protocols.
Recommendation #4: Strengthen local natural resources management institutions.

The strengthening of local institutions, both formal and informal, is vital to sustainable success in SLWM. The role of informal institutions and social networks is essential for local ownership and implementing best local environmental practices. There are some encouraging examples of new bylaws protecting local resources. For this to happen, actions are needed in devolution of responsibility, along with capacity building and an ability to generate finances. The capacity-building action requires considerable resources and is a long-term effort that requires commitment, adequately designed measures (workshops, publications, radio) and resources. Besides community resources, landscape resource management requires urgent attention as competition over resources continues to be a key cause of conflict and violence in rural Africa. This can only pose new challenges as well as opportunities for the climate change agenda. Governance systems at landscape level thus also need to be developed and strengthened to better manage landscape resources such as rangelands, woodlands, and water.

Recommendation #5: Build strong national policies that support the scaling up of SLWM in Sub-Saharan Africa.

None of the recommendations can be implemented without serious policy reforms at the national level. The first shift needs to be a long-term commitment to agriculture and rural communities. Although governments had pledged that 10 percent of their budgets would be devoted to agriculture, few have met their pledges. Second, there is urgent need to formulate mitigation and adaptation policies and strategies and to commit resources to implement such policies and strategies on a long-term basis. Climate change requires appropriate political and strategic response that goes beyond environmental degradation and loss of agricultural productivity; current knowledge on the scope of climate change should be integrated into a whole range of initiatives from national to local levels. There is also an urgent need to solve problems of climate change, natural resources management, and agriculture in a more coordinated and collaborative manner. Intersectoral dialogues are often held, but such processes are generally not empowered, and the bulk of planning is still done at sectoral level. Decentralization can help, but it can also lead to the marginalization of longer term SLWM over urgent needs in social services. There are many justifiable reasons for supporting SLWM, such as the environmental services they produce or the stewardship of resources for future generations. There is need for more vertical integration between facilitating policies and public programs, and local-level initiatives, with a view to creating a favorable environment for the spread of local initiatives. Funds are now also becoming increasingly available. But governments must lead and indicate a strong demand for this to happen. This requires much more than approval of projects; it requires a long-term commitment to programs that will have impact at scale. The NEPAD Planning and Coordinating Agency and the regional economic communities have been building their capacity in both climate change and SLWM and would be expected to play key roles in supporting national government planning processes and in securing financing for the resulting programs.
SUMMARY OF CONTEXT-SPECIFIC POLICY RECOMMENDATIONS AND RESPONSIBILITY FOR IMPLEMENTATION

Table 2.11 provides a summary of context-specific policy recommendations, briefly stating the government institutions responsible for implementation, the time frame of implementation, and the location of implementation. In the responsibility column, donors are not mentioned due to their large number for each of the government institution in each country. The private sector, farmers, and civil society organizations are de facto considered to have a role to play in each of the recommendations.

The proposed actions are classified according to the five main recommendations. They either address the adaptation gap or the adaptation deficit, sometimes both of them. Most of the recommendations provided below respond to the adaptation deficit. The ones that mainly respond to the adaptation gap are recommendations #7, 8, 10, 16, 17, 20.
Table 2.11: Context-specific Recommendations

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>WHO$^1$</th>
<th>How</th>
<th>When</th>
<th>Where</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promote the use of SLWM practices that have a strong potential for climate adaptation and mitigation.</td>
<td></td>
<td>• Improve livestock productivity and marketing</td>
<td>Medium-term and continuous</td>
<td>Pastoral communities in semi-arid areas and in subhumid areas with predominantly crop production</td>
</tr>
<tr>
<td>1. Promote mixed production of crop and livestock systems</td>
<td>ML, MA, MNR, MW</td>
<td>• Promote drought tolerant crops in predominantly pastoral dry areas</td>
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<td></td>
<td></td>
<td>• Promote significantly manure application</td>
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<tr>
<td>2. Develop and promote integrated land and water management practices</td>
<td>Agricultural extension, research, civil societies with focus on agriculture</td>
<td>• Strengthen Research, Development and Extension (RD&amp;E) in integrated land and water management practices that enhance productivity and reduce production risks</td>
<td>Short-term and continuous</td>
<td>All countries and all zones, especially in remote and poor areas</td>
</tr>
<tr>
<td>3. Develop and promote integrated soil fertility management practices</td>
<td>Agricultural extension, research, civil societies with focus on agriculture</td>
<td>• Strengthen Research, Development and Extension (RD&amp;E) in integrated soil fertility management practices that enhance productivity &amp; reduce production risks</td>
<td>Short-term and continuous</td>
<td>All countries and all zones, especially in remote and poor areas</td>
</tr>
<tr>
<td>4. Develop and promote improved livestock feeding systems in the drylands</td>
<td>ML, MA, MNR, MLG</td>
<td>• Strengthen RD&amp;E services of controlled grazing, communal rangeland management;</td>
<td>Short-term and continuous</td>
<td>Drylands: for example, northern Kenya, Uganda, Nigeria, and Niger</td>
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<tr>
<td></td>
<td></td>
<td>• Enhance communities to enact and enforce bush-burning byelaws, rotational grazing, tree cutting and other regulations</td>
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</tr>
<tr>
<td>5. Invest in irrigation and water-harvesting practices</td>
<td>MW, MA, ML, MNR, MLG, Poverty reduction &amp; rural development programs</td>
<td>• Promote community-driven small scale irrigation programs (e.g., Fadama irrigation in Nigeria and other countries);</td>
<td>Short-term and long-term investment</td>
<td>All countries, with focus on dry areas where impact of climate change is more severe.</td>
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<tr>
<td></td>
<td></td>
<td>• Ensure access to credit for acquiring irrigation pumps and other equipment.</td>
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<tr>
<td>6. Invest and promote community-driven development small-scale and medium-scale irrigation</td>
<td>MW, MA, ME, MLG, MTI, and private sector</td>
<td>• Promote water user groups with technical support for water and land management</td>
<td>Short-term and continuous</td>
<td>Dry areas or humid areas for production during dry seasons. However, irrigation should not be promoted if it compromises other water needs with higher priority, e.g., drinking water.</td>
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<td></td>
<td></td>
<td>• Promote improved land management that increases water use efficiency (e.g., mulching, carbon-enhancing practices, etc.)</td>
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<tr>
<td></td>
<td></td>
<td>• Enhance credit access to support irrigation investment</td>
<td></td>
<td></td>
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<tr>
<td>Recommendations</td>
<td>Who</td>
<td>How</td>
<td>When</td>
<td>Where</td>
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</tbody>
</table>
| 7. Revise and widely promote planting calendars | Meteorological department, MA, RD&E, mass media | • Conduct location-specific research on new rainfall and temperature long-term changes  
• Develop new agriculture calendars that consider these changes | Short-term and long-term | All AEZ, especially the dry zones where climate change has shown significant change |
| 8. Develop and promote use of crop varieties and animal breeds well suited to climate change | MA, ML, MLG, international research institutions, universities, extension services, and civil societies with focus on agriculture and environment | • Develop crop varieties and livestock breeds well-adapted to new climate-related biophysical characteristics | Medium-term to long-term | All countries and AEZ |
| 9. Develop and promote multipurpose trees | MNR, MA, ML, ME, MLG, MW, local and international RD&E institutions, and universities | • Develop and promote community nurseries, and extension services on agroforestry;  
• Enhance ownership of trees so that land users can directly benefit from tree planting & protection | Medium-term and continuous | All countries, and AEZ, especially where land clearing has been severe, e.g., high market-access areas |
| 10. More policy and action oriented research on capturing potential co-benefits of adaptation and mitigation | MNR, MA, ML, RD&E institutions, MLG, MTI | • Awareness raising and capacity building both at local and national levels on carbon finance and other mechanisms for carbon sequestration in agricultural landscapes | Medium and long term | All countries |
| **Strengthen and disseminate technical knowledge.** | | | | |
| 11. Strengthen capacity of agricultural extension services to provide climate-change-smart SLWM practices | MA, MNR, ML, MLG & ME | • Develop short-term and long-term training;  
• Develop extension messages on how to adapt to climate change | Short, medium & long-term | All countries |
<p>| 12. Promote pluralistic agricultural extension services | MA, MNR, ML, MW, MLG &amp; ME | • Strengthen and coordinate provision of agricultural extension by NGOs and other providers with comparative advantage of providing various SLWM technologies, climate change, agroforestry, and other climate-change-smart SLWM practices | Short-term and continuous | All countries with predominantly traditional public extension services (e.g., Niger) |</p>
<table>
<thead>
<tr>
<th><strong>RECOMMENDATIONS</strong></th>
<th><strong>WHO</strong></th>
<th><strong>HOW</strong></th>
<th><strong>WHEN</strong></th>
<th><strong>WHERE</strong></th>
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</thead>
<tbody>
<tr>
<td>13. Reinforcing the linkages between local and national levels for information</td>
<td>MA, MNR, ML, ME, MLG</td>
<td>• Facilitate the creation of platforms for sharing best practices as well as integration</td>
<td>Short-term and</td>
<td>All countries</td>
</tr>
<tr>
<td>sharing and exchange of knowledge</td>
<td></td>
<td>of local traditional knowledge, both vertically and horizontally</td>
<td>continuous</td>
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<tr>
<td>Improve access to market through better marketing of rural products and services.</td>
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<td>14. Improve input marketing systems</td>
<td>MTI, MA, ML, MTC, private sector</td>
<td>• Facilitate more efficient input marketing systems</td>
<td>Short-term and</td>
<td>All countries, with special</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>continuous</td>
<td>focus on remote areas in</td>
</tr>
<tr>
<td>Strengthen local natural resource management institutions.</td>
<td>MLG, MA, ML, ME, MW, MNR, NGOs, and civil societies organizations</td>
<td>• Facilitate operation of NGOs and civil society groups to enhance capacity of local</td>
<td>Short-term to</td>
<td>All countries, with special</td>
</tr>
<tr>
<td></td>
<td></td>
<td>governments and institutions to enact and enforce natural resource management byelaws;</td>
<td>long-term</td>
<td>focus on Kenya and others</td>
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<td></td>
<td></td>
<td>• Revise statutes to give legal rights to local governments and communities to pass and</td>
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<td>with weak decentralization</td>
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<tr>
<td></td>
<td></td>
<td>enforce byelaws</td>
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<tr>
<td>Build strong national policies that support the scaling up of SLWM in Sub-Saharan</td>
<td>ME, MA, ML, MW, MLG, and parliament</td>
<td>• Formulate or convert formulated (short-term) National Adaptation Programmes for Action</td>
<td>Short-term and</td>
<td>Kenya and Nigeria—New NAPA</td>
</tr>
<tr>
<td>Africa.</td>
<td></td>
<td>(NAPAs) to long-term programmatic investments that are well aligned with stated adaptation</td>
<td>long-term updates</td>
<td>Uganda and Niger—update to</td>
</tr>
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<td></td>
<td></td>
<td>policies and strategies;</td>
<td>to incorporate</td>
<td>current NAPAs to long-term</td>
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<td></td>
<td></td>
<td>• Incorporate ministry of local governments</td>
<td>changes</td>
<td>programs and address its</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>weaknesses</td>
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<tr>
<td>16. Formulate policies and strategies specific on adaptation to and</td>
<td>All ministries but with focus on MA, ML, ML, ME, MLG, and development</td>
<td>• Form an effective coordinating committee to oversee integrated approach</td>
<td>Medium-term and</td>
<td>All countries</td>
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<td>mitigation of climate change</td>
<td>partners</td>
<td></td>
<td>long-term</td>
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<tr>
<td>17. Harmonize and integrate adaptation to and mitigation of climate change</td>
<td>All government ministries, development partners and</td>
<td>• Formulate or convert formulated (short-term) National Adaptation Programmes for Action</td>
<td></td>
<td></td>
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<tr>
<td>policies and investments with other rural development programs</td>
<td></td>
<td>(NAPAs) to long-term programmatic investments that are well aligned with stated adaptation</td>
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<tr>
<td></td>
<td></td>
<td>policies and strategies;</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Incorporate ministry of local governments</td>
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<tr>
<td>18. Develop long-term and greater investment in agricultural</td>
<td></td>
<td>• Long-term integrated planning and investment to ensure all relevant ministries and</td>
<td>Long-term and</td>
<td>All countries, especially</td>
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<td></td>
<td></td>
<td>departments harmonize efforts for</td>
<td>continuous</td>
<td>those spending less than 10</td>
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<td>percent of 10 percent of</td>
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1. The list of WHO includes different agencies and organizations.
<table>
<thead>
<tr>
<th>RECOMMENDATIONS</th>
<th>WHO</th>
<th>HOW</th>
<th>WHEN</th>
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</tr>
</thead>
<tbody>
<tr>
<td>development and natural resource management</td>
<td>local governments</td>
<td>enhancing adaptation to climate change</td>
<td>Short-term and continuous</td>
<td>budget on agriculture and natural resources</td>
</tr>
</tbody>
</table>
| 19. Promote diversification of rural livelihoods with a view to creating a favorable environment for the spread of local initiatives | MTI, MTC, MLG, MA, ML, MW, MF, private sector, and NGOs | • Promote rural non-farm activities by:  
  • increasing access to rural credit services, formal education, rural electrification, and  
  • improving rural roads and other forms of communication infrastructure and institutions & vocational training targeting the youth | Short-term and continuous | All countries but with focus in areas with high population pressure and remote areas. |
| 20. Programs for enhancing adaptation to climate change (discussed above) should target women and the poor | MWC, MTI, MTC, MLG, MA, ML, MW, MF, private sector, and NGOs | • Promote and support adoption of programs for enhancing adaptation to climate change that target women and the poor | Short-term and continuous | All countries with focus in areas with severe poverty (e.g., northern Kenya, Uganda, Nigeria, etc.). |

1Notes and acronyms: Since country ministries in Sub-Saharan Africa are structured differently from each other, the table uses ministry names that broadly cover several sectors. MA = ministry of agriculture (crops), ME = ministry of environment (environment), MNR = ministry of natural resources (including lands and forestry), ML = ministry of livestock (livestock & fisheries), MW = ministry of water, MLG = ministry of local governments (including cooperatives); MTI = ministry of trade and industries, MTC = ministry of transportation & communication.
CONCLUSION

Despite the close linkage between land degradation processes and vulnerability to climate variability and change, evidence of the role of SLWM for increasing resilience of rural communities to climate variability and mitigating the effects of climate change in Sub-Saharan Africa was rather scattered to date, and more importantly, there was very little practical guidance and policy recommendations available for development practitioners and policy makers.

In such context, the objective of this work was to improve practical knowledge resources available to Sub-Saharan African countries, regional institutions and development practitioners from the World Bank and other partner institutions to make informed decisions (i) about the risks posed by climate variability and change to land resource dependent livelihoods in Sub-Saharan Africa, and (ii) about what sustainable land-management approaches and practices are best suited for meeting development objectives while also addressing the challenge posed by climate-change adaptation and mitigation.

Several analytical and research activities have been carried out under this work and the following has been achieved (i) generating or consolidating the existing body of knowledge on the land and climate nexus, and combining these various knowledge inputs in order to come up with practical guidance made available through specific tools; (ii) testing this practical guidance in four countries through case studies which generated context specific operational and policy recommendations in terms of SLWM approaches and practices which are best suited to improve food security and economic prospects while reducing climate related risks and greenhouse gas emissions.

The findings and recommendations of this work have been and will continue to be disseminated in order to promote the scaling-up of SLWM in Sub-Saharan Africa in support of the climate-change adaptation and mitigation agenda.

As a result, both analytical and practical knowledge outputs are made available for Bank TTLs and client countries to better take into account climate variability and change in their development projects and consider SLWM as a relevant way to improve rural livelihoods’ resilience to climate risks in Sub-Saharan Africa. The main outputs of this ESW are:

- case studies country reports and a synthesis report including policy recommendations,
- a discussion paper for policy makers on the role of SLWM to adapt to and mitigate climate change,
- a resource guide for TTLs and development practitioners to assess the potential of SLWM practices for climate adaptation and mitigation,
- a database of publications and other resources related to the land and climate nexus as a “go to” information center for development practitioners and policy makers,
• a web-based Africa Land & Climate Portal to provide practical guidance through: (i) the visualization of climate, land and development data, (ii) a map of actual and projected hazard exposure vis-à-vis climate change and land degradation, and (iii) a database of SLWM best management practices,

• a series of short films to be used as advocacy and awareness rising tools by development practitioners, and by WBI as part of training programs.

These reports and tools are available on line48 or on the CD that accompanies this report.

Through this report, many interesting results have come up and their implications should guide the development of future analytical pieces, operations and policies in African countries.

Under Pillar 1, the collection, combination, data analysis and elaboration of new information have been very useful. The Land & Climate Portal gathers many data, information and applications: these tools have been designed to be dynamic and should be improved, updated and maintained to ensure up to date information for Bank TTLs and country clients. There is space for improvement of these tools through (i) adding new datasets related to land degradation and other environment or development data, (ii) improving the design and accessibility of information, (iii) better connecting this regional portal to the global Climate Data Portal, (iv) uploading case studies reports and short films, and so forth. Both environment units (ENV and AFTEN) should work hand in hand to improve the Africa Land & Climate Portal in the coming months and make it a valuable tool in support of the implementation of the Africa Climate Change Strategy.

The analysis undertaken under Pillar 2 provided interesting results and context specific recommendations to support the scaling up of SLWM in Sub-Saharan Africa. It showed that SLWM practices are not adopted as much as they could by African farmers and when they are, it is more often for an economic reason rather than to cope with climate variability and change. When there are clear responses to climate change, major factors that drive these responses include the level of access to rural services, household head gender, level of education, and household capital endowment. The climate-change-smart land management practices for crop production are those that integrate land and water, enhance soil carbon, and use crop varieties adapted to the agroecological zone. The study proved that combined SLWM practices such as integrated soil fertility management provide multiple benefits: they are more profitable, they are competitive on the labor market, they increase land productivity and soil carbon stocks—therefore improving resilience to climate variability mitigating climate change effects. The methodology adopted for the case studies proved that national policies and strategies play a critical role in the level of the adoption of SLWM practices. Last but not least, the results of the research showed that SLWM practices are proven to have a potential for sequestrating carbon, therefore increasing soil fertility and further mitigating climate change. In response to these findings, it is recommended to (i) develop and promote SLWM practices, (ii) improve access to inputs, disseminate technical knowledge and strengthen capacity of agricultural extension services to provide SLWM and climate-change advisory services, (iii) improve the marketing of rural products and services, (iv) support capacity building for local institutions to better manage

48 See websites mentioned in annex 12.
natural resources, (v) strengthen SLWM national policies and programs that improve resilience to climate change.

**Some analytical and methodological areas have not been covered under this work and could be further explored.** The methodology selected for the case studies was carefully considered and not everything could be done in the context of this work. For instance, the Advisory Group suggested that, in addition to focusing on impacts of climate variability and change on land productivity and degradation, it would be valuable to come up with results that are more prospective such as different scenarios which would tell more about how to better adapt to climate change according to the identified climate scenarios. It was agreed that this would require a different methodological approach. This prospective scenarios analysis could be an area of additional work that would provide very specific practical guidance according to various climate scenarios.

**Knowledge sharing and dissemination is critical**—and it is the ultimate objective of this work—to provide sufficient guidance to development practitioners and policy makers to make a difference on the ground and scale-up SLWM in Sub-Saharan Africa for a climate-smart development. Therefore, dissemination activities should be expanded to make knowledge and information available to the policy makers at the country level. Policy briefs will be developed and circulated to SLWM and climate-change focal points in African countries for them to include such considerations in new national policies, programs and strategies.

**Even though a lot has been achieved, it is clear that this work and its related outputs should be considered as a first attempt to fill this practical knowledge gap** rather than being seen as an exhaustive and comprehensive piece of work that is sufficient in itself. As environment and climatic data is improving, as researchers further explore the linkages between land degradation, climate change and SLWM, additional relevant knowledge should be gathered and made available to development practitioners and policy makers to respond to the development challenges faced by Africa in the context of the changing climate.

We hope that the information provided in this report will allow World Bank TTLs, country clients, African institutions and other development practitioners and policy makers to take on critical development challenges in Africa, while conserving ecosystems and protecting rural livelihoods from climate-change impacts.
REFERENCES


Benhin, J. 2006 Climate change and South African agriculture: Impacts and adaptation options, CEEPA Discussion Paper no. 21, University of Pretoria.


FAO. Food security? Report 98/0. Wageningen.


Nellemann et al., 2009, The environmental food crisis—the environment’s role in averting future food crises. UNEP, Norway.


## ANNEX 1: BODY OF WORK CARRIED OUT IN SUPPORT OF THE ESW

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Reference</th>
<th>Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Study</td>
<td>Regional climate profiles were developed by Richard Washington of the Oxford University Centre for Environment, with a view toward informing the Africa Region’s climate strategy and guiding the current ESW and other TerrAfrica work.</td>
<td>Washington, R. 2008. <em>Climate Profiling Sub-Saharan Africa under Current and Future Conditions</em>; and <em>Making Development Climate Resilient: A World Bank Strategy for Sub-Saharan Africa</em>. Oxford University Centre for the Environment.</td>
<td>See CD ROM</td>
</tr>
<tr>
<td>Scientific Study</td>
<td>A review of methodologies to downscale climate projections of global circulation models (GCMs) to the finer resolution used in hydrological applications was also carried out by Casey Brown of IRI.</td>
<td>Brown, C., et al. 2008. <em>Review of Downscaling Methodologies for Africa Climate Applications</em>. New York: IRI, Columbia University.</td>
<td>See CD ROM</td>
</tr>
<tr>
<td>GIS Data Server</td>
<td>A database was developed by Christian Crepeau making available land and development information selected from a review of 68 data sources against a set of agreed-upon criteria. The final selection of data for the Africa Land &amp; Climate Portal was peer-reviewed by a group of internal and external experts for the different data categories. Data has been uploaded to the Africa Land &amp; Climate Portal, accessible online.</td>
<td>Crepeau, C. 2009. <em>Land and Development Data Download, Homogenization and Metadata Creation. Elaboration and Delivery of the African Geospatial Database</em>.</td>
<td><a href="http://sdwebx.worldbank.org/climateportal/home.cfm?page=africamap">http://sdwebx.worldbank.org/climateportal/home.cfm?page=africamap</a></td>
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<td>Type</td>
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<tr>
<td>Self-standing Report</td>
<td>A review of SLWM practices that not only contribute to restoring ecosystem functions but can also contribute significantly to adaptation and mitigation of climate change in the context of Sub-Saharan Africa was carried out by Anne Woodfine. Based on the review, a Resource Guide of Best Management Practices was developed.</td>
<td>Woodfine, A. 2009. <em>Using Sustainable Land Management Practices to Adapt to and Mitigate Climate Change in Sub-Saharan Africa, A Resource Guide</em>. TerrAfrica/FAO, Washington, DC.</td>
<td><a href="http://knowledgebase.terrafrica.org/ter-documents/ter-view-doc/en/?uid=44977">http://knowledgebase.terrafrica.org/ter-documents/ter-view-doc/en/?uid=44977</a></td>
</tr>
<tr>
<td>Self-standing Report and Knowledge Tool</td>
<td>A stock-taking exercise consolidating the current body of knowledge was carried out. The result is a database with over 200 of the most relevant publications and knowledge resources on the land and climate nexus.</td>
<td>Wadja, P. and D. Bonnardeaux. 2009. <em>Climate Change and Sustainable Land Management Nexus in Sub-Saharan Africa: A Stocktaking Exercise</em>. TerrAfrica, Washington, DC. (Updated by Ymene Fouli).</td>
<td><a href="http://knowledgebase.terrafrica.org">http://knowledgebase.terrafrica.org</a></td>
</tr>
</tbody>
</table>
ANNEX 2: THE AFRICA LAND & CLIMATE PORTAL AND ASSOCIATED SLWM TOOLS

One of the main outputs of Pillar 1 is a set of practical tools that consolidates and makes accessible the body of knowledge available on the land and climate nexus. These tools are presented in more detail as follows:

The Africa Land & Climate Portal was developed to collate scientific datasets and make them accessible to end-users. The portal has a map interface from which the user can query any location on the African continent and obtain corresponding climate information (historic, current, and projected trends), physical environment information (both biophysical and human-induced), and socioeconomic information (historic and current population, administrative boundaries, and so forth). The Land & Climate Portal is intended to serve as a common platform to collect, display, and overlay different levels of information, for example, different temporal scales, as well as different scales of resolution (regional, national, and local). In order to achieve the geographical visualization of different data variables, an enormous amount of spatially referenced data was gathered and combined. The Africa Land & Climate Portal builds on the existing World Bank Climate Change Portal and strengthens the corporate effort of providing a one-stop shop for climate-related data and tools. However, the data collected for this Economic and Sector Work (ESW) goes beyond GIS-based data sets, and additional knowledge resources are available to those interested in better understanding the current status of the scientific debate on land and climate, including the methodologies and approaches used to record, quantify, and assemble data. For this purpose a separate database with over 200 of the most relevant academic publications and knowledge resources has been compiled—searchable by themes and with short abstracts available on each of the resources.

The Africa Land & Climate Hazard Exposure Map was created to identify areas at risk for climate-change and land-degradation impact. The hazard exposure map is based on a combination of critical factors—such as land-use type, slope gradient, population density, precipitation, and evapotranspiration—to generate georeferenced risk assessments for current as well as predicted future rainfall conditions (for 2100). The Africa Land & Climate Hazard Exposure Map provides instant visual identification and understanding of the high- versus low-risk areas on the African continent and thus helps guide development practitioners, project managers, and other decision makers in strategically focusing investments for SLWM. The map is designed to evolve and improve over time as the analysis model is populated with additional emerging datasets that will further factor into the vulnerability analysis. Consequently, the data outputs will progressively become more refined, more substantiated, and more accurate.
The third tool that was developed, the Best Management Practices (BMP) Database, helps users identify practical land- and water-management approaches that respond to both land degradation and climate risks. The BMP Database is a collection of land management practices that not only help to reduce and arrest different forms of land degradation (water erosion, wind erosion, nutrient depletion, and so forth) but also provide cobenefits in terms of climate-change adaptation (through reducing vulnerabilities to floods, droughts, changes in growing seasons, and so on) and mitigation (through increased soil carbon sequestration and/or reduced GHG emissions). The database is accessible from the Africa Land & Climate Portal and allows users to customize various search criteria to easily identify SLWM practices that respond to specific considerations: targeted land-use type, opportunity costs, corresponding production benefits, and so forth. Detailed technical data sheets provide information and further references for each identified SLWM practices.

More information on the practical application of the above tools is available in a separate user guide on the Africa Land & Climate Portal.
ANNEX 3: AFRICA LAND & CLIMATE HAZARD EXPOSURE MAPS: METHODOLOGY, STRENGTHS AND LIMITATIONS

This annex describes in more detail the methodology used for data overlay and analysis to develop the Africa Land & Climate Hazard Exposure Maps. Further, strengths and constraints in the interpretation of the map are discussed.

METHODOLOGY FOR DATA OVERLAY AND ANALYSIS

To develop the Africa Land & Climate Hazard Exposure Maps, a team of five experts in the area of soil science, GIS mapping, land use, and climate change was convened to select and combine the most relevant georeferenced data available on land and climate factors at the scale of the African continent. The team first carried out a literature review and analysis of available models and methodologies for combining data such as precipitation, temperature, land cover, NDVI, farming systems, slopes, population density, and so forth across the African continent. Based on its review, the expert team proposed a custom-tailored methodology for combining data for the Land & Climate Hazard Exposure Maps. Data on land-use type, slope gradient, population density, precipitation, and evapotranspiration were considered most relevant for identifying risk exposure. These factors were determined to serve relatively well as proxies for more complex aspects of geoclimatic conditions as well as land-use and land-cover conditions. Information on NDVI would have added considerable value to the accuracy of the Land & Climate Vulnerability Map, in particular with regard to mapping the current status of land degradation. However, the NDVI data available to the expert team were not rainfall-adjusted and were thus not included.

The main factors based on which risk exposure was determined are the following:

- **Precipitation and evapotranspiration difference**: A factor was created based on the difference between precipitation and potential evapotranspiration data to serve as a proxy for water availability for plant uptake as well as the potential water runoff of subsurface drainage (downward and lateral flow, capillary rise, and so forth). A significant difference between annual rainfall and evapotranspiration was considered to indicate risk for flood or drought conditions, which weighed into the identification of areas at risk.

- **Topographic variation**: The inclusion of topographic mapping, particularly the mapping of slope gradients,\(^\text{49}\) helped to define risk related to precipitation runoff and associated land erosion. A higher risk factor was correlated to increasingly steep slope gradients. Information on topographic data is also important to users when trying to identify appropriate SLWM practices in areas with steep slopes.

\(^{49}\) Based on remotely sensed elevation data (STRM data) with a data grid of 90 meters. Slope data was considered in weighted cells of 4 x 4 km resolution.
• **Land-use class (LADA)**: These were used to provide information on the types of ecosystems, types of land-uses, and differentiation of broad land-cover classes. Land-use classifications were weighted according to the estimated vulnerability to climate change and impact on land degradation for each land-use type.

• **Population density**: This was used to highlight areas of production systems likely to be at risk due to unsustainable land-use practices: for example, due to intensive cropping, nutrient mining, overgrazing, and so forth. Higher population density was aligned with higher risk factors for land degradation and higher climate risk exposure. Population density above 1,000/km² was considered a threshold for urban and peri-urban settlements and excluded from the scale of risk factors.

**MAP INTERPRETATION: AREAS OF HIGH RISK EXPOSURE**

The Land & Climate Hazard Exposure Map was developed by overlaying the data sources just described after assigning a weighted factor to each data set. For example, rainfall and evapotranspiration was considered twice as important as the other layers in both the map of current high-risk areas and the map of predicted high-risk areas for land degradation and climate impact. When interpreting the map, it is important to take into consideration that different combinations of factors can cause the same final risk ratings across the continent. As such, an area of high risk exposure can be the result of multiple factors or simply a single factor of significant strength. For example, an area could be considered at high risk to land degradation due to steep slopes and high population densities of people, whereas elsewhere the same risk value could occur simply due to extreme drought conditions or due to a completely different combination of factors. There is no straightforward interpretation to the different gradients of risk exposure on the Land & Climate Hazard Exposure Map. Instead the user will need to source underlying data that is available in the different accessible layers of the map.

**STRENGTHS AND LIMITATIONS OF THE HAZARD EXPOSURE MAP**

There are strengths and limitations to the interpretation of the Land & Climate Hazard Exposure Map. A key lesson learned during the exercise was that surprisingly little information exists on the geographical extent of land degradation and the use of SLWM practices at the scale of the African continent. Without basic, spatially projectable data on the status of land resources and management systems available, the interpretation of climate risks is limited, as, in essence, the baseline for the status quo is missing. As such, the Land & Climate Hazard Exposure Map attempts to apply proxy data to assess and predict risk exposure in terms of land degradation and climate impact on land resources. Consequently, users of the map must take into account a number of constraints when interpreting the map.

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50 LADA is a Land Degradation Assessment in Drylands carried out by FAO and UNEP, financed by the GEF. [www.fao.org/nr/lada/]
The following points aim to guide correct interpretation and reduce the risk of misinterpretation:

- While slope gradients are a good proxy for identifying erosion risks, actual risks may be overinterpreted in specific locations where soil protection and erosion control efforts are already in place. Similarly, while the current map identifies areas of steep slopes and high densities of people as being at high risk for land degradation, this may not be the case in all areas, as land users may already be applying appropriate land-management systems (terracing, sufficient stabilization with vegetation, and so forth). Areas identified as high risk are best verified with local experience and knowledge to confirm results provided by the vulnerability map.

- While areas with a combination of steep slopes, heavy rainfall, and high population density (for example, parts of western Kenyan highlands, such as Katamega) are identified as high risk, they may still be able to support intensive agriculture due to extremely good soils and may in fact be less at risk than neighboring areas fringing Lake Victoria, which are considered less at risk on the map due to gentle slopes and comparatively less population pressure yet have significantly more fragile soils.\(^5\)

- Areas under protected management status, such as national parks or designated natural areas, do not appear to be at risk based on the risk methodology applied for the map, as they are considered to have no or low population pressure and typically high land-cover classes. However, experience on the ground in Sub-Saharan Africa shows that many such areas are at risk, particularly along boundaries where human activities (grazing, deforestation, overharvesting of forest products, and arable agriculture) are gradually depleting natural resources and associated biodiversity and compromising the capabilities of these areas to perform vital ecosystem services.

- Areas that are already degraded due to previous or ongoing unsustainable use, but currently do not face particularly high population densities, steep slopes, or particularly extreme climate conditions, may not be identified as being at risk on the current map. An example may be the Masaii Steppe in Tanzania, which is susceptible to land degradation due to a combination of factors.

There is scope to improve the accuracy of the Land & Climate Hazard Exposure Map with supplementary data—most importantly, further details on predictions of climate-change impact as well as more detailed information on the status of land degradation and the quality of land management practices in use. The following points provide an overview of opportunities for further improving the accuracy and knowledge content of the Land & Climate Hazard Exposure Map:

- The map currently does not take into account the impacts of various socioeconomic and development factors, including:
  - access to markets and/or transport costs;
  - levels of education;
  - ability to take up new approaches in farming;

\(^5\) Future updates of the Land & Climate Hazard Exposure Map would include soil type as an additional factor in the analysis to reduce interpretation constraints.
- ability to take up new livelihoods;
- rates of population growth; and
- levels of education and skills.

Considering that people whose livelihoods are already marginal and people who live in remote areas will be more at risk from the impacts of climate change, the inclusion of the above information would provide a more accurate and holistic risk rating.

- Climate change is having significant effects on the distribution of pests and diseases as well as resulting in pressure on productive systems. A more detailed analysis of applicable crop and livestock pests and diseases and their epidemiology would be required to integrate these effects in the overall risk rating.

- The current hazard exposure map does not illustrate or take into account the predicted impacts of increased variability of weather, for example, an increasing frequency of droughts and floods, which are likely to be locally catastrophic events and are expected to have much more significant impact locally (and particularly in the short term) than the more gradual but progressive changes in temperature and/or precipitation.

- The methodology of the risk assessments focuses on identifying risks but does not consider areas with new opportunities for improved productivity, such as highland areas (for example, in Ethiopia and Kenya), which could be net beneficiaries of climate change, as rising temperatures enable farmers working at high altitudes to grow a wider range of crop varieties and possibly have more than one crop cycle per year.

- The risk analysis does not at this time include information on the current status of land degradation or the current SLWM practices in place, which hence does not allow for a more accurate point of departure for localized definitions of land and climate risks. Whereas the type of available SLWM practices have been well documented due to substantial efforts in the past few years, the extent of coverage of SLWM practices is still practically unknown. Information on the actual area under SLWM practices as well as an updated inventory of the spatial extent and degree of land degradation would substantially improve the understanding of the Land & Climate Hazard Exposure Map. It will be important that future efforts contribute to mapping both the status of degradation and efforts for conservation in order to provide key information for decision making—specifically, where investments are most needed and can be best made, where SLWM practices could be scaled up rapidly and most effectively, and which SLWM practices have demonstrated the best potential for further uptake.
ANNEX 4: REGIONAL CLIMATE PROFILES: CURRENT, OBSERVED, AND PROJECTED

This annex presents more details on the regional climate profiles that include both observed and projected data. This is valid for the African continent, and another annex will later on present the climate conditions in the four case-study countries. The full report related to these regional climate profiles is available as a stand-alone report in the CD that accompanies this report.

WEST AFRICA

Current Climate Characteristic

The West African monsoon and precipitation peaks during the boreal summer months govern the rainfall pattern of this part of Africa. The West African monsoon and overall rainfall conditions in the region are influenced by multiple factors, including sea-surface temperature anomalies in the Gulf of Guinea, the eastern Pacific and Indian oceans, and the southern Atlantic.52

The flat topography of the region results in largely homogenous climatic and ecological zones, which run largely parallel to latitudinal lines. Southward from the Sahara is an increasing rainfall total and decreasing variability, allowing for the differentiation of the West African climatic regions into three subregions.

- **The Sahel subregion** has the lowest annual rainfall totals and highest variability of the West Africa subregions. The Sahel has experienced a marked downturn in rainfall from the mid-1960s to the near present. This multidecade drying trend is not observed in the subregions further south.

- **Mean annual rainfall in the Sudan subregion** is higher than in the Sahel, while the coefficient of variability (20 to 30 percent) is lower. The rainy season also tends to last longer, covering a period of up to five months.

- **The Guinea coastal subregion** has the longest rainfall season, resulting in annual rainfall in excess of 1,200 millimeters. Parts of the coast experience a bimodal rainfall season. The Atlantic sea-surface temperatures are important for modulating the year-to-year variability of the rainfall along the Guinea coast.

Observed Climatic Changes

The climate of West Africa is dominated by the Sahel drought, which is the longest observed downturn in rainfall in the instrument record. Observation records also show an increase in warm spells and a decrease in the number of cold days. Persistent drought in West Africa is well

52 See, for example, Maracchi et al. 2007, Vizy and Cook 2001, and Fontaine and Janicot 1996.
documented, yet still very little is known about the length, severity, and origin of droughts before the 20th century. Evidence suggests that the West African monsoon is closely linked to changing Atlantic sea surface temperatures and intervals of severe drought lasting for periods ranging from decades to centuries are characteristic of the monsoon. Consequently, the severe drought in the Sahel of recent decades (i.e., 1970s) is not anomalous in the context of the past three millennia, indicating that the monsoon is capable of longer and more severe future droughts. (Shanahan et al. 2009)

**Projected Climate Change**

There are large uncertainties concerning implications of global warming for rainfall patterns in the Sahel (see figures A4.1 and A4.2), with both wetter and drier conditions a possibility. An average result of all IPCC AR4 models suggests increased rainfall by the middle of the 21st century. By contrast, predictions based only on GCMs, which reproduce the current climate of the Sahel well, point to the possibility of a drying trend. There are considerable systematic errors in climate simulations of the Atlantic Ocean temperatures, which limit the skill of reproducing the climate of West and Central Africa. Consequently, the direction of change is currently highly uncertain for the two regions, particularly the Sahel. However, variability is expected to stay, and adaptation measures for both drought and flood risks should be factored into development efforts.

**Figure A4.1: Rainfall Projections for Guinea Coast, West Africa**

Median rainfall changes (mm/day) are shown for the IPCC’s scenario over the Guinea Coast for the 2020s (left) and 2080s (right). The lowest model median and highest model median are shown in the bottom left and top right hand corner of each grid box, respectively.

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53 See, for example, Hoerling et al. 2006.
54 See, for example, Cook and Vizy 2006, Held et al. 2005.
The Horn of Africa

Current Climate Characteristic

While this region shares some similarities with the Sahel subregion in terms of latitudes, rainfall seasonality, and high interannual variability, its climatic characteristics are distinct. The circulation associated with the Asian Monsoon strongly influences the climate of the Horn of Africa. The region is further topographically distinct, with the Ethiopian Highlands imposing an effective barrier to Atlantic Ocean influences on the climate. Instead, the climate of Ethiopia and neighboring Somalia is strongly conditioned by the circulation over the Indian Ocean.

Observed Climatic Changes

The region is characterized by frequent drought conditions and high interannual variability. In the 1980s the region experienced prolonged dry periods with a particularly severe drought in 1984. While rainfall has recovered in the central and northern highlands since then—although with intermittent dry years—droughts continued in the south and east in the 1990 and 2000s. Due to the high interannual variability, no clear long-term trends in rainfall amounts, frequency, or intensity of extremes can be determined.
Projected Climate Changes

Increased temperatures through all seasons are likely to lead to a greater frequency of heat waves with increased evaporation rates—assuming other influences remain unchanged—and to accelerated surface-water evaporation and higher soil-moisture deficits. Modest gains in mean annual rainfall are projected for parts of the region (A4.3), but positive effects may be offset by higher evaporation rates. Over Ethiopia, climate models show a range of projected annual rainfall changes. Some models project more rain, others less, but the mean model response suggests slightly wetter conditions, particularly in the annual mean and in the October through December season. There are modest changes in mean annual rainfall from all models for the 2020s (+0.4 percent) and 2050s (+1.0 percent). There are some marked regional differences in the size and direction of rainfall change, and some models project large changes in rainfall—these cannot be discounted. This is a region that would benefit from downscaled climate information.

Figure A4.3: Rainfall Projections for the Horn of Africa

Central Africa

Current Climate Characteristics

Central Africa is characterized by high annual average rainfall amounts and bimodal rainfall seasonality. The region is sensitive to Atlantic sea-surface temperature and circulation anomalies, however it is not influenced by ENSO events. It is also one of the world’s largest zones of tropical convection. The Congo River Basin is often considered the definitive feature of this ecological region, but it is hugely understudied. Only five or six key papers have thus far been written in the area of climate science research in this subregion, which is partly due to the dearth of available climate data, as there are just six rain gauges covering the basin.
Observed Climatic Changes

There is no conclusive observational evidence of long-term rainfall change in Central Africa. While data shows that rainfall over the tropical rainforest zone in south Congo and West Africa has decreased between 2 to 4 percent from 1960 to 1998, other research suggests that these variations are the result of multidecade variability linked to the Atlantic atmospheric circulation rather than long-term declines, as stream flow measured by the Congo River gauge stations show no long-term change in trends.

Projected Climatic Changes

Climate-change projections for Central Africa, and the Congo Basin in particular, suggest an increase in annual rainfall amounts over time (figure A4.4). For the early (March to May) and late transitional (September to October) seasons, increases of about 25 percent are projected by the middle of this century. However, the validation of climate projections for Central Africa is constrained by lack of observational data and limited understanding of climate mechanisms important to the region.

Figure A4.4: Rainfall Projections for Central Africa

Median rainfall changes (mm/day) are shown for the IPCC’s scenario over central Africa for the 2020s (left) and 2080s (right). The lowest model median and highest model median are shown in the bottom left and top right hand corner of each grid box, respectively.

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55 Malhi and Wright 2004.
EAST AFRICA

Current Climate Characteristics

East Africa is characterized by a bimodal seasonality with a long rainfall season in March to May and a shorter more variable rainfall season from October to December. East Africa is distinct from Central Africa largely on the basis of the degree to which the Pacific and the Indian Ocean influences East Africa but not Central Africa. The Pacific Ocean, through ENSO, as well as patterns of variability in the Indian Ocean (such as the Indian Ocean Dipole or the Indian Ocean Zonal Mode), exert an important control on year-to-year variability of the rains. However, no recognizable multidecade rainfall variability has been observed. Climatic gradients are tied to distinct topographic gradients within this region.

Observed Climatic Changes

While no homogenous and statistically significant trend in rainfall can be observed for East Africa, there is some evidence for changing rainfall patterns. Recent research suggests an increase in precipitation during the short rains for northern Kenya, while the southern parts of Kenya and Tanzania may be becoming drier. These changes, although not statistically significant, may be the forerunner of future climatic changes in the region.

Projected Climatic Changes

The East African climate is expected to become wetter, particularly during the short rains. Intense precipitation events are likely to become more frequent, but droughts and prolonged dry periods will also remain a problem. (See figure A4.5) There is a strong consensus toward wetter conditions in the climate simulations for East Africa. Further detail in this topographically complex region requires downscaling of climate simulations. East Africa will become warmer in all seasons over the coming decades, increasing the risk of heat waves. For example, regional simulations suggest an increase in annual average temperature between 1 °C and 5 °C across the whole of Kenya, with projected warming to be most pronounced in the northern parts. Hence precipitation gains would be offset to some extent by increased evaporation.

57 Schreck and Semazzi 2004.
Figure A4.5: Rainfall Projections for East Africa

Median rainfall changes (mm/day) are shown for the IPCC’s scenario over East Africa for the 2020s (left) and 2080s (right). The lowest model median and highest model median are shown in the bottom left and top right hand corner of each grid box, respectively.

SOUTHERN AFRICA

Current Climate Characteristics

Like East Africa, Southern Africa is strongly influenced by the Indian and Pacific Ocean ENSO sea-surface temperatures. However the climatic response to ENSO events is opposite to that of East Africa. El Niño conditions are associated with wet conditions over East Africa but dry conditions over Southern Africa. Unlike neighboring equatorial regions of Central and East Africa, there is only a single rainfall peak per year. The peak rainfall season in Southern Africa differs between the eastern-central and western subregions, with rainfall peaks during December to February and January to March, respectively. Tropical cyclones are a characteristic threat to eastern parts of Southern Africa, particularly Madagascar and Mozambique.

Observed Climatic Changes

There is strong observational evidence for a warming trend in Southern Africa. The vast majority of climate stations in Southern Africa show an increase in mean annual maximum temperature over the period 1960–2003, with temperature increases higher in the interior compared to the coastal areas. Half of the recorded increases are statistically significant. Further, 70 percent of stations show statistically significant increases in minimum temperature, again with a bias toward the interior areas. No conclusive trend could be recorded for rainfall in Southern Africa except for strong interannual and interdecadal variability.
Projected Climate Change

There is uniform agreement of a warming trend over Southern Africa, which is most pronounced over the western part of southern Africa. The warming discussed for the observed record over Southern Africa is evident in the climate model data for the periods 2020–2029 and for the extended period 2050–2069. Projected warming is not as strong for the eastern-central part of Southern Africa. Although not conclusive, models generally suggest a drier western Southern Africa and wetter eastern Southern Africa (figures A4.6 and A4.7). However, considerable differences and uncertainties between individual model projections remain as global climate models have difficulty simulating the relative influence of the major ocean systems on the region’s rainfall patterns. Regional downscaling efforts, which take into consideration a larger suite of local climate factors, provide further insight and suggest increases in precipitation over central and western parts of Southern Africa.58

Figure A4.6: Rainfall Projections for the Eastern Part of Southern Africa

Median rainfall changes (mm/day) are shown for the IPCC’s scenario over eastern Southern Africa for the 2020s (left) and 2080s (right). The lowest model median and highest model median are shown in the bottom left and top right hand corner of each grid box, respectively.

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58 Hewitson and Crane 2004.
Figure A4.7: Rainfall Projections for the Western Part of Southern Africa

Median rainfall changes (mm/day) are shown for the IPCC’s scenario over western Southern Africa for the 2020s (left) and 2080s (right). The lowest model median and highest model median are shown in the bottom left and top right hand corner of each grid box, respectively.
ANNEX 5: CATALOGUE OF THE SCIENTIFIC BODY OF KNOWLEDGE

As part of this ESW, a stocktaking exercise was undertaken to (i) synthesize what is already known across key areas of SLWM and climate change in Sub-Saharan Africa, drawing on existing published sources and grey literature, and (ii) identify gaps in existing knowledge that may have important implications for the elaboration of relevant public policies within the World Bank ambit and/or at the country level. The stocktaking was done following a set methodology and criteria for choosing studies/reports.

As a result of the stocktaking exercise, the extensive catalogues and compilations of information and knowledge resources on SLWM and climate change were assembled:

1. **A key output of this stocktaking exercise is a compilation of almost 200 publications** deemed most relevant to the climate change/variability and SLWM nexus. Development practitioners can use this database as a source of information for their projects that may include issues related to the nexus. The list of key publications, research papers, studies, briefs, policy papers, and so forth can be found in the CD ROM that accompanies this report. The list does not purport to be exhaustive but is targeted toward papers, studies, and reports that look at the interactions between land, sustainable land management, climate change, and climate variability. The underlying assumption is that the studies and papers are a good and balanced representation of the full body of work in their subjects. A **corresponding database** (in Excel format) includes information on authors and institutions and provides URLs, synopses, and a compilation of key issues touched upon for ease of use and reference. All knowledge resources are labeled according to country/geographic focus as well as their relevance to one or more of the following subthemes: mitigation, adaptation, climate data, land data, development data, and policy. As such, the database serves as an entry point from which development practitioners can quickly identify relevant pieces of knowledge and the current status of the academic debate.

2. **During the compilation process, key journals, conferences, and discussion forums were identified and listed.** This information will help readers undertake their own research and identify more current papers and studies and at the same time assess the evolution of the science around climate change, variability, adaptation, and mitigation as it pertains to SLWM in Sub-Saharan Africa.

3. **Key research institutions and centers of excellence were catalogued.** These organizations work on climate change, land management, and cross-sectoral issues around the world but focus on Sub-Saharan Africa.

This stocktaking report is a first step in learning more about the interactions that occur between SLWM and climate change, where the focus currently lies, and how the international community can move forward on policies to combat the effects of climate change while securing fragile livelihoods throughout Sub-Saharan Africa.
ANNEX 6: METHODOLOGY OF THE CASE STUDIES

This annex presents the site selection, data collection, and analytical methods in more details.

SITE SELECTION METHODS

Selection of the four case study countries was done to represent Sub-Saharan Africa regions’ experience with common patterns of climate change. The team selected countries sharing boundaries to capture the impact of different policies on farmers’ responses to climate change. The team matched transboundary sites based on similar agroclimatic conditions within each country. The selection ensured that the transboundary sites had comparable biophysical and livelihood characteristics and that the major difference between the sites across the border would be the policies of each country. The steps used in site selection are as follows:

1. Using monthly rainfall data from CRU (1981 to 2001) and NASA (2002 to 2007) for the four countries, the mean and standard error of annual rainfall and the year trend and year squared trend coefficients for each pixel (0.5 degree pixel for CRU data and 1 degree pixel for NASA) were computed. The regression models also had month dummy variables and a dummy for the period from 2002 to 2007 to account for any shift due to the use of a different data source for this period. T-tests of the coefficients revealed a linear trend since the coefficients for the quadratic coefficients were not significant. Hence the subsequent steps use only the linear trend model.

2. Using the nearest neighbor matching procedure (Abadie and Imbens 2007), matching pixels in Niger and Nigeria in West Africa and Kenya and Uganda in East Africa that were from areas having common support in terms of mean annual rainfall were selected based on the mean and standard error of annual rainfall, the rainfall trend coefficient, and standard error of the coefficient. In some cases one pixel from one country was the best match for more than one pixel from the other country. The matches with minimum percentage difference in these statistics between the matching pixels were kept. In West Africa, a minimum cutoff point of 10 percent difference was set to ensure that only matches that are close were included in the matched sample. In East Africa, the matching pairs were fewer and therefore the cutoff point was 20 percent.

3. In the case of East Africa, elevation was also included in the matching characteristics to take into account the large differences in terrain.

4. To determine the impact of access to market and technical support on farmer response to climate change, the matching pairs were further grouped according to market access and the presence of an SLWM project.

5. The selected pixels were overlaid on boundaries of administrative units (districts in Kenya and Uganda, communes in Niger, local government authorities in Nigeria), and the pixel that represented the best the administrative division was selected.
In East Africa, three different agroecological zones (AEZs) were selected.

1. The semi-arid zone is where pastoral communities predominate. This zone represents 18 percent of the land area in Sub-Saharan Africa (table A6.1). The matching sites selected were in Samburu District in Kenya and Moroto District in Uganda. In both districts, rainfall and population density are low and the major livelihood is transhumant even though crop production is an emerging livelihood undertaken as a diversification strategy to adapt to climate change.

2. The second AEZ was the subhumid zone, receiving rainfall above 800 millimeters per year. In Kenya, Bondo District in Nyanza province bordering Lake Victoria was chosen. The district is affected heavily by malaria, a disease affected by climate change. The sites matching Bondo in Uganda are located in Kamuli District. The subhumid zone represent about a fifth of Sub-Saharan Africa’s land area.

3. The third AEZ was the highlands, which account for 4.4 percent of Sub-Saharan Africa’s land area. Though small in area, the highlands are important in East Africa in terms of population and agricultural production and the fact that land management in the highlands has important effects on lowlands. Sites selected in Kenya were located in the Bungoma District, and in Uganda they were in Kapchorwa District.

In each of the three zones, two villages with high market access—one with an SLWM project and another without an SLWM project—were selected. Similarly, two villages in low market-access areas—one with and another without an SLWM project—were selected.

A similar approach was used to select case study villages in West Africa. Eight villages were selected in Tahoua region and four matching villages were selected in Sokoto state in Nigeria. An additional four villages were selected from Niger state in Nigeria. To exploit synergies between this study and another on cost-benefit analysis (CBA) of SLWM practices in Nigeria, all eight villages from Nigeria were located in or around the SLWM-CBA study sites that covered larger areas in Sokoto and Niger states. See figures A6.1 and A6.2.

### Table A6.1: Land Area and Human Population by Agroclimatic Zone in Sub-Saharan Africa and the Sites Selected Matching Each Zone

<table>
<thead>
<tr>
<th>Zone</th>
<th>Area (’000 km²)</th>
<th>% of SSA area</th>
<th>% of rural population in SSA</th>
<th>Rural population density (persons/km²)</th>
<th>Sites selected to represent the zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arid</td>
<td>8,327</td>
<td>37.3</td>
<td>5.3</td>
<td>1.7</td>
<td>Moroto (Uganda); Illela (Sokoto, Nigeria); Niger; Samburu (Kenya)</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>4,050</td>
<td>18.1</td>
<td>27.0</td>
<td>14.8</td>
<td></td>
</tr>
<tr>
<td>Humid</td>
<td>4,137</td>
<td>18.5</td>
<td>28.0</td>
<td>15.0</td>
<td>Kamuli (Uganda); Bondo (Kenya)</td>
</tr>
<tr>
<td>Subhumid</td>
<td>4,858</td>
<td>21.7</td>
<td>20.3</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>Highlands</td>
<td>990</td>
<td>4.4</td>
<td>19.4</td>
<td>44.2</td>
<td>Kapchorwa (Uganda); Bungoma (Kenya)</td>
</tr>
<tr>
<td>Total</td>
<td>22,362</td>
<td>100.0</td>
<td>100.0</td>
<td>10.7</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Adapted from Jahnke 1982.*
Figure A6.1: Case Study Sites in East Africa
Figure A6.2: Case Study Sites in West Africa
DATA COLLECTION METHODS

This study used five major sources of data, each for a specific purpose of the study. Detailed discussion of data collection methods are given in the individual country reports. What follows is a brief description of the data collected is presented, and whenever necessary, the country in which the data were collected:

- Satellite and secondary data were used to determine changes in land use and land cover and the carbon density of the different types of use or cover. These data are used to analyze changes in carbon stock at the landscape scale and the contributing influence of different livelihoods and management practices. The data were used in all sites, but for the sites in East Africa, additional carbon data were collected from communities and households to determine carbon density and stock of different use types.

- Community resource mapping was used to determine biophysical changes and used also for ground truthing and updating the satellite imagery data.

- Focus group discussion was used to obtain community perceptions on biophysical and socioeconomic changes, the timeline of their occurrence, and their drivers and impacts. Information was also gathered about what the communities have been doing in response to these changes. Information gathered from focus groups was also used to design the questionnaire for the household survey. Further information on the focus groups is presented in the next section.

- Household-level data were collected and analyzed to understand the determinants of adaptation to climate change and the impacts of SLWM practices on agricultural productivity. Table A6.2 reports the number of households and communities that participated in the study in each site.

- Crop simulation models were used in the Nigerian sites, which coincided with the SLWM-CBA study, which analyzed returns of SLWM practices.

Table A6.2: Selected Sites and Household Sample in Each Agroecological Zone in Each Country

<table>
<thead>
<tr>
<th></th>
<th>Kenya</th>
<th>Uganda</th>
<th>Niger</th>
<th>Nigeria</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-humid</td>
<td>62</td>
<td>69</td>
<td>-</td>
<td>-</td>
<td>131</td>
</tr>
<tr>
<td>highlands</td>
<td>60</td>
<td>66</td>
<td>-</td>
<td>-</td>
<td>126</td>
</tr>
<tr>
<td>Semi-arid</td>
<td></td>
<td></td>
<td>63</td>
<td>245</td>
<td>120</td>
</tr>
<tr>
<td>Total</td>
<td>122</td>
<td>198</td>
<td>245</td>
<td>60</td>
<td>468</td>
</tr>
<tr>
<td>Communities</td>
<td>16</td>
<td>16</td>
<td>8</td>
<td>60</td>
<td>48</td>
</tr>
<tr>
<td>High market access,</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>High market, no SLWM</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Low market, SLWM</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>8</td>
</tr>
</tbody>
</table>

59 Household surveys in Samburu District were planned but could not be undertaken due to insecurity in the area in late 2009.
60 Four communities and 60 households from Sokoto state (Sudan-Savannah zone) participated in the study, but the household data analysis was not ready during writing of this study.
Focus Group Discussion

Qualitative analysis of drivers and responses, including technological and institutional responses and their impact, was done via focus groups and key informants. The focus group discussions were held with members of the general public, but with an emphasis on agriculturalists in the selected communities. About 12 to 15 community members were invited to participate in each group discussion. Participants were selected based on their age, gender, primary activity, and knowledge of the community. Participants were required to be old enough to have good knowledge of major changes that have occurred in their village in the past 30 years. To ensure that women were well represented in the discussion, an equal mix of gender was required. A guideline was used to discuss the following major topics: (i) timeline of major recent events, (ii) livelihoods and changes, (iii) resource management practices and changes, (iv) reasons for changes and perceptions of drivers, (v) responses to drivers, (vi) institutional responses, and (vii) impacts of responses.

When discussing drivers of change, care was taken not to inadvertently lead the group toward specific responses. Team members were especially concerned that if they mentioned the true emphasis of the project on perceptions of and responses to climate change, it would have biased the community’s responses and given more importance to the issue as compared to other possible drivers. Specific aspects of climate change were probed and pursued after more general questions about changes or drivers were asked.

Household Surveys

A common household and plot survey instrument was designed by the team for implementation in all countries. Some adjustments were done to adapt the instrument to suit the needs and circumstances in a given country. The household survey captured data on household capital endowment and related shocks to the household, climate change perceptions and responses, land holdings, tenure and management, plot production, inputs and outputs, livestock assets and production, access to rural services, and expenditures on food and nonfarm income. In Kenya and Uganda, plot-level soil samples were taken from each of the major land-use types. To capture farmers’ knowledge and ability to assess carbon stock, farmers were asked to identify plots that are poorly managed and those that are well managed. Soil samples were taken from each of these two categories and compared.

Analytical Methods

The qualitative information and data collected from the focus group discussions were compiled and summarized in tabular and graphical format to capture commonalities and divergence of responses across different sites.
The household surveys also provided significant quantitative analysis related to the key questions. Descriptive analysis was made on household perceptions of (i) climate shocks and longer term changes, (ii) the effects of the shocks and changes, (iii) responses implemented to address those shocks and changes, (iv) the impacts of those responses, (v) the identification of additional desired adaptation measures, and (vi) the constraints in implementing them. Descriptive analysis was also conducted on household capital endowment and the prevalence of household land and water management practices.

A second set of analyses involved econometric methods, including the following:

- Awareness of climate change = f (social capital, human capital, physical capital, access to services, meso level factors…)
- Responses to climate shocks and change (drought, longer term change) = f (social capital, human capital, physical capital, access to services, meso level factors same…)

Both models were estimated at the household level. At plot level, the following models were estimated:
- Adoption of SLWM = f (social capital, human capital, physical capital, access to services, meso level factors, land tenure, other plot level characteristics…)
- Impacts of different SLWM practices on plot productivity, risk of production, and soil carbon.

- Plot productivity is measured by using the value of output per area as well as the net value per area (subtracting purchased inputs). Value is used because many plots have more than one commodity (for example, maize and beans) and there needs to be some basis for aggregation.
- The risk of production is determined using the mean-variance method of Just and Pope (1978) to deal with cross-sectional data. In order to estimate the effect of a particular SLWM practice on risk, the team divided the sample into those with and those without the SLWM practice. The mean productivity for the subsample is calculated, and then for each plot observation a deviation about the mean or variance measure can be calculated. The hypothesis tested is that the SLWM practices will help to reduce the variance of production among those who have adopted the practices.
- The analysis of the impact of SLWM practices on carbon stock was not done for all plots since soil samples were taken from only selected plots—well managed and poorly managed plots for each major land-use type.
ANNEX 7: CLIMATE CHANGE AND VARIABILITY IN THE CASE STUDY COUNTRIES

This annex assesses climate change using rainfall data obtained from stations around the case study sites. Although these data may not reflect the actual rainfall where the case study villages are located, the trends are expected to be very similar. The data also cover different time periods. The time covered depended on data availability.

KENYA

Rainfall data for a 25-year period were obtained from the study sites to assess trends and variability. Samburu District represents the semi-arid zone, Bondo District represents the subhumid zone, and Bungoma represents the highland zone.

Figure A7.1 shows the annual rainfall amounts in the three study districts. The mean rainfall for the 1980s, 1990s, and 2000s were calculated for each district. In Bungoma, the mean moved from 1,280mm in the 1980s to 1,422mm and back to 1,375mm in the most recent years. In Bondo, the mean has edged up over time, from 1,307mm to 1,335mm and finally to 1,359mm in the 2000s. In Samburu, the mean has dropped dramatically in recent years, from 927mm and 954mm in the decades before 2000 to only 627mm since 2000. Although these indicate significantly different situations, communities and farmers indicate uniformly that they perceive reductions in rainfall.

In terms of the degree of variation, the standard deviation of annual rainfall was calculated for each decade. In Bungoma, the standard deviation increased moderately from the 1980s (219) to the 1990s (239) and then more significantly in the 2000s (333). In Bondo there was a rapid increases in variability in each decade as the standard deviation moved from 140 to 222 and then to 354 by the 2000s. The case of Samburu was yet again different. The standard deviation decreased monotonically over time from 195 to 174 and eventually to 85.
NIGER

Rainfall trends from 1936–2000 from Madoua station in the Sahel zone, which covers only 1 percent of Niger’s surface area (RON 2006), is represented in figure A7.2. This area receives an average of 600mm to 800mm of rainfall annually. The decadal mean annual rainfall (figure A7.3) showed a steep decline from 1936–45 to 1976–85, during which there were prolonged droughts in Niger (1968–73 and 1977–85), which caused significant crop failure and livestock decimation. For example, more than 50 percent of livestock died during the 1977–85 drought (RON 2006). Rainfall has been increasing ever since but has not yet reached its level in 1936–45.

The rainfall variability—represented by standard deviation—has shown an upward trend but the change is not significant. As noted above, the Illela rainfall station, which is also in Sahel zone, shows a downward trend with an increasing variability.
Figure A7.2: Mean Annual Rainfall and Variability, Illela, Niger

Source: created by IFPRI for this study.

Figure A7.3: Decadal Mean Annual Rainfall, Madoua Station (Sahel Zone, Tahoua Region), Niger

Source: created by IFPRI for this study.
NIGERIA

In Niger state Nigeria—located in the Guinea Savanna—decade mean annual rainfall does not show a clear pattern. Rainfall decreased significantly in the 1981–90 period but picked up from 1991 to 2000, almost reaching its level of 1971–80. The average in the 2000–06 period was lower than in the 1990s. The standard deviation shows a clear downward trend. However, analysis of the rainfall during the rainy season shows that rainfall in May has been declining over time while monthly precipitation in June has been increasing. Communities reported that onset of rainfall has moved from March to May. However, analysis of monthly rainfall did not support this perception. Farmers also perceived an increase in rainfall variability. Based on the standard deviation shown in figure A7.4, however, rainfall variability has shown a downward trend from 1971–80 to 1990–00 but started increasing in the 2000s. The most recent trend could have influenced the community perception.

Figure A7.4: Annual Rainfall Trend in the Guinea Savannah (Minna, Niger state), Nigeria

Source: created by IFPRI for this study.
In Sokoto state, which falls in the Sudan-Savannah zone, the quantity of rainfall has increased in 2000-2005 compared to 1986-95 (figure A7.5). Similarly, annual rainfall standard deviation decreased during the two time periods (figure A7.6). In the Illela site, located in southern Niger and with comparable agroclimatic conditions to northern Sokoto, the rainfall shows a downward trend with an increasing variability (figure A7.2). Even though the period used is short, there is a pattern showing a declining rainfall trend and increasing variability in the drier northern Sokoto and an improving rainfall and decreasing variability in the wetter southern zone. The Illela rainfall station is much closer to the selected villages in Sokoto, and its downward precipitation trend and increasing variability are both consistent with the perception of climate change in communities.
**UGANDA**

Similar to the Samburu District in Kenya, rainfall in the semi-arid zone of Uganda (Moroto District) generally decreased during the rainy season (March–August) from its levels in 1981–85 (figure A7.7). This is consistent with the communities’ perceptions in Moroto. Focus group participants reported decreasing rainfall. In October, however, the mean monthly rainfall trended upward. Communities may not have taken this increase into account, since this is not a planting season. On the variability of rainfall, the coefficient of variation (CV) shows no clear pattern of increasing variability reported by the communities. The trend of CV for October, November, and December actually shows a declining variability. However, these are dry season months in which farmers do not plant crops.

For the highlands zone (Kapchorwa District), figure A7.7 shows a declining mean monthly rainfall for April and May but an increasing trend in June and October. However, communities in Kapchorwa District did not report erratic or less rainfall—in accordance with GCM predictions for a wetter climate in the humid highlands of East Africa (Christiansen et al. 2007; Cline 2007). However, one community (Kongta) reported that the onset of rain has shifted from March to May. However, figure A7.7 does not show such a shift. Again, this is a short period and may not portray a clear shift in rainfall pattern.
In the subhumid zone (Kamuli District), there was a downward trend for the average monthly rainfall for April and May, the two most important months for the district’s main cropping season. However, the CV of monthly rainfall during the main cropping season (March–June) was low. Farmers in Kamuli reported experiencing erratic rainfall, frequent droughts, and new rainfall onset patterns. Consistent with the community perception, however, the CV of monthly rainfall for December and January showed an upward trend.
ANNEX 8: CURRENT NATIONAL EFFORTS TO ADDRESS NEGATIVE EFFECTS OF CLIMATE CHANGE AND VARIABILITY

Each of the four case study countries have grappled with climatic shocks and long-term climate change and have designed various strategies to cope and adapt. However, it is only Niger and Uganda that have prepared NAPAs. A description of each country’s strategies to promote adaptation to and mitigation of climate change follows:

KENYA

In Kenya, climatic events are cited as drivers of reduced and/or variable agricultural and rangeland productivity, urban water shortages, electricity rationing, soil erosion, river siltation, and mudslides resulting in loss of housing and lives. A number of floods, droughts, and other climate-induced catastrophes have also affected the country. These in turn have induced national debate on mitigation and adaptation, resulting in the creation of a ministry for the arid areas, recent efforts to reprotect key water-tower forest areas (for example, the Mau), and the December 2009 announcement that all farmers should plant 10 percent of their farm area in trees.

In response to the climate-induced catastrophes, Kenya established a National Disaster Operation Centre in 1998, but the government has recognized that this has been inadequate for the task. In 2009 the government drafted a new National Policy for Disaster Management in Kenya. While this will allow better short-term planning and reaction to disasters, other agencies will be involved in the longer term strategic planning and implementation of program to adapt to and mitigate climate change. These include all the relevant line ministries and the National Environmental Management Authority (NEMA), which manages several SLWM programs, including a forest and rangeland rehabilitation program. NEMA does not have a long-running program on climate change, but it does manage projects on climate-change adaptation. Indeed, Kenya currently hosts numerous climate-change adaptation research and development projects that focus on SLWM activities.

Kenya has invested significantly in promoting irrigation. Table A8.1 shows that about a third of the irrigable area is used for irrigation. Among the four case study countries, Kenya’s irrigated area as share of irrigable area is the largest. One of the reasons for such development is the large share of drylands in the country, which account for two-thirds of the country. The development of the high-value commercial agriculture in the country has also contributed significantly to the development of irrigation.

Kenya has long promoted important SLWM practices. A soil conservation program implemented through the extension system ran for about 20 years up through the 1990s and was deemed to be highly successful in terms of reach and adoption (Thompson and Pretty 1996). Compared to neighboring countries, the use of manure and mineral fertilizer is high among farmers in Kenya. This is due to a number of factors, including the widespread practice of high value crop production and marketing, high adoption of intensive dairy farming and manure availability (SDP 2006), significant extension efforts in fertilizer use, and efforts to improve efficiency in fertilizer
value chains (Jayne et al. 2003). Similarly, tree-planting campaigns on farms have been prolific in Kenya, perhaps best exemplified by the Greenbelt movement led by Nobel Laureate Wangari Maathai. The government has facilitated efforts of its own extension staff and of many NGOs in terms of accessing tree germplasm and in information dissemination. These successes are not uniform, however, and SLWM practices are found to be more advanced in the areas with higher ecological and market potential, such as central Kenya (Place et al. 2006).

Table A8.1: Irrigation Development in the Case Study Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Irrigated area (000 ha)$^1$</th>
<th>Irrigated area as % of irrigable land$^1$</th>
<th>Value of irrigated output as % total output$^2$</th>
<th>Drylands as % of land area$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya</td>
<td>103.203</td>
<td>29</td>
<td>10</td>
<td>68</td>
</tr>
<tr>
<td>Uganda</td>
<td>9.150</td>
<td>10</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Niger</td>
<td>73.663</td>
<td>27</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td>Nigeria</td>
<td>293.117</td>
<td>13</td>
<td>4</td>
<td>53</td>
</tr>
</tbody>
</table>

Source: $^1$FAOSTAT, 2007; $^2$FAO 2003; $^3$WRI 2003. Note: drylands include arid, semi-arid, and dry subhumid areas, i.e., areas with an aridity index between 0.05 and 0.65. Drylands exclude deserts (hyper-arid areas with aridity index of less than 0.05.

Perhaps one of the weaknesses in Kenya emanates from its centralized form of government. Due to the size and complexity of the central government, planning tends to be done in a highly sectoral manner. Moreover, the current structure of nearly 40 ministries places further strains on the integration of programs. The management of natural resources such as land, water, and vegetation is a key area that suffers from this structure. Agricultural objectives sometimes come into conflict with environmental objectives in terms of land use. There is conflicting advice on using irrigation from stream water and setting aside land near streams; on protecting indigenous trees and planting of high-value exotic trees; and on protecting forested areas and finding land for the landless. There are good examples of integrated resource management at landscape levels, but those are often through specific projects that have sufficient funding to create innovative governance mechanisms at local levels.

A Thematic Working Group on Land Management was formed in 2009 under the joint leadership of the Ministries of Agriculture and Environment and began the process of identifying organizations involved in land-management activities and creating a platform for information sharing and collaboration. This was to be a first step in trying to overcome the lack of cooperation and partnership across ministries and their stakeholders.

Kenya also ratified the United Nations Convention to Combat Desertification (UNCCD) in 1997 and prepared a National Action Plan (NAP) in 2002, in which the country planned to design policies and institutions for coordinating and supporting community participation in natural resource management and to provide information on control of desertification (NES 2002). The NAP also identified actions required to increase vegetation cover and productivity of the agricultural and pastoral sectors and protection of the wildlife, 70 percent of which is located in the drylands (NES 2002).
Responding to its arid climate, limited vegetation and water resources, and severe land degradation, Niger designed a NAPA in 2006 that identifies 14 adaptation action strategies with the broad objective of ensuring food security, sustainable resource management, and poverty reduction. The 14 strategic activities are achieved through the following broad activities: (i) pasture and rangeland improvement, (ii) increase in livestock productivity by improving livestock local breeds; (iii) development and protection of water resources for domestic use, irrigation, and livestock; (iv) promotion of SLWM practices that enhance adaptation to climate change; (v) promotion of peri-urban agriculture and nonfarm activities; (vi) capacity building of organizational skills of rural community development groups; (vii) prevention of and fight against climate-related pests and diseases, and (vii) dissemination of climate information.

As is the case in other countries, however, the total budget set for the NAPA is small and its implementation horizon is short term (two to three years). The NAPA has been funded for the most part by donors, with limited contribution by the government. This reveals the weak political will of the government to make the NAPA a sustainable and long-term operation. Hence, the effectiveness of NAPA has been limited even though it has spurred country-level policy awareness of climate change and the need to design policies and strategies to enhance adaptation and mitigation. As mentioned earlier, tree planting is one of the success stories that have attracted attention. As part of implementing its NAP, the government started promoting sustainable pasture management, water harvesting, tree planting, developing livestock markets, and other strategies. A large area of degraded land has been rehabilitated through the presidential program on land rehabilitation and several donor-funded projects. According to Adam et al. (2006), at least 250,000 hectares of land have been rehabilitated using tree planting and soil and water conservation measures, while more than 3 million hectares have been reforested through farmer-managed natural regeneration since the mid-1980s (Reij et al. 2009). The area of unexplained regreening in Niger is centered in the area where Projet Intégré Keita For example, Mortimore et al. (2001) found that despite (or perhaps because of) the decreasing availability of natural woodland in Maradi, tree densities on farms were increasing as a result of a widespread practice of farmer protection of valuable natural onfarm trees.

The success of regreening of the Sahel in Niger could be explained by two major changes. First, institutional changes gave more local ownership and local authority for the management of natural resources. The government has embarked on strategies to promote vegetative technologies, which are supported by policy changes to replace the unwritten “right of axe” by giving ownership rights to those who plant trees (Abdoulaye and Abase 2005). Likewise, a 2004 forestry law grants ownership rights to those who plant woodlots or protect forest resources on their private land. The government also decentralized the management of natural resources through the 2003 Rural Development Strategy. The RDS gives the local governments the responsibility to manage natural resources. These institutional changes have contributed to the success of natural regeneration of vegetation in Niger.
Second, farmers changed behaviors in response to the institutional changes and the severe land degradation following the prolonged drought in the 1970s and 1980s, which increased the value of trees and other natural resources and prompted farmers to protect and own them.

About 8 percent of the country is protected, and the country has one of the largest game parks in West Africa (FAO 2007). Niger also has considerable irrigation. Table A4.1 shows that 27 percent of irrigable area is used for irrigation, the second largest share among the case study countries. The necessity of irrigation in Niger is dictated by large share of land area in the Sahara desert (77 percent) and drylands (23 percent).

Change in greenness in northern Nigeria—with comparable or better climatic environment—was poorer, reflecting the heavy influence of policies on SLWM practices. Despite the success of regreening the Sahel in Niger, land degradation in the country remains a major problem. Between 1990 and 2005, Niger lost nearly 26 percent of its forest and woodland habitat (Butler 2006).

**NIGERIA**

Like Kenya, Nigeria has not yet formulated policies to coordinate adaptation to climate change. However, the country invested significantly in irrigation long before climate change became a major issue. Food security policies, which Nigeria has been implementing for more than four decades, are one of the key drivers of investment in irrigation. This demonstrates that even though Nigeria has not prepared a NAPA, its existing policies and strategies address the common adaptation goals identified by 41 countries that have already prepared their NAPAs—water resource development and food security (Mutunga and Hardee 2009).

Irrigation investments in Nigeria were done as part of the country’s efforts to address drought problems in the northern part of the country. A total of 11 river basin rural irrigation authorities were formed in the 1970s to develop irrigation schemes in the country, and a total of 162 dams were constructed (Olubode-Awosola et al. 2005; AQUASTAT online). About 70 percent of the irrigated area is situated largely floodplains (fadama) with no irrigation infrastructure (A4.1). However, the government has started investing in small-scale irrigation in the floodplains (fadamas). Recent major projects promoting small irrigation include the Fadama II and III projects. The projects support the development of irrigation infrastructure and the acquisition of tubewells to lift water from the shallow aquifer. Support of the small-scale irrigation has helped to increase the development of irrigation in Nigeria. The country is among the six African countries where irrigated area has grown by at least 3 percent annually in 2000-2003 (Svendsen et al. 2009).  

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61 See www.fao.org/nr/water/aquastat/countries/nigeria/index.stm
62 These countries are Central African Republic, Kenya, Mauritius, Nigeria, Senegal, and Zambia.
UGANDA

Like neighboring Kenya, Uganda has experienced increasing climatic catastrophes that led to widespread losses. A number of studies show that climate change will have a net negative impact on the majority of farmers, most of whom depend on rainfed agriculture and are poor and hence have limited ability to cope with climatic variability and other shocks (Oxfam 2008; Hepworth and Goulden 2008; Kabassa 2008; MWLE 2007). A study conducted by the Ministry of Water, Land and Environment (MWLE) showed that the frequency of droughts increased from an average of one per decade to about seven in the past decade. Such results have been questioned (for example, by Hepworth, and Goulden 2008), but it is worthwhile to note that they reveal that rainfall variability has increased, consistent with GCM predictions for East Africa (Christensen et al. 2007).

Uganda’s NAPA spells out the strategies for enhancing adaptation to and mitigation of the negative effects of climate change and variability (ROU 2007). The NAPA designed nine intervention strategies with a cost of about $39.8 million, including some related to SLWM. The country is also a signatory of the United Nations Framework Convention on Climate Change (UNFCC) and UNCCD, both of which aim to coordinate international efforts to address climate change and the related problem of desertification. However, policies and strategies for NAPA implementation are still weak and under-developed (ROU 2007), and this study provides aims to aid that process.

Despite the abundance of wetlands and the presence of the Nile River and other water resources, only 10 percent of irrigable area in Uganda is irrigated, and the value of production as a share of the total value of crop production is only 0.5 percent—the lowest among the four study countries (table A4.1). This illustrates the limited investment in irrigation by both the government and farmers. The limited development of irrigation reduces Uganda’s ability to adapt to climate change, especially in the drier areas in the north. Water harvesting and irrigation are one of the NAPA strategies to enhance adaptation (ROU 2007). The country has also developed water-harvesting programs along the cattle corridor. A total of 425 microdams have been constructed in the cattle corridor, but these have been poorly constructed and managed and that their effectiveness is limited (Bashar et al. 2003).

NAPA and other government policies and strategies have also promoted SLWM practices aimed at addressing climate change and increasing agricultural productivity and conservation of natural resources. The Ugandan NAPA aims to develop SLWM practices aimed at rehabilitating degraded lands and preventing degradation, increasing the availability of water, and integrating natural resource management (MAAIF 1999). The country also has established a number of policies and programs aimed at increasing agricultural productivity. However, the major weakness is the poor alignment of policies with investment. A recent study showed that the government contributes only 29 percent of the public expenditure on SLWM, which raises

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63 The strategies are (1) community tree planting, (2) land degradation management, (3) strengthening meteorological stations, (4) community water sanitation, (5) irrigation, (6) climate change and development planning, (7) drought adaptation, and (8) indigenous knowledge.
questions about sustainability (World Bank 2008). As is the case in Kenya, poor coordination among ministries and departments dealing with SLWM is also evident in Uganda.
ANNEX 9: DESCRIPTION OF THE MOST COMMONLY USED LAND AND WATER MANAGEMENT PRACTICES MENTIONED BY RURAL COMMUNITIES IN RESPONSE TO CLIMATE VARIABILITY AND CHANGE

Protection and planting of trees

Protection and tree planting was the most common adaptation strategy across borders and across agroecological zones in each country. In the semi-arid zone of East Africa, two of the four communities in Uganda and two of the three communities in Kenya reported planting or protecting trees in response to climate change. In Niger—with an agroecological zone comparable to the East African semi-arid zone—seven of the eight communities reported protecting or planting trees. Likewise, one of the four communities in Sokoto state reported practicing assisted regeneration of trees and two communities reported planting leguminous trees. Protection and planting of trees was done to address the fuelwood shortage, to provide a windbreak and for animal browse needs. Empirical evidence has shown that increasing fuelwood scarcity leads to more time spent collecting fuelwood from communal woodlands or forests, and this provides incentive for communities to plant and protect trees around their living places (Cooke et al. 2008; Arnold et al. 2003).

Livestock and rangeland management

In the semi-arid zones, controlled grazing was reported by all four communities in Uganda and by five of the eight communities in Niger as a response to climate variability. Pastoral communities in the semi-arid zone in Kenya did not report controlled grazing but reported moving livestock to other areas in response to prolonged drought. Communities explained that controlled grazing has been prompted by the decreasing pasture, which is due to more severe droughts and decreasing rainfall. Similarly, pastoral communities in Uganda reported controlled access to water resources, which is a result of drying rivers and other water sources. In Niger, seven out of the eight villages have established livestock corridors to reduce farmer-herder conflicts. In Sokoto state, three of the four communities reported harvesting and storing crop residues that are used during the dry season. This practice will likely deplete more soil carbon.

Irrigation and water harvesting

Of interest is the lack of irrigation as an adaptation strategy among farmers in the semi-arid zones. It was only in Nigeria where two of the four communities in Niger state and one of the four communities in Sokoto state reported using irrigation as an adaptation strategy to climate variability and change. One community in the subhumid district in Kenya also reported using irrigation in response to drought, although on a modest scale. No community in Uganda or Niger reported having used irrigation as an adaptation strategy. On water harvesting, four of the eight communities in Niger increased use of a zai, a half-moon water basin to trap rainwater. One of the four communities in the semi-arid zone in Uganda also reported introducing restricted access to water. Like the case of controlled grazing, restricted access to water resources is a new trend among the pastoral communities and has been prompted by the dwindling water resources. Three

158
of the four communities in the highlands and two of the four communities in the subhumid zones of Uganda also reported an increase in water management. Considering the fact that integrated land and water management practices have a high potential for increasing resilience to climate variability (Pandey et al. 2003; Bationo 2001), the low adoption rate of irrigation and water harvesting practices constitutes an opportunity for rural communities to developed such practices and therefore become more resilient.

**Early maturing varieties**

Improved crop varieties provide one of the key technologies for addressing climate variability and change—especially in areas where rainfall is expected to be more erratic or to decrease (Lobell et al. 2008). Planting early maturing varieties was mentioned by two of the three communities in the subhumid zone of Kenya and by three of the four communities in Niger state in Nigeria. In Uganda, one community in the highlands zone and two communities in the subhumid zone reported using early maturing varieties to address climate variability. Surprisingly, no community in the semi-arid zone (Moroto district) reported having used improved crop varieties as an adaptation strategy. This could be a reflection of the high production risks and the poor crop extension services in Moroto, where 12,750 people are served by one public extension agent, compared to about 9,600 people in the humid zone around Lake Victoria (raw data). The lack of adoption of improved crop varieties could also be due to the limited input market access in Moroto in Uganda and Niger.

**Mulching**

Mulching has been identified as one of the most important SLWM practices for adaptation to climate change. For example, a study in semi-arid areas in Kenya showed that mulching could increase the length of growing period from 110 to 113 days (Cooper et al. 2009). Eight of the 12 communities in Uganda reported mulching as an adaptation strategy. In Kenya, communities in the highlands also reported using more mulch than before. Two of the four communities in Sokoto state (Nigeria) also reported mulching, although none in Niger and Niger state in Nigeria reported mulching.

**Fertilizer and manure application**

Two of the three communities in subhumid zone in Kenya, two of the four communities in both semi-arid and subhumid zones, and three of the four communities in the highland zone in Uganda increased the use of manure. Likewise, four of the eight communities in Niger and two of the four communities in Niger and Sokoto states (Nigeria) increased use of manure or fertilizer. Use of fertilizer was particularly higher in both states in Nigeria. Sokoto is among the three states that provide the largest fertilizer state-level subsidy (50 percent), and use of fertilizer in the state is high. As was the case in Niger state, communities stated that one of the reasons for the increased use of fertilizer was to enhance crop production while yields tend to decrease because of droughts.
Horticultural crops

One of the most striking results of the focus group discussion is the tendency of communities to start using horticultural crops as an adaptation strategy to climate change. One of the three communities in the highlands of Kenya (Bungoma district) reported having switched to horticultural crops. Three of the eight communities in Niger also reported an increase in horticultural crop production. Likewise, three of four communities in Sokoto state also reported increased production of onions. No community in Uganda reported a switch to horticultural crops. Horticultural crops will increase farmers’ income and diversify livelihoods, both of which will enhance their resilience to climate change. The switch to horticultural crops in Kenya, Sokoto state, and Niger was also driven by new market opportunities and decreasing farm size and was done by communities with access to irrigation.

Livelihood diversification and new crops

Contrary to Jones and Thornton (2009), who predicted climate variability and change would induce a shift from crop production to livestock production in the drylands, one of three and two of the four pastoral communities in the semi-arid areas of Kenya and Uganda respectively reported diversifying their livelihoods by planting crops. The major reasons given for planting crops was the decreasing livestock population due to prolonged drought and cattle rustling in Uganda. However, household level results showed that all households interviewed reported 100 percent crop failure due to severe drought. This underscores the riskiness of crop production in the semi-arid areas, of which farmers are fully aware. Asked the methods used to increase resilience to erratic rainfall in the dry environment, three of the four communities in the semi-arid region of Uganda reported to use mulching. New crops were reported in all countries among predominantly crop farmers. Five of the eight communities in Niger have introduced new crops, while all four communities in both Niger and Sokoto states (Nigeria) reported having introduced new crops. No community reported new crops in Kenya or Uganda—apart from the horticultural crops mentioned.

Changing of planting date

Changing the planting date was a common adaptation strategy among communities who reported that the onset of rainfall has changed in West Africa. All communities in Sokoto state, three of the four in Niger state, and five of the eight communities in Niger reported having changed their planting dates in response to perception of the changing onset of rainfall. As discussed, some of the community perceptions are not supported by actual rainfall data, revealing the need for advisory services to help farmers make informed decisions on planting date.
ANNEX 10: LAND MANAGEMENT PRACTICES AND THEIR INFLUENCE ON SOIL CARBON: THE CASE OF UGANDA

This annex presents the work on soil carbon that was done in Uganda as part of the case studies. The objective is to understand farmers’ capacity to assess soil carbon rate and to verify through scientific methods whether or not their assessment is right. This helps consider the determinants of carbon stock in order to gain a deeper understanding of the drivers of higher soil carbon.

Soil samples were collected from different land-use, land-cover, and management practices from the selected households. Four broad land-use classes were identified: (i) perennials (banana, coffee, and orchards); (ii) annual crops (beans, sorghum, maize, millet, vegetables, and so forth); (iii) grasslands; and (iv) bushlands or woodlands. To determine the capacity of farmers to assess the carbon stock and fertility of plots, farmers were asked to indicate their best-managed and poorest managed plots and to provide a basis of their perception. Composite soil samples were collected from each land-use and management type at 0–15 cm and 15–30 cm soil depth. The soil samples were analyzed in the lab to determine soil carbon under each land-use type and level of management practice (good and poor management).

Farmers perceived soil organic matter (SOM) and fertility generally by soil color, texture, and vegetation. Farmers’ perceived SOM as the main provider of plant nutrients and understood its ability to conserve water. The major strategies farmers reported using to maintain or augment SOM levels were (i) manure application, (ii) mulching with crop residues, (iii) slashing weeds without burning, (iv) composting, and (v) shifting cultivation (natural fallow) in the semi-arid zone in northeastern Uganda. As shown in figure A10.1, farmers were well able to predict plots with higher SOM. The difference in soil carbon between well-managed and poorly managed plots was greatest (44 percent) in the semi-arid zone, where impacts of land management have the greatest impact due to the low carbon stock. In the subhumid zones and in the volcanic soils in the highlands, fertility attributes other than SOM contribute to higher fertility and reduce farmers’ ability to determine SOM.
Carbon stock was also measured across market access. As expected and as will be seen, carbon density in annual crops grown in areas with the low market access was higher than the equivalent density in the high market-access communities. However, in the semi-arid areas with low population density, the converse is the case, suggesting that high-market areas provide incentives for communities to invest in SLWM practices or that they are located in more fertile areas. However, community-level data show that carbon density in low market-access areas is higher than the case in high market-access areas in all agroecological zones (figure A10.2).
ANNEX 11: CARBON DENSITY ACROSS LAND-USE TYPES AND LAND-USE CHANGE AND ITS IMPACTS ON CARBON SEQUESTRATION

Land-use change has contributed a large share of the world’s greenhouse gas emissions. It is estimated that deforestation and other forms of land-use change contribute 17 percent of global carbon emission (World Bank 2009). The carbon stock endowment in the selected countries differs significantly. Uganda has the highest carbon density (about 20 tons/ha) and per capita carbon stocks (about 15,000 tons/capita) while Niger has the lowest density and per capita carbon stock (table A11.1). The deforestation rate in the selected countries ranges from 0.3 percent in Kenya to as high as about 3 percent in both Niger and Nigeria.

The main contributor to forest loss in all countries has been the expansion of cropland. As shown in figure A11.1 in all four countries, forest area has been declining while crop area has been increasing. The change is especially large in Nigeria, where cropland increased by about 21 percent while forest area decreased by almost the same percentage.

Table A11.1: Carbon Stock and Rate of Deforestation in the Selected Countries

<table>
<thead>
<tr>
<th></th>
<th>Kenya</th>
<th>Uganda</th>
<th>Niger</th>
<th>Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon stock (Million tons)</td>
<td>425.2</td>
<td>479.8</td>
<td>63.3</td>
<td>1,171.8</td>
</tr>
<tr>
<td>Carbon density (tons/ha)</td>
<td>7.3</td>
<td>19.9</td>
<td>0.5</td>
<td>12.9</td>
</tr>
<tr>
<td>Carbon stock per capita (000 tons)</td>
<td>12.1</td>
<td>15.0</td>
<td>4.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Contribution of carbon stock to total carbon in Africa (%)</td>
<td>1.0</td>
<td>1.1</td>
<td>0.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Deforestation rate per year1</td>
<td>0.3</td>
<td>2.0</td>
<td>2.8</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Source: Calculated from Baccini et al. 2008.
1Lebedys 2008.
Note that deforestation rates do not include tree cover on farms, which, as noted earlier, has increased dramatically in Niger.
Land-use changes in Nigeria were further analyzed using case studies in Niger and Sokoto states in the Guinea-Savannah and Sudan-Savannah agroecological zones. The results were extrapolated to areas with comparable land use and market access in each zone. The Guinea-Savannah and Sudan-Savannah agroecological zones, which match the land-use types and market access of the selected villages, cover 26 percent and 50 percent of Nigeria’s land area, respectively. The results show that, at the expense of forest and shrublands, agricultural area in the Guinea-Savannah zone increased by 40 percent in 1990–2000 and by 24 percent in 2001–2005. Forest area in the high market-access area decreased by 26 percent in both periods but increased by 14 percent in the low market-access areas during the same time. However, area under shrublands in the low market-access area decreased significantly due to expansion of agricultural area. Satellite imagery data analyzed in this study also showed an increase in burnt area. Bush burning is a common practice in Guinea-Savannah (Savadogo et al. 2007). In the Sudan-Savannah, cropland increased by 35 percent while sparse grasslands and shrublands decreased by 13 percent and 10 percent, respectively, between 1990 and 2005. With dwindling forest and shrubland resources, some communities set bylaws prohibiting bush burning. Emigginda community—located in the low market-access area in Niger state—was one such community. Satellite imagery data showed that the burnt area decreased by 53 percent in 2005 from its level in 2000. The bylaw prohibiting bush burning was set in the early 2000s. In the three selected villages in Niger state, burnt area increased in 2000–2005, even though a bylaw prohibiting bush burning was set in two of the three villages. This highlights the importance of enforcement of such regulations.

Overall, the land-use changes led to a net increase in carbon stock in the agricultural land and a net decrease in the forest and shrublands. Overall there was a decrease of 3.1 percent of the carbon stock in the Guinea-Savannah area from 1990 to 2005. The losses were due mainly to depletion of forest reserves and shrublands in the high market-access area and bush burning. In the Sudan-Savannah, carbon stock decreased by 9 percent in the low market-access area and by 40 percent in the high market-access areas. Declining carbon stock is not a sustainable pathway.
It increases vulnerability to climate change and other biophysical and socioeconomic changes (Dixon et al. 2003). This is especially critical in the Sudan-Savannah zone, with an already low carbon stock and more severe decreasing precipitation.

Carbon density in the low market-access areas was more than twice the level in the high market-access area. Carbon density in cropland in Badeggi (high market-access village) was only 14Mg/ha compared to 38–40 Mg/ha in low market-access villages (Emigginda and Fuka villages in Nigeria).

Similarly, in Uganda, carbon density in low market-access villages across all agroecological zones was more than 30 percent higher than the density in high market-access villages (figure A11.2). The difference was especially pronounced in the highlands with higher population density, while the difference was lowest in the sparsely populated semi-arid areas.

**Figure A11.2: Difference in Carbon Density across Levels of Market Access and Agroecological Zones, Uganda**

In Niger, however, carbon stock in the high market-access villages was 90 percent higher than in the low market-access areas (carbon density in high market-access areas was 1.2 tons/ha and only 0.627 tons/ha in low market-access area). The big difference is due to the large reforestation program in Tcherassa, Goune, and Kenouar villages—both in the high market-access area. These results are different from the pattern observed in Nigeria and Uganda. Analysis of the carbon stock changes using Landsat data for 1990 to 2005 showed a decrease in carbon stock in all selected villages, but the decrease in the high market-access villages was 8 percentage points lower than the case in the low market-access areas (figure A11.3).
The decrease was due largely due to conversion of shrublands to cropland and sparse grasslands. The results demonstrate that interventions such as reforestation programs can overcome the pressure exerted by the high demand of forest products in high market-access areas. Even though such analysis has not been done in Kenya, it is well known that much of deforestation is currently occurring in remote areas, since the forests in the high market-access areas have long been depleted. Figure A11.1 shows that grasslands in Niger increased the most in 2000–2007. This underscores the large importance of the livestock sector in Niger. It is estimated that Niger’s livestock population is 30 million, and the sector contributes 15 percent of the GDP, the largest in the four case study countries.

The team extrapolated the results obtained from the study villages in Uganda to areas with comparable agroecological zones and market access. The land area that matched the case study sites was 35 percent of the total land area in Uganda. The extrapolated results in table A11.2 show that there was a decline of 8.5 percent of carbon stock between 1973 and 2009. The largest contributor to the drop was the conversion of grassland, woodlands, and shrublands to annual crop production in all three agroecological zones. The largest conversion took place in the semi-arid areas, where about 47.3 percent of carbon stock was lost due to conversion of grasslands and woodlands to annual crops. The land conversion in this area is due in large part to cattle rustling and climate change, both of which have prompted pastoral communities to diversify from pastoral livestock production to crop production. The second largest change in carbon stock was in the highlands zone, where the loss was also due to conversion of woodlands and forests to cropland.

The subhumid zone gained carbon stock during the same period, and the gain was due largely to crops rather than from reforestation programs, as seen in Niger. Farmers in the subhumid zone plant more trees in crop plots due to the ease of establishing trees in the zone. Planting trees in banana and coffee plots is also common, and it contributed to increasing carbon stock.

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64 New immigrants have also been settling in the pastoral communities and establishing crop production in Kenya, but this is not the case in northeastern areas of Uganda.
Table A11.2: Above-ground and Below-ground Carbon Stock Changes across Agroecological Zones, Uganda, 1973–2009

<table>
<thead>
<tr>
<th></th>
<th>Semi-arid</th>
<th>Highlands</th>
<th>Subhumid</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total above-ground and below-ground carbon stock (million tons)</td>
<td>167.137</td>
<td>21.944</td>
<td>172.444</td>
<td>369.525</td>
</tr>
<tr>
<td>Carbon stock, 2009</td>
<td>92.378</td>
<td>17.126</td>
<td>228.501</td>
<td>338.005</td>
</tr>
<tr>
<td>Change as % of initial</td>
<td>-47.256</td>
<td>-21.962</td>
<td>32.508</td>
<td>-8.531</td>
</tr>
</tbody>
</table>

*Notes:* The corresponding agroclimatic zones to which results of each agroecological zone were extrapolated are as follows: Unimodal moderate rainfall (semi-arid zone), unimodal high rainfall (highlands zone), and bimodal moderate rainfall (subhumid zone). For details of agroclimatic zones, see Ruecker et al. (2003).

Table A11.3 shows land use and land-use change in Kenya’s Bondo and Bungoma districts between 1999 and 2008. In Bondo, agriculture, shrubland, and grassland were the dominant land uses over the entire period—nearly 90 percent of area. In terms of land-use change, smallholder agriculture land use increased by 235 square kilometers over the period, mainly at the expense of shrubland. In Bungoma, smallholder agriculture was the most dominant land use by far in the 1990s, accounting for just over 50 percent of land area. Woodlands were the second most dominant land use, but their size diminished greatly over the period. The decreases in woodlands, grasslands, and other land uses furnished crop land for smallholder agriculture, which saw its land area increase by nearly 500 square kilometers over the period. In both cases, the expansion of cultivated area does not represent new clearing of natural habitats but rather an intensification of cultivation on what are almost exclusively private lands. In much of Kenya, there is mixed land use on farms, with crops, trees, and grasses growing. Remote sensing interpretation reclassifies the same land when there is a change in emphasis of the different components.

In summary one finds higher carbon density in remote areas than in areas with high market access. This demonstrates the potential these areas hold for carbon sequestration. Results from Niger—where carbon density in high market-access areas was greater than in low market-access areas—demonstrate that reforestation programs can overcome the pressure exerted by high market access. The results show that interventions such as reforestation programs can overcome the pressure exerted by the high demand of forest products in high market-access areas. In other countries, however, such as Kenya, the rate of forest loss in the past 30 years used in this in this study is lower in the high market-access area than in the low market-access areas, since forests in the high market-access areas were cleared more than 30 years ago.
Table A11.3: Land-use Change in Kenya (Bondo and Bungoma), 1999–2008

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Km$^2$ in 1999</th>
<th>1999–2008 Change in Km$^2$</th>
<th>Km$^2$ in 1999</th>
<th>1999–2008 Change in Km$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>3.7</td>
<td>-0.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Woodlands</td>
<td>9.1</td>
<td>1.0</td>
<td>554.6</td>
<td>-322.4</td>
</tr>
<tr>
<td>Shrublands</td>
<td>434.0</td>
<td>-203.8</td>
<td>4.8</td>
<td>-2.4</td>
</tr>
<tr>
<td>Agriculture (smallholder)</td>
<td>233.2</td>
<td>235.4</td>
<td>1194.2</td>
<td>497.9</td>
</tr>
<tr>
<td>Agriculture (plantation)</td>
<td>0.0</td>
<td>3.9</td>
<td>39.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Grasslands</td>
<td>213.0</td>
<td>-14.1</td>
<td>231.2</td>
<td>-175.5</td>
</tr>
<tr>
<td>Swamps</td>
<td>69.8</td>
<td>-24.6</td>
<td>4.5</td>
<td>-2.2</td>
</tr>
<tr>
<td>Urban</td>
<td>1.6</td>
<td>3.8</td>
<td>12.1</td>
<td>9.9</td>
</tr>
<tr>
<td>Water</td>
<td>10.9</td>
<td>-1.0</td>
<td>4.4</td>
<td>-0.1</td>
</tr>
</tbody>
</table>

In all countries there has been an expansion of cropland land. It replaces forests, grasslands, and other land-use types with higher carbon density. The impacts of the changes on carbon stock have been significant. For Nigeria and Uganda, for which impacts of the changes were assessed and extrapolated to comparable areas in each country, the overall impact of land-use changes contributed to the reduction of carbon stock. In Nigeria, the carbon stock in the Guinea-Savannah zone, which matched the case study villages in Niger state, decreased by 3.5 percent from 1990 to 2005. Likewise, the carbon stock in the semi-arid, highlands, and subhumid zones that matched the selected villages in Uganda decreased by 8.5 percent from 1973 to 2009.
ANNEX 12: KNOWLEDGE SHARING AND DISSEMINATION PLAN

INTRODUCTION

The productivity and environmental benefits of the African landscape are threatened by land degradation and climate change. In order to mitigate risks and help adapt rural livelihoods to these changes, sustainable land management (SLM) investments must be scaled-up. One of the bottlenecks identified by TerrAfrica partners to the expansion of SLWM in Sub-Saharan Africa is the lack of specific knowledge related to the land and climate nexus. There is an urgent need to generate, gather, and disseminate practical knowledge. The dissemination activities presented here are critical to ensuring that the findings of this Economic and Sector Work (ESW) inform new policies and investments and have an impact on taking SLWM to a larger scale in Sub-Saharan Africa. The knowledge products generated through this work aim to inform policy and strategy formulation, provide operational guidance, and catalyze national and regional actions in SLWM.

The TerrAfrica platform can provide a way of reaching an ideal target audience. TerrAfrica is a multi-stakeholder platform that works to facilitate a programmatic scaling-up of SLWM investments in Sub-Saharan Africa. Its stakeholders include government policy makers and development partners involved in promoting SLWM in about 20 countries in Sub-Saharan Africa. The World Bank has played a critical role in this partnership platform since its inception. There is a strong consensus within the partnership that climate-risk management needs to be better integrated into all of its work. The platform provides them an effective, additional vehicle for the dissemination of the findings of this study.

Although TerrAfrica partners are the general target audience for this information, there is a need to further tailor the products for specific audiences, so that solutions can be specific to the needs they are trying to meet. The primary audience includes the Bank’s task team leaders (TTLs), other development staff, and African institutions—at either the regional level, such as the New Partnership for Africa’s Development (NEPAD), or at the country level, such as policy makers or government officials. Secondary target audience includes farmers, local authorities/governments, bridging institutions, NGO staff, researchers, academia, and the media.

A partnership with specific research organizations—for example, the International Food Policy Research Institute (IFPRI) or the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT)—could help strengthen this effort’s relationship with the scientific community and help guide applied research. It could result in timely input from newly available data and analysis of climate change, adaptation, and mitigation potentials from SLWM activities in Sub-Saharan Africa. Through partnering with regional research and academic communities, there is a potential to develop training modules specially targeted toward policy communities, extension services, and farmers’ organizations. This training could have a long shelf life and influence ongoing change in policies and projects.
The following sections of Pillar 3 provide information about and examples of SLWM dissemination, knowledge-sharing, and capacity-development activities that have already occurred through this ESW, others planned in the coming months, and additional ones for which funding and partnerships will be sought.

I. Initial Knowledge Dissemination: Past and Ongoing Activities

In terms of dissemination, the emphasis has been and will continue to be on activities that are practical examples of the cobenefits of SLWM for climate-change mitigation and adaptation. Such activities have taken place both within the Bank and under the umbrella of the TerrAfrica platform as consultations, development of tools, and so forth. For a summary list of the tools and products available as of March 2010, see table A12.2 at the end of Pillar 3.

Initial Consultations, the Strengthening of Linkages with the Research Community, and a Quality Review Process

Most of the pieces that make up this ESW were developed through an extensive consultation process. The stocktaking exercise was based on consultation with specialized researchers working on the land and climate nexus and representing African and other institutions. Some of them were personally consulted during a mission, and others were contacted by email and telephone. They have reviewed and provided comments on the initial data and information gathered in the stock-taking report and on additional inputs that strengthened it. These consultations may continue through the Web-based consultative forum under creation by TerrAfrica to further share knowledge and information.

An advisory group composed of key Bank staff ensured a quality review process for this ESW. The group was invited to several meetings since the inception of the ESW to discuss the methodology, ensure that main potential issues were raised, and ensure that this ESW was complementing similar studies at the Bank. The group was mobilized also during the finalization process, with the draft report being circulated for review and comments before the Decision Meeting. This process helped improve the methodology of the various pieces of the ESW, valorizing the findings and strengthening the dissemination within the Bank.

The quality process was strengthened by the technical Brown Bag Lunch that was held at IFPRI in November 2009 to present and discuss the findings of the case studies. This was the opportunity for specialized researchers to meet and discuss the results and related recommendations from the case studies in Niger, Nigeria, Uganda and Kenya. Comments were provided and taken into consideration for the revision of the reports.
Influencing Bank Operations

The findings of this study have already been disseminated and used in the following policies and investment operations at the country level:

- Elaboration of the Rural Development Strategy programs in Niger (especially programs 2, 10 and 14);
- Preparation of the Pilot Program on Climate Resilience in Niger;
- Preparation of new climate-change operation in Mauritania;
- Implementation of the Community Action Plan in Niger;
- Preparation of a new ESW on climate change and watershed management in Niger;
- Preparation of the new agriculture operation in Mali;
- On-going preparation of a major new agriculture operation in Uganda: Agricultural Technology and Advisory Services (financed under the umbrella of the Bank-led Strategic Investment Program of the Global Environment Facility);
- Preparation of Investment Frameworks by the many governments (Nigeria, Uganda, and so forth) and inputs into CAADP roundtables in these countries.

Design and Development of the Africa Land & Climate Portal

Historical, current, and projected climate information is not easy to find, especially gathered in a single tool. In coordination with the environment (ENV) and information systems units (SDNIS), there was investment in the creation of an interactive knowledge platform to support knowledge sharing on these topics in a visual format. The decision of using an existing corporate tool (the global Climate Data Portal) as a basis to develop the Africa Land & Climate Portal was taken during an advisory meeting gathering various units of the Bank. The African Land and Climate Portal draws on information from numerous sources and provides access to visual information on (i) current climatic conditions, (ii) hydrologic characteristics of key river basins, (iii) the state of natural resources and land degradation, (iv) projected climate change (based on multiple IPCC scenarios), (v) key climate vulnerabilities, and (vi) guidance on adaptation strategies in Sub-Saharan Africa. Information generated under Pillars 1 and 2 is integrated into the portal, ensuring consistency and providing continued guidance for operations and investments in SLWM in a changing climate. The Africa Land & Climate Portal is operational, it is a living tool that will be updated on a regular basis by the team in charge of the global Climate Data Portal.
Dissemination through Seminars and International Forums

Inputs for the African Ministerial Meetings and the Regional Climate Change Adaptation and Mitigation Framework for Agriculture

In early 2009, findings from the ESW, and specifically from the *Discussion Paper on Land and Climate*, were used as a basis from which TerrAfrica partners developed a technical background paper including some proposed recommendations for the African ministerial meetings (agriculture and environment). These inputs were subsequently incorporated into the final declaration of the ministers. In addition, some materials, such as the *Discussion Paper on Land and Climate*, were disseminated during these meetings.

Moreover, the findings of this ESW influenced the development of the *Climate Change Adaptation and Mitigation Framework for Agriculture*, under the leadership of NEPAD. ICRAF, which was at the same time working on the case studies, the above-mentioned *Discussion Paper on Land and Climate*, and the elaboration of the *Climate Change Adaptation and Mitigation Framework for Agriculture*, was the main player in this process, using the findings of this ESW as a main input to design the Framework.

UNCCD Conference of Parties in September 2009

A side event titled “Promoting Sustainable Land Management in its potential to Mitigate and Adapt to Climate Change” was held in the margins of the UNCCD COP9 in Buenos Aires. The side event was based primarily on the findings and outputs of this ESW, and it focused on the importance of mobilizing knowledge and tools on SLWM and climate change. Developed products were disseminated (as hard copies and in DVD format). These included the *Discussion Paper on Land and Climate* (French and English), the *Resource Guide for Using SLM Practices to Adapt to and Mitigate Climate Change in SSA*, two climate briefs from Eco-Agriculture Partners, the Africa Land & Climate Portal, a *Stocktaking Analysis on Land & Climate*, and a short film created on the basis of the case studies in Uganda and Kenya. Given the timing of the meeting, inputs into the UNFCCC COP15 held in Copenhagen in December 2009 were also discussed, especially on soil carbon sequestration and the role SLWM can play.

UNFCCC COP 15: December 2009

During the UNFCCC COP15 in Copenhagen, a side event titled “Synergies between Agricultural Mitigation and Adaptation to Climate Change: African Experience” was held jointly by IFPRI, ILRI, University of Georgia, University of Pretoria and the Kenya Agricultural Research Institute. During this side event, some of the results of the case studies were presented by IFPRI in the presentation “Synergies between Mitigation and Adaptation to Climate Change: What is the Potential for Sub-Saharan Africa?” In addition, during the “Agricultural Day” event at UNFCCC COP15, a poster was shown that benefited from the case studies’ insights.

Sustainable Development Network Week: January 2010

The World Bank’s SDN week in 2010 focused on climate change and provided an avenue for dissemination of the policy and operationally relevant conclusions of this ESW. During the Water Sector Practice Day, IFPRI presented the findings of the case studies during the
Development of Short Films to Showcase Climate Risks and Adaptation Strategies

In addition to the present ESW, two other Bank analytical studies—*Area-based Development and Climate Change* (ABDCC) and *Costing Adaptation through Local Institutions* (CALI)—have generated information and knowledge relevant to adaptation to climate change at local levels. Together, the three studies focused on 11 countries (Burkina Faso, Ethiopia, Kenya, Mali, Mexico, Niger, Nigeria, Peru, Senegal, Uganda, and Yemen). It was decided to join these studies dissemination strategies, with support from the World Bank Institute (WBI), to produce a set of short films (about 25 films have been produced). They showcase the role of SLWM and local institutions in adaptation strategies. The films will be used for trainings and by local, regional, and interregional stakeholders to share knowledge about operational recommendations. The film narratives, embedded in local experience, can help all stakeholders share the knowledge effectively and help local institutions move toward climate resilience and explore links with potential for mitigation and financing.

The films try to capture information from local institutions, farmers, and leaders in the 11 countries and address issues such as the following:

1. How government institutions can take advantage of opportunities and options to engage in climate-change adaptation and mitigation at the local level;
2. How to create an enabling local institutional environment for participation of multiple and diverse local stakeholders in climate-change adaptation and mitigation;
3. How to manage climate risks and adaptation through area-based management;
4. How to sequence policy interventions to effectively improve local adaptive capacity;
5. What types of capacity strengthening programs can support key local institutions to improve local adaptive capacity;
6. How learning and knowledge networks and linkages can be built or strengthened in support of the respective countries’ objectives for climate change, among other objectives;
7. How to manage climate risks through SLWM;
8. What the effectiveness has been of the SLWM-related projects/programs carried out until now;
9. What the determinants and impacts of adoption have been of SLWM practices on agricultural productivity, household income, and carbon stock;
10. What are the determinants and impacts of land use changes have been on agricultural productivity, household income, and carbon stock;

11. What current policies, strategies, and institutions need to be changed or enhanced to increase adoption of SLWM practices that enhance adaptation and mitigation of impacts of climate change;

12. What can be done to enhance the capacity of local institutions to enact regulations that increase adoption of SLWM practices that increase adaptation to and mitigation of impacts of climate change and variability; and

13. What can be done to increase community members’ compliance with SLWM practices that enhance adaptation to and mitigation of climate change and variability.

As mentioned earlier, the lack of practical information and knowledge targeted toward multiple audiences on SLWM and climate change—the focus of this ESW—has been a constraint in adaptation and mitigation efforts. In Kenya, Niger, Nigeria, and Uganda, the films raise the main issues related to the land and climate nexus and illustrate practical actions that showcase how sustainable land and water management has helped enhance climate resilience. Such communications tools are very much appreciated on the African continent, where knowledge is best disseminated through storytelling and images rather than through written documents, especially for the rural populations that are the more vulnerable to climate change and land degradation.

The films draw from the focus group discussions held as part of the case studies. During these discussions, elders were invited to respond to questions related to climatic conditions and livelihoods in the past 30 years. Local people’s perceptions on climate variability and change, land-use change, and their causes and impacts since the 1980s were captured. The film captures their description of responses and adaptation practices to these changes, including land management and investments as well livestock and water management techniques. People also described the impacts of these changes on poverty, food security, and other aspects of human welfare and on environmental conditions. Communities were also asked to discuss the compliance of community members with bylaws and regulations. This is a rich set of information that the video team captured by interviewing pre-identified individuals.

As a result of this work, many short films have been produced for each country, focusing on specific issues related to the country case studies. For instance, for Uganda, the following films have been produced:

• Adapting farming practices to improve crop resilience to climate change,
• Managing livestock in a changing climate,
• Protecting and planting trees to limit land degradation, and
• Improving grazing resilience to climate change.
They can be accessed on the TerrAfrica YouTube channel, www.youtube.com/user/TerrAfrica.

Most of the activities carried out during the course of this ESW focused on developing tools and products for dissemination, such as the Africa Land & Climate Portal or the short films. In addition, dissemination at various conferences and public forums constitutes a good start for the implementation of the dissemination strategy, which will intensify during the next few months.

II. STRENGTHENING KNOWLEDGE DISSEMINATION: ACTIVITIES TO BE CARRIED OUT IN THE NEAR FUTURE

In the coming weeks and months, dissemination will focus on making the outputs and findings of the ESW available to Bank TTLs and the African clients (at regional and national levels) and on supporting the integration of these findings in ongoing and future Bank’s operations or analytical studies.

Inputs into the Bank’s Regional and Country-level Work

The current ESW received funding from the country unit in charge of regional integration and regional programs. As of June 2008, it was one of the three regional flagships on adaptation. As stated earlier, this work has already influenced the design of operations with SLWM activities that can also maximize the adaptation and mitigation cobenefits.

In some countries, additional analytical work and operations have started, building on the findings of this study. For instance, the new ESW How SLWM Contributes to Climate Resilience and Food Security: An Analysis of Options for Scaling-up Support to the Niger RDS (P117725) will build on the findings of the Niger country case study developed as part of the present work. Also, the Pilot Program for Climate Resilience in Niger (P118165) will benefit from the findings of this ESW.

Recently, the Bank published Convenient Solutions to an Inconvenient Truth: Ecosystem-Based Approaches to Climate Change. Further work is planned across different sectors to incorporate the ecosystem-based approach. Given the similarities between SLWM and an integrative approach, such as the ecosystem-based approach, the task team currently working on the development of a new Concept Note on this topic has requested use of the present work as an input for their study. The ecosystem-based approach is also being put forward as an adaptation response within the Biodiversity Convention and in the upcoming fifth assessment report of the IPCC. Hence, peer-reviewed publications and seminars would be essential parts of incorporating the findings of this ESW into future analytical and policy advisory work in multiple forums.

Other Bank operations related to SLWM might benefit from the findings of this study. Overall, all the operations carried out as part of the Strategic Investment Program of the Global Environment Facility will benefit from this ESW. However, other World Bank operations might also benefit from the results and recommendations of this ESW. The list below does not pretend to be exhaustive; it only mentions a few projects and could be extended:
**Table A12.1: Selected List of Projects That Could Benefit from the Findings of This ESW’s Studies**

<table>
<thead>
<tr>
<th>Country</th>
<th>Project name</th>
<th>Project ID</th>
<th>Status</th>
<th>Date approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burkina Faso</td>
<td>Country partnership program for SLM project—eastern region</td>
<td>P104700</td>
<td>Pipeline</td>
<td>July 9, 2009</td>
</tr>
<tr>
<td>Burundi</td>
<td>Agriculture Rehabilitation &amp; Sustainable Land Management Supplement Project</td>
<td>P110904</td>
<td>Active</td>
<td>June 19, 2008</td>
</tr>
<tr>
<td>Cameroon</td>
<td>Sustainable agropastoral and land management promotion under the PNDP</td>
<td>P089289</td>
<td>Active</td>
<td>June 6, 2006</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>Sustainable Land Management Project</td>
<td>P107139</td>
<td>Active</td>
<td>April 29, 2009</td>
</tr>
<tr>
<td>Ghana</td>
<td>Environmental services for sustainable land management</td>
<td>P098538</td>
<td>Active</td>
<td>September 24, 2009</td>
</tr>
<tr>
<td>Kenya</td>
<td>Kenya Agriculture productivity and sustainable land management projects</td>
<td>P088600</td>
<td>Active</td>
<td>January 15, 2009</td>
</tr>
<tr>
<td>Mauritania</td>
<td>PDRC</td>
<td>P069095</td>
<td>Active</td>
<td></td>
</tr>
<tr>
<td>Mauritania</td>
<td>Community Based Watershed Management Project</td>
<td>P087670</td>
<td>Active</td>
<td>June 22, 2006</td>
</tr>
<tr>
<td>Niger</td>
<td>Community Action Program (PAC2)</td>
<td>P102354</td>
<td>Active</td>
<td>August 29, 2008</td>
</tr>
<tr>
<td>Niger</td>
<td>Carbon Sequestration and Rural Livelihoods Improvements through Acacia Plantations</td>
<td>P095346</td>
<td>Active</td>
<td>December 18, 2006</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Nigeria scaling up sustainable land-management practice, knowledge, and coordination</td>
<td>P109737</td>
<td>Pipeline</td>
<td>December 10, 2009</td>
</tr>
<tr>
<td>Rwanda</td>
<td>Sustainable Land Management—Support to Investment Framework and Preparation of National Climate Change</td>
<td>P115344</td>
<td>Active</td>
<td>May 1, 2009</td>
</tr>
<tr>
<td>Senegal</td>
<td>Sustainable Land Management Project</td>
<td>P108144</td>
<td>Active</td>
<td>August 4, 2009</td>
</tr>
</tbody>
</table>
Beyond new analytical studies and operations, the results of this ESW could be used as technical inputs during the revision process of the Country Assistance Strategies. The CASs are critical to defining the strategy of the Bank in client countries. In some African countries, including the inputs of this ESW in the CAS would ensure that the new operations and analytical pieces will consider the challenges related to land degradation and climate change. Developing seminars for Bank staff would help with such an effort.

**Series of Seminars for Bank Staff**

As part of the Africa SLWM Community of Practice led by the Environment Unit of the Africa Region (AFTEN), a series of brown bag lunches (BBLs) is currently being developed. The BBLs will target World Bank staff but could later be adapted for other audiences. One of these BBLs will be specifically focused on the potential of SLWM for climate adaptation and mitigation. Another will focus on Web-based tools to support the scaling up of SLWM in Africa. As part of this BBL, the Africa Land & Climate Portal will be showcased. A third BBL will complete the previous two by focusing on financing for climate-change projects. The documents and resources produced as part of the ESW will be disseminated during these BBLs.

**Wider Dissemination of the Case Studies Outputs**

Outputs of the case studies will include multiple products that will be used in BBLs, capacity-development activities, and other outreach activities under this ESW. Some have already been disseminated, and there will be continued disseminations in the future. The outputs include the following:

- The *Discussion Paper on Land and Climate*, which has served as a conceptual framework for the case studies and informed the broader development community by making the case for SLWM as an essential component to mitigate and adapt to climate change in Sub-Saharan Africa;

- A full synthesis report of the case studies;

- Subregional reports of the case studies (one report for East Africa and one for West Africa) and a report for each country;

- A CD-ROM that includes the detailed results of the case studies, including data collected and processed in a GIS format with a user-friendly demonstration;

- Two policy briefs (one for each subregion) summarizing the main findings and recommendations of the case studies; and

- Communication materials to be disseminated to wider audiences through the media, such as photos and press releases and short films.
Access to Study Findings on the Internet

The main tools and outputs produced in the context of this ESW are and will continue to be made available for a broad audience. External audiences can find the information on the following Internet sites:

- TerrAfrica YouTube Channel, http://www.youtube.com/user/TerrAfrica

These sites can be accessed by various audiences and they constitute a very good way to disseminate the findings of this study related to the potential of SLWM for climate-change adaptation and mitigation.

Specific Dissemination in Client Countries

In addition to the aforementioned Web sites, the results of the ESW will be made available to the countries through the following:

- Wider outreach through formal media, with the use of the short films on SLWM as an approach for adaptation to climate change and climate mitigation cobenefits through soil carbon sequestration.
- The national Web-based SLM information systems: a pilot has been developed in Mali as part of the TerrAfrica work program, and it should be duplicated and adapted in other countries in 2010 and 2011. The national Web-based SLM information systems could benefit from the datasets collected under this ESW and from the results of the case studies.
- The national SLM communication strategy: as part of the TerrAfrica activities in many countries, national communication strategies are under development and will support the implementation of the national SLM investment frameworks. These communication strategies should include the dissemination of the short films or other country-level outputs from this ESW.

Workshops on SLWM and Climate Change for Multiple Stakeholders

As part of capacity-development work on adaptation to climate change, workshops are planned. They aim to further disseminate and share knowledge from this study and also to use the film material developed. These workshops include face-to-face or Web-based (for example GDLN or Webex/Adobe) “meetings” connecting different Sub-Saharan African countries—South-South knowledge sharing.
As of early 2010, planned workshops include the following:

- **March 9-13, 2010: Managing Agricultural Water under Climate Change**, Nairobi, Kenya. The course will bring 35 people together and aims to enhance their knowledge and skills on fundamental concepts of climate change and the impacts and responses related to sustainable land and water management. Many of the participants are client country counterparts to Bank-funded projects and are looking for knowledge on integrating climate-change risk management to agriculture-water-natural resources management projects. The agenda includes sharing the Africa Land & Climate Portal and SLWM as an approach for climate risk management. This is a WBI and Africa Institute for Capacity Development course in partnership with ICRISAT, the International Fund for Agriculture Development, the Japan International Cooperation Agency, and the Improved Management of Agricultural Water in. East and Southern Africa.

- **March 11-12, 2010: The Role of Sustainable Land Management and Local Institutions in Adapting to Climate Change**, Bamako, Mali. This regional workshop through sharing knowledge from the studies, will aim to raise awareness on climate risks in Africa and the potential of SLM for climate mitigation and adaptation, and will provide guidance on SLM practices best suited for climate-risk management. All of these could help mainstream climate adaptation into national policies and inform the design of new projects, including those funded by the Bank. Participants from Burkina Faso, Mali, Mauritania, Niger, and Senegal will be attending.

- **May 17-21, 2010: Options and Technologies for Adaptation in Agriculture-water and Natural Resource Management**, Nigeria. This is a meeting of practitioners who have formed the West African Agricultural Network for Climate Change to share knowledge on practical approaches and technologies for managing the risk from climate variability and change. The agenda includes a presentation on the tools and information (historical, current, and projected changes in climate) that can be accessed through the Africa Land & Climate Portal and the global Climate Data Portal. The meeting will also cover steps and guidance for adaptation (Guidance Notes); guidance on the role of local institutions; and case studies to illustrate the roles of knowledge, approaches, tools, and so forth in developing and implementing local and national climate-adaptation programs and policies.

In addition to activities already been planned for the next few weeks and months, others are being considered in order to ensure long-term dissemination and to strengthen capacity building in Sub-Saharan African. These are under consideration by AFTEN and WBI and further information will be forthcoming.
III. Completing the Knowledge-Sharing and Dissemination Strategy: Activities to Be Carried Out in the Medium Term

Since knowledge dissemination about the land and climate nexus has been limited to date, further activities will continue within the context of the TerrAfrica platform and other forums. These activities have not yet been planned; suggestions from Bank staff or TerrAfrica partners include the following:

Further Sharing and Use of the Africa Land & Climate Portal, Especially for Bank Staff

Dissemination of information related to land and climate will continue through the portal. To allow use of the information in the portal, the following products could be developed:

- “Model” country snapshots of climate change and the SLWM practices developed, which could be used as learning tools and workshop material;
- Guidance on developing these snapshots for specific countries, depending on data availability.

Outreach to Scientific, Research, and Policy Communities

A number of opportunities exist for reaching out to these communities, especially drawing on the findings of the case studies. Specific plans include the following:

- Presenting the results of the case studies at research conferences: For instance, the results of the case studies will be presented at the 2nd International Conference on Climate, Sustainability and Development in Semi-Arid Regions—ICID 2010, in Fortaleza, Brazil, August 16-20, 2010.
- Developing policy notes with support from the TerrAfrica Land & Climate Special Advisory Group: As part of the case studies, IFPRI is developing such notes based on the findings of the case studies. The draft documents will be submitted to the review of the experts of the Land & Climate Special Advisory Group to become a joint output.
- An editor from the Economist met recently with IFPRI and discussed the opportunity of a paper related to the case studies, which would be an excellent way to reach a broader audience.

Given that the Copenhagen Accords include both adaptation and soil carbon as a potential mitigation action, further outreach to UNFCCC and UNCCD through side events is envisioned, such as the ones held in at the COPs in September and December 2009. The task team and TerrAfrica partners will bring the findings of the case studies and use the films to further promote their analytical and policy work. For this purpose, leaflets and general publicity material and CDs would be extremely useful and can be distributed through NEPAD/TerrAfrica, WB, and IFRI booths at these international events.
Capacity Building through Learning Programs and Workshops

In the context of the Climate Change for Development Professionals (CCDP) Program, some formal learning programs could be developed that would provide practical guidance to TTLs on how to better take into account climate-risk management and adaptation in their development projects and how SLWM practices can support climate adaptation and mitigation in Sub-Saharan Africa. Such training programs could be adapted for client countries. This should be discussed with the World Bank Institute and the Environment Unit (ENV) for later development.

As part of the SLM Strategic Investment Plan of the Global Environment Fund, many operations have been prepared and are under implementation, led by various agencies (WB, IFAD, FAO, the United Nations Program for Development, the United Nations Program for Environment, and so forth). One of these projects, led by UNEP, focuses on strengthening regional and subregional capacities through a new knowledge management set up: the Country Service Network. As part of this network, a schedule of knowledge-sharing events will be developed in the coming months. It is expected that the findings of the ESW will feed into this curriculum of events, which will benefit a large audience in Sub-Saharan Africa.

The dissemination and knowledge-sharing activities already undertaken and the dissemination plan for the next few months are critical to ensure that this analytical study achieves its objective in providing practical guidance to Bank TTLs and client countries. While activities carried out under the first two pillars of this ESW provide both analytics and practical knowledge, their dissemination is a key to further improving capacity of the African counterparts on the land and climate nexus, especially in the context of the 2010 UNFCCC agenda.
<table>
<thead>
<tr>
<th>Title</th>
<th>Audience</th>
<th>Where to find it</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change in Sub-Saharan Africa, A Resource Guide—Anne Woodfine</td>
<td>extension services</td>
<td></td>
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<td>and Mitigation in Sub-Saharan Africa—John Pender and al,—TerrAfrica</td>
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<td>Climate Change Adaptation and Mitigation in Sub-Saharan Africa”—</td>
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<td>Communication 4 pager of “The Role of Sustainable Land Management</td>
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<td>for Climate Change Adaptation and Mitigation in Sub-Saharan Africa”</td>
<td>projects managers</td>
<td></td>
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<td>Climate Change and Sustainable Land Management Nexus in Sub-Saharan</td>
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<tr>
<td>Africa: A Stocktaking Exercise – Wadja, P. and D. Bonnardeaux—</td>
<td>managers</td>
<td></td>
</tr>
<tr>
<td>World Bank, Washington DC, 2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and the database of SLM best management practices)</td>
<td>managers</td>
<td></td>
</tr>
<tr>
<td>Series of short films related to the Land &amp; Climate nexus</td>
<td>Extension services, development practitioners,</td>
<td><a href="http://www.youtube.com/user/TerrAfrica">http://www.youtube.com/user/TerrAfrica</a></td>
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<td>projects managers and policy makers</td>
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<td>Title</td>
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<td>Various power point presentations delivered during workshops and conferences</td>
<td>Development practitioners and projects managers</td>
<td>CD of deliverables associated to this ESW</td>
</tr>
<tr>
<td>Full synthesis report of the case studies</td>
<td>Development practitioners and projects managers</td>
<td>CD of deliverables associated to this ESW</td>
</tr>
<tr>
<td>Country reports for each case study</td>
<td>Development practitioners and projects managers</td>
<td>CD of deliverables associated to this ESW</td>
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