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Resilient Adaptation to Climate Change in African Agriculture

Chinwe Ifejika Speranza

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German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE)

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Preface

This study was conducted in the context of a research project on "Adaptation to climate change in Africa and Latin America" under the project lead of Dr Imme Scholz and Dr Susanne Neubert, in Department IV: Environmental Policy and Management of Natural Resources of the German Development Institute. The project was funded by the German Ministry for Economic Cooperation and Development (BMZ).

The study analyses how smallholder agriculture in sub-Saharan Africa adapts to or can be adapted to climate change using the concept of a "resilient adaptation" as an analytical lens. I adopted a multi-level and multi-actor approach for analyses at two levels: the farm-level and the policy and institutional level. In the course of the study, I developed an analytical tool and operational instrument, "the Resilience Check" to assess the contributions of adaptations to the resilience of SSA agriculture to climate change. The study also identifies ways through which adaptation in smallholder agriculture can be promoted and made more resilient.

During the study, I benefited from discussions with various colleagues: I gratefully acknowledge the contributions of Dr Susanne Neubert and Dr Imme Scholz for their helpful comments and for reading through the pre-versions of this study. I thank the review commission, comprising Dr Imme Scholz, Dr Susanne Neubert, Dr Michael Brüntrup and Mr Steffen Bauer, for their insightful comments. I am also grateful to Dr Carmen Richerzhagen for reviewing the pre-version, Ms Isabel van de Sand and Dr Waltina Scheumann for their comments. I would like to thank the other members of the project team Britta Horstmann, the project coordinator Anette Köhler-Rahm, and the secretary, Ms Ina Gampfer. I also benefited from discussions and collaboration with Prof U. Wiesmann (Univ. of Bern, NCCR-North-South research programme), Prof M. Nüsser (Univ. of Heidelberg, Volkswagen research project), and the WOCAT team at CDE. I thank the Department IV research assistants for collecting and managing literature: Ina Jacoby, Miriam Bishokarma-Wenner, Simone Dohms, Katharina Graf, and in particular, Michael Eichholz for support in cartography. I am grateful to Silvano Speranza, Chidi and Ikechi Speranza for their patience, understanding and support.

Chinwe Ifejika Speranza Bonn, March 2010

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Abbreviations

ACMAD	African Centre of Meteorological Application for Development
AF	Adaptation Fund
AFB	Adaptation Fund Board
AFS	Agricultural Finance Services
AHTEG	Ad Hoc Technical Expert Group
AoA	Agreement on Agriculture
BLR	Buyers of Last Resort
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung / Federal Ministry for Economic Cooperation and Development
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CARE	Cooperative for Assistance and Relief Everywhere, Inc.
CBO/NGO	Community Based Organisation / Non-Governmental Organisation
CBD	Convention on Biological Diversity
CDE	Centre for Development and Environment (CDE), University of Bern, Switzerland
CDM	Clean Development Mechanism
CEEPA	Centre for Environmental Economics and Politics in Africa
CER	Certified Emission Reduction
CGAP	Consultative Group to Assist the Poor
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center (Spanish: Centro Internacional de Mejoramiento de Maíz y Trigo)
CIP	International Potato Center (Spanish: Centro Internacional de la Papa)
CPAs	CDM Programme Activities
CO_2	Carbon dioxide
CTA	Technical Centre for Agricultural and Rural Cooperation
DFID	(UK) Department For International Development
DJF	December, January, February

DRN	Development Researchers' Network, Italy
DTMA	Drought-Tolerant Maize for Africa
DTR	Diurnal Temperature Range
EAC	East African Community
ECF	European Climate Forum
ECOWAS	Economic Community of West African States
ELPF	Early Livelihood Protection Facility
ENSO	El Niño-Southern Oscillation
ES	Ecosystem Services
ESTs	Environmentally Sound Technologies
EU	European Union
EWS	Early Warning Systems
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organisation Statistics
FCCC	(United Nations) Framework Convention on Climate Change
FEWS-NET	USAID Famine Early Warning Systems Network
FiBL	Research Institute of Organic Agriculture / Forschungsinstitut für biologischen Landbau
FRA	Zambia Food Reserve Agency
FRI	Farm Radio International
FS	Financial Service
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green-House-Gas
GLASOD	Global Assessment of Human Induced Soil Degradation
GNI	Gross National Income
GTZ	Gesellschaft für Technische Zusammenarbeit
HDR	Human Development Report
HIV/AIDS	Human Immunodeficiency Virus / Acquired immune deficiency syndrome
IIASA	International Institute for Applied Systems Analysis
IAASTD	International Assessment of Agricultural Science and Technology for Development

ICPAC	Eastern Africa Climate Prediction and Application Centre
ICM	Integrated Crop Management
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communication Technologies
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFOAM	International Federation of Organic Agriculture Movements
IFPRI	International Food Policy Research Institute
IGAD	Intergovernmental Authority on Development
IICD	International Institute for Communication and Development
IITA	International Institute of Tropical Agriculture
IMF	International Monetary Fund
INGO	International Non-Governmental Organisation
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute
IRIN	Integrated Regional Information Networks
ISDR	International Strategy for Disaster Reduction
ISFM	Integrated Soil Fertility Management
IWMI	International Water Management Institute
JJA	June, July, August
JLG	Joint Liaison Group
LDC	Least Developed Countries
LEAP	Livelihoods Early Assessment Protection
LEG	LDC Expert Group
LGP	Length of Growing Period
LULUCF	Land-Use Change and Forestry
MDG	Millennium Development Goals
MEA	Multi-lateral Environmental Agreement
MFI	Microfinance Institution
MFS	Microfinance Services
NAPA	National Adaptation Programme of Action

NAP	National Action Programme
NARS	National Research Centre
NASFAM	National Smallholder Farmers' Association of Malawi
NBSAP	National Biodiversity Strategies and Action Plan
NC	National Communications
NCCR	The Swiss National Centre of Competence in Research
NCPB	National Cereals and Produce Management Board (Kenya)
NDVI	Normalized Difference Vegetation Index
NEPAD	New Partnership for Africa's Development
NERICA	New Rice for Africa
NFRA	Malawian National Food Reserve Agency
NFSP	National Food Security Programme
NGO	Non-Governmental Organisation
NMHS	National Meteorological and Hydrological Services
NORAD	Norwegian Agency for Development Cooperation
NRC	National Research Council
N_2O	Nitrous oxide
OA	Organic Agriculture
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
OPV	Open Pollinated Variety
ORCHID	Opportunities and Risks of Climate Change and Disasters
P	Phosphorous
PES	Payment for Ecosystem Services
PoA	Programme of Activities
PRSP	Poverty Reduction Strategy Paper
PSNP	Productive Safety Nets Programme
RFP	Rural Finance Programme
RFS	Rural Finance Service
ROK	Republic of Kenya
RWH	Rain Water Harvesting
S	Sulphur
SACCO	Savings and Credit Cooperative

SADC	Southern African Development Community
SAP	Structural Adjustment Policies
SARCOF	Southern African Regional Climate Outlook Forum
SBI	Subsidiary Body for Implementation
SCCF	Special Climate Change Fund
SER	Social-Ecological Resilience
SES	Social Ecological System
SOEL	Stiftung Ökologie und Landbau
SGR	Strategic Grain Reserves
SHFG	Self Help Financial Groups
SIDA	Swedish International Development Cooperation Agency
SLM	Sustainable Land Management
SRES	Special Report on Emissions Scenarios
SSA	sub-Saharan Africa
SST	Sea Surface Temperature
SWC	Soil and Water Conservation
TNA	Technology Needs Assessment
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP/GRID	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
URT	United Republic of Tanzania
USAID	United States Agency for International Development
USEPA	US Environmental Protection Agency
WA	West Africa
WAM	West African Monsoon
WARDA	West African Rice Development Center
WCCD	World Congress on Communication for Development
WCED	World Commission on Environment and Development
WDR	World Development Report
WFP	World Food Programme

WOCAT	World Overview of Conservation Approaches and Technologies
WRI	World Resources Institute
WMO	World Meteorological Organization
WRS	Warehouse Receipt System
WTO	World Trade Organization
WUA	Water Users Associations

Summary

Climate change will intensify the already adverse conditions of crop production in the drylands. Considering the socio-economic and political contexts of climate change in sub-Saharan Africa, a central argument is that adaptations to climate change need to be resilient, that is, to have the ability to deal with stresses and disturbances as a result of change, while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to learn and adapt to change.

Thus this study analyses how a resilient adaptation of smallholder agriculture to climate change in Africa can be achieved. It also aims to develop an analytical tool that can be used to assess the resilience of SSA agriculture to climate change. Based on the findings it identifies ways through which adaptation can be promoted and made more resilient at policy, institutional and smallholder levels.

To achieve these objectives, literature was analysed and concepts for analysing adaptation to climate change elaborated. Considering the subject and context, resilience is a superior but complementary concept to vulnerability and adaptation as it explicitly addresses the ability to deal with change, whether adverse or beneficial. Based on this understanding, a tool, the resilience-check was developed. Using the developed resilience-check, various farmer practices as well as policy and institutional instruments and services were analysed for their contributions to a resilient adaptation to climate change in smallholder agriculture.

Smallholder farmers (or small-scale farmers), that is, those operating a farm of 2 hectares or less were chosen as the focus of analysis. They constitute the majority of the rural poor, practice rain-fed agriculture, and account for most food production in SSA. They are also among the worst hit by climate change due to their dependency on rain-fed agriculture.

Agriculture and development in sub-Saharan Africa

This study departed with an analysis of SSA agriculture, and examined how climate change impacts on it. The analysis of SSA agriculture showed that many non-climate factors determine the success and failure of smallholder agriculture. Climate change will overlay and interact with these

factors to further worsen the crop production conditions in SSA. However, the recent improvements and prospects in agricultural growth propelled by the commitments of many SSA countries to allocate 10 percent of their respective budgets to agriculture will likely lead to growth in the sector.

Other developments include the recent leasing out of agricultural lands in some African countries to countries outside Africa to produce food for export back into the investor countries. This indicates that significant potentials for land suitable for agriculture still exist. Yet, such an arrangement (at least under the mostly disadvantageous terms for locals) is odd considering that many of those African countries that lease out land do not produce enough food for their own consumption. The overriding claims of the national governments that lease out the land and the communities that perceive the land to be theirs hold potentials for conflict considering that land has been at the root of many social upheavals in SSA. Such lease agreements highlight the need for an international reference framework. Land tenure and security of tenure thus continue to play key roles in smallholder farming and are crucial for various adaptation practices.

Observed and projected climate change impacts and agriculture

Most of the emissions in Africa come from the agricultural and related forestry sector implying that an integrated approach, which simultaneously addresses adaptation and mitigation, is more appropriate.

The observed changes in climate give a picture of *increased variability*, of *decreases as well as increases in rainfall and temperature*. A spatially differentiated analysis of the observed impacts as derived from climate impact studies did not yield any distinctive messages on the spatial and temporal manifestations of the impacts. Precipitation amounts will decrease for most parts of SSA while rainfall variability and intensive rainfall events will increase. Future climate change is expected to *intensify the already observed changes* if no remedial actions are taken to reduce emissions.

Further, climate projections for SSA do not fit the spatial and temporal scales of agricultural processes, practices or planning and cannot yet produce the details needed for impacts assessments. These limitations of climate change projections need to be understood and accounted for in research, policy and planning that depart from or aim to account for climate change impacts. Thus *"dealing with uncertainty"* becomes a major focus for adaptation.

From the perspective of political regimes, projections are provided for the distant future (20, 30, 50, 80 years) and as such this distant future may not be the priority of current political regimes. Thus, downscaling of climate models and projections remains crucial.

Developing tools that enable decision makers at various levels to factor climate change into policies and their activities can promote adaptation. Projecting climate change impacts could be one way of informing decisions on climate change but the current drawback is that many projections have coarse spatial resolutions and are thus not so useful for decisions pertaining to smaller geographic areas.

Concepts and approaches for analysing adaptation to climate change

Analyses showed that the concepts of vulnerability, adaptation and resilience are interlinked but that the distinctions between poverty and vulnerability are sometimes blurred. It remains difficult to differentiate development activities from adaptation actions and in many cases adaptation actions will be the same as development action. In this tension between development and adaptation, it is prudent to build adaptations on robust foundations. This is why *adaptation essentially has to be developmental* and the issue of additionality in adaptation while important is rather political as it does not reflect the actual realities. Various criteria for evaluating adaptation such as effectiveness, flexibility, economic efficiency, social acceptability, timeliness, equity, institutional compatibility, farmer implementability, and net benefits independent of climate change, were discussed.

Evidence collected showed that SSA will mainly experience adverse impacts but a major challenge is to deal with the uncertainties in climate predictions. Considering the uncertainties, the widespread poverty and lack of capacities, the resilience concept offers a superior entry point to analyse adaptations to climate change under conditions of uncertainty compared to vulnerability. A central argument is thus that *adaptations to climate change need to be resilient*, by building buffer capacities, enhancing self-organisation as well as being able to learn and adapt. A resilience approach focuses on underlying causes as well as long-term capacity to deal with change. It was shown that resilience underpins adaptive capacity without which adaptations will not be possible. Thus, resilience takes adaptive management – iterative planning and management – as an entry point. While the development approach was found to have some overlap with the resilience approach, the latter was found superior in addressing development under conditions of change.

An analytical tool and operational instrument for assessing adaptation and resilience to climate change was developed: the "resilience check". The basic assumption is that the widespread poverty of smallholder farmers and the uncertainties surrounding the spatial and temporal manifestations of climate change impacts require an approach that strengthens the capacity of smallholder agriculture to persist under varying production environments. Considering that agriculture is positioned at the intersection of social and environmental systems, a *socio-ecological approach* was selected to guide the analysis.

The various actors and the various levels at which smallholder agriculture and related activities take place lend themselves to *multi-level and multi-actor perspectives* for analyses and for implementing adaptations. Two levels were chosen for analysis: the farm-level and the policy and institutional level. At the farm level, the agricultural practices of smallholder farmers and their contributions to resilience were analysed and assessed. At the policy and institutional level, the international environmental policy framework and the contribution of support services at national levels to the resilience of smallholder agriculture were assessed.

Farm-level resilience and adaptations of agriculture to climate change

Adaptation was examined at the level of the farm management and at the level of farm practices. Analysis of adaptation at the level of farm management examined conventional, organic, conservation, integrated crop management and other integrated approaches. Irrespective of farm management chosen, *resource use efficiency* is critical both for maintaining or increasing production in the face of climate change as well as for protecting the environment and mitigating climate change. In many cases, an integrated management approach, in which farmers choose bundles of practices applicable to their context, is recommended.

In analysing adaptation options, it has to be considered that most SSA smallholders practice *various forms of organic farming by default* – meaning their pecuniary circumstances force them not to use fertiliser, pesticides, high yielding seeds, and mechanisation. Thus, their management approaches do not (yet) pollute the environment as would be the case if they intensified their production with chemical fertilisers and mechanisation. Yet these two factors belong to the core factors for increasing food production. Thus, an adaptation strategy for smallholder farming systems in Africa has to ensure that adaptations in agriculture keep to a *low carbon path* but at the same time increase production – an integrated approach that combines the merits of organic practices with those of *low carbon intensification*. This means that smallholders need new and affordable farm technologies that are environmentally friendly and allow them to practice integrated nutrient management. What is clear in the SSA context is that *any shift of farm management in the context of adaptation must not be at the expense of sustained food production*.

At the level of practices, analysis showed that there are several ways to adapt to climate change at the farm-level. These different ways are mainly complementary as they address different components of the smallholder farming system. *Adaptation was confirmed to be a continuum of practices* which ranges from activities that are predominantly developmental to those that focus on reducing climate change impacts. No one single measure is sufficient to adapt to climate change. Rather, *a mix of measures* is needed which targets the various farm variables – water, soil, micro-climate, seeds and crops as well as labour and capital.

Analysing farm practices highlighted the *close link between climate change adaptation and mitigation* in the agricultural sector. Many of the adaptation practices like mixed cropping, green manures that fix nitrogen, agro-forestry and improved range land management sequester carbon, thereby reducing greenhouse concentrations in the atmosphere. Other measures like rain water harvesting and soil conservation measures reduce soil erosion and the silting of rivers. Considering these *environmental services* and the pecuniary circumstances of smallholders, providing smallholders with incentives or compensation for good land management practices holds potentials for poverty reduction, environment and climate protection. Development and climate policy, as well as development cooperation need to exploit these potentials.

For adaptation to be sustainable, *local knowledge should be combined with other knowledge systems*. Local production should not be reliant mainly on external inputs as this is one factor that ultimately spells the failure of adaptations. Input in this sense covers both factors of production as well as the knowledge and skills needed to run the agricultural system. This does not mean that all of the knowledge should remain with the farmers at the local level but that a system of cascading and overlapping knowledge creation in which the various national to local institutional frameworks play their expected roles is needed. This means a coordinated approach between the research institutes, the agricultural extension officers, private sector actors, other government bodies, NGOs, civil society and not the least the farmers to promoting adaptation practices.

Since the emission portfolio of SSA countries is dominated by emissions from agriculture and forestry, reducing emissions by these countries will have to target these sectors. The contributions of agro-forestry to resilience – carbon sequestration, nitrogen fixation and a source of income are similar to those of crop management practices, but on a longer-term scale and of a larger quantity. In line with linking adaptations to poverty reduction, agro-forestry was found to be an adaptation strategy that could benefit from the global carbon credit market. The fact that SSA has gained very little from the current carbon trading schemes (in contrast to large commercial farms in Asia) hints at the *inadequate existence of know-how and resources* required for establishing such schemes as well as the disadvantageous structures of the CDM scheme of the UNFCCC whereby most certifying companies are located outside Africa. Agro-forestry could be eligible for a programmatic CDM of small-scale afforestation and reforestation in which the district, provincial or national government (or even private entities) offers farmers incentives through a CDM programme to promote afforestation and reforestation.

Farmer social network and group organisation are effective in regulating the use of natural resources such as in water users associations or forest users associations. Such group organisations offer an effective governance instrument to deal with the conflicts that are likely to increase as a result of climate change triggered resource scarcity.

The resilience check at the farm-level showed that each adaptation practice contributes to the resilience of smallholder farming to climate change in one or several dimensions (ecological, economic and social). Notable is the fact that building resilience in one dimension has mostly significant positive effects but in a few cases negative effects. Thus, adaptations have to be screened to avoid mal-adaptation. Using the resilience check to screen the expected outcomes of an adaptation is one way to use this tool. Ordinarily, not all adaptation measures would be found within the same farm and at the same time. Rather, farmers *will adopt certain adaptation measures based on their utility* at a particular point in time and may switch to others as opportunities arise. Thus, using the resilience check in the collection and analysis of data will provide more detailed and differentiated data and insights about the contribution of adaptation practices to resilience at the farm-level. The resilience check needs to be used at periodic intervals in order to capture the changes in the contributions of adaptation measures to resilience. This will also promote the early identification of mal-adaptations.

In addition, the time, labour and financial costs of each adaptation practice or strategy can determine their adoption or non-adoption. While some adaptations are relatively quick to be established (several weeks to one year), others require longer periods or continuous adjustments. For example, assuming that heat-tolerant crops or varieties are available to a farmer, the farmer will gradually test these seeds over a period of two to six seasons (circa 3 years) and will successively increase the acreage covered depending on their performance and socio-economic acceptability. Compared to capital, smallholder farmers have better access to labour (own and social network). It should be expected that smallholders will be slower to adopt the adaptations that are cost-intensive compared to those that are labour-intensive, although motivation to adopt certain adaptation practices also plays a role.

The Rio Conventions and their link to national policy frameworks

Moving up to the national level, the issue of how national policy frameworks link to the Rio Conventions (CBD, UNCCD, UNFCCC) was analysed using the action plans as entry points. The reason for also analysing the action plans of the CBD and the UNCCD is because of their overlapping domains and interactions: sustainable land management reduces land degradation and positively affects agricultural productivity. Agricultural management in turn can adversely or positively affect land quality and biodiversity. The conventions provide international reference frameworks for national governments to address and mainstream climate change adaptation, desertification and biodiversity into national policies and programmes. In that way, they build the adaptive capacity of the developing countries. Most action plans have significant relevance and potential synergies in relation to country priorities, and are in a few cases integrated into regular country planning processes. Thus, they have made their mark in country planning frameworks.

While some level of harmonisation may have been achieved, a more important goal is the *actual planning and implementation* of the conventions' action plans at the national and local level. Thus synergy in implementation is crucial and this requires close cooperation among the national focal points of the multi-lateral environmental agreements, as well as explicitly providing funds for the implementation of identified synergies.

Drawing lessons from past experiences in technology transfer was found crucial in the framework of developing the NAPA as some of the prioritized projects on developing drought resistant crops are unclear. This is because crop research institutions that work on the major grains of the drylands suggest that drought-tolerant varieties are already developed and only need to be diffused. Placing the evidence of the research institutions against such prioritized NAPA projects and the way the projects are presented hint that such crucial information on advancements in crop research were not considered. It may also be that the proponents plan to do so, but this information is not explicit in the reporting format of the NAPA documentations.

A fundamental question that needs to be posed is this: could the three conventions not be adequately addressed within a common action programme? Instead of having NAPA, NAPs and NBSAPs, would it not be enough to have one action programme instead of spending resources to ensure that the synergies are addressed? The process has been piecemeal. First the NBSAPs, then the NAPs, then the NAPAs. Then, along the way, one realises there are synergies that need to be addressed. A more viable way would be to take the synergies as the departure point and *address these environmental problems together in one integrated action plan*.

Integrated approaches are also needed in development interventions aimed at promoting adaptation to climate change. Smallholders are exposed to global environmental change and economic globalisation leading to competition between smallholder produce and highly subsidized produce from industrialised countries. There is a need to *examine the trade-offs and synergies between international climate and trade policies* as these can impede or enhance adaptations. This means that any introduced *adaptation measures should be tested through the whole chain* from smallholder producers to consumers to ensure that adaptation practices are really providing layers of resilience against climate change. It does not make sense to improve productivity and not have a market for the produce thereby leaving this to waste – this does not contribute to poverty alleviation in the long-term.

The costs of many adaptation measures cannot be borne by smallholder farmers in Africa. Considering that the UNFCCC funds are not enough to address the problems caused by climate change, there is a need to look for complementary funding sources. Since knowledge on how to access such funds is still exclusive, capacity building is crucial in this area. Otherwise, the danger of the funds being used exclusively for what the few that have access to them deem fit, without acknowledging the needs of the vulnerable, is high. In this sense, development policy and donor coordination in development cooperation need to be improved so that the scarce resources can be bundled to achieve increased benefits.

Policy and institutional level adaptation frameworks and instruments

Departing from the policy frameworks, various services were assessed for their contributions to a resilient adaptation. They include early warning systems, crop research, extension services, rural radios, rural finance and micro finance, weather indexed crop insurance, payment for ecosystem services and the strategic grain reserves.

Analyses revealed the interdependencies between various services. This means that limitations in a base service lead to limitations in the depending services, which cannot always be compensated by any other means. For example, effective decisions in providing extension services or managing strategic grain reserves depend significantly on the correctness of the weather forecasts and other information provided by Early Warning Systems (EWS). Thus, the basic services on which others build, in this case the EWS, need to be improved first, before other depending services can profit from their potentials.

Crop research is a crucial area for adaptation to climate change in order to deal with changes in the length of growing seasons, increased droughts and periodic water logging as well as increased temperature and salinity. Some crop research institutions report that they have already *developed improved varieties that address most of the above challenges as known in the medium term* (2010–2050). This is good news that needs to be spread to the relevant actors. Thus, efforts should be concentrated to bring these improved varieties of maize, rice, cassava, pearl millet, sorghum, chickpea, pigeon pea and groundnut to the farmers. National Agricultural Research Centres and the private sector in areas expecting more droughts in future should be supported to re-deploy and re-target the existing germplasm of crop research institutions.

Some of the services discussed are new and promising, for example, index-based weather insurance. This means that monitoring and evaluation will be necessary in a few years time in order to ascertain how effective these are in supporting adaptation to climate change.

Associated with the foregoing, and a prominent feature of most of the services is the *high level of external dependence*. This donor-driven and donor-controlled feature raises the issue of ownership and sustainability of interventions. It also raises the question of what the primary responsibilities of African governments are. How to ensure that such projects and programmes continue after the donors have left is not highlighted. Available data does not provide sufficient information to draw conclusions at the moment. However, the issue of the sustainability of interventions is fundamental for development policy and cooperation and should therefore be given more attention or prominence in the reporting.

In this light, the foregoing analyses show that building capacity should not be an add-on in the establishment of these services but should be explicitly accounted for from the outset, especially for those areas that require special knowledge and skills. A tool for measuring the contributions of development/adaptation projects/programmes to capacity building need to be developed and used. This also holds for the mechanisms of the international environmental regimes.

While some services are predominantly donor-driven, the Strategic Grain Reserve is the only service analysed where donors are generally absent. This reflects the *divergences in the understandings of international development policy and national development policies on the importance of holding a physical grain reserve* for the SSA countries. In principle, holding a Strategic Grain Reserve (SGR) is good because it gives countries a manoeuvring space to address short but acute food shortages and time to moderate widespread food shortages before food imports arrive. Food is also a political issue as a government that cannot provide its inhabitants food is seen by the hungry to have failed them and thus loses legitimacy. However, the poor performances of the SGRs so far do not speak for their further existence. Considering that the principle is good but the practice bad, corruption and mismanagement need to be addressed by improving the guidelines and having the political will to penalise corruption.

As is the case with farm practices, no one single service analysed above is sufficient for adaptation to climate change. Rather, a mix of services that targets the various farmer categories – from "very poor smallholders" to "not so poor smallholders" is required. Further, the effects of various measures across scales need to be accounted for as certain measures carried out at farm-levels may have positive or negative consequences downstream. Similarly, measures carried out at higher decision-making levels need to be coordinated.

How to reach the *very poor and very marginal areas* remains a challenge. While interventions may reach the poor generally and contribute to poverty alleviation, the very poor remain shut-off from participating in development activities, due to entry barriers like payment of membership fees by a farmer group which is crucial for being able to access farm support instruments like micro-finance or micro-insurance. Even in the adoption of recommended improved technologies, it is those who have the money to invest that do so and succeed. Therefore, the danger of increasing the gap between rich and poor has to be accounted for in interventions that aim to promote climate change adaptation. Specifically targeting the very poor is crucial to achieving a sustainable adaptation to climate change, but since this group is not economically interesting for the private sector, it remains in the hands of governments and NGOs to specifically target the very poor. Inadequate extension resources imply that the poorer farmers cannot be adequately targeted. A solution would be to shift the focus of public extension services to the poorer farmers and marginal areas, while allowing private extension providers to service the cash crop sector and the high-potential areas. In order not to keep on perpetually targeting the poor, it might be worthwhile to invest in the human capital of the poor. Educating and training the very poor to provide extension and other relevant services to their own communities (instead of external persons doing so) is one way to improve the access of marginal communities to agricultural services and also reduces the poverty levels of the new local service providers.

Each of the adaptation strategies analysed in this study requires a capacity-building component whose aim should not only be to disseminate knowledge and skills but also to do so in such a way that this leads to the empowerment and self-organisation of smallholders. Since in some drylands, agriculture may no longer be a viable alternative, enhancing human capital to be able to earn livelihoods in other economic sectors becomes a prerogative to adapting to climate change.

Like for the agricultural practices, the resilience check was used to analyse the contributions of the services to a resilient adaptation to climate change in smallholder agriculture. Results show that *most of the services contribute to economic resilience, in some cases to social resilience, but hardly directly to ecological resilience*. This is plausible because the direct benefits of most services are in increasing financial, human and social capital. However, these benefits extend to ecological resilience in that with improved financial, social and human capital, smallholders are able to invest in farm production and improve their farm management practices, thereby strengthening their adaptive capacity.

Analyses conducted in this study confirm that buffer capacity, self-organisation and increasing the capacity to learn and adapt (adaptive management) underpin adaptations. The interactions between resilience and adaptation have been confirmed to be reinforcing. However, mal-adaptations can reduce buffer capacity and increase vulnerability. The insights gained in this study will be used to improve the resilience-check tool. A follow-up to this study could examine how to make the tool more operational to be used for adaptation planning and evaluation purposes at national, district or local levels but even within the programmes of international development cooperation. The resilience check could provide the socio-economic complement lacking in most climate-proofing tools that have been developed so far.

Finally, empirical studies are needed at different levels to test its contribution to adaptation planning. Since this study focussed mainly on the agro-pastoral production system, there is a need to carry out a similar study on adaptation in other agricultural production systems.

1 Introduction

Climate change (including climate variability) already affects physical processes in many parts of the world, leading to changes in temperature and rainfall patterns, in wind direction and increased intensity and frequency of extreme events like droughts, floods and cyclones (Trenberth et al. 2007). The time-lagged nature of climate change implies that the currently observed climate change is attributable to greenhouse gas emissions of the 19th and 20th centuries and that the effects of current greenhouse gas emissions will also lag into the future. This means that focussing on mitigation alone will not address the inevitable impacts of currently observed climate change. Adaptation, that is adjustments which moderate harm or exploit beneficial opportunities in response to actual or expected climatic stimuli or their effects is therefore imperative (IPCC 2007). However, a central argument of this study is that it is not sufficient merely to adapt but that *adaptations need to be resilient* (see Box 1).

Box 1: Resilience and resilient adaptation
Resilience refers to the ability of a system to deal with stresses and disturbances, while retaining the same basic structure and ways of functioning, capacity for self-organisation, and capacity to learn and adapt to change. Resilience is therefore about managing changes and adaptations should contribute to *climate-resilient development*, i. e. adaptations that can stand the test of current and future climate risks. A resilient adaptation is thus one that contributes to the various features of resilience in the short and long-term. Resilient adaptation complements the concept of the "precautionary principle" in Article 15 of the Rio Declaration of 1992 (Glantz 2008). The concept of resilient adaptation can serve as a guiding principle for planning adaptations which account for uncertainties in future climate change. Considering this uncertainty and the dynamic nature of climate change, mal-adaptations, i. e. adaptations that may appear appropriate and beneficial in the short-term but increase vulnerability with time are non-resilient.
Sources: Carpenter et al. 2001; Berkes / Colding / Folke 2003; Folke 2006; IPCC 2007; Glantz 2008

Because many biological and socio-economic processes such as crop growth and produce prices depend in part on production conditions (of which climate is one), changes in climate affect food and livelihood security. It also reverses development achievements, for example, crop failure due to frequent droughts contributes to increased poverty. However, climate change also holds some opportunities, for example, areas that were hitherto not conducive to agriculture, like higher altitudes, become so due to increases in temperature. However, in global comparison, Africa is expected to experience mainly negative climate change impacts, in terms of an increase in the already high temperatures and a decrease in the largely erratic rainfall in its context of widespread poverty and low development.

Therefore, planning and financing adaptation as well as adapting to climate change require an understanding of current conditions – in social (incl. economic, political and cultural) and ecological as well as sector-related dimensions. It requires an understanding of the adaptive capacities, resilience and livelihood strategies of the local population who are directly affected by the impacts of climate change and who must cope with the realities of multiple pressures (e. g. climate variability and change, market and institutional failures, environmental degradation, poverty and diseases to mention just a few). It also requires an understanding of how the various levels of governance enable or hinder local actors to improve their well-being. Knowing the what, how, when and where of climate change and the options for adaptation will allow for well-informed decision-making by farmers, policymakers and practitioners. These spatio-temporal (where and when) dimensions and multi-actor perspectives promise relevant insights for achieving sustainability in adaptation and in reducing poverty and vulnerability to climate change.

Poverty is one of the major factors accountable for the vulnerability and limited adaptive capacity of sub-Saharan Africa (Misselhorn 2005; Boko et al. 2007; World Bank 2007a; Ifejika Speranza et al. 2008). It is also the poor who first bear the brunt of climate change impacts and at the same time have little or no capacity to withstand or adapt to climate change. Thus, climate change will worsen the situation for the poor. This constellation has implications for development cooperation – meaning that in the context of climate change, development cooperation must orient itself inter alia towards adaptation to climate change (hereafter referred to as adaptation). For adaptation, this means that adaptation must be development-oriented to achieve the Millennium Development Goals (MDG), in particular, to halve the proportion of the world's population whose income is below 1 US$ a day by 2015 (UNDP 2003). A large proportion (>40 percent) of the poor (living with < 1 US$ a day) in sub-Saharan Africa (SSA) live in rural areas (World Bank 2007a) and depend mainly on agriculture despite the increasing growth of off-farm incomes and rural-urban migration (Akonga / Downing 1985; Powell / Pearson / Hiernaux 2004).

Smallholder farmers (or small-scale farmers), that is, those operating a farm of 2 hectares or less (World Bank 2007a, 269) and inhabiting the drylands are the focus group of this study. They are among the worst hit by climate change but few comprehensive studies exist which discuss how they adapt to climate change and the various ways that policies and institutions support them in this process. Thus, this study analyses the various ways that climate change impacts on smallholder livelihoods and the actions taken by various actors at different levels to address the threats and opportunities posed by climate change to smallholder agriculture. The fact that many smallholders are poor, practice rain-fed agriculture, and account for most food production in SSA implies that (a) any policy which aims at poverty and hunger reduction needs a major focus on the rural population (cf. Jama / Pizarro 2008); (b) since most of the rural population depend on rain-fed agriculture, increasing agricultural growth, although not solely sufficient (Prowse / Chimhowu 2007) is in most cases crucial for poverty reduction (World Bank 2007a); (c) although rainfall is an important factor, the contribution of other aforementioned multiple pressures and factors framing the adaptive capacity of smallholders also needs to be considered, and finally (d) since rain-fed agriculture is directly dependent on rainfall, and climate change will manifest itself in changed temperature and rainfall patterns, it is prudent to examine how adaptation in SSA agriculture and in particular among smallholder farmers can be promoted in a more resilient manner.

1.1 Aims and objectives

Considering the aforementioned, the general goal of this study is to contribute knowledge on adaptation to climate change in SSA agriculture. The specific objectives are to

1. develop an analytical tool (of indicators) that can be used to measure/ assess the resilience of SSA agriculture to climate change;
2. analyse ongoing climate change (including climate variability) adaptation strategies in SSA agriculture, their barriers and any gaps using the developed analytical tool for selected illustrations, and
3. identify ways in which adaptation can be promoted and made more resilient at policy, institutional and smallholder levels.

To achieve these objectives, analyses of literature (peer-reviewed articles, project reports and other documents) are carried out. In Chapter 2, the background context of smallholder agriculture and climate change is discussed. In Chapter 3, concepts are introduced and a method for assessing the resilience of agricultural practices to climate change is proposed. Subsequently, adaptation practices at farm, institutional and policy levels are analysed in Chapters 4 and 5. Finally, the study concludes by highlighting the major findings and implications for national governments, climate policy, development policy and cooperation as well as for research.

2 Background

An analysis of the context of smallholder agriculture in sub-Saharan Africa (SSA) is crucial for this study in order to understand the ramifications of climate change for the sector. This chapter provides these insights by first examining agricultural development in Africa, the interactions of climate and agricultural systems, the observed and expected climate changes and their impacts.

2.1 Agriculture and development in sub-Saharan Africa

Many SSA countries have agricultural-based economies. Agriculture contributes on average 34 percent to the GDP of SSA countries and employs 64 percent of the labour force (World Bank 2007a, 27). It accounts for about 40 percent of exports and provides various ecosystem services. Agriculture and rural development are thus key pillars of the SSA economy.

Currently, many SSA countries are *net importers of food* and barely produce enough for the own population (World Bank 2007a). World Bank (2007a) reports that most agriculture-based countries are net importers of staple foods (p. 95) and of cereals (p. 106), and spend a large share of their export earnings on staple food and cereal imports. For example Benin, Burundi, Ethiopia, Mozambique, Niger, Rwanda, and Sudan spent more than 10 percent of their export earnings over the past 10 years on cereal imports while Burkina Faso spent as much as 20 percent (World Bank 2007a, 106). In case of food staples, World Bank (2007a, 95) reports that almost all the agriculture-based countries imported "on average 14 percent of their total consumption over the past 10 years". Guinea-Bissau was reported to have reached dependency levels of more than 40 percent in staple food imports in the same period.

The implication of this high dependency on imported food is that such countries are more likely to be affected by high world food prices, global price fluctuations and volatility (OECD / FAO 2008; FAO 2008). The rise in world food prices in 2008 was associated with constrained access to food in many African countries and resulted in social unrests and protests in Burkina Faso, Senegal, Ivory Coast, Mauritania and Cameroon. Meanwhile OECD / FAO (2008, 11 and 58) in its agricultural outlook indicates that "commodity prices – in nominal terms – are expected to remain at higher average levels over the period 2008–2017 compared to 1998 to 2007". This means for example that average wheat and maize prices may be some 40 to 60 percent higher for 2008 to 2017 compared with that over 1998 to 2007. According to IMF (2009) Africa is also likely to be hit hard by the current global financial crises. The IMF projects growth in sub-Saharan Africa to "decrease from about 5.25 percent in 2008 to about 3.25 percent in 2009".

In several cases, SSA countries like Ethiopia, Kenya, Mali or Niger have had to resort to food aid to feed their populations in times of food crises (cf. WFP 2006a) because of failures in governance and production. Undernourishment also persists in SSA: in the 1990–92 period, the proportion of undernourished in the total population was 35 percent, in the 2001–2003 period, it was still 32 percent. Thus, the region has the highest proportion – one-third – of people in the world suffering from chronic hunger (FAO 2006a). Hunger is both a political and an agricultural issue: political, due to the mismanagement of strategic grain reserves (cf. Devereux 2002; Harrigan 2003; Tschirley et al. 2004), the neglect of smallholder farmers relative to cash crop farmers, and the hitherto poor market prices for agricultural produce. Agricultural reasons relate to the direct dependence on a highly variable rainfall, the small farm plots, low farm input (low fertilizer use, mechanisation and irrigation) and the sometimes poor management practices of farmers and pastoralists-turned-agro-pastoralists.

Food imports are projected to double by 2030 if no remedial measures are put in place to change the incentives for production, design equitable trade conditions, balance out the terms of international trade and at the same time increase own agricultural production (World Bank 2007a, 63). The 2008 recent rise in prices of agricultural produce is an incentive to increase production, but these favourable economic conditions need to be communicated to smallholders in a timely manner in order to avoid late responses.

Although SSA agriculture has experienced growth in recent years (around 5–6 percent in many countries), agricultural production and growth in SSA still lags behind that of many world regions (World Bank 2008a). Some of the major explanations given in literature can be categorised under *resource availability and quality*, *access to resources*, *human resources and social networks, resource utilization* as well as *markets, policies and institutions*.

Availability and quality of resources

1. Rain water

The drylands are characterised by resource limitations for rain-fed agriculture. According to Sant'Anna (1993) average rainfall ranges from 200 to 800 mm in the semi-humid wooded to semi-arid savannah zone. This means that the types of crops that can be grown successfully are limited: millet, sorghum, groundnuts, cotton and maize. However, these crops are mostly grown on the mainly low fertile soils of SSA.

2. Water for irrigation

Another important farm resource in SSA is blue water, i. e. water from rivers, lakes and groundwater, for *irrigation*. On a continental scale, SSA has substantial water quantities. However, this varies from region to region as sub-Saharan Africa has the largest number of water-stressed countries of any region (UNDP 2006). Using 1,700 cubic metres per person as the national threshold for meeting water requirements for agriculture, industry, energy and the environment, it is projected that by 2025, nine SSA countries will have less than 1,000 cubic meters per person per year (water scarcity) while further twelve countries will have only 1,000 to 1,700 cubic meter per person per year (water stress) (UNEP / GRID Arendal 2002; UNDP 2006). Currently, about 25 per cent of the African population experiences water stress while 69 percent live under conditions of relative water abundance (Vörösmarty et al. 2000), without considering water quality and access (Bates et al. 2008). While investments in irrigation have been found to alleviate poverty, only 4 percent of cropland is irrigated in Africa (World Bank 2007a). In cases where blue water availability is not a constraint, *irrigation infrastructure and access pose limitations* for smallholders. Evidence from the Sahel region of West Africa and the Pangani river of Tanzania shows that smallholders lose out in competition over irrigation water to commercial farmers (UNDP 2006, 18). Nevertheless, in contrast to global levels where agriculture uses 70 percent of total global "blue water" withdrawals mainly for irrigation, in Africa this potential is yet to be fully exploited in the areas where water is available. The case of Ethiopia (see Box 2) illustrates this point.

3. Soils and land degradation

Sandy soils (Arenosols and Regosols) are most widespread in the semi-humid wooded to semi-arid savannah zone while ferruginous tropical soils (mainly Lixisols and Cambisols) dominate in humid to sub-humid wooded savannah zone of SSA (Sant'Anna 1993). The major constraints limiting the ability of these soils in the semi-humid to semi-arid zones to produce high yields of crops are moisture stress, low fertility, salinity and alkalinity, low organic matter content, deficiencies of iron and zinc. This is in addition to the constraints on soils in the sub-humid wooded savannah zone: "sensitivity to erosion, low cation exchange capacity, high base saturation, low phosphorus availability, micro-nutrient deficiencies, low aggregate stability and surface sealing under the effect of rains resulting in increased runoff; root-zone limitation due to surface layers of plinthite, ferruginous concretion and/or ironpan" (Sant'Anna 1993). However, islands of high potential soils intersperse with vast areas of low potential soils.

Box 2:	**Irrigation potential and actual use in Ethiopia**
UNDP (2006, 197) considers Ethiopia a water abundant country – it is located at the head of the Nile, covers 12 river basins and has a per capita water availability of 1,644 cubic metres. However, due to "large spatial and temporal variations in rainfall, farmers can produce only one crop a year. Frequent dry spells and droughts give rise to high vulnerability and poverty, with the well-being of rural populations tied to rainfall. *The main problem is predictability rather than availability*. Up to 2.7 million hectares of land in Ethiopia have irrigation potential, but less than 300,000 hectares are developed (FAO 2005a). The country has one of the lowest rates of artificial reservoir storage capacity in the world, less than 50 cubic metres per capita in total. Irrigation development could address the problem, but finance is a major constraint. Limited infrastructure means that Ethiopia, like most countries in sub-Saharan Africa, faces *far higher costs per hectare* in large-scale irrigation schemes than does South Asia". Research "by the IWMI has demonstrated the potential for expanding small-scale irrigation. Combined with low-cost drip irrigation technologies, it is estimated that with small-scale irrigation infrastructure, Ethiopia could double yields over the next 10–15 years at per hectare and per capita costs lower than those required for formal irrigation investments".	
Source:	UNDP 2006, 197 based on Awulachew et al. 2005; Inocencio et al. 2005

Despite poor soils, *arable and permanent croplands* of varying quality are abundant in some SSA countries and production from there should be adequate to feed the respective populations. However, since 1961, arable and permanent cropland per capita of the agricultural population is falling in SSA (FAO 2006b; World Bank 2007a).

Due to poverty, the breakdown of rules governing the commons, smallholders' opportunity costs and the limited opportunities for livelihood diversification, soil nutrient mining and land degradation are widespread. *These contribute to low crop yields and indirectly to the vulnerability of smallholders to climate variability and change.* Land degradation is a creeping process that affects large tracts of land in Africa (Berry / Olson / Campbell 2003; Vlek / Bao Le / Tamene 2008). Vlek / Bao Le / Tamene (2008) used changes in Normalized Difference Vegetation Index (NDVI) to identify areas of land degradation in Africa and compared these to land use and population density. The authors found that over the last two decades of the 20th century nearly 50 percent of the vegetation cover in sub-Saharan Africa experienced a greening trend, mainly in the Sahel (greening of the Sahel) due to improved rainfall. Vlek, Bao Le and Tamene (2008, 1) suggest that other areas with increasing NDVI might have been subject to CO_2 or nitrogen oxide fertilization. Evidence of past greening of the Sahel in the mid-Holocene also exists and climate models suggest that the "greening of the Sahel" is expected to continue in the first few decades of the 21st century (Held et al. 2005; Cook / Vizy 2006; Lucht et al. 2006). If the projections hold true, then agricultural production may increase in the Sahel during the projected period.

However, Vlek, Bao Le and Tamene (2008) found that lands not previously identified as degraded in the land assessments of the 1980s are now degraded. This means that additional areas different from those identified in earlier assessments are degrading, in addition to previously identified degraded areas (Bai et al. 2008; Vlek / Bao Le / Tamene 2008). Of concern is the fact that irrespective of rainfall zone the large majority of the degrading areas have below average population density, suggesting that (a) more fragile lands (poor and unsuitable soils and topography) of limited carrying capacity are being converted to agricultural use, (b) some lands suitable for agriculture but with poor soils are degrading, (c) deforestation is likely degrading areas in the humid tropics where population pressures are low, and (d) some degrading areas of high agricultural potential and high population density (breadbaskets) are in urgent need of remediation. The authors suggest for (a) that the development community seeks alternatives/incentives for farmers to vacate such unsuitable lands, for (b) to identify the causes of declining ground cover and to develop more sustainable farming practices and for (d) to support fertilizer markets and land conservation measures.

Access to resources

Resources may be available but various factors constrain smallholders in accessing these for agricultural production. Such factors can be related to the low asset endowments, institutions and societal processes.

1. Land tenure regime and security of tenure

A major factor constraining smallholder access to land is the *land tenure regime*. Past and current land regimes (e. g. colonial land policies and their post-colonial variants) across SSA play a key role in agricultural production (Kiteme et al. 2008). These can be negative or positive for agricultural production and growth. Depending on the context, formalising land rights so that land can be used to access credit can improve agricultural production and provide security of tenure (cf. Deininger et al. 2003, 2007), but customary land tenure also provides adequate security (cf. Toulmin / Quan 2000; Deininger et al. 2003). Nkonya et al. (2008, 87) found that customary land tenure in Uganda has a statistically significant positive relation with crop productivity when compared to freehold and leasehold land and explain that those farmers on freehold and leasehold land may have other more profitable non-crop enterprises or be holding land for speculative purposes, hence do not invest as much effort into crop production as those under customary tenure. However, holders of land under customary tenure are unable to sell or use their land as collateral for formal credit services therefore limiting their livelihood strategies; hence group collateral may be one way to work around this constraint (Nkonya et al. 2008, 102).

S*ecuring access to adequate land* is a pre-requisite for agricultural production and is a key to various adaptation practices. This is a complex task in that in SSA tenure rights are in many cases overlapping in certain respects, with different individuals claiming rights of access to the same piece of land. Orindi / Murray (2005) suggest that communal, rather than individual, titles may be preferable in pastoral areas because pastoralists not just need land but also access to fodder. However, overlapping regimes like statutory (State) and customary regimes tend to be disadvantageous for smallholders' access to communal lands as governments tend to override such claims (see for example Box 3 on land leasing).

Often areas where staple food is produced are the less fertile regions in many countries because cash crops are grown in the fertile areas. In cases where smallholders have access to larger plots, expensive farm inputs limit the areas that can be farmed (Ifejika Speranza 2006b). Thus, the context-specific nature of land tenure is important.

Table 1: SSA countries leasing out land and the investing countries

Country providing land	Investor country / company	Land size (hectares)	Lease duration (years)	Lease conditions	Media sources
Angola	Lonrho, a pan-African conglomerate listed in London	25,000	50	Currently unknown	Financial Times January 16 2009
Kenya	Qatar	40,000	Currently unknown	Construction of a new Sh180 billion (£ 2.4 billion) port on Lamu island to serve as Kenya's second port after Mombasa	Guardian, UK, December 2 2008; Daily Nation (Nairobi), December 19 2008; February 1 2009
Madagascar (Fate of project unclear due to public protests)	South Korean conglomerate Daewoo Logistics	1.3 million	99	Employment of locals	Financial Times January 16 2009; Madagascar Tribune February 15 2009
Sudan	Saudi Arabia's Hail Agricultural Development Co (Hadco)	9,239	48	No information	Reuters February 17 2009
Many other SSA countries have been mentioned in such land lease agreements but currently no concrete information is available.					

Women, who constitute the majority of the farmers in SSA (IAASTD 2008, 5: 70 percent of agricultural workers and 80 percent of food processors in SSA), do not have guaranteed access to land and this reduces the range of decisions they can make, such as on the proportion or mix of crops to grow. Often land belongs to the family or community and in such cases farmers are unwilling to invest in structural measures to control erosion or improve soil fertility. These limitations to investments adversely affect agricultural production.

Current access to land and water for pastoral and agro-pastoral populations also does not foster smallholder resilience to drought-triggered crises. Very little or no manoeuvring room is available for pastoral groups to secure their livelihoods in times of drought, forcing them and their livestock to move to unfavourable environments or lay claims to lands already occupied by other users (Blench 1996; 2001). Such conditions give rise to tensions which only become evident when the resulting social crises dismantle the levels of development previously achieved. Similarly, no provisions for buffer grazing areas are made for agro-pastoral communities to graze their animals during droughts. Despite long-term policy statements on benefits sharing by national parks and protected areas with local communities, these modes of earning are only slowly gaining ground. Thus, restriction of access contributes to food insecurity as pastoral and agro-pastoral populations account for the majority of those that receive food aid in SSA (WFP 2000).

Besides the unfavourable land tenure in many SSA countries, the recent *leasing out of high potential agricultural lands* (so-called "land grabbing" or "scramble for land") in SSA by countries outside Africa (Table 1) potentially reduces the land available for agricultural expansion. This aspect is raising public concerns and is politically explosive considering that many of the countries that lease out their land do not produce enough food to feed their own population and in many cases depend on food aid (see Box 3). Although some of the lands to be leased are so-called "government lands", there are overlaying claims on the land by the local population, which uses these lands for farming or grazing (see Box 3).

Box 3:	**Land lease agreements and implications for smallholder agriculture**
The recent global food crisis and the expected reduction in agricultural lands due to climate change has led some countries to secure their national food supply through diversification of food sources such as leasing land in foreign countries, provision of agricultural grants to friendly producer countries and agricultural investment partnerships. While these developments can be an impulse for increasing efficiency in agricultural production and for agricultural development, key officers of the FAO expressed their concerns about the forms of partnership: According to the Wall Street Journal (September 10, 2008), Jacques Diouf, the director-general of the FAO finds that: "Foreign direct investment in agriculture is the only way we are going to eradicate global poverty". However, the Financial Times (19 August 2008) quotes Jacques Diouf: "The risk is of creating a neo-colonial pact for the provision of non-value-added raw materials in the producing countries and unacceptable work conditions for agricultural workers". The Bahrain Tribune (7 September 2008) quotes another FAO key officer, David Hallam, Head of Trade at the FAO: "Everyone wants to avoid a situation where one country is investing in another using a model of agriculture that is highly mechanised, so it doesn't create much employment; is reliant on imported seeds and fertilisers, so there is not that much local sourcing; and is large-scale, so you do not get spillover into smallholder agriculture." The Financial Times (November 20, 2008) quoting David Hallam, reports that farmland investments need to benefit the host country not only in terms of generating jobs but also through "technology transfer, food security, poverty reduction and income growth through the multiplier effects of local sourcing of inputs...". Hence such agreements should be true partnerships "where all parties share benefits and risks". The foregoing highlights the need for an international reference framework to regulate such investments so they balance trade-offs and do not lead to social instability. This is important as climate change reduces land suitable for agriculture.	
Sources:	The Wall Street Journal (September 10, 2008); The Financial Times (August 19, 2008; November 20, 2008); The Bahrain Tribune (September 7, 2008).

Most of the leased lands are prime agricultural lands. With the climate change-related projected shift in seasons and reduction in lands suitable for agriculture, leasing out land further reduces land that smallholders could potentially move to. Many smallholders have limited knowledge of modern state land laws and do not understand that the lands which belong to them under customary law may not belong to them under formal statutory law but to the State. Therefore, many are likely to lose their tenure rights, especially in countries with overlapping land regimes and weak legal frameworks. In some recent land leasing agreements, local farmers have had to be relocated or compensated for land, highlighting the fact that even if land is "unused", certain communities lay claims to these lands and use them periodically. This brings to fore the importance of land reforms and land registries and of dealing with the question of who owns land – a question that has been at the root of many social upheavals in SSA.

Thus, *pluralistic institutions and their effects* (the duality of customary and modern statutory laws) in rural Africa, have no doubt contributed to the insecurity of land tenure among African farmers. Although in many countries the modern state claims ownership of all national land, local-traditional norms govern the daily management and allocation of land and favour subdivision of agricultural land. In such cases where there are overlapping claims on land or where land has not yet been subdivided, farmers farming those lands are slow to invest in improving soil fertility or preventing soil erosion.

2. Population growth and pressure on land

This led to the expansion of agriculture to more marginal lands, where high temperatures and high rainfall variability are the norm, making rainfed agriculture from the outset a risky undertaking (cf. Ogallo 2000; Williams 2000; Burton / Lim 2005; Laube / Awo / Schraven 2008). This expansion led to further deforestation and degradation of already marginal lands of limited carrying capacity (Vlek / Bao Le / Tamene 2008). The consequence is reduced soil carbon storage and erosion. In such areas, like the drylands (arid and semi-arid East Africa, the Sahel, the semi-arid areas of Southern Africa), crop failures are often and bumper harvests rather exceptions.

Within the low-potential agricultural drylands are pockets of resource islands that richer actors acquired during government land reforms (Ifejika

Speranza 2006b). These richer actors, who are often *absentee landowners,* block access to resources such as river water for smallholder farmers (Ifejika Speranza 2006b). Often those that have access to power and capital occupy prime agricultural lands without cultivating them, depriving the smallholder producers of access to better quality land and to river water for irrigation. Ownership of land by absentee owners generally reduces the manoeuvring room of the resident smallholders in cases where access to such lands for production is blocked (for example, some areas in Kibwezi district in Kenya). In contrast, there are also cases in which resident smallholders access lands of absentee owners. In such cases, the maintenance of livelihood security by resident smallholders has been partly attributed to the manoeuvring space that the unoccupied and uncultivated lands of absentee owners provide (e. g. the wider Laikipia district in Kenya; Künzi et al. 1998). However, increases in population and land degradation have reduced this manoeuvring space.

Low human capital and weakening social networks

Low human capital reduces smallholder choices of livelihoods diversification, constrains them to surviving on their land and thereby reduces their adaptive capacity and resilience to climate change. Under the aforementioned contexts of resource abundance and scarcity as well as powerful deciding actors, own *human capital* is one resource that the smallholder can exercise decision-making power over its use. However, most smallholders are illiterate and lack the formal skills to enable them to move from agricultural production to post-harvest processing, or skills that would allow them to take up livelihoods in the non-primary sectors. There is also a need to increase knowledge on post harvest processing as 30 to 40 percent of agricultural produce is lost due to "poor post-harvest handling, storage and processing methods" (FAO / UNIDO 2008, 3).

The *prevalence of HIV/AIDS and malaria* has decimated a large proportion of the labour force in many Southern African countries (IAASTD 2008) and has left in its wake a knowledge gap, which those left behind are too young to fill. With a high percentage of HIV positive/AIDS people in SSA this weakening of the labour force is expected to continue until preventive campaigns take effect. It is important to note that the problem of HIV/AIDS adds to the problems of malaria, other neglected (forgotten) diseases and poor health infrastructures, which together limit the ability of the population to work.

The *limited power of social networks of poor smallholder farmers* also implies limited spheres of influence. In SSA, family and clan networks are the "insurance lifelines" for their members in times of crises, strife and as source of investment capital. However, with the advance of modern culture and economy, where the family and clan is constantly being redefined, the efficacy of family networks and clans as insurance lifeline is rapidly declining while no alternative insurance forms have been established. Hence, having the family as insurance is better than having none at all. The use of family networks as insurance and source of investment capital has positively influenced development. On the other hand, it can be negative for the income earners in a household, where the dependency ratio between those earning and giving support and those receiving is high, leading to a high dependency burden on the income earners. The frequency of droughts, floods, and their overlap with market failures continue to erode this insurance buffer but formal insurance schemes are only being introduced in a few areas. Further, while policies support farmer cooperatives in the cash crop sector, no such explicit support for cooperatives for staple-food growers exist.

Resource utilization

Under the above mentioned conditions, the dominant smallholder strategy is to ensure livelihood security and where and when favourable, take advantage of opportunities to maximise profit (Wiesmann 1998). This strategy results in *low agricultural intensification*. While area expansion of agriculture in countries like Ghana and Mozambique contributed to increased yields, intensification and use of modern inputs have generally been limited in SSA (World Bank 2007a). Irrigated areas comprise only 4 percent of arable and permanent cropland, and improved cereal varieties covered only 22 percent of the cereal area in 2000 (World Bank 2007a, 51).

Low use of chemical fertilizer and the low use of agricultural technologies contribute to stagnation in agricultural growth. The widespread poor soils in the drylands require continuous application of biomass or fertilizer to maintain soil fertility. However, due to high prices for farm inputs like fertilizer, smallholders can ill afford them. IAASTD (2008, 5) reports a low total fertilizer input of less than 10 kg ha-1 on average, as contributing to SSA's low crop yields. In comparison, Egypt used 572kg ha-1, Germany 217kg ha-1, India 107kg ha-1 and South Africa 49kg ha-1, on average for the period 2003–2005 (World Bank 2007a). Acknowledging considerable variation across farming systems, IAASTD (2008, 5) reports that every SSA country was estimated to have a negative soil nutrient balance for nitrogen, phosphorus and potassium in the mid-1990s.

To address this problem, African Union members adopt various strategies "to reduce costs through national and regional level procurement, harmonization of taxes and regulations, the elimination of taxes and tariffs, and improving access to fertilizer, output market incentives, and credit from input suppliers" (IAASTD 2008, 5). Some African countries also subsidize fertilizers in order to ease access by farmers. While the cost of chemical fertilizers can be reduced through the intensified use of organic fertilizer, the natural conditions limit the amount of biomass that can be produced and competition between biomass as fodder for livestock and as organic fertilizer further reduces the amount that can be used as fertilizer. Livestock manures are also not abundant as the small number of livestock kept by smallholders do not provide enough manure for the whole farm. The risk of fertilizer "burning" the crops, i. e. dehydration of plants due to (excess) nitrogen application under conditions of inadequate soil moisture (low rainfall), makes farmers to apply less manure in drier areas (Powell / Pearson / Hiernaux 2004; Ifejika Speranza 2006b).

Another contributory factor to low productivity is the *low level of agricultural mechanisation*. Excluding Egypt and Mauritius, 28 tractors work 1,000 hectares in Africa (World Bank 2007a, Table 32). About 65 percent of farm power sources are from manual labour, 25 percent from animal traction while tractor power accounts for only 10 percent compared to 35 percent for South Asia and 60 percent for the Near East/North Africa (Source: FAO 2005b, Table 4.16). Considering other labour constraints such as health problems, urban migration and demographic shifts, manual labour becomes a scarce and weak resource that places severe limitations on farm production (FAO / UNIDO 2008). FAO / UNIDO (2008, 5 ff.) attributes the disappointing performance and low contribution of mechanization to agricultural development in Africa to the following factors:

- The fragmented approach to mechanization issues due to poor planning by government agencies and over-reliance on unpredictable or unsuitable, one-off aid-in-kind or other external mechanization inputs.
- Lack of teamwork or coordination within and between governments and the inherent competition with private-sector business initiatives in mechanization services.
- Lack of national agricultural mechanization strategic and implementation plans.
- Lack of planning for sustainable mechanization in most African countries. FAO / UNIDO (2008, 5 ff.) reports that "in many cases where mechanization has made a positive contribution to agricultural development, it has been a question of getting the right machine on the right enterprise by chance, not by credible project or programme design".
- Very short term planning for tractor-hire schemes for small-scale farmers and poorly trained management staff.

According to FAO / UNIDO (2008, 12 ff.), to achieve sustainable mechanisation through a systematic enhancement of entrepreneurial potential of the African farmers, agricultural engineers, artisans and traders, the following framing conditions need to be addressed: security of tenure, discourage further fragmentation of farms, supportive fiscal regime for agricultural machinery, increase finance for agriculture, education and training (e. g. farmer field schools), research and extension, certification of machinery for use under local conditions, local access to the inputs they need, including seeds and fertilizers, electricity and water as well as machinery and the supporting infrastructure that mechanization requires (e. g. repair services, spare parts supply, fuel and lubricants), in short, a comprehensive agricultural mechanization strategy.

FAO / UNIDO (2008, 11 ff.) suggest that machines produced in Asia are more suited to Africa in terms of both specification and price than those produced by European and North American farm machinery manufacturers which are rather for "Western large-scale and capital-intensive farming markets, increasingly sophisticated, large and expensive". The authors recommend that the producers in Asia need to adopt the same marketing and technical support practices as those of the European manufacturers to expand their market in Africa.

While mechanisation is not widespread in SSA, it is seen as a source of increased farm productivity. However, no studies could be found that investigate the trade-offs between fossil fuel use in farm machinery, emission reductions and farm productivity, as the use of machinery in a climate change context requires research on the use of alternative energy sources such as biomass, wind, solar, micro-hydropower and bio-diesel for operating farm machinery, to reduce GHG emissions. The adoption of conservation agriculture is also one way to reduce power demands for cultivation while reversing soil degradation and loss and increasing soil fertility.

Less favourable policies, institutions and markets

Markets, policies and institutions together form the framing conditions within which smallholders access inputs, grow and harvest crops and sell their produce.

The mostly *low smallholder participation in staple food grains markets (e. g. maize, beans, rice, wheat, sorghum)* has been attributed to entry barriers such as inadequate household assets, lack of infrastructure leading to high transport and marketing costs and inappropriate incentives (Barrett 2007). These barriers also limit the effectiveness of national level policies in fostering market integration of smallholders and thus need to be addressed. In addition, policy instruments are needed which promote market integration for the minority of smallholders that already participate in the market.

Thus the state of agriculture is largely dependent on how effective *government policies and institutions* (including organisations) are and whether they make livelihood conditions conducive for smallholders and address the challenges that smallholders face. However, dwindling agricultural productivity has been attributed to the neglect of the agricultural sector in budget allocation (Djurfeldt et al. 2005, 5; World Bank 2007a) and the general decline of ODA for agriculture in the 1990s (World Bank 2007a, Box 4). This trend of declining agricultural production was checked by the increased budget allocations by some African governments to the agriculture sector (e. g. Ghana; World Bank 2007a) and the favourable world market prices for agricultural produce.

Box 4:	**Reasons for the decline of Official Development Assistance (ODA) to agriculture and rural development in the 1990s**
1.	Falling international commodity prices that made agriculture less profitable in developing countries;
2.	Increased competition within ODA especially from social sectors;
3.	Emergency responses to numerous crises;
4.	Opposition from farmers in some donor countries to supporting agriculture in their major export markets; and
5.	Opposition from environmental groups that saw agriculture as a contributor to natural resource destruction and environmental pollution.
Source:	World Bank 2007a, 42

Policies focus on agriculture as if it were the only economic sector in the rural areas and do not give adequate attention to the linkages between agriculture and other sectors such as trade and industry (Eriksen 2000); for example the fact that farmers are at the same time workers in local industries. In addition, more policy attention given to large-scale commercial farming shuts the majority smallholders out of agricultural development and adequate government support.

Policies and government actions led to price legislations that favoured urban consumers relative to rural food producers. The costs of agricultural inputs remained high while the prices for the produce were low. This was accompanied by reliance on the import of food grains due to low international prices and misdirected advice (Djurfeldt et al. 2005, 5)

In addition, policies at various levels influence smallholder agricultural production and marketing. Djurfeldt et al. (2005) and Laube, Awo and Schraven (2008) identified the negative influence of regional (e. g. ECOWAS) and international trade (e. g. WTO) agreements on local production and marketing and the inability/unwillingness of the SSA countries to tackle the problem.

In many cases *counterproductive dismantling of extension services in the wake of Structural Adjustment Policies* (SAP); misfit in extension models that required poor farmers to pay for extension services (Djurfeldt et al.

2005, 5) – which most do not do. Due to limited finances and the value accorded livestock relative to crops, the farmers preferred to invest in livestock extension services (e. g. in Kenya, personal communication Extension Officer). The result was stagnating and in some cases declining agricultural production.

Low infrastructure development

Inadequate rural road infrastructure led to high transportation costs for agricultural produce thereby exposing smallholders to the low farm-gate prices offered by middlemen and brokers (Ifejika Speranza / Wiesmann 2006).

Early Warning Systems (EWS) and their challenges to communicate weather information to farmers meant that not all the information made available by the EWS could be communicated to the farmers in an easily understandable format (for example the translation of technical terms into a local language).

Under the above circumstances, *limited availability, inadequate access to and adoption of micro-credit* further compound the challenges to increase agricultural productivity. In SSA the traditional form of storing wealth in livestock still persists despite the changing livelihood conditions where access to cash is crucial (Ifejika Speranza 2006b). Availability of micro-credit services is still limited to a few rural areas and countries but potentials for expansion exist. Yet in areas where rural credit has been introduced, access is restricted by membership in groups, and smallholders still need to be trained in using formal finance instruments. Further, the attachment to livestock as a store of wealth still persists despite the risks (drought, diseases, market failure) of savings in livestock. According to Djurfeldt et al. (2005), food crisis is policy related as a majority of the farm population is trapped in a situation of financial and institutional insecurity in which inadequate on-farm resources result in low labour and area productivity. Assuming the stability of financial institutions, savings stored in rural banks forestall the risk of depreciation and mortality of livestock-savings due to droughts, floods or diseases and thereby increase smallholder resilience.

Cultural norms and traditions

The foregoing hints that *cultural norms and traditions* still shape rural practices. From the outside, cultural norms may seem insignificant in the lives of the rural population but it is traditions that define social relations and access to resources despite the advance of the modern state in Africa. The ways through which traditions shape vulnerability to climate impacts are summarised hereunder:

- The smallholder nature of African agriculture has been blamed for the stagnating and declining food production. This "smallness" of plots is further exacerbated by cultural practices whereby land is sub-divided among the younger generation based on the traditional notion of providing land resources to sons to enable them to farm, as "farming is a way of life". This tradition further reduces land available for agriculture and the units that individual farmers can access. On the other hand, under conditions of low input and manual agriculture, the small plots are just big enough for the farmers to be able to work them manually.
- The dominance of patriarchal systems of land inheritance that hinders access to land by women, who constitute the larger proportion of SSA agricultural labour (Verma 2001; Eriksen et al. 2005; Ifejika Speranza 2006a).

Recent improvements and prospects in agricultural growth

Despite the many factors mentioned above that adversely affect agricultural growth and reduce adaptive capacity, there have also been improvements in the sector in recent years. In 2004, a majority of SSA countries spent only 4 percent of their budget on agriculture (World Bank 2007a, 40). Recognising that the neglect has led to stagnation and in some cases decline in agricultural growth, African countries have through the Maputo declaration of the New Partnership for Africa's Development (NEPAD) Comprehensive African Agriculture Development Programme (CAADP) committed themselves to revitalising agricultural growth, rural development and food security by agreeing to allocate at least 10 percent of their respective national budgets to agriculture (African Union 2003). It is expected that this increase in budget allocation will bring about sustained growth in the agricultural sector. Yet the current global financial crises and the advancing climate change pose challenges to the stability and growth of the agricultural sector in SSA.

However, the foregoing shows that smallholder agriculture already operates under limiting conditions due to socio-economic, political and cultural factors which climate change will overlay. These social-ecological conditions, i. e. the social, economic, cultural, political and environmental factors and their interactions, which together shape vulnerability, resilience and adaptive capacity, need to be addressed. Otherwise, the abovementioned underlying limitations will continue to stew in the background, compromise adaptation actions and can lead to social unrest.

2.2 The SSA climatic zones and their implications for agriculture

The *less favourable climatic conditions* of the sub-humid, semi-arid and arid areas (drylands) such as high temperatures and high rainfall variability limit water availability for agriculture even in the absence of climate change and make rain-fed agriculture a risky undertaking.

Thus, rain-fed agriculture is very sensitive to climate variability and change due to its direct dependence on rainfall in time and quantity. In addition to the large proportion of the population working in this sector, as well as the constraining social-ecological conditions, SSA (besides Latin America, see Cline 2007, 96) is one of the most vulnerable regions in the world to climate change.

The *direct dependence on rainfall* accounts for the high sensitivity of SSA agriculture to climate conditions and is reflected in agricultural yields, which fluctuate with climate conditions. For instance, the bumper harvests of the El Niño rains of 1998/1999 in East Africa or the subsequent decrease or loss as a result of droughts in 1999/2000, 2005/2006 in the East Africa sub-region reflect this direct dependence (Ifejika Speranza 2006b).

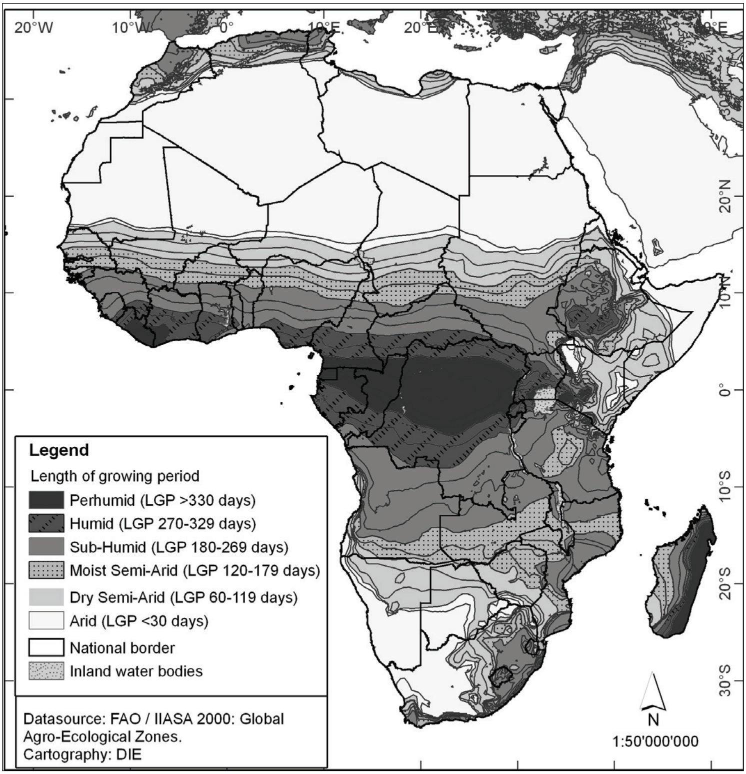
Thus, a consideration of climate change impacts for SSA must necessarily depart from the constraints and opportunities that the current average climate (which is also changing) holds for agriculture. This study focuses on the arid and semi-arid regions of SSA (Figure 1) which cover large parts of SSA because they suffer more than the other climatic regions (see also World Bank 2007a, 5 categorisation of "favourable" and "less favourable" regions) from high variability in rainfall amounts and distribution (see Table 2). Since climate change is expected to cause shifts in climate zones, the area of focus has also been extended to cover the sub-humid zone.

Table 2: Major climatic zones of Africa			
Climatic Zone	**Annual Rainfall (mm)**	**Wet period* (months)**	**Vegetation**
Desert	Less than 100	0 – 1	Little or no vegetation
Arid	100 – 400	1 – 3	Some scrubs, some grassland
Semi-arid	400 – 600	3 – 4	Scrubs & bushes, grassland
Sub-humid	600 – 1200	4 – 6	Bushes to woodland, grassland
Moist sub-humid	1200 – 1500	6 – 9	Forest and woodland
Humid	more than 1500	9 –12	Tropical rain forest

Source: FAO 1986; **According to FAO (1986), "the wet period refers to the period during which the rainfall is higher than the evapotranspiration".*

An important feature of drylands is the low seasonal rainfall amounts and the high rainfall variability. High rainfall variability as manifested in variable onsets and rainfall amounts, dry spells, recurrent droughts and floods are intrinsic characteristics of many SSA regions, especially the arid and semi-arid regions. This implies that rain-fed agriculture already has to account for these various characteristics. Yet, the widespread impacts of droughts and floods often force national governments to declare a state of emergency and appeal for external aid (WFP 2006a), indicating that smallholders are yet to meet the challenge of crop and livestock production under such climatic conditions.

Figure 1: Major climate zones of Africa according to the length of the growing period



Still studies report that SSA has the potential to produce its own food needs, but constraining societal and environmental factors (cf. Cline 2007, 96), in particular structural deficits such as inadequate infrastructure and services, encrusted institutional frameworks, inadequate political will and courage, interact with adverse climatic processes to cause food crises. Examples of such regions that are often dependent on external relief related to drought and floods are the northern and south-eastern arid and semi-arid parts of Kenya, Ethiopia and Malawi (Ifejika Speranza 2006a; WFP 2006a). This highlights that such SSA countries are currently unable to cope with the effects of climate-related hazards on their own and must depend in part on external interventions (e. g. food relief) to recover from drought or flood impacts. The immediate question that arises is: how can such countries cope with and adapt to climate change if they (partly but significantly) depend on external support to deal with and recover from droughts and floods, which are part of the "natural" climate variability? This means that to be able to deal with these climate risks, SSA countries must improve on planning and management, earlier highlighted as major underlying inadequacies.

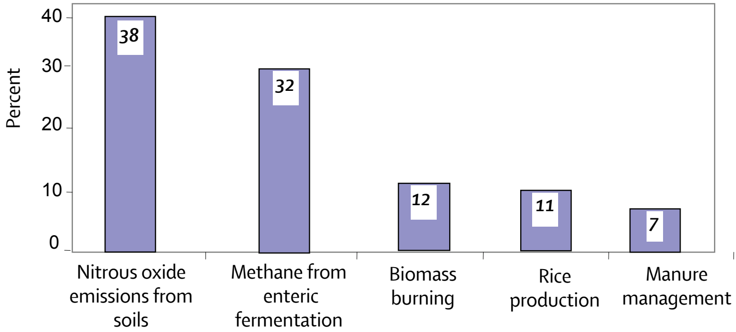
2.3 Climate change and SSA agriculture

The relationship of agriculture to climate change is three-fold:

1. Globally, agriculture emits about 14 percent (in 2004) of the GHG which cause atmospheric warming and in effect climate change (Smith et al. 2007, 501).
2. Climate change will have positive and negative impacts on agricultural production.
3. Agriculture has the potential to avoid and mitigate climate change through reducing GHG emissions and sequestering carbon, respectively.

Therefore adaptations need to be climate-resilient and not contribute to GHG emissions. According to estimates made by Smith et al. (2007, 503) agriculture contributed 10 – 12 percent of total global anthropogenic GHG emissions in 2005, ranging from 5120 $MtCO_2$-eq/yr (based on Denman et al. 2007) to 6116 $MtCO_2$-eq/yr (based on US-EPA 2006a). Figure 2 shows percent estimates of the various sources of non-CO_2 GHG emissions in agriculture. Emissions of carbon dioxide (CO_2) are mainly from land use and clearing forests for agricultural use. Increased use of fertilizer and the growth of agriculture account for the nitrous oxide (N_2O) emissions while fermentative digestion by ruminant livestock, stored manures, and swamp rice production cause Methane (CH_4) emissions (Smith et al. 2007, 501). Of global anthropogenic emissions in 2005, agriculture accounted for about 58 percent of N_2O and about 47 percent of CH_4 while the net flux of CO_2 (excluding emissions from electricity and fuel use in agriculture) between the atmosphere and agricultural lands is estimated to be approximately balanced (Smith et al. 2007, 503).

Figure 2: Total global non-CO_2 emissions from agriculture in 2005

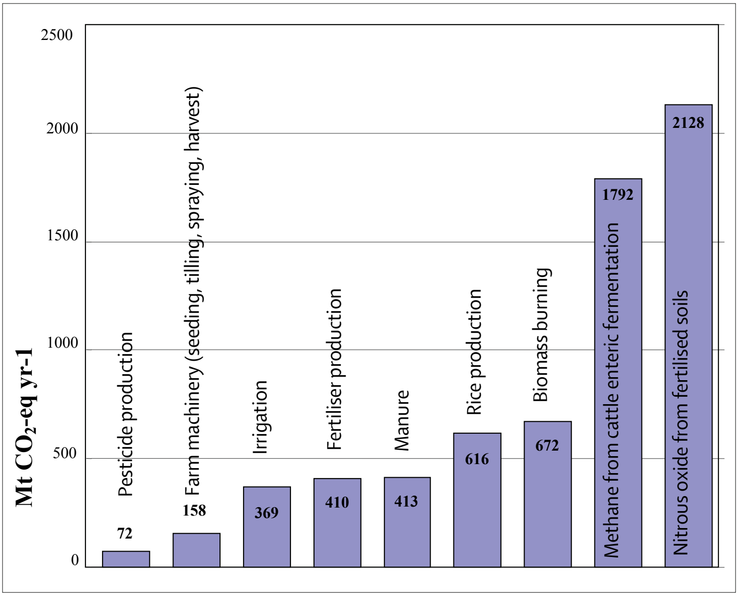


Source: Smith et al. 2007, 503

Figure 3 also shows the global average contributions (in Mt. Co_2-eq yr $^{-1}$) of various agricultural activities to GHG emissions. However, depending on the nature of agriculture in a region, the major sources of emission differ. Thus, in 2005, N_2O from soils (mainly from fertilisers and manure applied to soils) was the main source of GHG in African agriculture (US-EPA 2006b).

Generally, emissions in agriculture are expected to increase as agricultural-based economies (most of SSA) shift to intensification and use of modern inputs. However, while intensification and use of modern inputs contribute to development, measures need to be put in place to ensure that such developments are climate resilient. In addition, understanding the contribution of agriculture to observed climate change is important for designing mitigation measures as most often many adaptation practices (as will be shown later) also mitigate climate change.

Figure 3: Estimates of sources of agricultural greenhouse gases, excluding land use change



Source: Bellarby et al. 2008, based mainly on Lal 2004

2.3.1 Observed climate change and its impacts on SSA agriculture

The observed changes (see also Figure 4) are already having effects on smallholder production. At the farm-level, the observed changes are noted in the drier hotter weather in arid and semi-arid areas, increased variability in onsets, concentration of rainfall in few rainfall events, increase in extreme/storm rainfall and droughts succeeding floods and *vice versa* (Ifejika Speranza 2006b). In Kenya for instance the drought of 2005 was so intense that the people named it "ndyaanou" – meaning "I have never seen such a thing before" (cf. Ifejika Speranza et al. 2009). The already experienced adverse effects of the observed changes also imply that more effective measures are needed to adapt to climate change.

In order to facilitate spatial localisation of changes in climate, the following is structured according to the five main regions of SSA (see Figure 4). Details of the observed changes are listed in Annex 1 to 8.

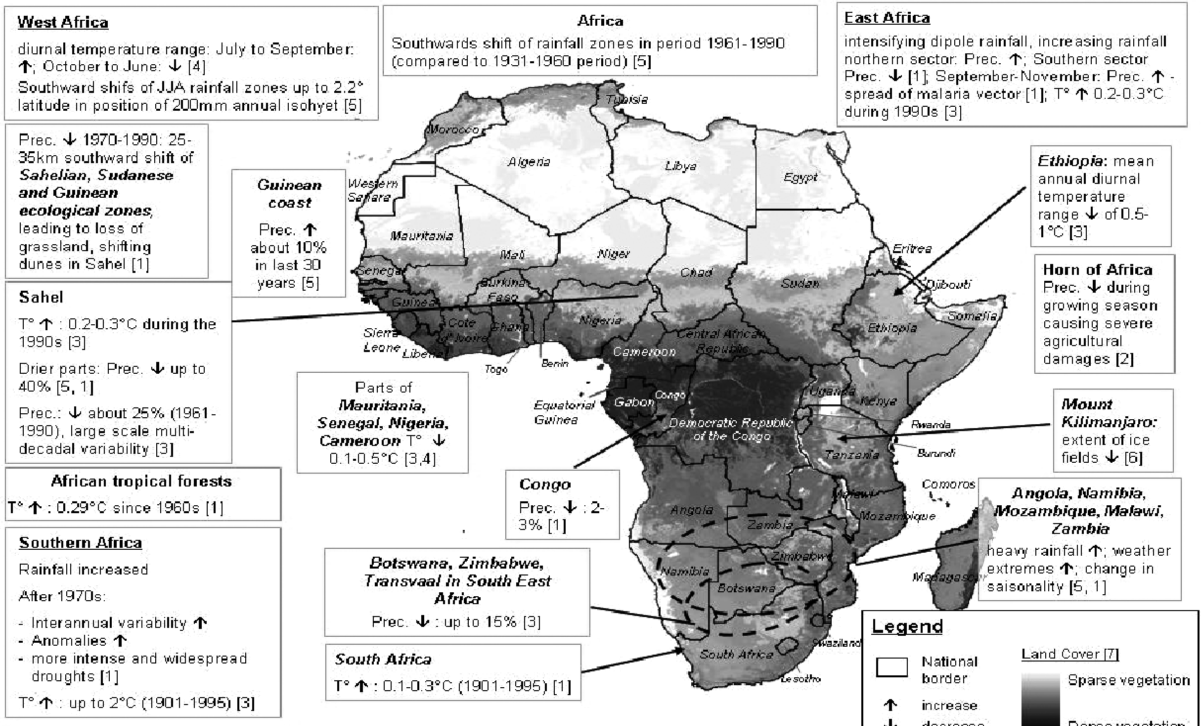
African continent

– *Southward shifts:* Generally, for Africa, Hulme (1992) identified southward shifts of 120 km of the June–July–August rainfall in the period 1961–1990 compared to the 1931–1960 period. This means a drying of the Sahel.

West Africa

– *Temperature increases* of 0.2 to 0.3°C in the Sahel during the 1990s (Hulme et al. 2001). Increases in temperature do not matter as much if rainfall is adequate but a critical situation is when temperature increases and rainfall decreases, leading to less water available and increased evaporation. Such conditions are likely to be not conducive for many crops and plants and will therefore adversely affect crop production.
– *Temperature decreases* of 0.1 to 0.5°C in parts of Nigeria, Senegal and Mauritania (Hulme et al. 2001).
– *Both increases* (July to September) and *decreases* (October to June) in *diurnal temperature range* have been identified (Nicholls et al. 1996; Brooks 1999).
– *Decline in annual rainfall* has been reported in all climate zones of West Africa with major declines of up to 40 percent being observed in drier Sahel parts (Nicholson / Some / Kone 2000; Gonzalez 2001; Chappell / Agnew 2004; Dai et al. 2004; Malhi / Wright 2004). Towards the end of the 20th century, a recovery of Sahel rainfall in the last two decades was observed (Held et al. 2005), and this is expected to continue for the first few decades of the 21st century.
– *Rainfall increase* of about 10 percent in the last 30 years in the Guinean coast of West Africa (Nicholson / Some / Kone 2000). Hulme et al. (2001) report for the period 1900 to 1996 a large-scale multi-decadal variability in the Sahel with a decrease of about 25 percent (1961–1990) and recent drying in the Sahel.
– *Southward shift* of June–July–August rainfall zones up to 2.2° latitude (240 km) in position of 200 mm annual isohyet (Tucker et al. 1991; Sivakumar et al. 2005). A *decline in rainfall* in the period 1970–1990 led to a 25–35 km southward shift of the Sahelian, Sudanese and Guinean ecological zones leading to the loss of grasslands and acacia, and shifting sand dunes in the Sahel (Gonzalez 2001).

Figure 4: Observed climate change impacts



Sources: [1] Boko et al. 2007; [2] Fischer et al. 2005; [3] Hulme et al. 2001; [4] Hulme et al. 2005; [5] Sivakumar et al. 2005; [6] Lemke et al. 2007; [7] Source Map: Global Land Cover 2000

East Africa

– *Intensifying dipole rainfall,* that is, increasing rainfall over northern sector, declining rainfall in the southern sector (Schreck / Semazzi 2004)
– *Rainfall increase* between September and November (warm period) that led to spread of the malaria vector (Chen et al. 2006; Pascual et al. 2006; Schreck / Semazzi 2004)
– *Temperature increase* of about 0.2°C to 0.3°C during the 1990s (Hulme et al. 2001)
– *Decrease in the extent of ice fields* in Mount Kilimanjaro are also linked to climate change (Lemke et al. 2007; Mölg / Hardy 2004)

Horn of Africa

– *Decline in rainfall* during growing season causing severe agricultural damages (Slingo et al. 2005; Fischer et al. 2005)
– *Decrease* of 0.5°C – 1°C of the mean annual diurnal temperature range in Ethiopia (Nicholls et al. 1996)

Central Africa

– *Temperature decrease* of 0.1°C to 0.5°C in Cameroon (Hulme et al. 2001). Temperature increases since the 1960s of 0.29°C in African tropical forests (Malhi / Wright 2005)
– *Rainfall decrease* of 2 to 3 percent in Congo (Malhi / Wright 2004)
– *Rainfall increase* in South Congo (Nicholson / Some / Kone 2000). For the 1901 to 1995 period only Equatorial Africa and the Red sea coast were found to experience precipitation increases of up to 10 percent (Hulme et al. 2001).

Southern Africa

– *Rainfall increase* but also *increased interannual variability* and anomalies in the post 1970-period leading to more intense and widespread droughts (Richard et al. 2001; Fauchereau et al. 2003)
– *Temperature increase* of up to 2°C between 1901 to 1995 (Hulme et al. 2001) in Southern Africa and an increase of 0.1°C to 0.3°C in South Africa (Krueger / Shongwe 2004)
– *Significant increase in heavy rainfall and weather extremes* in Angola, Namibia, Mozambique, Malawi, Zambia (Mason et al. 1999; Usman / Reason 2004; Tadross et al. 2005; New et al. 2006). The more intense and widespread droughts in the post 1970 period in Southern Africa have been associated with an *increase in rainfall anomalies* (Richard et al. 2001; Fauchereau et al. 2003).

- *Change in seasonality* in Angola, Namibia, Mozambique, Malawi, Zambia (Usman / Reason 2004; Tadross et al. 2005; New et al. 2006)
- *Rainfall decrease* of up to 15 percent in rainfall in Botswana, Zimbabwe, Transvaal in South-East Africa (Hulme et al. 2001)

The above changes have had various impacts on agriculture including crop and livestock loss and in extreme cases caused destitution. The *picture of increased variability* reflected in the above reports, of *decrease as well as increase of rainfall and temperature* implies the need to adopt a risk management approach in dealing with climate change. This is also in view of ongoing and projected climate change, which is expected to further intensify if remedial actions taken do not significantly reduce GHG emissions.

2.3.2 Projected climate change impacts on African agriculture

Precipitation amounts are likely to decrease for most parts of SSA while rainfall variability and intensive rainfall events are expected to increase. There will likely be shifts in rainfall seasons, highland areas will likely be won for agriculture but also affected by malaria, and "new" diseases and pests are expected to manifest in areas where they were hitherto unknown/ uncommon. Box 5 provides a summary of projected changes in climate for Africa.

Box 5: The IPCC's Fourth Assessment Report of Projected Climate Changes for Africa

- All of Africa is *very likely* to warm during this century.
- Warming is *very likely* to be larger than the global annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics.
- Annual rainfall is *likely* to decrease in much of Mediterranean Africa and the northern Sahara, with a greater likelihood of decreasing rainfall as the Mediterranean coast is approached.
- Rainfall in Southern Africa is *likely* to decrease in much of the winter rainfall region and western margins.
- There is *likely* to be an increase in annual mean rainfall in East Africa.
- It is unclear how rainfall in the Sahel, the Guinean Coast and the southern Sahara will evolve.

Source: Christensen et al. 2007, 850, 866 ff.

The already observed climate changes show that Africa is highly afflicted by climate impacts, considering that future climate changes are expected to bring more dryness. With regard to projected climate change an attempt has been made to explicitly localise the projected changes both in temporal and spatial terms. Due to the bulk of information, the projected impacts have been summarised in Annex 9 to 17. This is with the assumption that knowing *how* future climate change will be, *what* the projected impacts are, *when and where* to expect them can greatly facilitate adaptation planning. This is a difficult task as the projected periods of certain climate changes vary widely and sometimes overlap (see Annex 9 to 17). Also no consistent or specific references are made to affected climatic or agro-ecological zones or regions. This makes temporal and spatial localisation difficult if not impossible and makes the task of designing policy responses even more challenging. Another finding from the spatial differentiation (see Annex 9 to 17) is that apart from the highlands, both temperature or precipitation decreases and increases can be projected for the same region. This makes targeting adaptation difficult. Suggestions have been made to use temperature as a reference anchor since temperature increase is often used as an indicator of climate change, and as such impacts ordered by "temperature increase" rather than "time" allow for better definitions of policy targets (Müller 2009). However, the above limitations and uncertainties remain. Another option will be to use the observed changes (see Section 2.3.1) as a reference since the projected changes (Annex 9 to 17) point in the same direction as the observed changes. What is certain is that temperatures will continue to increase in a "business as usual" development pathway.

Under these circumstances, it can be concluded that future climate change is expected to *intensify the already observed changes* if no remedial actions are taken to reduce GHG emissions. Yet the limitations of current projections have implications for adaptation research, planning and financing.

2.4 Implications of climate change projections for adaptation

The uncertainties in future climate change as shown in the Section 2.3.2 arise from the complex nature of climate (Solomon et al. 2007) and feedbacks with its drivers, which are difficult to capture in models. Uncertainties also arise from the inadequate data basis, the differing and uncertain scenarios of GHG emissions, the coarse spatial and temporal resolutions, contentious assumptions in the emission scenarios and the non-consideration of seasons as they occur in reality (e. g. wet/dry season). Further, there are no standard model specifications of input parameters and internal variations exist in the General Circulation Models (GCM) resulting in differing projections of future climates (Müller 2009). These characteristics, which are also limitations, can be summarised as follows:

1. *Limited (digitised) climate data:* In comparison to other parts of the world, meteorological records for Africa are short and there are few stations with long-term records, while many cease to be active or only record climate data intermittently. This affects the quality of climate records that can be used for climate research on Africa. Where climate data exists, it still needs to be digitized before they can be used in modelling.

2. *Rainfall poorly captured:* What is noteworthy for SSA is that while the GCMs can project past temperatures relatively well, the reliability of the projected future climate change is uncertain. Rainfall which is a key climate variable in Africa and on which most African livelihoods depend on is poorly captured in the models (cf. Gleckler et al. 2008; Randall et al. 2007).

3. *Coarse temporal resolution of global models:* The unit of 3 months used for simulations does not depict the wet and dry seasons as experienced in the SSA regions and this makes for a poor basis for developing agricultural impact models. Only few assessments exist that use the length of the wet season (cf. Marengo et al. 2003; Zhao / Camberlin / Richard 2005)

4. *Coarse spatial resolution of global models:* The shortcomings of GCMs are acknowledged in the IPCC reports (cf. Randall et al. 2007; Christensen et al. 2007, 852 ff.; Boko et al. 2007, 458). Randall et al. (2007) report that while observed temperature is well modelled, models of precipitation deviate greatly from that observed. This deviation is attributed to the nature of African rainfall, which is driven by Sea Surface Temperatures (SSTs), tropical cyclones and the difficulties of the GCMs to represent the interannual variability of SSTs (see also Müller 2009). Yet, the accuracy of projected climate change impacts depends on the accuracy of the projected climate change.

5. *Lack of regional models:* Reducing the spatial resolution of the GCMs to regional models is one way to provide tailored data for the

SSA region and to validate projections made at coarser scales. Yet studies on South Africa show that there are considerable variations between predictions of average temperature between the global models and local climate models (Craig / Sharp 2000; Turpie et al. 2000). For the rest of SSA such regionalised climate change studies are few to inexistent.

6. *Quantification units of changes and impacts:* Burton / Lim (2005, 193) note that projections are mainly expressed in terms of changes in mean temperature and precipitation. They argued that "the scale and the variables used in global climate models (GCMs) are not those most relevant to choices in the agricultural sector", but many climate models continue to use such scales and variables. Farmers and decision makers need information on short-term seasonal, intra-seasonal, and intra/inter-annual variability but climate change projections are not yet providing this information for SSA. These limitations, for example, the misfit of the temporal scales in which climate data is captured and disseminated to the public on the one hand, and the temporal scales of interest to farmers, also pertains to the seasonal forecasts of Early Warning Systems (EWS; Ingram / Roncoli / Kirshen 2002; Ifejika Speranza 2006b). Thus climate change projections are facing similar limitations like the EWS.

7. *Emissions Scenarios do not depict the context of many SSA countries:* An examination of the Special Report on Emissions Scenarios (SRES) characteristics used for the projections shows that these rarely depict the African situation or account for the various trends of socio-economic development pathways of SSA: Many SSA countries have a high population growth, low GDP growth, low energy use (World Bank 2007a), medium to high land use changes, low availability of conventional and unconventional oil and gas (with few exceptions), and a low pace of technological change. This currently depicts a rather low emission scenario. However, if future development in Africa becomes faster and follows a "business as usual" development path with practices that favour high CO_2 emissions, then such a situation will be depicting a high emissions scenario. Emission scenarios that better fit the SSA context (acknowledging such exceptions as the oil-producing Nigeria or the technologically advanced South Africa) can facilitate better adaptation planning.

Thus the projected changes only show trends and as such are not adequate to identify ecosystems, or regions most vulnerable to climate change. Development of more short-term climate information that fits the planning horizons of government organisations remains a concern (Nyong 2005). While the knowledge from the GCMs is very useful for managing climate issues at global levels (monitoring, change detection, global climate regimes) the foregoing indicates the need to refine the resolutions of climate models as GCM-based projections are less useful for adaptation planning at lower social-ecological units like the national, sub-national and community levels (see for example Wilbanks 2002).

The foregoing suggests that climate projections for SSA do not fit the spatial and temporal scales of agricultural processes, practices or planning and cannot yet produce the details needed for impacts assessments. These limitations of climate change projections need to be understood and accounted for in research, policy and planning that depart from or aim to account for climate change impacts. It also shows that *"dealing with uncertainty"* becomes a major focus for adaptation. The situation analysis in this chapter also highlights that climate change is but one of the many factors that SSA agriculture has to deal with and that adaptation has to account for the multiple stresses facing the sector.

2.5 Conclusion

So where should interventions in smallholder agriculture start? Considering the plethora of challenges facing smallholders in SSA and the multiple dynamic stressors (among them climate change), the answer seems to be *by learning to deal with change* while maintaining the quality of land resources. Considering that many smallholders are poor and have low human capital, one entry point is to increase their knowledge and skills and to encourage those smallholders holding knowledge to share this with others. Considering the progression of land degradation, it is crucial that the development community encourage Sustainable Land Management (SLM) practices as SLM not only improves soil fertility and crop yields, but also increases soil carbon. However, considering that many smallholders are poor, there are limits to their capacity to influence framing conditions – the availability and access to services. Hence, the governments need to improve the provision and quality of services like roads, rural financial services, information dissemination, to mention just a few, and development cooperation should support them. The implementation of the *many good policies on paper* needs to be evaluated, not only for their effectiveness, but also for identifying entry points for integrating adaptation, where these do not exist already.

The above considerations provide three complementary entry points for adaptation to climate change:

- at a conceptual level through adopting resilience as an analytical lens
- at the local level through examining smallholders' practices, adaptation and livelihood strategies, and
- at the policy and institutional levels by examining how they support smallholders to adapt through various instruments.

In the following, the conceptual and analytical frameworks are elaborated.

3 Concepts and approaches for analysing adaptation to climate change

Climate change adaptation can be addressed from different conceptual perspectives – the vulnerability approach, the impact approach, a resilience approach or from a sustainability approach. Each approach has its limitations in terms of extent of addressing adaptation and its general acceptance by the various communities (for example research, climate change policy, development policy and cooperation) engaged in climate change issues. Thus each approach gives more weight to certain dimensions of adaptation, but they are interlinked and generally complementary. In the following, the various concepts and approaches are analysed, after which the resilience concept is developed into an operational tool that is later used in this study to analyse the contributions of adaptation measures to resilience to climate change.

3.1 Uncertainty, climate change, social-ecological systems and sustainability

The discussions in the foregoing chapter show that projected climate changes and impacts point towards negative consequences for African agriculture with very few gains in the humid areas, while the semi-arid and sub-humid areas rather should expect more droughts.

Since climate change *impacts are uncertain in spatial and temporal terms*, enhancing the resilience of society to climate risks and improving information seems a realistic approach (cf. Fankhauser et al. 1999). Adopting the concept of resilience offers the possibility to identify and examine the factors and processes that hinder or enable certain actors to moderate and overcome the adverse consequences of climate variability and change. The concept provides an analytical lens both to address already observed impacts (as in adaptive capacity) and the underlying non-climatic causes of vulnerability by shifting the focus to the characteristic features of the Social Ecological System (SES) and how these features interplay to shape vulnerability. Thus, climate change alone does not cause vulnerability; socio-economic factors and their interactions already cause vulnerability, which climate change intensifies.

A SES comprises social (human) and ecological (biophysical) subsystems and their interactions (Gallopín 1991). *Social systems* are made up of rules and institutions, their cross-scale interactions that together mediate human use of resources as well as systems of knowledge, worldviews and ethics concerning human/nature relationships (Berkes / Folke 1998; Berkes / Colding / Folke 2003; Adger 2006). *Ecological systems* or ecosystems refer to "self-regulating communities of organisms interacting with one another and with their environment" (Berkes / Colding / Folke 2003, 3). According to Adger (2006) the concept of an SES reflects the idea that human action and social structures are part of nature hence distinguishing between them does not reflect reality.

A focus on SES also raises the issue of *sustainability*, i. e. the use of resources to meet the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). According to Berkes, Colding and Folke (2003, 2), sustainability is "a process rather than an end product, a dynamic process that requires adaptive capacity for societies to deal with change". For the authors, sustainability implies maintaining the capacity of ecological systems to support social and economic systems and to sustain this capacity requires analysis and understanding of feedbacks and the dynamics of interactions between social and ecological systems. Moreover, sustaining the functioning of a social ecological system implies the presence of resilience and adaptation. Thus, the concept of an SES offers a robust platform for understanding how human societies deal with change, in this case, climate change.

3.2 Vulnerability and poverty and their reduction

Vulnerability is exposure to livelihood risks and the incapacity of the people to cope (Chambers 1989; Wisner et al. 2004). Conceptually, vulnerability has an external side of risks, shocks, and stress, which individuals or household are subjected to, and the internal side, which is defencelessness, signifying a lack of means to cope without a damaging loss (Chambers 1989). In system dimensions, vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. "Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC 2007, 883). Sensitivity refers to the degree to which a system will respond to an external disturbance. It is "the degree to which a system is affected, either *adversely or beneficially*, by climate variability or change. The effect may be direct (e. g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e. g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)" (IPCC 2007, 881). Vulnerability is specific to exposures; hence an SES can be vulnerable to disturbance A but not to B.

Three principal components of vulnerability are usually identified (Chambers 1989; Wisner et al. 2004; Eriksen / O'Brien 2007), namely:

1. *The risk of exposure to a stress event*, for example climate change-induced extreme drought. Exposure may thus be in both climatic and social dimensions. Climatically, exposure reflects the probability of a climatic hazard occurring and that its severity may vary, both between areas and population groups and between different events. However, this exposure dimension seems to be the most challenging component of vulnerability, considering the uncertainties identified in the previous chapter, the complexity of climate and the time-lagged effects of mitigation measures. The social dimension of exposure refers to the construction of social, economic and political factors that place specific population categories at risk. This dimension of exposure is equally challenging, although the understanding of these social, economic and political problems seems more advanced than that of understanding the problem of climate change.

2. *The ability of the population to cope with a stress event (adaptive capacity).* The ability of a given population to cope, i. e. to survive

with its livelihood more or less intact, will depend on the type of climatic event, the options (endowments/entitlements) open to the population and their ability to utilise those options. In this sense, poverty is often linked to vulnerability.

3. *The vulnerability context (the livelihood context)* – The ability of the social structure (society) to maintain or enhance the adaptive capacity of the population. This relates to the construction and interaction of social, economic and political factors: for example, political and economic marginalisation, neglect of enhancement of adaptive capacity, weak institutional frameworks and social networks, as well as market failures, influence the ability to cope or recover. These factors and their interactions place specific population categories, activities or the environment at risk. However, they (factors) are context specific and in continuous flux.

This study regards vulnerability as an inherent property of the SSA agricultural system. It is the pre-existing/current inability to cope with and recover from external stressors. Socioeconomic and political factors (Wisner et al. 2004) as well as the magnitude of climate change determine this inability. Thus, for this study vulnerability is a starting point of analysis (cf. Kelly / Adger 2000; O'Brien et al. 2004). The assumption is that the vulnerability of any individual, social group or SES to natural hazards is determined primarily by their current state and capacity to respond to a particular hazard. Therefore, addressing the current vulnerability will reduce vulnerability to future climate conditions (Burton et al. 2002) and increase resilience.

Vulnerability is often associated with poverty. However, what poverty is depends on who asks and who answers the question (Chambers 2006). Whether poverty is material lack or want, a shortfall in consumption and income, or deprivation in various dimensions, poverty denotes a "lack" of various livelihood resources. This "lack" inherently captures the incapacity to deal with risks, thereby making poor people vulnerable to a wide range of risks and shocks. Most often, poor people are the ones that suffer more injury, loss, death or harm from climatic events and have less capacity to recover (Ifejika Speranza 2006b; Eriksen / O'Brien 2007). Thus, poverty contributes to vulnerability and vulnerability to climate change and this development can exacerbate poverty. This interaction with vulnerability leads to a blurred distinction between poverty and vulnerability and makes distinguishing both concepts key to achieving conceptual and analytical clarity, as well as designing sustainable adaptation measures. Poverty can be linked to the three dimensions of vulnerability (Eriksen / O'Brien 2007).

Linkage 1. Exposure to risk (for example, climate change induced extreme drought) – This entails reducing risks (for example, climate risks) to current ways of securing well-being. However, exposures are location and time-specific. One may be wealthy and vulnerable to drought (for example, wealthy livestock owners living in the drought prone arid and semi-arid lands).

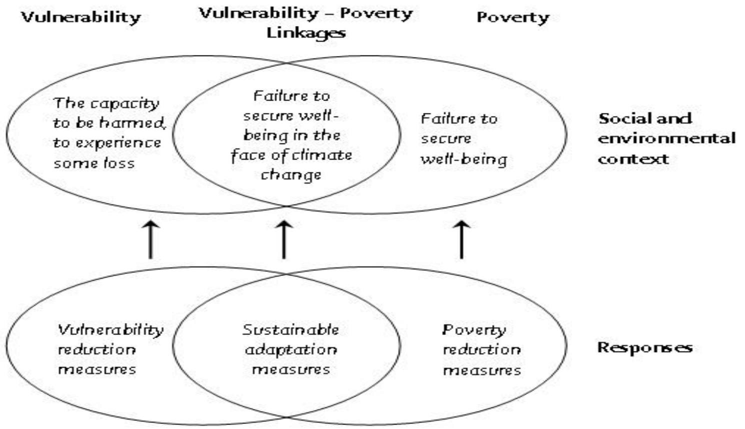
Linkage 2. Strengthening the adaptive capacity of the poor. This entails improving the livelihood assets of the poor and reducing vulnerability to drought, even before the occurrence of the drought.

Linkage 3. Processes generating vulnerability (causes of vulnerability). This addresses the causes of vulnerability among the poor: socio-economic and political processes shape the vulnerability of the affected population to drought and food insecurity. Sometimes, development contributes to increased vulnerability, e. g. in some areas local seed varieties that are well adapted to the local climate conditions are disappearing because of agricultural development projects (Orindi / Ochieng 2005).

The size of the overlap between poverty and vulnerability depends on the particular context. According to Eriksen and O'Brien (2007, 340 ff.), factors that lead to failure to secure well-being define this overlap. For the authors, sustainable adaptation measures (Figure 5) are those that address the overlaps / inter-linkages and should contribute positively to one linkage and at least do not contribute negatively to the other two. Therefore, policies and interventions should focus on the area of overlap between poverty and vulnerability.

Past, current and potential future practices and conditions shape vulnerability and poverty. Hence, both can be area specific, people specific or activity specific. However, there is no one to one mapping between poverty and vulnerability. Not all poor people are vulnerable all of the time and in the same ways (Wisner et al. 2004; Eriksen / O'Brien 2007).

Figure 5: Vulnerability-poverty linkages and sustainable adaptation measures



Source: Eriksen / O'Brien 2007 (with permission)

Both poverty and vulnerability reduction measures have similar objectives; to improve the well-being of the poor but approach the problem from different angles (Eriksen / O'Brien 2007, 342). Vulnerability reduction focuses on responses that reduce risks and address processes that influence well-being and adaptive capacity. Poverty reduction measures depend on how poverty is defined. Using a welfare approach to poverty definition means focusing solely on economic growth as a tool for poverty reduction but this is criticized, as it tends to ignore non-material, non-economic aspects of poverty and the processes of exclusion and marginalisation that cause poverty (Eriksen / O'Brien 2007, 341).

There is need to address both of these factors in order to achieve sustainable adaptation measures. However, not every adaptation or vulnerability measure contributes to poverty alleviation and not every poverty reduction measure reduces vulnerability to climate change (Eriksen / O'Brien 2007). For any particular case, the conditions that create poverty may not be the same as those that create vulnerability.

The mode of implementing adaptation measures must capture the specificity of both the vulnerability and poverty context, as there is no "one-size-fits all" response to poverty and climate change (Eriksen / O'Brien 2007). Hence *targeting vulnerability-poverty linkages is a key to sustainable adaptation measures*.

3.3 Definition of adaptation to climate change and its linkages with resilience

IPCC (2007, 869) defines "adaptation as an adjustment in natural or *human systems* in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". Various types of adaptation can be distinguished, namely, anticipatory, autonomous and planned adaptation:

1. Anticipatory (proactive) adaptation takes place before the impacts of climate change are observed.
2. Autonomous adaptation does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems.
3. Planned adaptation 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 (adapted from IPCC 2007, 869).

In practice, the distinction between these categories may be fuzzy as they blend into one another. In literature anticipatory and autonomous adaptation are attributed to private individuals while planned adaptation is seen to be a preserve of the public sphere (governments). However, this study argues that all three types can be implemented by both private and public actors and that anticipatory adaptation is inherently "planned". Further adaptation is a continuous process. Based on this consideration, adaptation can be reactive (spontaneous) or proactive (planned) and it can be at different actor levels spanning the private and public spheres. McGray et al. (2007, 2) suggest that "adaptation is a continuum of responses to climate change that range from "pure" development activities on the one hand

Box 6: The additionality principle / criteria

As previously discussed climate change overlays many development problems facing developing countries and is thus an additional burden with additional costs that need additional funding.

In recognition of the additional costs of adaptation, the UNFCCC states that developed country parties

"provide new and additional financial resources to meet the agreed full costs incurred by developing country Parties in complying with their obligations" to implement the convention (Article 4.5).

"provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of implementing measures" under the convention (Article 4.3).

"... also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects" (Article 4.4).

"... take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention" (Article 4.5).

The additional costs are understood to be additional to Official Development Assistance (ODA). The views are that ODA targets of providing 0.7 % of GNI of developed countries for development aid should remain focussed on achieving development goals, like reducing poverty and improving health. The funding for adaptation should thus be additional and also be provided by developed countries, due to their historical responsibility of emitting GHG that cause climate change.

However, the close link between adaptation and development makes it very difficult to distinguish adaptation from development and to prove the additionality criteria. It remains difficult to clearly identify what constitutes additional costs of adaptation or additional funding sources for adaptation. The fact that the Adaptation Fund (AF) is partly financed from the proceeds (2 % of certified emission reductions) of the clean development mechanism projects points at an interpretation of additionality in terms of additional funds to ODA. However, whether the "other sources of funding" are additional to ODA remains to be seen.

Sources: UN 1992; McGray et al. 2007; Horstmann 2008; http://www.adaptation-fund.org, accessed 12 Sept. 2009 to very explicit adaptation measures on the other". Such activities would range from addressing the drivers of vulnerability, building response capacity, managing climate risk and confronting climate change. The authors note that vulnerability reduction and capacity building should be funded in adaptation projects but concede that although vulnerability reduction and capacity building are at the heart of enabling effective adaptation, such adaptation activities may not qualify for adaptation funding under the "additionality principle" (see Box 13), and that it is therefore critical that funders include them in adaptation projects. McGray et al. (2007) highlight that two factors shape the type of adaptation response, namely, the existing capacity of the affected communities, and the level of information about climate change impacts. Hence for cases where capacity is low, as in most of SSA, the major focus of adaptation would be to address the underlying sources of vulnerability, hence rather addressing development than adaptation *per se*. With higher certainty about climate change, the major focus would be on addressing the impacts.

Adaptation thus involves

1. *Reducing vulnerability,* by addressing the drivers of vulnerability to climate change. Such activities generally aim to reduce poverty and other problems associated with a lack of capabilities, for example through improving livelihoods. Although such activities do not address specific climate change impacts, they do help buffer actors from climate trends and shocks (McGray et al. 2007) and therefore build resilience. This means that resilience is at the core of adaptation actions (see Figure 6).

2. *Building adaptive capacity*, thereby increasing the ability to adapt to changes (e. g. communicating climate change information, building awareness of potential impacts, investing in livelihood capital), and

3. *Implementing adaptation decisions* – transforming the capacity into action. This focuses on reducing the cumulative impacts of climate change, ensuring that no externalities occur from adaptation actions (i. e. adaptation by one actor does not adversely affect other actors), avoiding anticipated adverse impacts of climate change and ensuring that the distributional impacts of adaptations are minimised (Adger / Arnell / Tompkins 2005).

Adaptation actions are difficult to distinguish from other actions as actors are constantly adapting to changing social and economic conditions.

Hence, attributing adaptations to climate change can be difficult. However, some adaptations like government adaptation programmes are purposeful and directed at impacts triggered by climate change (for example, drought) (Adger / Arnell / Tompkins 2005).

Adger, Arnell and Tompkins (2005, 79) propose three components of adaptation:

1. Reducing the sensitivity of the system to climate change – "increasing storage capacity", "planting hardier crops" (but this overlaps with the "buffer capacity" of the resilience concept as will be show later in Section 3.4).

2. Altering the exposure of the system to climate change, "investing in hazard preparedness and undertaking climate change mitigation activities", and

3. Increasing the resilience of social and ecological systems to cope with changes – through generic actions that not only aim to enhance well-being and increase access to resources and insurance, but also include specific measures to enable specific populations to recover from loss.

These components of adaptation are similar to those of vulnerability discussed earlier and overlap with the concept of resilience (see Section 3.4).

Adaptation to climate change is in many cases nothing new (cf. Füssel 2007). New are the climate extremes and the magnitude of climate change to be adapted to (cf. IPCC 2007; Füssel 2007). So the accusation from certain discourses of re-packaging (to put old wine in a new bottle) livelihood strategies as adaptation strategies cannot detract from the fact that many adaptations in agriculture will remain of the same nature give or take climate change. A rather productive way to go about it would be to ask why that old wine (adaptation strategies so far) was not drunk (inadequate) and had to be re-packaged, and how the wine (adaptation strategies) can be improved so it is drunk and does not need to be repackaged.

Adaptation can be positive where it enhances livelihood security and sustainability or negative, as in mal-adaptations that increase vulnerability to climate change. Experience thus far shows that it is very difficult to distinguish adaptation from classical livelihood practices and strategies, or adaptation practice from development practice. This distinction is not sought so much by those who need to adapt, as people have adapted to different disturbances across time. However, the issue of financing adaptation in addition to official development assistance (additionality principle; see Box 13) makes this question not so trivial after all, but the uncertainties prevalent in climate change projections makes such an undertaking difficult.

3.3.1 Criteria for evaluating adaptation options

Due to the wide range of adaptation options, it is important to evaluate these in order to determine which adaptation actions should be promoted or implemented under specific circumstances (Dolan et al. 2001). Planned (anticipatory) adaptations can be evaluated using methods such as cost-benefit analysis, cost effectiveness analysis or multiple criteria evaluation. Evaluation of adaptations to climate change needs to be considered as part of an ongoing assessment of choices in a context of multiple risks. "Evaluations are intended to assess the overall merit, suitability, utility or appropriateness of potential adaptation strategies or measures" (Dolan et al. 2001, iv).

Various criteria such as *effectiveness, flexibility, economic efficiency, social acceptability, timeliness, equity, institutional compatibility, farmer implementability, and net benefits independent of climate change,* are used in literature to evaluate adaptation options (Titus 1990; Dolan et al. 2001; Adger / Arnell / Tompkins 2005). These criteria are context specific and are based on competing values as their importance varies from context to context:

1. *Effectiveness* relates to the capacity of an adaptation action to achieve its expected/target objectives and can be measured by robustness to uncertainty and flexibility, that is, ability to change in response to altered conditions.

2. *Flexibility*, that is, the ability of an adaptation to perform well for a range of likely climate changes (Titus 1990). This is important given the uncertainties in climate change, so that adaptations can accommodate "adjustments as new information becomes available, or as experience is gained" (Dolan et al. 2001, 8). According to Dolan et al. (2001), a flexible adaptation option in agriculture is one that is "functional in the light of unforeseen climate changes and effects. For example, planting crop varieties that are tolerant to a wide range of climate conditions is considered more flexible than planting crop varie-

ties that are productive in very particular climate conditions" (Dolan et al. 2001, 9).

3. *Efficiency* of adaptation actions requires considerations of

   a) The distribution and costs of the benefit of the action. *Economic efficiency* captures whether adaptation benefits are greater than the costs. Economic efficiency is important as an adaptation criterion because perceived lack of profitability is often cited as a constraint to adoption of a wide range of farm-level innovations. Dolan et al. (2001, 8) highlight that "costing procedures for evaluation of adaptation options pose a significant challenge, particularly in agriculture" where "the costs and benefits of adaptation are often shared by more than one party".

   b) The social costs and benefits of adaptations in those goods that cannot be expressed in market values may deter farmers from adopting them. For example, being perceived as not conforming to societal values hinders female farmers from selling livestock in the market in the absence of their migrant husbands, thereby limiting their access to cash.

   c) The timing of adaptation has to be weighed against the consequences of delayed implementation (Titus 1990). The timing of adaptation action in relation to climate change impact will also affect the potential economic efficiency of an adaptation option. For example, farmers are interested in which crops to plant in the next season and less so for projected climate in 50 years time (Adger / Arnell / Tompkins 2005). Similarly, politicians are interested to see the results of their policy decisions during their legislative period. Thus, focusing on climate variability and observed climate change might be a viable way as it highlights current needs for adaptation.

4. *Equitable* adaptations can be evaluated from the perspective of outcome – who wins and who loses from the adaptation as well as who decides which adaptations to take. Adger, Arnell and Tompkins (2005) note that assessing equity shows that present day adaptations reinforce existing inequalities and do little to alleviate underlying vulnerabilities (see also Section 3.4).

5. *Institutional compatibility* tests whether adaptations are consistent with existing institutional structures (laws and institutions) and jurisdictional authority, as these are more likely to be adopted than those that require changes to existing structures. Institutional frameworks

and actions can thus hinder or facilitate adaptations (Dolan et al. 2001). The *legitimacy* of an adaptation policy depends on cultural expectations and interpretations as these define what is or is not legitimate, or socially acceptable (Adger / Arnell / Tompkins 2005).

6. *Farmer implementability* refers to a lack of complexity, compatibility, "triability" and observability (Dolan et al. 2001). "Complexity represents the degree to which new knowledge and skills are needed for implementation, and compatibility refers to the ease with which an innovation can be integrated into a current farming system" (Dolan et al. 2001, 9–10). 'Triability', is the degree to which an innovation may be experimented with prior to full adoption, and 'observability', the degree to which the results of an innovation are visible to others.

7. *Net benefits independent of climate change* refers to adaptations that provide benefit regardless of whether or not climate change effects occur. "Adaptation options are preferred if they will result in no net losses (or damages)", if they are 'no regrets' or 'win-win' measures (Dolan et al. 2001, 10).

According to Adger, Arnell and Tompkins (2005), achieving a balance between these criteria can lead to tradeoffs, which the stakeholders themselves must decide. Weighting (whether qualitative or quantitative) provides an instrument for the actor (farmer, extension officer decision-maker) for gauging its path to and the achievement of desired outcomes. Determining the unit (individual, organisation, government, society) for which success is measured also determines who is to be involved in such a process.

Issues of scale in adaptation are important as regards who (as in actor categories), or what (as in social structures and processes) adapts to climate change. Cross-scale dynamics in implementing adaptations can create new or amplify existing conflicts. Therefore, the temporal and spatial dimensions determine the success of adaptation actions. While adaptation may be effective for the adapting actor, it may produce "negative externalities and spatial spill over potentially increasing impacts on others and reducing their capacity to adapt" (Adger / Arnell / Tompkins 2005, 80). Therefore, specifying who undertakes an adaptation is a fundamental part of differentiating adaptations and is necessary in any evaluation of adaptation options (Dolan et al. 2001, 10).

The sustainability of adaptation depends on the heterogeneity of adaptive capacity across different stakeholders (Adger / Arnell / Tompkins 2005) – this relates to "diversity" as used in resilience terms (see Section 3.4). Considering the foregoing, one can interpret that *the perceived success of an adaptation lies in achieving resilience to climate change.*

3.4 Social-ecological resilience and adaptive capacity

Although resilience has major roots in research on ecology (Holling 1973), it is widely used in research on human-nature interactions. *Social-Ecological Resilience* (SER) refers to the capacity (ability) to absorb (withstand) disturbances (for example, climate change impacts) while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress (e. g. climate change) and change (cf. Carpenter et al. 2001; Berkes / Colding / Folke 2003; Folke 2006; IPCC 2007). It is the magnitude of disturbance that can be tolerated before an SES moves to a different state controlled by a different set of processes or to a different domain of attraction (Carpenter et al. 2001). Adger (2000) defines *social resilience* as the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change, and *ecological resilience* as a characteristic of ecosystems to maintain themselves in the face of disturbance.

In some studies, *resilience* is regarded as the opposite of vulnerability (Folke et al. 2002), while in others this distinction is not so clear (cf. Gallopín 2006; Adger 2000). This study adopts the former view but expands it to include aspects of dealing with change and focusing on the system, system components and interactions. It is however important to note that resilience and vulnerability are not always two sides of a coin: under different circumstances (time, context), a resilience factor can exacerbate vulnerability to climate change: for example, keeping livestock can be a resilience factor under non-drought and the early stages of drought as livestock can be sold for income. However, under advanced drought conditions, holding onto livestock increases vulnerability to drought impacts (Ifejika Speranza 2006b). Therefore, time and context matter. Although portraying resilience as the opposite of vulnerability harbours the danger of "circular reasoning: a system is vulnerable because it is not resilient; it is not resilient because it is vulnerable" (Klein / Nicholls / Thomalla 2003, 40), there are certain variables of the system and certain contexts where this is actually so. For example, under drought conditions, certain pastoral and agro-pastoral areas and households are almost always vulnerable to food insecurity.

A review by Boyden and Cooper (2007, 1) on resilience in the context of chronic poverty shows that literature generally ascribes resilience to three characteristics: (a) good outcomes despite high-risk, (b) sustained competence under conditions of threat, and (c) recovery from shocks and stressors. The authors therefore note that the "risk of adversity is the mirror against which resilience is appraised" (Boyden / Cooper 2007, 1). Thus, research on resilience aims to identify those factors and processes that enable actors to overcome adversities. Carpenter et al. (2001, 766) note that "unlike sustainability, resilience can be *desirable or undesirable*. For example, system states that perpetuate poverty can be highly resilient but not desirable and in system states with high vulnerability resilience is desirable. In the latter sense, resilience overlaps with sustainability", and together these can be regarded in general as desirable system states (cf. Carpenter et al. 2001). Encrusted (rigid) institutional frameworks that need de-crusting can also be resilient.

For areas where agriculture is resilient to climate change, the challenge is to maintain or increase resilience while for SESs where agriculture is vulnerable to climate change the challenge is to reduce the vulnerability and build resilience. The latter is the case for SSA agriculture. Hence, resilience is also the ability to create sustainable options and responses, which open new pathways for living with change (Kessy / Mayumana / Obrist 2007). Resilience interpreted as facilitating and contributing to the process of recovery after a disaster does not reduce vulnerability to natural hazards. However, resilience in terms of (socio-) economic standing is an important factor determining whether resilience reduces vulnerability (Klein / Nicholls / Thomalla 2003).

The *strength of the resilience concept* is that it focuses on variables that underlie the capacity of the SES to function, to provide ecosystem services and to deal with disturbances, uncertainties and change. That way, it offers a way to cope with surprises.

The resilience of an SES thus has three characteristics (cf. Carpenter et al. 2001):

i. The buffer capacity, that is, the amount of change the system can undergo and still retain the same structure, function, identity, and feedbacks on function and structure. Used for social actors, it refers to the ability to cope and adjust.

ii. The degree to which the system is capable of self-organisation as opposed to lack of organization or organization forced by external factors. The connectedness or controllability of a network determines the degree to which it can direct its own actions and outcomes (Holling 2001).

iii. The ability to build and increase the capacity for learning and adaptation, as in adaptive management.

The concept of resilience is a promising tool for analysing adaptive change towards sustainability because it provides a way to analyse how to maintain stability (Berkes / Colding / Folke 2003) and functioning in the face of change. Resilience takes into account an SES and takes adaptive management – iterative planning and management – as an entry point. Vulnerability and resilience have common features – the exposure of the SES to stresses, the response of the system and the capacity of the SES to adapt. IPCC (2007, 869) defines *adaptive capacity* as the ability of a system to adjust to climate change (including climate variability and extremes), moderate potential damages, take advantage of opportunities, or cope with the consequences.

Some studies regard resilience, exposure and resistance as components of vulnerability (for example Pelling 2003), while others see resilience, exposure and sensitivity as three elements or determinants of vulnerability (for example Folke et al. 2002). Besides common features, distinctions exist between resilience and vulnerability (see Table 3).

Considering that climate change is overlaying and interacting with other non-climatic factors affecting agriculture (as discussed in Chapter 2), it follows that taking *the impacts of climate change as a starting point of analysis* has serious limitations. Firstly, it is uncertain where and when the

Table 3: Distinguishing between resilience and vulnerability

Resilience factors	Vulnerability factors
– *Moderating impacts and outcomes* – *Protective factors and processes*	– *Exacerbating impacts and outcomes* – *Fostering exposure (risks)*
Resilience approach	Vulnerability approach
– *Reflecting strengths* – *Recognising capacities and competencies (actors as competent social agents)* – *Reflecting sustained competence / functioning*	– *Emphasises problems or deficits* – *Emphasises dependencies on others for survival and development*

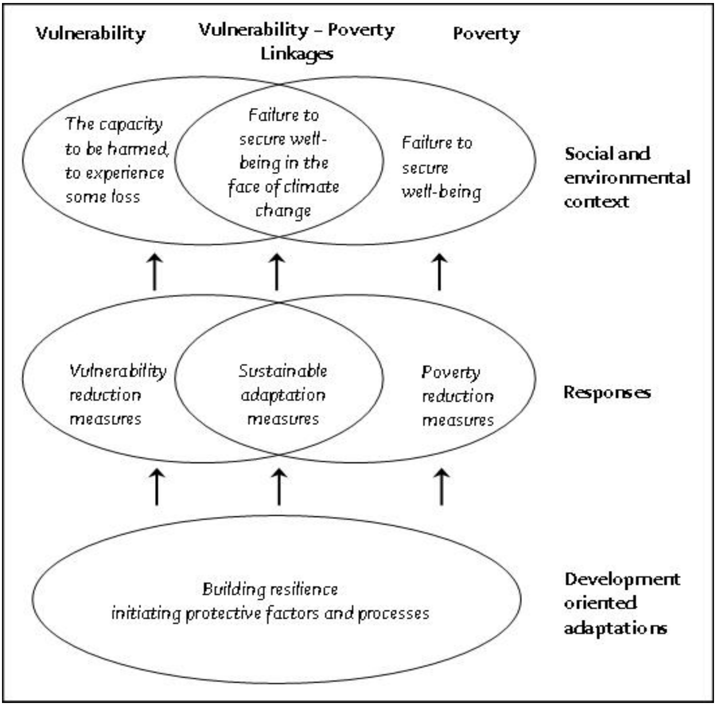
Source: Adapted from Boyden / Cooper (2007)

climate impacts will occur. Secondly, the differing results of the GCMs are sending confusing signals. Thirdly, focussing on impacts will be treating mainly the symptoms and not the causes.

Another approach would be to focus on vulnerability. However, the *vulnerability approach* seems static. Although it considers risks, it does not explicitly consider uncertainty, a major factor in climate change. A vulnerability lens is still useful as it seeks to answer the question of who is vulnerable, why the person is vulnerable and when (under what conditions) but it does not explicitly address increasing adaptive capacity to deal with change. This is where the *resilience approach* comes in – this focuses on underlying causes as well as long-term capacity to deal with change (implicitly including the risks and uncertainties that come with change). It also focuses on the system as a whole, dealing with the risks and the vulnerability and their interactions. *Adaptation* on the other hand highlights the aspect of dealing with change and taking opportunities but does not explicitly deal with vulnerability.

Building resilience thus not only addresses the area of overlap between vulnerability and poverty (see Figure 6), but also addresses poverty and vulnerability in the non-overlapping areas. Buffer capacity, self-organisation and adaptive management thus underlay adaptations (see Figure 6 and 7). Figure 7 illustrates a summary of what literature tells us about resilience, adaptation and vulnerability. The interactions between resilience and adaptation seem to be generally reinforcing. However, based on current conceptual developments in literature, the details of these interactions cannot yet be made explicit. What is clear is that resilience underpins adaptive capacity, which in the first place makes implementing adaptations possible.

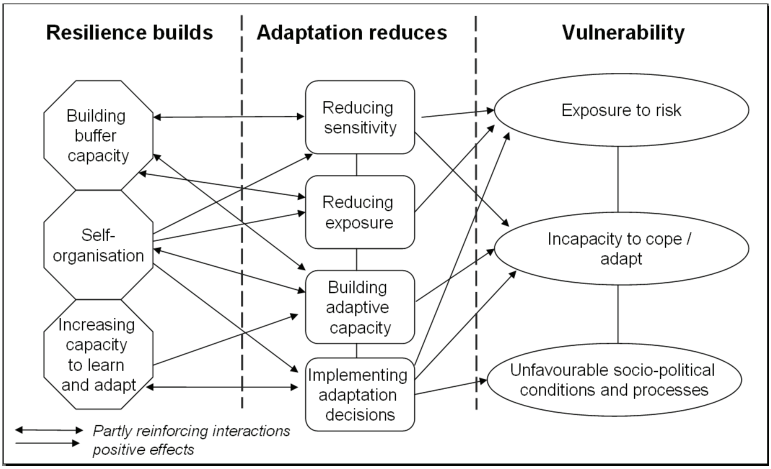
Figure 6: Resilience, vulnerability-poverty linkages and sustainable adaptation measures



Sources: Adapted from Eriksen / O'Brien 2007 and own design

In recognition of the integrative nature of the resilience concept, scholars are suggesting that taking a resilience approach might provide superior insights on how to achieve sustainability (cf. Nelson / Adger / Brown 2007; Boyd et al. 2008). *A development approach and a resilience approach have some overlap.* However, while a development approach aims to reduce poverty, it does not explicitly ask the question of whether those that are no longer poor will remain so under future conditions of uncertainty.

Figure 7: A summary of what literature tells us about vulnerability, adaptation and resilience as well as their linkages



Source: Own design

This study links the concepts of SES, resilience, vulnerability and adaptive capacity to the "sustainable livelihoods framework", as livelihood assets, livelihood strategies, policies and institutions (DFID 2000) shape the capacity of actors to cope and adapt. Livelihood assets are the resources at the disposition of the people, which they use to achieve their self-defined goals. Livelihood assets include human capital (skills, knowledge, ability to labour and good health), social capital (social networks, membership in groups), natural capital (natural resources such as land, water, biological resources, the environment), physical capital (basic infrastructure and services), and financial capital (cash and credit) (DFID 2000). The notion of SES also indicates active actors, whose actions can lead to changes in the resilience, vulnerability and adaptive capacity of the system. Thus within such a system, action theories can be used to explain the rationale of action of the various actors (cf. Giddens 1984; Bourdieu 1977; Wiesmann 1998), the issue of power differentials, endowments and entitlements (Sen 1987; Chambers 1989; Chambers / Conway 1992) and how these influence outcomes for the SES and its components. In the following, the concept of resilience is developed into an operational tool – a resilience check – that can be used for implementing and analysing adaptations.

3.5 The resilience check – an analytical and operational tool

Based on the definition of social ecological resilience by Carpenter et al. (2001), Milestad and Darnhofer (2003) and Milestad (2003) developed the concept of farm resilience to analyse the resilience of organic farming systems in Austria. This study builds on these achievements and integrates other insights from the preceding sections to develop further the principles of resilience into *an analytical tool and operational instrument for assessing adaptation and resilience* to climate change in SSA agriculture. The components are

1. *Buffer capacity*: At the farm-level the question would be whether buffer capacities exist and whether adaptation strategies enhance the buffer capacity that allows the farmer to adapt to climate change (Holling 2001). This can be related to

    a. *Endowments* (livelihood capitals) *and entitlement* (access through production, exchange and trade),

    b. *Diversity* of system components and diversity of livelihood options that are able to offer farmers a choice (flexibility) of adaptation and livelihood strategies (cf. Chambers / Conway 1992). In terms of ecological resilience, mixed cropping can reduce the risk of drought-induced crop loss since not all crops are susceptible to drought to the same degree. In terms of soil management, soils with more humus can absorb and retain more moisture than soils without.

c. *Site specific knowledge* refers to an actor's knowledge of the SES within which adaptation is carried out.

d. *Institutions*, that is, the norms and rules of society (Ostrom 1990) as well as formal institutions like groups, organisations and government bodies and how they enhance or limit farmers' adaptive capacities;

e. *Stewardship*, that is, an ethic that embodies co-management of environmental resources to achieve long-term sustainability, as in many indigenous knowledge and management systems (cf. Berkes / Colding / Folke 2000).

2. *Self-organisation*: According to Milestad (2003), self-organisation of farming systems refers to the ability of a group of farms to form flexible networks as well as the ability to be involved with the social, economic and institutional environment on other scales than the local. Self-organisation includes

   a. *Opportunity for self organisation* which relates to the question of whether the SES offers opportunities for farmers to organise themselves.

   b. *Cooperation and networks* among farmers can decrease dependence on external actors for information, innovations, and capital. Lack of cooperation among farmers can in turn lead to lack of trust (or *vice versa*), which is a poor basis for self-organisation.

   c. *Reliance on farm's own resources and farmer's own knowledge* reduces dependency on external inputs and saves time for prompt action at the farm-level. It needs to be noted here that depending on how the SES is defined, subsidies are external to the SES but can have both positive and negative effects on farm resilience.

3. *Capacity for learning and adaptation*: This refers to a farmer's management approach and openness for learning (learning ability). Since an SES is dynamic, in temporal and spatial terms, farmers are constantly adjusting their activities and learning from what other farmers are doing to maintain and increase production. Adaptive management is seen as the key management approach as it emphasises the importance of understanding feedback from the social and ecological systems and their management. In this sense, management is a tool not

only for changing the system but also for learning about the system (Milestad / Darnhofer 2003). Learning requires

a. *Existing learning platforms/mechanisms* – that create opportunities for combining different types of knowledge.

b. *Functioning feedback mechanisms*: Milestad (2003) notes that feedback mechanisms are crucial for learning as they allow farmers to receive (monitor) signals from the ecosystem, which they process and interpret and subsequently respond with relevant changes in farm management. At a cross scale level, an examination of the feedback between the various levels of actors (for example between farmers, extension officers, ministry directors and politicians) provides information on how feedbacks shape the resilience of a farming system.

Certain sub-components of the three main features of resilience could well fit under other components (e. g. endowments – livelihood capital like the level of education or skills can contribute to capacity for learning; they also provide buffers to farmers to take on off-farm income earning activities). However, knowledge from empirical research can help refine this construct. It is important that each resilience factor is considered only once in an assessment.

The resilience building components described above are summarised under a framework, called "*a resilience check*" (Table 4), which can be used for evaluating adaptation strategies at farm-level (Table 4) and at the level of institutions/support services (Figure 7), a goal being to monitor progress towards resilience. Since the principles of resilience apply in many cases, several potential users can use the check, while giving the various components different weighting. With modifications, a farmer that has functional literacy can use this to evaluate own practices. An extension officer can use it to evaluate services and recommendations to the farmers. A CBO/NGO can use it to evaluate own activities. Permanent secretaries and Ministers – the decision-makers – can use it to evaluate their policies and implementation, while international organisations and development cooperation agencies can use it to evaluate the contributions of international agreements, policies and programmes to building resilience. Table 5 can be used to assess the ways and the extent to which support services (for example government extension, NGOs or research organisations) positively or negatively influence the resilience of smallholder agriculture, a possible aim being to identify entry points for improving adaptation interventions. This check (Table 4 and Table 5) will be used for a future empirical research, in interviews and workshops. This practical test of a method based on the farm resilience concept extends the work of Milestad and Darnhofer (2003) and Milestad (2003). As an initial step, this study will assess identified adaptation strategies based on the aforementioned criteria of resilience, two major question being; in what ways and to what extent are such factors or processes identified as resilience factors or services provided, do they reduce vulnerability and foster adaptation; and – in what respects do the adaptation strategies strengthen the resilience of SSA agriculture to climate change?

A weighting based on different sustainability dimensions has been chosen to analyse how well such a tool can be used also in capturing the contributions to sustainability. Sustainability dimensions can be in terms of economic, social, and ecological gains achieved through an adaptation or services to support the adaptation. Depending on the indicator, a positive (+) or negative (-) contribution can be either in one, two or all three dimensions. For purposes of analysing empirical data (which this study does not cover), a potential weighting scheme of the contributions could be for example, in using the signs + Positive or – Negative, with a weighting scheme of the contributions to resilience in both directions, starting with N: None, Very Low (+VL or -VL), Low (+L or -L), Medium (+M or -M), High (+H or -H), Very High (+VH or -VH). Alternatively or in complement, such a scheme could also range from zero for none to + or -1 to + or -5. Thus a positive and high contribution could be depicted as "+H" or "+4" while a negative but high contribution could be depicted as "-H" or "-4". Important to note is that the indicators and questions phrased in Table 4 and Table 5 provide coarse frames that need to be refined after pilot testing them.

An appraisal of Table 4 shows that achieving buffer capacity lays the foundation for and provides the critical mass to achieve a basic level of resilience for building self-organisation and increasing adaptive capacity.

Since current adaptation measures can turn out in future to be mal-adaptations. Capturing the time dimension in resilience is important for dealing with uncertainty. To do this, the Resilience Check can be used periodically, such as every 3 to 5 years, or according to identified dynamics of the adaptation measure and its context. Such a periodical assessment can help ascertain whether adaptations are changing to mal-adaptations, so that countermeasures can be implemented early enough.

Various tools exist or are in development (for example the "Climate Check" of GTZ or the ORCHID of DFID) to mainstream adaptation to climate change into development cooperation. At their current levels of design, these tools screen various development projects for climate risks, based upon which relevant adaptation and mitigation actions are taken. The resilience tool is complementary to such climate risk-screening tools, in that it can link up to analyse how effective (by maintaining resilience and reducing vulnerability) the adaptation measures are in reducing climate change impacts, thereby highlighting which aspects of an adaptation strategy should be improved.

Finally, the resilience check analyses adaptation measures to see whether they promote resilience based on the assumptions that

a. Adaptation practices and strategies already exist.

b. Evaluating how effective these practices are to maintain or increase resilience in the face of climate change and other stressors provides information on necessary improvements and adjustments.

c. Increasing resilience shapes the capacity to adapt and implement adaptation measures.

d. A resilient livelihood or activity is less vulnerable to climate change, that is, it is less likely to suffer climate impact on the same magnitude like a non-resilient livelihood.

By focussing on concrete strategies or activity lines, the resilience check provides information/insights on which dimensions to improve on in order to achieve progress in adaptation.

Table 4: A resilience check at farm-level: Assessing the contributions of farm practices to resilience of smallholder agriculture to climate variability and change

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
		In what ways and how much does the adaptation …			
Buffer capacity (robustness to uncertainty)	Spheres of action	Increase livelihoods activity options?			
	Human capital	Promote human capital (endowments)?			
	Access (rights)	Promote entitlements (access)?			
	Income	Improve incomes?			
	Climate protection	Promote climate protection?			
	site-specific knowledge	Require or use site-specific knowledge?			
	Incentives	In what ways and how much do policies promote (at least not hinder) the adaptation option (incentives)?			
	Diversity	In what ways and how much does the adaptation promote diversification or diversity?			

Source: Based on literature / own design

Table 4 continued

Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
Buffer capacity (robustness to uncertainty)	Stewardship	In what ways and how much is the adaptation geared towards steward ship (in contrast to exploitation/mining resources) rather than just management?			
	Environmental protection	In what ways and how much does the adaptation practice benefit the environment?			
Self-organisation	Local resources use	In what ways and how much does the adaptation depend on locally available resources?			
	Cooperation and networks	In what ways and how much does the adaptation promote cooperation and networks among farmers?			
	Farm resources use	In what ways and how much does the farmer rely on own resources in practicing the adaptation?			

Source: Based on literature / own design

Table 4 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Self-organisation	Farmer knowledge	In what ways and how much does the farmer rely on own knowledge in practicing the adaptation?			
	Flexibility	In what ways and how much does the farmer have the freedom to decide?			
Adaptive capacity	Knowledge combination	In what ways and how much does the adaptation create opportunity to combine different types of knowledge			
	Feedback among stakeholders	In what ways and how much does the adaptation promote feedback among various stakeholders?			
	Feedback among peers	Among farmers?			
	Feedback farmer-extension	Between farmers and extension officers?			

Source: Based on literature / own design

Table 4 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Adaptive capacity	Feedback farmer-policy-makers	Between farmers and policy makers?			
	Feedback extension-policy-makers	Between extension and policy makers?			
	Feedback farmer-researchers	Between farmers and researchers?			
	Power differentials	In what ways and how much does the adaptation narrow power differentials?			
	Local ecological knowledge	In what ways and how much does the adaptation build on or transmit local ecological knowledge?			
Other adaptation criteria					
Efficiency	Costs-benefits (Market values)	How much is the cost-benefit ratio of the adaptation practice or strategy?			

Source: Based on literature / own design

Table 4 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Efficiency	Costs-benefits (Non-market values)	In what ways and how much are the social benefits relative to the costs?			
	Right timing of adaptation	Is the timing right?			
Gender	Gender positive / negative	In what ways and how much does the adaptation reduce existing gender inequalities?			

Source: Based on literature / own design

3.6 Stakeholders and actor-oriented perspectives for analysing adaptation to climate change

Assessing resilience offers an approach to exploring actors' perspectives and how to enhance adaptive capacity. Approaching adaptation from the actors' perspective enables us to understand how certain actors are more or less successful in adapting to climate change, the barriers and the needs for increasing their resilience to climate change. An actor-oriented perspective orients analysis towards the social actor, "*the interplay, contestation and negotiation of values and interest amongst actors*" (Long 1997, 2). Such a focus on the actor contributes to an understanding of the dynamic relationship between social actor and structure and highlights the fact that actors have scope to realise their strategies. However this 'scope or freedom to act' can vary.

Table 5: A resilience check of support services: Assessing the contributions of support services to the resilience of smallholder agriculture to climate variability and change

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
		In what ways and how much does the service offered in respect to an adaptation …			
Buffer capacity (robustness to uncertainty)	Spheres of action	Increase livelihoods activity options?			
	Human capital	Promote human capital (endowments)?			
	Access (rights)	Promote entitlements (access)?			
	Income	Improve incomes?			
	Climate protection	Promote climate protection?			
	site-specific knowledge	Require or use site-specific knowledge?			
	Incentives	Promote (at least not hinder) the adaptation option (incentives)?			
	Diversity	Promote diversification or diversity?			

Source: Based on literature / own design

Table 5 continued					
Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
Buffer capacity (robustness to uncertainty)	Stewardship	Encourage stewardship (in contrast to exploitation/mining resources) rather than just management?			
	Environmental protection	Benefit the environment?			
Self-organisation	Local resources use	Use locally available resources?			
	cooperation and networks	Promote cooperation and networks among farmers?			
	Farm resources use	How much can/does the farmer rely on own resources in using/ practising the services (e. g. advice, tools) provided?			
	Farmer knowledge	In what ways and how much does the farmer rely on own knowledge in practicing the adaptation?			
Source: Based on literature / own design					

Table 5 continued					
Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
Self-organisation	Flexibility	In what ways and how much are farmers flexible in using the services provided (e. g. sequencing of farm activities like farm preparation, planting/sowing, spraying, and weeding)?			
Adaptive capacity	Knowledge combination	In what ways or how much do the services support/ provide incentives for farmers to combine different sources of knowledge on an adaptation?			
	Feedback among stakeholders	**In what ways and how much does the service promote/ provide incentives for feedback** among various stakeholders?			
	Feedback among peers	Among farmers?			
	Feedback farmer-extension	Between farmers and extension officers?			

Source: Based on literature / own design

Table 5 continued					
Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
Adaptive capacity	Feedback farmer-policy-makers	Between farmers and policy makers?			
	Feedback extension-policy-makers	Between extension and policy makers?			
	Feedback farmer-researchers	Between farmers and researchers?			
	Power differentials	In what ways and how much does the service narrow power differentials?			
	Local ecological knowledge	In what ways and how much does the service build on or transmit local ecological knowledge?			
Other adaptation criteria					
Efficiency	Costs-benefits (Market values)	How favourable is the cost-benefit ratio of the service provided to the farmer in respect to the adaptation?			
Source: Based on literature / own design					

Table 5 continued

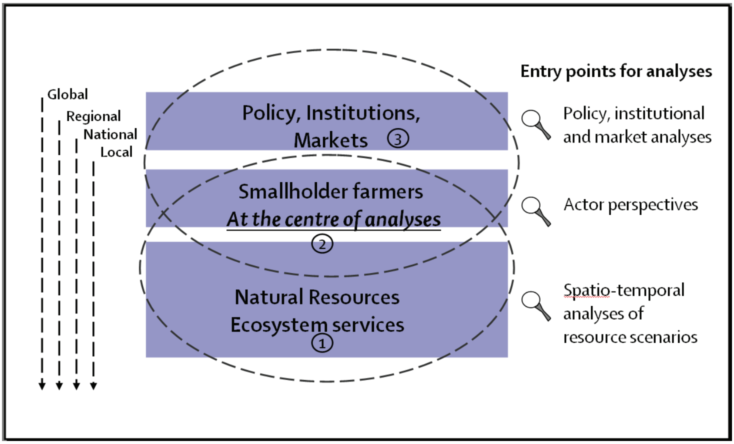
Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Efficiency	Costs-benefits (Non-market values)	How favourable are the social costs relative to the benefits of supporting farmers to practice various adaptation options?			
	Right timing of adaptation	Is the timing of the services with respect to the adaptation practice right?			
Gender	Gender positive / negative	In what ways and how much does the service reduce existing gender inequalities?			

Source: Based on literature / own design

In adopting an actor-oriented perspective, an important notion is that "individuals and social groups are, within the limits of their information and resources and the uncertainties they face, ‘knowledgeable’ and ‘capable’, that is, they devise ways of resolving ‘problematic situations’ and thus actively engage in constructing their own social worlds" (Long 1992, 32). However, this active engagement can lead to positive or negative outcomes for the actors themselves and their environment.

As *adaptation to climate change is multifaceted*, various actors at different levels can implement adaptations to the benefit of the general public or the individual implementing the adaptation. Since different actors carry out adaptations, the question of *hierarchies and power differentials* is fundamental for an adaptation as individual adaptations can be constrained by

Figure 8: A framework for analysing the interactions between smallholders, natural resources, policies and institutions



Source: Own design

institutional processes (cf. Adger / Arnell / Tompkins 2005). Figure 8 illustrates the multi-level approach used in this study for analysing adaptation.

Due to the multi-scale nature of an SES, the analyses of the interactions between various levels and how these shape vulnerability or resilience to climate change are important.

1. Departing from resource conditions and ecosystem services (Figure 8), a spatio-temporal analysis of the SES can be used to capture the conditions of resources.

2. From the perspective of the smallholders (Figure 8), who are in direct contact with natural resources and will bear the brunt of climate change impacts, access to resources and how this shapes adaptive capacity can be examined. Smallholder adaptation to climate change is not only shaped by smallholder practices but also by the framing conditions posed by policies, institutions and markets. According to Eriksen and O'Brien (2007, 348–349), ad-

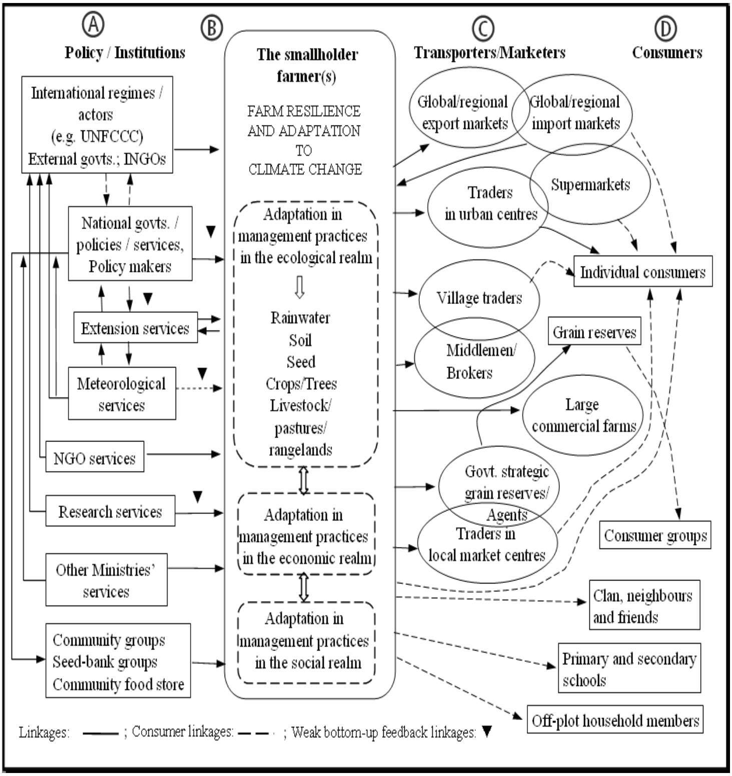
aptation is a social development issue as much as environmental and technological issue. "This means that adaptation to climate change is not only a local activity, since enhancing empowerment and equity often entails addressing the political and economic structures and frameworks within which people adapt". Examining how these different levels interact to shape adaptation can offer insights on how to achieve successful adaptation to climate change.

3. *Policies, institutions and markets* at local, national, regional, and global levels (Figure 8) influence the adaptive capacity of smallholders. These factors regulate access to and control of resources crucial for adaptation. For example, land use regulations may constrain a farmer in the type of adaptations s/he carries out. Understanding how they do so can offer insights on how to improve adaptive capacity and resilience. Policy, institutional and market analysis can be used to highlight the ways through which these components interact to promote or hinder effective adaptation by smallholders.

Taking account of the various actors in agriculture, their positions, roles, aims and interactions can offer insights on institutional arrangements, policy formulation and access of smallholders to resources and benefits. Thus, adaptation of agriculture to climate change is not just the prerogative of smallholder farmers but of all stakeholders (see Figure 8) in the farming system albeit at different levels and intensities of commitments. Figure 8 is unpacked in Figure 9, that illustrates stakeholder networks in agriculture (cf. Djurfeldt et al. 2005; Oluoch-Kosura / Karugia 2005; Ifejika Speranza / Wiesmann 2006; Laube / Awo / Schraven 2008; to mention a few). This illustration may vary depending on specific contexts. Figure 9 shows the linkages between smallholders and various institutions ranging from community groups at local levels to international actors like the UNFCCC and on the right side the linkages with marketers and consumers.

As policies are the product of interactions between various stakeholders (Walker et al. 2002) taking a stakeholder view of adaptation in agriculture allows a differentiation of the different roles (positive or negative, complementary, collaborative, conflicting or competing) that the various actors

Figure 9: An illustration of actors and services in the smallholder agriculture sector and their linkages



Source: Own design

play and their power differentials. This can provide insights on which stakeholder nodes in the network to focus on to achieve widespread effect and on the degree of freedom of smallholders to carry out certain adaptation practices. It also gives an impression of the feedback linkages between the various stakeholders.

At the level of policies and institutions and taking *international actors* for example (upper left, Figure 9 (A)), global governance regimes, development agencies of industrialised countries, international NGOs, these stakeholders support agricultural development of developing countries through various finance mechanisms.

At national levels, governments are also signatories to various international agreements on climate, biodiversity, environment and trade. Depending on geographical location, these international agreements can limit the geographical action space of smallholders (Figure 9 (B)), for example, protected areas may keep to international agreements on biodiversity but cut off smallholders from grazing resources, especially in times of climate-induced scarcity such as drought (cf. Mbeyale / Sorongwa 2008).

Thus while a certain level of coherence has been achieved between international policies and national policies, incoherence between national policies and smallholder realities persist, as until recently most national policies are designed without (adequate) participation of local actors (the National Adaptation Plan of Action, being a known exception). Similarly, regional and global trade liberalisations constrain smallholders' access to markets (cf. Laube / Awo / Schraven 2008) as they compete with subsidized produce from industrialised regions like the EU. Yet, it is paradoxical that many smallholder regions cannot survive without the financial development assistance of the same international actors, channelled through the development cooperation. With financial support of the international actors, smallholders invest in technologies (e. g. irrigation) the result of which is increased production. However, smallholders compete with agricultural products of industrialised countries in the African market, making them lose out since their goods are of lower quality and have higher production costs.

Hence in resilience terms, there is need to strike a balance between the trade-offs, the benefits from and the dependencies on the international community. An important point to note from Figure 9 is that international actors have multiple channels (nodes) of reaching the smallholder, through the national governments, NGOs, or research institutes.

On the other hand, the bottom-up linkage to the above-mentioned nodes, which are in many cases weak, mediates the feedback from the smallholders to the international actors. The *national government* can reach the smallholders through its policies and institutions, which define the framework within which smallholders carry out their activities. Depending on how effective the government implementing agencies are, these frameworks may be so rigid (e. g. land tenure regime in Ethiopia; cf. Little et al. 2006) that they stifle individual initiatives. Yet the *extension services*, provided by the same governments, remain the major linkage between smallholders and the national government. From the literature (cf. Devereux 2002), extension and local NGOs seem to be the only nodes with strong bottom-up linkages. *Bottom-up linkages* refer to channels through which smallholders can communicate their experiences to higher levels of policy. Yet the weak bottom-up linkage between field extension and policy makers makes it difficult to communicate the rich knowledge that field extension officers have to policy makers. The exceptions to strong bottom-up linkages are related to food availability monitoring, which is rather reactive, as it does not focus on alleviating the underlying causes of food insecurity (e. g. in Kenya, cf. Ifejika Speranza 2006b).

Moving to mid-left of Figure 9 (C) to the *transporters and marketers*, there are different actors from global to local levels. Either they aim at profit maximisation by buying produce from the smallholders at the farm-gate – very low prices – to sell this to the urban and international consumers, or they sell the costly farm inputs (e. g. fertiliser, pesticides) required for farm production. Studies show that the prices for agricultural produce have remained rather low compared to the value of inputs (implements, labour and capital) that smallholders use to produce them (Laube / Awo / Schraven, 2008). This disadvantageous situation is further worsened by competition from regional markets like ECOWAS, EAC, SADC or globally from the EU and China. Looking at Figure 9, the actor nodes that can alleviate this condition for smallholders are the international actors and national governments. To be able to build resilience, these actors with the widest spheres of influence have to acknowledge that *competition among unequal actors* is a barrier to adaptation and should therefore be willing to take remedial measures. How to implement this is subject to empirical research.

Consumers (Figure 9(D)) are another actor category important for building farm resilience to climate change. Different factors determine consumer behaviour – poverty and the level of development, production origins and conditions, worldviews and ethics. In Europe, studies show that consumers can influence the national government and bring about policies that favour local production. This is yet to be the case in SSA and needs further research.

However, it must be mentioned that "Northern" consumers (in industrialised countries) that consume African produce (flowers, vegetables, herbs and spices) influence livelihood outcomes of smallholders in Africa. Thus such consumers must carefully weigh the pros and cons of desisting from consuming African agricultural produce as a way to protect climate because such actions can adversely affect development. Hence, certification (as is already the norm for many such produce) is one way to guarantee "Northern" consumers the environmental friendliness and ethical standards of the African production conditions.

The foregoing highlights the relevant stakeholders in SSA agriculture and indicates that achieving resilience in smallholder agriculture is dependent on their active participation and coordination. How to implement such an involvement in reality requires empirical, context-specific research. Understanding the perception of climate change by these various stakeholders is important as perception can shape the preparedness of actors to adapt and change their practices.

3.7 Conclusion

This chapter discussed various concepts and approaches used in analysing adaptation to climate change. It showed that the concepts of vulnerability, adaptation and resilience address similar issues. The distinctions between poverty and vulnerability are sometimes blurred. It remains difficult to differentiate development activities from adaptation actions and in many cases adaptation actions will be the same as development action. It was shown that resilience underpins adaptive capacity without which adaptations will not be possible. Various criteria for evaluating adaptation were also identified and discussed. Based on literature, a tool, a resilience check, for evaluating adaptation actions was developed. Since there are numerous actors in the smallholder agricultural sector, the focus for subsequent analysis narrows down to the smallholder farmers, their agricultural strategies and practices, and the policy and institutional instruments that can contribute to the resilience of smallholder farming. In the course of the analyses, the resilience check will be used to illustrate the contributions of certain farm practices and support services to building resilience to climate variability and change. Other concepts analysed in this chapter will be drawn on where relevant as explanatory frames.

4 Farm-level resilience and adaptations of agriculture to climate change

The resilience approach adopted for analyses is applied using multi-level and multi-actor perspectives. Analysis is thus structured according to adaptations that are implemented at farm-level by smallholders (this chapter) and those implemented by other actors (for example government, NGO, research) at other levels, to support smallholder adaptation to climate change (next chapter). This chapter analyses various farming approaches and the contributions of smallholder practices at farm-level to a resilient adaptation. The developed Resilience-Check is used in selected cases to analyse the contributions of adaptation measures to resilience and to demonstrate the use of the tool in assessing contributions to resilient adaptation.

4.1 Adapting farming systems to climate change

The major cropping systems in the drylands of SSA (Figure 10) include the agro-pastoral millet/sorghum zone and the cereal-root crop mixed zone in West Africa; the maize-mixed zone and the cereal-root crop mixed zone in Eastern and Southern Africa, as well as the agro-pastoral millet/sorghum zone in Southern Africa. Adapting these systems to climate change is not restricted to on-farm activities but also includes off-farm activities that influence the adaptive capacity of the farming system to secure on-farm production and household food security.

4.1.1 Integrated farming systems, conventional, conservation and organic agriculture

This section analyses various farming approaches for their contributions to a resilient adaptation. Such approaches include conventional farming, conservation and organic agriculture as well as integrated farming systems.

1. Conventional farming

Conventional farming has been criticized for its overt emphasis on intensification and the application of technology to increasing productivity and profits without accounting for the adverse effects of production on the environment. Adapting farming systems to climate change may thus imply some modification of the conventional approach by shifting farm management systems, for example, from conventional production to other production systems that account not only for economic gains, but also for environmental and climate protection in their management approaches. While the green revolution in Asia led to increased food production and productivity, care must be taken, that in canvassing for increased production and productivity in SSA, the adverse effects of such intensive agricultural production on the environment and natural resources are not repeated in SSA.

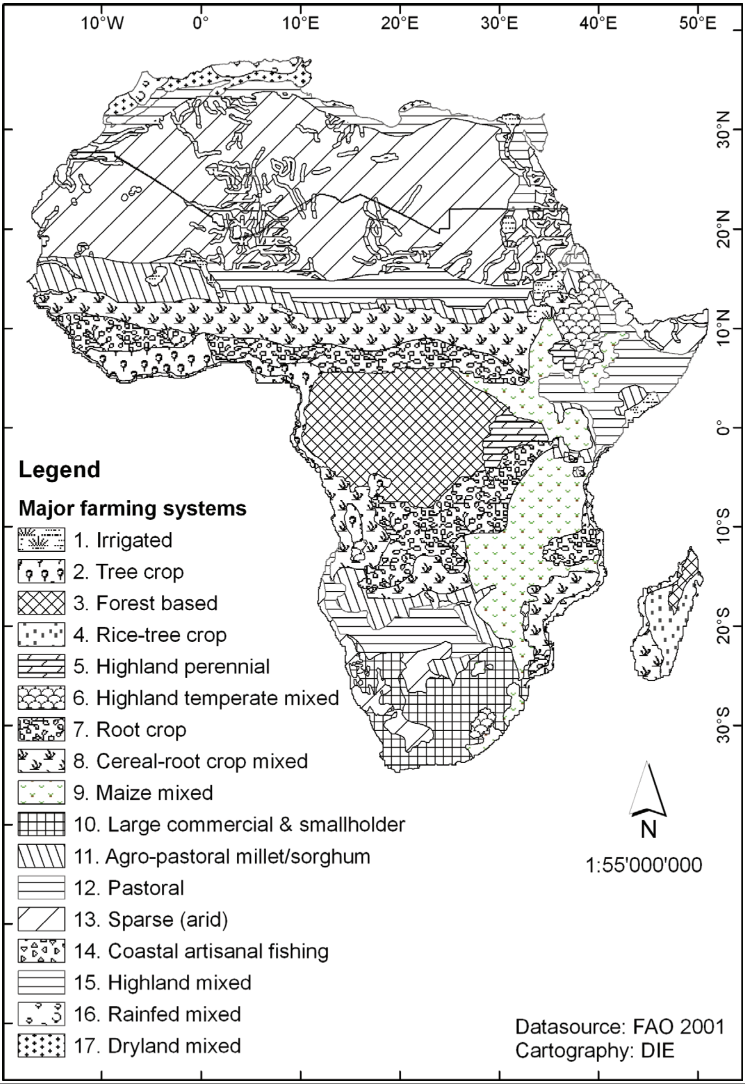
Already, poverty and lack of resources force many smallholders to forfeit the use of inputs like inorganic fertilizer, mechanisation and intensifying production. On the one hand, such low use of inputs means low environmental externalities, but on the other hand, it means persisting low yields which need to be addressed.

2. Integrated approaches

Sustainable agricultural production aims at maintaining productivity and incomes while ensuring benefits to the society without depleting the natural resource base. The World Overview of Conservation Approaches and Technologies (WOCAT 2007, 10) defines *Sustainable Land Management* (SLM) as "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and ensuring their environmental functions." Sustainability implies sustaining farm production across time against many odds, including climate change. Adopting a resilience approach in addition, provides answers to how farming systems can be sustained.

The multiple climate change impacts and their variability mean that *diversity* (a feature of resilient systems, see Chapter 3.5) is imperative. Diversity can be achieved through integration of various inputs and agronomic

Figure 10: The major farming systems in Africa



practices. Thus an *integrated system* is expected to be sustainable and more equipped to deal with the various climate change impacts and other socio-economic risks than one that is not. Depending on whether a farm is well or badly managed the contribution of farms to improving livelihoods, conserving natural resources and sequestering carbon varies. Various forms of integrated farm management are proposed in the literature. Most SSA smallholders already practice integrated farming through production of crops and livestock. Through mixed cropping, crop rotation and other crop-based integration, they practice some forms of integrated crop management. The utility of various management strategies and the limited resources are major factors that drive integration in smallholder agriculture and it is expected that these factors will also drive adaptation to climate change in Africa.

Integrated farming systems comprising crops and livestock aim to derive benefits from the interaction of crops and livestock, thereby reducing the impacts of climate change through diversification. The concept of integration thus runs through farm production comprising integrated crop management, which includes among others integrated pest, diseases, weed and nutrient management. *Integrated Crop Management* (ICM) can be understood as a compromise between organic production and conventional production. ICM evolved to address perceived problems with conventional production such as environmental pollution from herbicides, pesticides and inorganic fertiliser use. While organic agriculture uses only organic inputs, ICM uses both organic and inorganic inputs but aims for *efficiency in input use* in a way that avoids harm to the environment. Thus such an approach is expected to contribute to environmental and climate protection.

Various shades of ICM can be found on the continuum between these two farming approaches, ranging from those that are "near-conventional" to those that are "near-organic" (Kumar / Shivay 2008; Goldberger 2008). Considering the resource-poverty of many smallholder farmers in SSA, their management systems are scattered within this range, shifting as opportunities arise for them to implement certain adaptations. Thus, many adaptations in farm management practices discussed in this section are usually combined in practice.

Depending on the context, *integrated approaches* may be the viable option. Bationo, Christianson and Klaij (1993) analysed crop residue and fertiliser effects on millet yield, in Sadoré, Niger. The authors found that crop residue (organic fertiliser) and inorganic fertilizer can independently contribute to increased productivity but that combining crop residues with inorganic fertilizer application can further improve soil quality and lead to higher productivity (yields in kilograms per hectare). Sauer and Tchale (2006) showed that in Malawi, maize productivity in smallholder maize production under integrated and chemical-based soil fertility management (ISFM) is higher than when farmers use inorganic fertilizer only. The authors note that the scope for ISFM to resuscitate the productivity of the maize-based smallholder farmers depends on consistent integration of grain legumes with inorganic fertilizers and access to improved maize varieties.

3. Conservation agriculture

Conservation agriculture (CA) is another farming approach that can serve as an adaptation strategy. CA aims to conserve, improve and make more efficient use of natural resources through integrated management of soil, water and biological resources combined with external inputs (FAO 2000a). The three core principles of conservation agriculture are permanent residue soil cover, minimal soil disturbance (direct seeding) and crop rotation. These three principles are crucial for climate change adaptation in agriculture and mitigation – minimal soil disturbance contributes to maintaining soil carbon and crop rotation reduces susceptibility to crop specific pests and diseases. Smallholders in SSA are increasingly adopting CA or using some of the principles as entry points. Small-scale conservation tillage in Kenya (*Kupiga tindo*) is practised in Laikipia district characterised by a semi-arid climate. The farmers use ox-drawn ploughs, modified to rip the soil. In contrast to conventional tillage the soil is not inverted, thus leaving a certain amount of crop residue on the surface. Soil organic matter is closely related to soil fertility and has an impact on soil physical, chemical, and biological properties. With regard to observed and expected increase in the frequency and intensity of droughts, CA can help conserve soil moisture and improve rainfall infiltration thereby reducing erosion. According to (WOCAT 2007) about 88 percent of the Soil and Water Conservation (SWC) technologies reported indicated an increase in soil moisture, whereby in 71 percent of the cases, improvement was rated as medium or high. In places where it is practiced, CA not only increases soil nutrient holding capacity, carbon sequestration and water infiltration, but also reduces runoff, soil erosion and degradation. Thus practicing CA leads to improvement in productivity (FAO 2006c; 2007a). For example, yields increased in the Eastern Africa project areas, as farmers harvested at least double the yields ranging from below 0.5 t/ha to an average 1.5 t/ha of maize grain from the first year of adoption (FAO 2006c).

Because CA practices avoid GHG emissions through less use of machinery and fuel compared to conventional production and sequester carbon through the incorporation of residues and minimal disturbance of soil, they offer a potential instrument for paying smallholders for avoiding carbon emissions and for carbon sequestration. In this way, an adaptation practice blends into a mitigation practice. However, chemicals used in CA for weed control, if not well managed, can adversely affect the environment. Hence a further shift in agricultural management would be to avoid the use of synthetic products, as is the case with organic agriculture.

4. Organic agriculture

According to El-Hage Scialabba (2007, 2), *Organic Agriculture* (OA) is "a holistic production management system that avoids use of synthetic fertilizers, pesticides and genetically modified organisms, minimizes pollution of air, soil and water, and optimizes the health and productivity of interdependent communities of plants, animals and people". The term organic is also used as a label for products that have been produced in accordance with organic standards throughout production, handling, processing, and marketing (FAO 2000b). Organic agriculture thus includes both certified and non-certified systems.

The four overriding principles for organic agriculture (IFOAM 2006; El-Hage Scialabba 2007, 3) are related to health, ecology, fairness and care of the environment. Accordingly, OA should

1. Sustain and enhance the *health* of soil, plant, animal and human as one and indivisible.
2. Be *based on living ecological systems and cycles*, work with them, emulate them and help sustain them.
3. Build on relationships that *ensure fairness* with regard to the common environment and life opportunities.

4. Be *managed in a precautionary and responsible manner* to protect the health and well being of current and future generations and the environment.

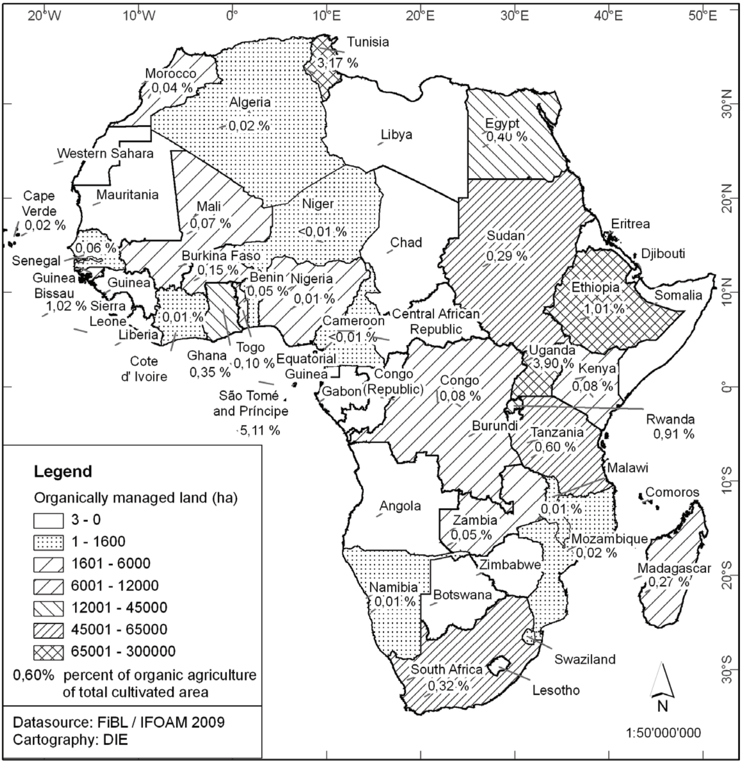
Thus ICM, CA, and OA have common features, namely, Nos. 1, 2, and 4. Depending on interpretations, ICM may also have No. 3 in common with OA.

Apart from using organic inputs, OA has the advantage of not using inorganic nitrogen fertilizers, whose production and transport by use of fossil fuel causes significant emissions of CO_2. However, high level agricultural intensification through use of mechanised equipments that depend on fossil energy, the use of synthetic nitrogen fertilizers and pesticides are not common features of SSA agriculture. Rather, agriculture in SSA is dependent on ecological principles and farmer's knowledge and is largely characterised by mixed cropping, use of animal manure where available (because of easier access than inorganic fertiliser), and the use of legumes. Other features, such as shifting cultivation, fallowing are fast disappearing due to population pressure on land, limited land available for agriculture and new land tenure regimes. Despite nutrient mining, African agriculture has characteristics of what is generally known as organic farming (and certified organic farming) and could be further adapted to take up full fledged organic farming. While poverty and lack of resources has contributed to low use of inorganic fertiliser by many smallholders, others reject its use in the drylands because it "burns" the crops (Ifejika Speranza 2006b).

Despite its positive effect on the natural environment, OA (as a production principle) is not yet widely adopted in Africa (Figure 11). While many smallholders practice what would pass as OA, they do so *by default due to lack of financial resources* to purchase inorganic fertilisers and pesticides. Besides the commercial farms, some few smallholders have adopted OA in growing horticultural crops or niche crops (like mushrooms). Conscious organic production of staple food is even fewer. The market for organic products depends mainly on export markets in Europe which means that the potential to generate income needs to be widened to include the urban African markets.

Apart from Egypt and South Africa, Tunisia is the only African country with its own organic (EU compatible) standards, certification and inspection systems (Parrott et al. 2005). The East African organic standard is still in the process of elaboration. Other countries are yet to fully develop their own standards despite recognition of the potential of OA to increase agricultural incomes. Parrott et al. (2005) report that the majority of African governments do yet not recognise the potential of organic approaches, making the organic sector in most African countries reliant on foreign standards and certifying bodies as well as large scale commercial private sector initiatives. This greatly limits the adaptive potential of OA for smallholder African agriculture.

Figure 11: Organic farming in Africa



Since it is mostly the urban population that buy organic products, there is need to increase awareness on how eco-products reduce carbon emissions and store soil carbon thereby protecting the climate. In that way, more people may be willing to switch from conventional products to certified organic-products, but this will require a change in consumer behaviour.

Thorup-Kristensen (2007) highlights that while organic agriculture can reduce many of the environmental problems caused by agriculture, some practices in organic farming, if not well managed, may also have adverse effects on the environment. Such practices include crop rotations and the use of cover crops, nitrogen management and fertilisation regimes related to the problem of synchronising nitrogen availability in the soils with periods when crops need it; as well as the use of copper and sulphur as broad range pesticides to treat pests and diseases. Thus, *improving resource use efficiency is also a challenge in organic farming*.

Based on the resilience check developed in Chapter 3, a resilience check of OA is displayed in Table 6. The table shows that OA contributes mainly to ecological dimensions – in buffer capacity through promoting environmental and climate protection, using site-specific knowledge and local resources, and fostering diversity.

However, the economic benefits of OA are still below potential as the level of self-organisation (for example farmer organisation) in this dimension is still low. The contribution to adaptive capacity is also below potential as the levels of feedbacks between the various actors are low. OA remains a predominantly private-sector export-oriented initiative with little support from the national governments. In the following, the contributions of OA to resilience to climate change are structured according to the ecological, economic and social dimensions of a resilient adaptation:

Contribution to ecological resilience

Organic crop systems have been found to excel in water- and climate-stress situations (Lotter et al. 2003; Badgley et al. 2007). Soils in organic plots capture more water and retain more of this in the crop root zone than in conventional plots. Lotter et al. (2003) in North-eastern USA show that during climate extremes such as drought and flood conditions, organic crop systems perform better than conventionally managed crop systems. The benefits of OA – lower long-term yield variability / yield stability, higher water-holding capacities, high content of soil organic carbon (C), reduced erosion in situations of rainfall excess and climate extremes – makes OA a potential option of an integrated approach to adapting smallholder farming to climate change.

Table 6: A resilience check at farm-level: Assessing the contributions of organic agriculture to resilience of smallholder agriculture to climate variability and change

Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
		In what ways and how much does the adaptation …			
Buffer capacity (robustness to uncertainty)	Spheres of action	Increase livelihoods activity options?	M	M	N
	Human capital	Promote human capital (endowments)?	VH	VH	L
	Access (rights)	Promote entitlements (access)?	NA	NA	NA
	Income	Improve incomes?	NA	H	NA
	Climate protection	Promote climate protection?	VH	N	N
	Site-specific knowledge	Require or use site-specific knowledge?	VH	N	N

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 6 continued					
Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
	Incentives	In what ways and how much do policies promote (at least not hinder) the adaptation option (incentives)?	L	L	NA
	Diversity	In what ways and how much does the adaptation promote diversification or diversity?	VH	VH	M
	Stewardship	In what ways and how much is the adaptation geared towards stewardship (in contrast to exploitation/mining resources) rather than just management?	VH	NA	NA
	Environmental protection	In what ways and how much does the adaptation practice benefit the environment?	VH	NA	NA
Self-organisation	Local resources use	In what ways and how much does the adaptation depend on locally available resources?	VH		

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 6 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
	Cooperation and networks	In what ways and how much does the adaptation promote cooperation and networks among farmers?	L	L	M
	Cooperation and networks	In what ways and how much does the adaptation promote cooperation and networks among farmers?	L	L	M
	Farm resources use	In what ways and how much does the farmer rely on own resources in practicing the adaptation?	VH	L	L
	Farmer knowledge	In what ways and how much does the farmer rely on own knowledge in practicing the adaptation?	H	L	L
	Flexibility	In what ways and how much does the farmer have the freedom to decide?	H	H	L

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 6 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Adaptive capacity	Knowledge combination	In what ways and how much does the adaptation create opportunity to combine different types of knowledge	H	H	H
	Feedback among stakeholders	In what ways and how much does the adaptation promote feedback among various stakeholders?	M	L	L
	Feedback among peers	Among farmers?	H	L	M
	Feedback farmer-extension	Between farmers and extension officers?	L	L	L
	Feedback farmer-policy-makers	Between farmers and policy makers?	N	N	L

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 6 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
	Feedback extension-policy-makers	Between extension and policy makers?	NA	NA	NA
Adaptive capacity cntd.	Feedback farmer-researchers	Between farmers and researchers?	H	N	H
	Power differentials	In what ways and how much does the adaptation narrow power differentials?	NA	H	H
	Local ecological knowledge	In what ways and how much does the adaptation build on or transmit local ecological knowledge?	VH	NA	NA
Other adaptation criteria					
Efficiency	Costs-benefits (Market values)	How much is the cost-benefit ratio of the adaptation practice or strategy?	H	H	NA

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 6 continued					
Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
	Costs-benefits (Non-market values)	In what ways and how much are the social benefits relative to the costs?	NA	NA	M
	Right timing of adaptation	Is the timing right?	NA	NA	NA
Gender	Gender positive / negative	In what ways and how much does the adaptation reduce existing gender inequalities?	NA	M	H

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

By not using inorganic nitrogen fertilizers, whose production and transport by use of fossil fuel causes significant emissions of CO_2, OA contributes to climate protection.

By using local resources and site-specific knowledge, OA reduces the use of external inputs that are not adapted to the natural environment, thereby contributing to environmental protection.

Contribution to economic resilience

Although organic crop systems yield on average approximately 90 to 95 percent of conventional crop systems (Lotter 2003 in North America – for lack of a similar example from SSA), OA could become more competitive than conventional agriculture if the costs of inorganic fertilisers and pesticides rise with increases in oil prices.

The OA certification system offers a potential platform to facilitate certification of carbon credits for small scale farmers. The already established standards and certification system of organic farming (as a label) can be extended to incorporate the standards of the Clean Development Mechanism and its successors. This then, builds on already established infrastructure, uses synergies and still keeps to OA's goal of sustainable land use.

The poor organisation of smallholder farmers practicing OA limits the economic contributions of OA.

Contribution to social resilience

- By using mainly local knowledge and local resources OA reduces farmers' dependence on external knowledge and inputs and reduces the costs of acquiring external knowledge.
- The dependence of OA on export markets in Europe indicates that conscious reflections on the principles underlying OA, which could increase its market share in African markets, is yet to occur.

The poor organisation of smallholder farmers can be addressed by sensitising farmers to the benefits of OA and by building trust among farmers by exchanging information and knowledge as well as maintaining transparent procedures.

Finally, having to adapt to climate change provides an opportunity to focus the development pathway of small-scale agriculture to organic farming. This does not mean that no benefits can be gained from conventional farming. In the end, a pragmatic mix adapted to the context of the smallholders may be the optimal choice.

4.2 Adapting agricultural practices to climate change

In the following, the contributions of various farm management practices to climate change resilience are discussed. Different combinations of such practices may be found in conventional agriculture, in integrated crop management systems as well as in conventional and organic agriculture.

4.2.1 Adaptation of rainwater management practices

Since climate change will result in increased frequencies of extreme events (droughts, cyclones, floods), and higher rainfall variability in terms of time, space and amounts, a potential adaptation measure would be to secure water availability for crop and livestock production.

One way of doing this is to harvest rainwater and runoff. At a first glance, inadequate water supply is a major challenge to agro-pastoral systems. However, studies show that the rains provide adequate water quantities for crop production but the water becomes lost through run-off, evaporation from bare soils and deep percolation beyond the rooting zone of annual crops (Pasternak et al. citing Fox / Rockstrom 2003). WOCAT (2007) notes that in the drylands rainwater is lost through seasonal surface run-off in the order of 15–20 percent and another additional 40–70 percent is lost through evaporation from soil surface leaving less than half of the rainfall available for crop and fodder production. In the following, the various ways that smallholders harvest rainfall are analysed.

While water is available (rainfall, flowing streams and rivers) during the rainy season, it becomes scarce during the dry seasons making people (especially women and children) walk long distances in search of water for domestic uses. In many dry regions of SSA (for example, Kenya, Tanzania, Ethiopia, and Namibia) people dig holes in the sand beds of streams and rivers to fetch water. This traditional practice has been enhanced by building *sand dams* – a concrete wall at strategic sites across the channel that sometimes serve as a bridge. Sand dams trap sand during flooding thereby blocking extra sub-surface water in the sand bed and thus increase available water for harvesting in dry times (Ifejika Speranza 2006b).

Sand dams have the *benefits* to improve water infiltration, provide drinking water for people and livestock, and control erosion. It also contributes to regenerating the environment as vegetation prospers in such sites thereby attracting other biological resources. Sand dams are estimated to be *costly* in terms of mobilising people to participate and labour intensive. Constructing sand dams depends on external financial support to purchase the materials needed for construction and often communities have to be mobilised by external agents (extension officers, NGOs, church organisations) to move from the traditional scooping of water from sand beds to building sand dams. Since the benefits are community-wide, ownership by the community is rapidly achieved. However, it is also culturally acceptable and in many cases a major source of water in the areas where it is used (ibid). Thus, the pressure on external dependence for inputs may compromise this adaptation practice. In order to improve resilience to climate change, communities need to be sensitized to maintaining the sand dams. Although they are long-lasting, some sand dams may require stabilisation and repairs due to flood damages. Thus, forming community groups in charge of maintaining the sand dams is a promising way to maintain resilience.

Micro-catchments water harvesting techniques (contour bunds) are used for planting crops and trees. An example of such micro-catchment method is the *trus cultivation*, that is, a traditional water conserving method of cultivation used on clay soils that harvests surface run-off by constructing low earth bunds called *trus* (Port Sudan: Osman-Elasha et al. 2006). According to Osman-Elasha et al. (2006), indigenous *trus* cultivation has gained in importance in recent years, as rain-fed farming on sandy soils became increasingly risky and people became unable to produce enough food for consumption. As a result of the good crops of sorghum from *trus* cultivation, Osman-Elasha et al. (2006) report that more farmers started to shift to clay soils and practice *trus* cultivation. *Magun cultivation* was adopted in response to sand encroachment on top of fertile soil, whereby holes of 10–30 cm in diameter and 5–15 cm deep, spaced at distances of 40–70 cm, are dug to plant seedlings of tobacco and water melon (Osman-Elasha et al. 2006).

Rainwater harvesting for crop and livestock production is an old farm management technology that is being re-examined due to its potential to address climate change impacts through stabilising on-farm water supply. Where they are practiced, farmers dig pans to harvest run-off, thereby stabilising on-farm water availability. The water harvested in such pans can sustain farm production through dry spells, dry seasons and seasons affected by droughts. However, despite its production and economic benefits, this practice of harvesting rain-water for crop and livestock production has not been widely adopted in the drylands. Hence rain water harvesting for crop production is being revisited by various research teams to examine why the technology has not been adopted widely despite the success of the few farmers that practise it.

Table 7: A resilience check at farm-level: Assessing the contributions of rain water harvesting to resilience of smallholder agriculture to climate variability and change

Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
		In what ways and how much does the adaptation …			
Buffer capacity (robustness to uncertainty)	Spheres of action	Increase livelihoods activity options?	VH	VH	VH
	Human capital	Promote human capital (endowments)?	VH	VH	L
	Access (rights)	Promote entitlements (access)?	NA	NA	NA
	Income	Improve incomes?	NA	VH	NA
	Climate protection	Promote climate protection?	N	N	N
	Site-specific knowledge	Require or use site-specific knowledge?	VH	N	N

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 7 continued

Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
Buffer capacity (robustness to uncertainty)	Incentives	In what ways and how much do policies promote (at least not hinder) the adaptation option (incentives)?	H	H	NA
	Diversity	In what ways and how much does the adaptation promote diversification or diversity?	VH	VH	VH
	Stewardship	In what ways and how much is the adaptation geared towards stewardship (in contrast to exploitation/mining resources) rather than just management?	M	NA	NA
	Environmental protection	In what ways and how much does the adaptation practice benefit the environment?	M	NA	NA

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 7 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Self-organisation	Local resources use	In what ways and how much does the adaptation depend on locally available resources?	VH	VH	VH
	Cooperation and networks	In what ways and how much does the adaptation promote cooperation and networks among farmers?	L	L	M
	Farm resources use	In what ways and how much does the farmer rely on own resources in practicing the adaptation?	VH	H	L
	Farmer knowledge	In what ways and how much does the farmer rely on own knowledge in practicing the adaptation?	H	L	L
	Flexibility	In what ways and how much does the farmer have the freedom to decide?	H	H	L

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 7 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Adaptive capacity	Knowledge combination	In what ways and how much does the adaptation create opportunity to combine different types of knowledge	H	H	H
	Feedback among stakeholders	In what ways and how much does the adaptation promote feedback among various stakeholders?	M		
	Feedback among peers	Among farmers?	H	N	H
	Feedback farmer-extension	Between farmers and extension officers?	L	L	L
	Feedback farmer-policy-makers	Between farmers and policy makers?	N	N	L
	Feedback extension-policy-makers	Between extension and policy makers?	NA	NA	NA

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 7 continued					
Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
	Feedback farmer-researchers	Between farmers and researchers?	H	N	H
	Power differentials	In what ways and how much does the adaptation narrow power differentials?	NA	H	H
	Local ecological knowledge	In what ways and how much does the adaptation build on or transmit local ecological knowledge?	H	NA	NA
Other adaptation criteria					
Efficiency	Costs-benefits (Market values)	How much is the cost-benefit ratio of the adaptation practice or strategy?	H	H	NA
	Costs-benefits (Non-market values)	In what ways and how much are the social benefits relative to the costs?	NA	NA	M
	Right timing of adaptation	Is the timing right?	NA	NA	NA
Source: Based on literature / own design Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High					

Table 7 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Gender	Gender positive / negative	In what ways and how much does the adaptation reduce existing gender inequalities?	NA	M	H

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

A resilience check in Table 7 shows the various ways that rain water harvesting (RWH) for crop and livestock production builds the resilience of communities to cope with and adapt to climate change.

Contributions of rainwater harvesting to resilience to climate change:

Contribution to ecological resilience

- Through harvesting rainwater, the destructive effects of runoff are reduced, thereby contributing to environmental protection. Reduced soil erosion means that the silt-load of rivers is reduced, thereby enhancing river flow, protecting river fauna and helping keep the costs of water purification for urban consumers low.
- Because of the harvested water, the range of crops that can be grown is expanded, thereby contributing to the diversity of the cropping system, and by extension to resilience.
- Research and extension tend to focus on progressive farmers to understand why one farmer succeeds against odds to derive beneficial outcomes while other farmers do not. Hence the feedback between such actor categories and the farmer is high. Through this feedback and practice the farmer increases his/her knowledge of the environment and

adapts his/her management accordingly, thus indirectly contributing to ecological resilience.

Contribution to economic resilience

- Harvesting rainwater for crop and livestock production increases the buffer capacity of smallholders to deal with climate change. By harvesting rainwater, the farmer increases the on-farm livelihood options – collected water can be used for growing crops through irrigation during dry spells, dry seasons and droughts. Thus farm production is decoupled from direct dependence on rainfall which will become more variable with climate change. The water pan can also serve as a fish pond thereby diversifying farm livelihoods and consuming the mosquito larvae which usually populate such ponds. By having crops to sell when other farmlands are dry and bare, the farmer increases own incomes and can maintain this source of income over time. Through adopting technologies like irrigation the farmer improves own human capital as he/she learns through practice. By recognising the value of water as a resource, such farmers are more likely to improve the efficiency of resource (water) use with time by adopting such technologies as drip irrigation.
- Rainwater Harvesting (RWH) depends highly on local (rainwater/runoff) and farm resources (labour). The farmer can phase the establishment of a RWH-system by starting small and successively expanding to the desired capacity. The farmer does not require a high level of knowledge for this practice but learns through experience. Thus, considering that farm labour is likely to be adequate in most cases to start this adaptation, the farmer has a high level of freedom to decide and self-organise.
- The practice of RWH increases adaptive capacity as the farmer is continuously learning and improving the RWH system. Through achieving food security and earning additional incomes, the practise of RWH reduces power differentials between the adopters and wealthier farmers. However, it also has the potential to increase the power differentials between adopters and their peers, which can reduce the social capital of the farmer among his/her peers.
- The economic cost-benefit ratio is high. Initially, the farmer may have to forfeit other activities in order to invest more time to establish the RWH infrastructure (pan, pipes and drip-irrigation infrastructure). However in the long-term the income derived from farm produce sale will likely exceed the costs.

- The ability of RWH to reduce gender inequalities in an economic context varies widely according to household organisation. In cases where it is the wife that sells farm produce to community members, it increases women's access to cash. It also increases access to food and reduces the time women and girls have to spend to fetch water from distant streams and rivers.

Contribution to social resilience

- The contributions of rainwater harvesting to social resilience are diverging. Through practicing RWH, the farmer becomes a node of knowledge that is potentially of interest to other actors in agriculture. However, non-adopters can perceive the farmer as behaving out of the norm and may reduce their contacts with the farmer. This argument is based on ongoing empirical analysis and the fact that RWH remains an island of technology adoption in many SSA regions despite the evidence that its adoption increases livelihood security. So answers must be sought to the question of why slow diffusion and limited adoption of farm technologies persist in many areas. Nevertheless, against the losses in social capital there are also gains in social capital as the farmer becomes a source where other villagers come to borrow food.

4.2.2 Adaptation of irrigation management practices

In the absence of water or under conditions of increased rainfall variability due to climate change, irrigation of crops from rivers, lakes and shallow groundwater offer opportunities for adaptation to climate change. Small-scale irrigation is practiced in many parts of the SSA drylands; for example in Mali (Aw / Diemer 2005), in northern Ghana (cf. Laube / Awo / Schraven 2008), in Kenya (cf. Ifejika Speranza 2006b; Neubert et al. 2007). Irrigation contributes to increased food production, reduced poverty and rural-urban migration (Neubert et al. 2007; Laube / Awo / Schraven 2008). However, in some cases, the benefits of irrigation, that is, increased food production and improved incomes vary with time and are therefore not sustained. The source of this paradox is to be found in competition for market (comparative advantage or disadvantage) between locally produced vegetables and grains and imported ones. Laube, Awo and Schraven (2008, 3) for instance report that "Ghana's market is flooded with cheap tomato paste from countries (European Union) where the production of tomatoes is highly subsidised". Further, the lack of processing industries means that the benefits achieved through irrigation cannot be sustained. The lesson of this paradox is that adaptation needs to be evaluated in a cross-scalar and multi-actor perspective and across the whole product chain from production to consumption. The case of the smallholder irrigators shows that improved on-farm production (and building resilience to environmental and climate change alone) is not sufficient for long-term poverty reduction and sustainability in development. The influences of policies and institutions on adaptations need to be considered. Thus, planned adaptations (for example, adaptation projects) need to consider the integrated social-ecological system and the inter-linkages as a whole in order to achieve sustainability in adaptations. Also the issue of local marketing, that is, transporting produce to the markets, dealing with middlemen and selling at fair prices, remains a challenge for the smallholders (Neubert et al. 2007).

Further, traders monopolise trade in certain agricultural produce, thereby depressing the prices for farmers (Laube / Awo / Schraven 2008). Thus farmers must also be in a position to deal with market failure (e. g. tomato, pepper, onions production); crop diseases, occasional water shortages, land conflicts; competition; and the phasing of production to take advantage of low supply periods.

In cases where commercial farms also use irrigation water or where premium plots block access to rivers and lakes (Ifejika Speranza 2006b), it is important to ensure rights of access to water by the poor smallholders. However, institutionalising rights and access through formal laws or the introduction of water fees by governments, where, poorly conceived, may constrain the rights and access of poor smallholders to water for irrigation (Maganga et al. 2003; van Koppen et al. 2004). This is contrary to the aim of the same governments to support small-scale irrigation.

While irrigation and water harvesting in dams might be an option, there have been cases where single storm rainfall events that exceed the capacity of storage and irrigation infrastructure, lead to flooding, devastation of crops and mortality (Laube / Awo / Schraven 2008). This means that constructed dams for harvesting irrigation water need "buffer capacity" to accommodate heavy rainfall events.

Often many SSA governments design large scale irrigation schemes where access to irrigation water and benefits are centrally managed. Authoritative management style of the irrigation authorities is one major factor that limited the adoption of irrigation by small scale farmers, but through reforms such management structures were replaced with co-management styles (cf. Aw / Diemer 2005 in Mali) or farmer management (cf. Laube / Awo / Schraven 2008 in northern Ghana). Irrigation has led to improved livelihoods but the "over-adoption" of this technology leads to increased conflict between up-stream and down-stream users and between farmers and conservation projects (e. g. Tanzania: Mbeyale / Songorwa 2008, 232 ff.; Cameroon: Fokou / Haller 2008). Thus, while implementing such adaptation practices on a large scale, the "side-effects" on other users and the environment need to be considered from the outset.

Van Koppen, Namara and Safilios-Rothschild (2005, 60) report that securing only access to irrigation by the poor or poorest does not automatically guarantee improvements in their wellbeing, hinting at the need for more integrated approaches. The authors found that poor people with access to irrigation operate at less than half the productivity levels achieved by the better-off farmers. They suggest that special consideration needs to be given to the poor in terms of training to upgrade their agronomic and other skills, and in terms of credit provision, extension and access to inputs and other services. For irrigation to effectively contribute to poverty reduction certain pre-conditions need to be realised. These include enhancement of road infrastructure, farmer willingness to participate, exchange of knowledge and experience among farmers, especially where there is no extension.

Neubert et al. (2007) found that irrigation in Kenya has lead to increased food security, higher incomes and more empowerment, in particular, in government schemes that target the poor. Women also profited as they could increase their incomes although this came with increased workload for them, which was eventually reduced through the modernisation of the irrigation systems.

However, over-abstraction of river water and bad management practices in irrigation also threaten the continued existence of irrigation. Environmental degradation such as deforestation and erosion, leading to the silting of rivers and irrigation canals on the one hand make irrigation less profitable but on the other hand make irrigation necessary in order to secure livelihoods. In addition, inequality in the distribution of water has led to conflicts (Liniger et al. 2005; Neubert et al. 2007). Neubert et al. (2007) point out that increasing on-farm water use efficiency is not adequate as it does not address inequality in water distribution and suggest linking this measure with reducing the absolute amount of water extracted. Water logging and salinity problems are usually associated with irrigation but few studies report them as major problems in irrigation agriculture in SSA.

Competition between unequal water users like commercial farms and smallholder farmers in some parts of Kenya like Lake Naivasha, Mount Kenya and the Upper Ewaso Ng'iro highland-lowland system led in many cases to violent conflicts over water not only between these two actor categories, but also with pastoral populations. In response to the increasing tensions over water, the various stakeholders are now organised in Water Users Associations (WUA) that have been successful in addressing and ameliorating conflicts related to over-abstraction (Liniger et al. 2005). The authors report that besides solving conflicts, the WUAs are also involved in environmental education, awareness creation, improved irrigation practices, afforestation and regulating water abstraction. Consequently, WUAs now have a formalised role in the Ministry of water and irrigation in Kenya.

Against the backdrop of increasing water scarcity in the Mount Kenya region, Notter et al. (2007) show that climate change will likely pose additional challenges to water management in the period 2040 to 2069. The authors found that the variability of discharge would increase, with an increase of annual runoff by 26 percent, associated with a severe increase in flood flows, and a reduction of the lowest flows to about a tenth of the 2006 value. Such scenarios highlight the importance of installing water storage facilities and encouraging rainwater harvesting as well as improving land management to reduce erosion by water.

The trend of rising food prices is expected to be a longer-term development that will have positive effects on most rural households if they are able to adapt and boost their output. This expected positive trend will also contribute to poverty reduction (Brüntrup 2008). Thus, this context offers a situation conducive to increase agricultural investment, both at the national and at the farm-levels. However, measures need to be in place to ensure that high transaction costs, middlemen and market inefficiencies, among other factors, do not rob the rural population of the opportunity to raise their incomes. In targeting such an increase in agricultural production, the climate change-induced increase in rainfall variability needs to be accounted for.

Contributions to resilience to climate change:

Contributions to ecological resilience

- The danger of over-abstraction is one factor that reduces the ecological resilience of irrigation systems to climate change. Rainfall variability and water abstraction need to be attuned to each other to ensure that irrigation does not adversely affect the environment. Although irrigation remains low in SSA, the potentials of irrigation to emit methane need to be accounted for in irrigation practices.
- Where institutional arrangements exist on the use of irrigation water, the negative effects of irrigation on the ecosystem can be reduced.

Contributions to economic resilience

- Through contributing to increased food security and incomes, irrigation improved the economic resilience to climate change. The assumption is that with increased food security and income, farmer households are better able to deal with fluctuations in production conditions due to increased rainfall variability.
- Through improving water use efficiency, more crops can be produced with less water thereby contributing to the economic resilience to high rainfall variability.

Contributions to social resilience

- Improving irrigation facilities that lead to reduced workload for women allows women to re-allocate their time and resources to other livelihood activities.
- The reduction of conflicts by water users associations has enhanced the social capital of their members.

The cross-scalar nature of the benefits and problems arising from irrigation as an adaptation practice highlights the strength of the resilience check as an analytical tool. At farm-level, irrigation increases agricultural production and food security. However, analysis of the contributions of the policy level to resilience shows that contradictory effects occur. Increasing irrigation upstream can lead to tensions between upstream and downstream users, and where practised can endanger downstream irrigation. Against the backdrop of increased production, the local produce competes for markets with imported and subsidised products from other origins, thereby reducing the economic gains that local farmers can derive from the irrigation-related increase in production.

4.2.3 Adaptation of soil management practices

The most limiting input in dryland farming is soil water. Climate change will affect soils by changing soil climate (moisture content, temperature) and affecting soil chemical processes, soil fauna and flora. The increase in the frequency and intensity of rainfall will further increase water erosion (soil erosion by water) and cause a decline in soil fertility. These impacts, in addition to agricultural practices, influence crop production.

Therefore protecting soils from these climate effects and adapting soil management practices to deal with these effects to *better manage climate and environmental extremes* are crucial. However, a challenge is the nature of dryland soils, which are mostly sandy, fragile and of poor structure (for example, lixisols, luvisols and acrisols). The WOCAT-book, "Where the Land is Greener" offers details on many land management technologies and approaches, with illustrations that can be used in practice to replicate them elsewhere (WOCAT 2007).

According to WOCAT (2007, 17) soil erosion is a predominant degradation factor. Other forms of degradation like gully erosion, mass movement and off-site degradation occur. Besides, the loss of top soil through wind erosion (soil erosion by wind) will also increase under conditions of drying. Thus *adaptation of soil management to climate change* will entail increasing the infiltration capacity of the soil, increasing water holding capacity, improving soil structure and conditions for soil fauna and flora, thereby increasing natural soil fertility.

An advantageous effect of many soil management practices is that they sequester carbon or avoid emissions to the atmosphere, thus contributing to mitigating climate change, albeit at varying degrees. For example, zero tillage reduces the amount of carbon dioxide released from the soil into the atmosphere, thus indirectly reducing emissions from the soil. However, the trade-off is that pesticides which are used to destroy weeds need to be bought and their inefficient use harms the environment. Further, the efficiency, effectiveness and impacts of zero tillage are poorly monitored and evaluated (WOCAT 2007).

According to WOCAT (2007) *soil and water conservation* requires long-term commitment and should not be restricted to the typical three-year project cycle. Depending on the magnitude of degradation, prevention, reduction and rehabilitation measures can be implemented. Prevention implies use of Soil and Water Conservation (SWC) measures that maintain natural resources and their environmental and productive function on land that may be prone to degradation. The implication is that adaptation has taken place prior to likely impacts. In cases where degradation is in process, measures can be put in place to halt degradation. The impacts of the measures tend to be noticeable in the medium-term. Rehabilitation is required when the land is already degraded to such an extent that the original use is no longer possible and land has become practically unproductive (WOCAT 2007). In this case, longer-term and more costly investments are needed to show any impact**.** WOCAT (2007, 3 ff.) suggests that direct material incentives (subsidies) in SWC should only be considered where there is need to overcome initial investment constraints and where subsequent maintenance does not require continued external support. In addition, the monetary and non-monetary costs and benefits of SWC need to be evaluated to facilitate informed decisions by government, development agencies and farmers, to justify SWC investments and appreciate the ecosystem services they provide (WOCAT 2007). Adaptation practices include the following:

Conservation tillage / Zero-tillage is practiced in many dryland areas (cf. Mrabet 2002) and entails the minimisation of soil disturbance and exposure by reducing tillage and using crop residues to cover the soil. Although conservation tillage is indigenous to Africa it was abandoned with the advance of modern technologies but is now being reactivated there. According to Fowler and Rockstrom (2001), conservation tillage is any cropping system that results in conservation of natural and other resources. It aims at conservation of soil resources and is the collective term for no-tillage, direct-drilling, minimum-tillage and/or ridge-tillage practices, in which at least 30 percent of the surface is covered by residues (Fowler / Rockstrom 2001; Baker et al. 2002). By avoiding inversion tillage (disturbing the soil and releasing soil carbon), zero tillage farming helps to conserve water and nutrients for crops, and reduces soil loss (Vogel 1994). Because not as much mechanical input is needed like in the use of plough, smallholders can save the time and labour for other activities; they can also respond more quickly to changing rainfall conditions and plant their crops in time for the rains.

Conservation tillage also increases the retention of soil water, improves soil structure and biotic activity (Fowler / Rostrom 2001), reduces soil loss and increases soil fertility (for example in Zimbabwe, Vogel 1994). However, periodical tillage may be needed in dryland soils to forestall the formation of soil pans, which will then lead to the release of soil carbon.

Conservation tillage may also be an answer to the labour constraints of female farmers who are left behind to tend the farms by their migrating male household heads. There are also other off-farm benefits like cleaner streams and rivers. In this way, the resilience of the farm as well as the surrounding environment is improved.

The potential of conservation tillage to mitigate climate change relates to the amount of carbon sequestered in the soil. Fowler and Rockstrom (2001, 96, citing van der Merwe / de Villiers 1998) note that "soil organic matter is the major terrestrial sink for Carbon (C), Nitrogen (N), Phosphorus (P) and Sulphur (S) and soil biota the major factor responsible for the mineralization, transportation and immobilisation of these elements". The authors report that no-till may increase carbon fixation and emissions of nitrous oxide due to anaerobic conditions as a result of soil compaction, the lack of soil disturbance and residue incorporation (see also Lal 2000). Apart from conserving soil and water, conservation tillage can lead to slower weed growth due to weed seeds remaining on the soil surface (Fowler / Rockstrom 2001).

However, pest and diseases incidence in conservation tillage systems is high, necessitating the use of pesticides and herbicides, which may harm the environment if badly managed and also requires money to buy, and hence may not be sustainable.

Mulching, that is using plant residue to cover soils and that way facilitate their incorporation during tillage into the soils as organic matter (soil organic carbon) is another way to improve soil resilience to climate change. This is because the integration of mulch into the soil increases its humus content, improves soil structure and soil organic carbon content. The effects are then improved water infiltration into the soil, increased water holding capacity of the soil thereby making water available to plants during dry spells. Such soils are also less prone to nutrient leakage and soil erosion by water (IFOAM 2006; Lotter et al. 2003 for North-eastern USA). Improved trash lines – weeds and crop residues laid in bands across slopes – are used in a sub-humid area of Uganda to reduce runoff and maintain soil fertility (WOCAT 2007). However, the effectiveness of mulching depends on environmental conditions, agricultural practices, type of crops and time of application.

The cost of mulching may be a limitation to conservation tillage as crop residues serves multiple purposes (fodder for livestock, fuel and for roof thatching). Apart from the labour constraints, farmers are also unwilling to mulch due to infestation of mulch by ants (Ifejika Speranza 2006b), due to roaming livestock that feed on them and the rapid mineralization of organic mater in semi-arid areas (Couper 1995).

Organic manure and composts are intended to improve soil fertility and simultaneously enhance soil structure (against compaction and crusting) and improve water infiltration and percolation (WOCAT 2007). Studies show that soils with high humus content contribute to increased crop yields. However, a challenge in using mulching in dryland conditions is the high temperature and limited water availability for producing organic matter. Further, there are competing farm uses for crop residues in the drylands. Plant residues are often fed to livestock, thereby making them unavailable as mulch. Since mulching is not a widespread practice, the tendency is that little or no mulch is put back into the soil thereby trading-off the beneficial effects of mulching. Alternative adaptation practices could be through promoting zero-tillage and fallow crops where possible. Fodder crops can also be grown for livestock but in many cases the high labour input required for mulching deters many farmers from this practice.

Planting pits (*Tassa* in Niger; *Zai* in Burkina Faso) are dug in semi-arid degraded areas of sandy/loam plains covered by hard pans (Stigter et al. 2005; Salinger / Sivakumar / Motha 2005; WOCAT 2007, 213) to grow millet and sorghum. Compost manure is then added to the pits, although its availability is often a problem in the dry lands. In combination with *stone lines*, the pits capture and hold rainfall and runoff and thereby improve water infiltration and nutrient availability. With time, grass grows between the stones thereby increasing its effectiveness. While this adaptation practice leads to beneficial results in terms of ecological improvement, increased crop yields and reduced downstream flooding and silting, it requires high manual labour input and other resources for digging. Conflicts also occur over land use rights of the rehabilitated lands and between farmers and pastoralists because of turning degraded pastoral lands into cultivated lands (WOCAT 2007, 213). Water logging of the pits may also occur after heavy rains.

Terracing controls run-off down a hillside and depending on where it is practiced can increase soil water storage or enhance drainage in areas of excess rainfall (WOCAT 2007). In the semi-arid and some sub-humid areas they are constructed to hold runoff (for example the Fanya juu terraces in Kenya and stone terracing in South Africa) while in other sub-humid areas, they are laterally build to discharge excess runoff. The terrace bund is often stabilised by growing strips of grass, mainly, Napieer (*Pennisetum purpureum*) or Makarikari (*Panikum coloratum var. makarikariensis*) which are also used as fodder crops (cf. WOCAT 2007).

Tchale and Wobst (2005) found that although soil fertility management technologies developed by researchers in Malawi somewhat improve farmers' yields, there is still a wide disparity between actual farmers' yields (under smallholder farmers' conditions) and those obtained on on-farm research trails. They attribute this to resource constraints, which influence farmers' choice of soil fertility management practices. The authors found that integration of chemical and organic sources of fertility management and complimentary policy interventions that address immediate cash constraints while simultaneously addressing soil fertility contributes to food security and soil nutrient balance.

Contributions to resilience to climate change:

Contributions to ecological resilience

- Various adaptations of soil management increase resilience to climate change through improving soil water retention, increasing soil biodiversity, increasing soil carbon and organic matter content.

Contributions to economic resilience

- Through the increase in soil organic matter, yields are improved, thereby increasing production and by extension, in most cases farm income.

Contributions to social resilience

- Adapting soil management practices to climate change holds some potential for greater social resilience by building social capital – through recognition of the ecosystem services that the farmers offer through good soil management practices (such as reduced erosion and run-off as well as reduced silting of rivers).

4.2.4 Adaptation of seed management practices

Climate change will lead to changes in micro climates for plants and in view of increasing temperatures and associated evapo-transpiration, robust crop species that are tolerant to heat conditions and to flood conditions need to be identified or newly developed. Thus, changing what is grown may be one way but also changing how crops are grown is another adaptation pathway. SSA farmers usually select the best crops from previous harvests to be used as seeds in the following season. However, this may not be adequate considering the magnitude of changes in temperature that is to be expected. Worthy to note is that under drought conditions seeds are sometimes consumed when no alternative food sources are accessible. Hence complementary and affordable seed sources (for example from seed producing companies) are needed.

Drought tolerant and faster maturing varieties will be needed under conditions of decreasing rainfall and drought. Across SSA, smallholders already use various variants of drought tolerant crops (for example in Zimbabwe: Salinger / Sivakumar / Motha 2005, in Kenya: Ifejika Speranza 2006b). The international Maize and Wheat Improvement Centre (CIMMYT) and partners in Southern Africa are already developing heat and drought resistance crop varieties. CIMMYT has released drought-tolerant maize varieties in Malawi, South Africa, Tanzania, and Zimbabwe. However, there have been cases in Kenya and Tanzania whereby farmers did not adopt the drought-tolerant maize (*Zea Mays*) varieties (e. g. Katumani, Makueni hybrid) developed by crop research institutes and promoted by the government (Eriksen et al. 2005; Ifejika Speranza 2006b), due to their low market value, low production relative to other varieties and consumer preferences. By growing crops more suited to the changing agro-climatic conditions smallholders will be in a better position to achieve food security. The cost of improved cultivar relative to traditional species has also been a deterrent to their adoption by smallholders (Ifejika Speranza 2006b).

In recognition of the potential of drought tolerant/resistant crop varieties as an adaptation option, the National Adaptation Programme of Actions (NAPAs), National communications (NC) and Technology Needs Assessments (TNAs) of many SSA countries to the UNFCCC propose to develop drought resistant crop varieties as an adaptation response (see for example RoK 2002; UTC 2006; URT 2007). However, this choice is odd considering that drought-resistant and drought-tolerant crops and crop varieties have long been developed but with little or no success in their diffusion and adoption. The question that should be asked therefore is why farmers have not adopted such crop technologies and what must be done so that such technologies are adopted by the farmers. We need to understand why the already developed technologies have had little success among the farmers so that the crop technologies can be improved to meet not only the challenge of climate variability and change, but also other prerequisites for farmers to adopt them. Where it is necessary to develop new crop varieties, this should be conducted in a participatory manner with the smallholders in order to address the identified factors hindering their widespread adoption.

Contributions to resilience to climate change:

Contributions to ecological resilience

– Adopting drought tolerant or faster maturing seed varieties increases resilience to dry spells.

Contributions to economic resilience

– Adopting drought tolerant or faster maturing seed varieties contributes to food production and sale. Although farmers prefer traditional non-drought tolerant maize varieties, produce from such crops can be sold and income derived used to purchase food. In this sense, drought tolerant crop species contribute to farm income especially under drought conditions when food prices tend to be high.

- However, the costs of these varieties deter farmers from purchasing them compared to the cheaper traditional varieties. The limited access thus reduces the contributions to economic resilience.

Contributions to social resilience

- Adopting drought tolerant or faster maturing seed varieties contributes to food production. Drought tolerant crops like cassava, millet or sorghum, despite their low market value, ensure that farm households have at least some food for consumption when crops like maize fail.

4.2.5 Adaptation of crop management practices

Crop management practices affect soil health, soil structure, soil nutrient content and soil climate, and can serve as an adaptation strategy to climate change.

Crop rotations (temporal diversity) and *mixed cropping* (within field diversity) are widespread throughout SSA. Well managed and synchronised crop rotations (for example, growing green manure legumes as fallow crops) help revitalise the soil and reduce the persistence and spread of crop pests and diseases (Borron 2006). Plants with a deep root system serve well for drought resistance and carbon sequestration (e. g. perennial crops and trees) while those with shallow roots (mainly annual crops) serve well for quick establishment of plants. As these different plants explore different and complementary regions of the soil profile they increase the water use efficiency and nutrient cycling (FAO 2005c; Thorup-Kristensen 2006).

Switching to other/high value crops is one form of adapting to climate change provided the crop is tolerant to heat or to dry conditions (which most high-yielding varieties are not). Pasternak et al. (2005) report that increasing the proportion of or switching to high value crops like Roselle (*Hibiscus sabdariffa*) – an annual herbaceous plant widely grown in the Sahel, can improve farmer incomes. The authors report that in the Sahel, farmers normally plant Roselle in small plots in the periphery of their millet fields. The dried succulent calices of this plant are used to produce a drink called *Bissap or Zobbo* herbal teas (in Sahel or in Nigeria), and are used as a natural food colorant. Roselle also has potentials as an income earner in the export market. Since cash crops generate higher income, increasing the proportion cultivated can increase smallholder income, provided that the storage and marketing aspects are well managed.

To adapt to a reduction in the length of the rainy season, maize, millet or guinea corn varieties as well as local groundnut varieties that have a long growing period, are substituted by other types that mature faster. Interestingly, Laube, Awo and Schraven (2008) report that production of groundnuts has increased in northern Ghana as farmers find that groundnuts do well in less fertile soils.

Fallowing entails non-cultivation of arable lands for a certain period with the aim to restore soil fertility. This can be in terms of bush fallows or improved fallows. Although fallowing is no longer as widespread as it once was in Africa due to pressure on land, certain fast growing local shrubs could be grown between seasons or on degraded lands. Since the soil surface is covered by the crops, soil loss is reduced and soil structure improved. Improved fallowing can be in form of *green manure,* that is, plants grown for the purpose of reinvigorating the soil, either to use them as manure or for mulching. Biologically fixed nitrogen from legumes (green manure) can be used to adapt to climate change. By growing nitrogen fixing crops, soil fertility can be increased without causing emissions as is the case when using inorganic fertilizers. In arid and semi-arid tropical regions, where water is limited between periods of crop production, drought-resistant green manures can be used to fix nitrogen. Through biological nitrogen fixation, grain legumes like groundnut (Arachis hypogea), velvet beans (Mucuna pruriens), soybeans (Glycine max.) and pigeon pea (Cajanas cajan) contribute to soil fertility, thereby lowering the costs of soil fertility management (Tchale / Wobst 2005; IFOAM 2006). Alternatively, intercropping and alley cropping with leguminous trees can also increase biologically fixed nitrogen.

Alley cropping increases nutrient cycling through increased total biomass production with or without fertilizer. Alley cropping can improve nutrient cycling whereby nitrogen-fixing trees are planted in parallel rows to crops. Through alley cropping, biomass production can also be increased. Food crops are then planted in between the rows in the "alley" while the trees protect the soil from erosion and fix nitrogen in the soil. Products from the tree like wood, fruits, livestock fodder can enhance farmers' incomes. However, Leihner (2000) notes that in West Africa the amount of harvest-able products is reduced through competition and removing the already limited biomass for construction or as carry away fodder for livestock reduces the effectiveness of alley cropping for nutrient cycling. For cases where the soil nutrient status is low, alley cropping with nitrogen-fixing species requires many years to replenish the soil with Nitrogen (Leihner 2000). For such cases a mix of various soil replenishment methods is needed.

With climate change some areas will become drier than before. Such areas could adopt the crops which are currently being grown in current dry areas (e. g. Mali). Areas where maize is currently being grown may in future be more suitable for sorghum and millet. However, those areas that are already dry, like the arid areas and which may become drier as a result of climate change will have fewer options than to shift completely from agriculture to other sectors. This will also depend on whether climate change is gradual or abrupt (in decades). With gradual change people and ecosystems may have enough time to adopt in contrast to abruptly changed conditions. Adapting to such changed conditions requires that social and ecological systems have buffer capacities in terms of diversification and flexibility to migrate (also plants and animals) and to take up other livelihoods.

Contributions to resilience to climate change:

Contributions to ecological resilience

- Through crop rotation and mixed cropping, crop management practices reduce the susceptibility of the farm to crop pests and diseases since a diversified range of crops is grown. This agro-biodiversity also stabilises farm production as climate risks do not affect all crops to the same degree. For example, mixing drought tolerant crops with non-drought tolerant crops ensures some harvests under drought conditions. Similarly, the nitrogen fixing plants contribute to soil fertility and by mixing both annual and perennial crops, efficient use is made of nutrients in different soil profiles.

Contributions to economic resilience

- Crop diversification ensures that income can be derived from produce as different crops have different market values. Using nitrogen-fixing plants reduces the amount of money needed to purchase inorganic fertiliser, thereby reducing the cash expenditure of smallholder farms.

Contributions to social resilience

- Like for soil management practices, adapting crop management to climate change also holds some potential for greater social resilience by building social capital – crop rotation and mixed cropping are good farm management practices that ensure that the farm does not become a source of risk for surrounding farms through the concentration of crop pest and disease as would happen without crop rotation or mixed cropping.

4.2.6 Agro-forestry as an adaptation measure

Tree management practices can reduce the effects of climate change on the ecosystem by increasing ground cover, improving soil structure and infiltration, decreasing erosion by water and wind. Water erosion, especially under extreme rainfall conditions and in already degraded land is a major hazard. However, water erosion is not a major concern on dry, flat, rolling lands, rather, wind erosion is a major problem in low-rainfall, high evaporation areas (Leihner 2000). Thus, conserving water and improving water use efficiency of crops are the adaptations that are practiced. Water is a limiting resource in semi-arid areas, but in West Africa it normally ranks second after nutrient limitations (Leihner 2000). The author suggests that when designing water-conserving cropping systems, components that reduce evaporation but have no water demand on their own should be preferred.

Indigenous and improved agro-forestry, that is, the cultivation of trees with crops, pastures or livestock, can address many challenges that farmers face in a variable climate (WOCAT 2007). In SSA, agroforestry (as live fences, fruit trees, alley cropping, shelter belts) is widespread. Agro-forestry can be another way to reduce competition on the use of crop residues for fodder, mulching and burning. If trees planted can provide fodder for livestock, farmers may be more willing to leave the residues to cover the soil after harvests. Planting trees between crops can help prevent soil erosion, restore soil fertility, and provide shade for other crops.

Shelterbelts and windbreaks, that is, trees planted to block or reduce wind speeds, also maintain soil moisture and reduce evaporation (Stigter et al. 2005). However, windbreak vegetation may compete with crops for water; hence least water consuming species should be selected. In higher rainfall areas, a vegetation cover maintained throughout the major part of the year conserves water best (Leihner 2000). The author also highlights that locally adapted crop varieties have an unrealized potential that can be tapped through improved management practices. Under changing climate conditions, the resistant characteristics of crops are crucial hence combining high yield potential with better yield stability should be targeted.

Live fences, that is, trees planted around homesteads or cultivated land, aim to protect the enclosure from roaming livestock and in many cases to provide fodder for livestock. *Grevillea robusta* (originally from Australia) are widespread in coffee and tea plantations of East Africa and in the drier areas of the Mount Kenya region. Grevillea is used to mark the boundary of plots, for alley cropping, for fuelwood, wood and building materials. The tree serves as wind break and contributes to nutrient recycling due to its deep roots. WOCAT (2007) notes that *Grevillea* alone is not used for soil erosion control but in combination with other measures like *fanja juu*, bench terraces or other vegetative measures. *Vegetative hedges* are also used as contour lines to slow runoff down the slope and protect the soil from erosion. An example is the use of vertiver grass (*Vetveria zizanioides*) in Kwa-Zulu Natal, South Africa (WOCAT 2007).

In addition, trees and shrubs sequester more carbon than crops, thereby contributing to mitigate climate change. These arguments speak for the participation of farmers in carbon emissions trading (see Box 13). Besides benefits from improved environmental services and yields, small-scale agro-forestry could provide farmers with additional incomes from carbon payments, no matter how small. However, the small quantity of sequestered carbon and the absence of a third party organisation to administer agro-forestry projects for carbon sequestration and bear the high transaction costs, delay the access of many smallholder dominated areas to additional income from carbon trade (Takimoto / Nair / Alavalapati 2008).

Although smallholder farmers in many SSA regions have been practicing agro-forestry for ages, the value of carbon is not a factor in their decisions. This means that tree species are chosen for other factors, such as wood production, fodder production or fruit production. Thus, such trees sequester carbon at varying levels. Ginoga, Wulan and Djaenudin (2004) suggest that the species in agro-forestry systems can be changed to longer-lived trees that sequester more carbon, if carbon payments are large enough to provide an incentive to farmers.

Since farmers already practice agro-forestry, existing agro-forestry systems are part of the baseline and therefore not additional to what would have occurred in the absence of a CDM project. For example, traditional agro-forestry systems in Ségou, a semi-arid region of Mali, were found to have high carbon stock in their biomass and soil, but little potential for sequestering additional carbon (Takimoto / Nair / Alavalapati 2008; Takimoto / Nair / Nair 2008). Thus, additionality criteria need to be identified. Ginoga, Wulan and Djaenudin (2004) suggest that addressing the barriers to more widespread adoption of agro-forestry such as the lack of technical skills or inadequate investment capital to establish the trees, might meet the additionality requirement.

Thus, for farmers to participate in carbon trading, modifications of various trading schemes are needed, in particular, the major ones such as the European Union emission trading scheme. Since smallholders farm only small portions of land, they need to form cooperatives or be assisted in doing so in order to access carbon markets where large carbon volumes are traded. An institution is also needed to arrange for the certification of carbon sequestration, to apply for carbon payments and distribute funds to the farmers (Fritschel 2006).

In the context of climate change, crops are no longer only for food, fibre or industrial raw material but also as carbon assets. Where agro-forestry is not yet established, the costs of planting trees might be too high for the smallholders and may need external support. However, the fact that SSA has gained very little from the current carbon trading schemes (in contrast to large commercial farms in Asia) hints at the inadequate know-how and resources required to establish such schemes as well as the disadvantageous structures of the CDM scheme of the UNFCCC whereby most certifying companies are located outside Africa. Thus, development cooperation needs to support SSA governments to set up the necessary infrastructure at country levels to simplify access to the carbon markets.

Box 7: Agro-forestry and its eligibility for programmatic CDM
Afforestation and reforestation are eligible under CDM but depending on agro-forestry types and how a party defines a forest, agro-forestry may or may not be eligible under the CDM small-scale afforestation or reforestation projects. "Small-scale afforestation and reforestation project activities under the CDM" are those that are expected to result in net anthropogenic greenhouse gas removals by sinks of less than 16 kilotonnes of CO_2 per year and are developed or implemented by low-income communities and individuals as determined by the host Party" (UNFCCC 2008a, FCCC/KP/CMP/2007/9/Add.1, Decision9/CMP.3, p. 26) Thus, those that practice agro-forestry could benefit from the global carbon credit market. However, under the Kyoto Protocol, only biomass carbon that is newly sequestered is recognized as "tradable" carbon, meaning that traditional agro-forestry systems are not likely to qualify as carbon sequestration projects. Despite this limitation, agro-forestry could be eligible for a programmatic CDM of small-scale afforestation and reforestation (UNFCCC 2006a, FCCC/KP/CMP/2005/8/Add.1, Decision 5–7/CMP.1, p. 61 ff.) whereby the district, provincial or national government (or even private entities) offer farmers incentives through a CDM programme to promote afforestation and reforestation. A programmatic CDM refers to a programme of activities (PoA) and "is a voluntary coordinated action by a private or public entity which coordinates and implements any policy/measure or stated goal (i. e. incentive schemes and voluntary programmes), which leads to anthropogenic GHG emission reductions or net anthropogenic greenhouse gas removals by sinks that are additional to any that would occur in the absence of the PoA, via an unlimited number of CDM Programme Activities (CPAs)" (CDM-Executive Board 2007, EB 32, Annex 38, paragraph 1).
Source: Mentioned in this Box

Contributions to resilience to climate change:

The contributions of agro-forestry to resilience to climate change are similar to those of crop management practices. However, the contributions of agro-forestry (carbon sequestration nitrogen fixation, source of income) are of a longer-term nature and of larger quantity than those of crop management practices, both of which are complementary.

4.2.7 Reforestation and avoiding deforestation

As discussed in Box 13, afforestation and reforestation are eligible under the CDM as greenhouse gas mitigation measures and can be used to rehabilitate degraded lands.

Globally, residue burning and clearing of forests were found to account for about 13 percent of the emissions from the agricultural sector (US-EPA 2006a). Many forest areas are being cleared for cultivation in SSA, thereby contributing to carbon emissions and reducing ecosystem diversity. Since many smallholders depend on forest resources during droughts, avoiding deforestation can help preserve these resources thereby maintaining the "buffer capacity" for periods of scarcity, such as drought. For example, in the Sahel and Eastern Africa, the fruits of the Baobab tree (*Adasonia digitata*) are used to complement diet. Other trees used include *Balanites aegyptiaca*, red Sorrel leaves (*Hibiscus saddarifa*), Kaopok leaves (*Ceiba pentandra*) and tigernut tubers (*Cyperus Esculentus L.*) (Eriksen 2000, 215 ff.).

Reforestation is another way to adapt to climate change impacts. By reforesting, degraded land is put into new use thereby offering the local communities access to forest resources. However, care must be taken in the selection of trees as they take many years to return benefits and ownership of the land must be clarified beforehand to avoid disputes over land.

Reforestation and avoiding deforestation can contribute to the UNFCCC objective of stabilising greenhouse gases in the atmosphere. The greenhouse gas emissions from the forestry sector in Niger, Malawi, Togo and Tanzania constitute more than 50 percent of the national greenhouse gas emissions (UNFCCC 2005a, 7). This means that for these countries their potential to reduce greenhouse gases largely lies in the land use, land use change and forestry sector.

While the CDM market allows only afforestation and reforestation projects, many types of forestry activities including avoided deforestation are eligible under voluntary markets. Thus, instead of expecting only the international climate policy mechanisms to provide financial resources for avoiding deforestation, potential exists to generate incentives for avoiding deforestation through other avenues, governments can encourage farmers and landowners to avoid deforestation through policy reforms and appropriate implementations. Development policy and development cooperation together with national governments can also encourage companies or organisations to offset some of their emissions by supporting adaptation activities that focus on improving farm incomes as well as protecting the environment. That way the companies demonstrate their corporate social responsibility.

Contributions to resilience to climate change:

The contributions of reforestation and avoided deforestation to resilience to climate change are similar to those of agro-forestry. However, in reforestation programmes, land ownership needs to be clarified to avoid conflict over land once the forest resources have improved. Forestry is usually community-based, and in addition to the contributions to resilience discussed for agro-forestry, reforestation and avoiding deforestation requires social cohesion but also reinforces social cohesion as communities claim responsibility for environmental and forest protection. In this way, both activities increase social resilience to climate change.

4.2.8 Adaptation of pests and diseases management practices

With shifting climates and with seasons getting wetter or drier, uncommon pests and diseases might become common while completely new pests and diseases to an area might emerge. While research may develop measures to deal with pests and diseases, depending on the rate of change and the emergence of the pests and diseases, research might not have adequate time to develop control measures. Thus, the use of organic pesticides and insecticides might be one effective way to address these new challenges. Pasternak et al. (2005) report that jatropha oil (*Jatropha curcas Linnaeus*) is an effective insecticide against cowpea pests in the Sahel. The incorporation of *Jatropha curcas* shrubs in the Sahel could provide low cost, effective and affordable insecticide for the control of cowpea pests. However, more farmers still need to be made aware of this bio-pesticide (Pasternak et al. 2005).

Many East African countries produce pyrethrin, a natural broad-spectrum insecticide derived from the dried flowers of *Chrysanthemum cinerariaefolium*. Globally, Kenya is the major producer of pyrethrin. According to Birech, Freyer and Macharia (2006), 95 percent of all Kenya crude pyrethrin is exported to industrialised countries while only 1 percent remains in Kenya. The authors explain that consumers in the industrialised countries are more environmentally conscious and prefer botanical-based insecticides and thus pay a premium price for the Kenya pyrethin. Conversely, cheaper synthetics or pyrethrin analogue with health risks are imported into Kenya. The authors propose that more environmentally-friendly agricultural protection measures could be adopted by using local pyrethrin preparation at farm-level, promoting locally available botanicals like Neem (*Azadirachta indica*), and using by-products from pyrethrum processing industries. Awareness campaigns on safe use of pesticides, favourable government policies, and possibly support by multinational chemical companies are necessary for such a shift.

The use of biological controls is one way to adapt to new pests. For example, the biological enemies of known pests can also be used to control them in new areas where such pests appear. Biological controls have been proposed to deal with *Striga spp*. which affects cereal and legume production (Zahran 2008) or to deal with *Aspergillus* which causes Aflatoxin in Maize (Donner et al. 2006). Zahran (2008) suggests that the efficacy of pest control can be increased by integrating biocontrol agents with compatible chemical herbicides. However, the biological controls and botanical pesticides are generally more environmentally friendly than their synthetic counterparts and have the advantage of being cheaper to access. In many cases, farmers have local knowledge of botanical-based products and this knowledge needs to be documented. As discussed at the beginning of this chapter, integrated approaches, like integrated pest and disease management approaches are likely to be more robust under a changing climate, since various dimensions of a pest attack are addressed simultaneously or differently. An integrated approach therefore forestalls the danger of pests becoming resistant to control measures.

Contributions to resilience to climate change:

Contributions to ecological resilience

- Using biological control and improving the efficiency in the application of synthetic pesticides reduce soil and water pollution, thereby improving environmental conditions.

Contributions to economic resilience

- Biological controls are cheaper and easier to access than synthetic pesticides. Therefore, farmers do not need to invest additional cash into purchasing pesticides or where they combine biological and synthetic pesticide they need less amounts of money to purchase the synthetic pesticides.

Contributions to social resilience

- By using biological pesticides, farmers use indigenous knowledge that is fast disappearing. Through this practice the farmers contribute to maintaining and transferring indigenous knowledge on handling crop pests and diseases.

4.3 Adaptation of livestock, pasture and rangeland management practices

Livestock production is intricately linked with crop production in smallholder farming. Livestock kept include ruminant animals like cattle, sheep, and goats, as well as poultry. Livestock feed on farm-based fodder and pastures as well as on communal pasture lands. Climate change will adversely affect pastures and rangelands. Improving the management of livestock production is thus a proposed strategy. Improved management of grazing lands relates to changing control and regulation of grazing pressure (WOCAT 2007). This can be achieved through initial reduction of the grazing intensity through fencing, followed either by rotational grazing, or ‘cut-and-carry’ of fodder, and vegetation improvement and changes in management (WOCAT 2007).

Fodder substitution addresses fodder shortage, which is a serious challenge in SSA drylands. An adaptation to climate change would be to ensure fodder availability for livestock. This can be achieved through fodder banks (Takimoto / Nair / Alavalapati 2008), or fodder substitution (Pasternak et al. 2005).

Grazing and fodder lands can also be conserved through *reforestation, enclosures and zero grazing*. In the UNFCCC adaptation database, it is reported that the enclosure of acacia-miombo woodlands provides farmers with dry season fodder for their cattle, as well as firewood and other essential products. According to the database, through enclosures, Sukuma agropastoralists in northern Tanzania have restored 250,000 hectares of degraded land since 1985. Involving local people in the whole process of development programmes, and building on local institutions is reported to be critical for the success of such projects. In addition, the allocation of clear land rights enhances security of tenure thereby fostering a sense of ownership and responsibility among actors (UNFCCC Adaptation database).

Grazing lands can also be rehabilitated by planting improved grass and fodder trees but few studies in SSA are available on this aspect. A current adaptation strategy is to successively replace a large proportion of the large stock (e. g. cattle) with small stock or camels which are more drought-tolerant (Ifejika Speranza 2006b) However, the marketing aspects of camel products still need to be addressed.

For poultry, Pasternak et al. (2005) report that Sahelian countries normally use two sources of protein in chicken rations: groundnut cake (10 percent) and fish meal (10 percent). The authors analysed the substitution of conventional protein sources by *Acacia colei* seeds in the diet of broilers and found that seeds of *Acacia colei* can replace 50 percent of the protein source of chicken rations. The sale of the seeds could provide additional revenue for the farmers and subsequently encourage them to maintain the *Acacia colei* trees.

Contributions to resilience to climate change:

Contributions to ecological resilience

- Contributions of improved grazing land management are similar to those of agro-forestry and other vegetative adaptation measures, namely, increase in soil carbon, which positively affects soil fertility and by extension increase fodder production.

Contributions to economic resilience

- Through improving grazing land management and the associated increase in fodder availability, farmers do not need to purchase extra fodder.

Contributions to social resilience

- A contribution to social resilience is in fostering collective management of community pastures, thereby enhancing social cohesion.

4.4 The contributions of farm-level adaptation practices to climate change mitigation

As discussed in Chapter 2, agriculture is a major contributor to GHG emissions but this chapter has highlighted that it is also a major sink for carbon. Many of the practices discussed in Chapter 4.2 store and sequester carbon. Although the potential for sequestering carbon in drylands is low (Lal 1999), increasing soil carbon can improve soil productivity. Just as agricultural practices contribute to GHG emissions, adapting to climate change in agriculture also contributes to reductions in GHG emissions through storing and sequestering carbon above ground in trees and below-ground in soils. Although infinitesimal in global proportions, the emission portfolio of SSA countries is dominated by emissions from agriculture and forestry. This implies that in order to reduce emissions in these countries these sectors need to be targeted. It also turns out that many adaptation measures although not aimed at mitigation, yield ancillary benefits to the environment by reducing and sequestering carbon (Fearnside 2008).

The temporary nature of agricultural CO_2 sinks has blocked agriculture from carbon credit schemes (cf. Kirschbaum 2006; Fearnside 2008). However, the acknowledgement by the IPCC and others (cf. Fearnside 2008) that agriculture has the potential to make cost-effective and relatively quick (within 5 – 10 years) contribution to mitigation (cf. Smith et al. 2007) is enough evidence to warrant the design of an agriculture-specific carbon credit scheme or to design complementary schemes. For poor smallholders, it would make a difference to earn additional income, and payment for sequestered carbon is one such option. However, since the proportions sequestered are small, adopting a programmatic CDM approach for small-scale afforestation and reforestation through government or private schemes (discussed in Box 13) that aim to compensate farmers for protecting the environment might be a way to increase smallholder incomes.

It must also be considered that the increasing use of fossil fuel in conventional agriculture increases the emissions from agriculture and if SSA countries are to follow the development pathways of the industrialised countries in conventional agriculture, it would mean more use of fossil fuels and increased emissions. Hence climate change offers an opportunity to adopt alternative development pathways in agriculture, for example by practicing organic agriculture or integrated crop management.

Yet it must be remembered that despite the potentials for storing and sequestering carbon, the potential of agriculture to sequester carbon in the drylands is low compared to other areas with better climatic conditions. Nonetheless, the argument for trying to derive benefits through carbon credits is that the income that smallholders could earn through carbon trading could make a big difference in reducing poverty levels. Since the amount of carbon provided by smallholders is small and not "attractive" in economic terms for carbon buyers like companies in developed countries, an incentive to engage in such trade nevertheless will be the improvement of "corporate image". Takimoto, Nair and Alavalapati (2008, 758) suggest that "multinational companies/corporations, who are often blamed for a large amount of GHG emission", could polish their image by participating in such schemes thereby gaining an "environmentally friendly" and "socially consciousness" image. The authors indicate that this image value may be a selling point.

Enteric fermentation in ruminants accounts for most of the methane emissions. With the export to markets in the Middle East and the increasing consumption of beef and dairy products, it is also likely that emissions from this sector will increase in SSA. However, few studies exist on how to address this problem, considering the extensive nature of livestock production in SSA. While rice production in Africa is small compared to China and the South-East Asian countries that produced about 90 percent of the methane emissions from rice cultivation in 1990 (US-EPA 2006a), growth in SSA agriculture may bring about an increase in emissions from rice cultivation if the current practice of permanent flood irrigation continues. Studies in Asia show that CH_4 emissions can be reduced through alternate wetting and drying and through mid-season drainage; although

Wassmann, Butterbach-Bahl and Dobermann (2007) report that the N_2O emissions increase as a result.

By improving efficiency in the application of organic fertiliser (as in organic agriculture) and inorganic fertiliser, the amount of nitrogen can be reduced thereby also reducing N_2O emissions. This again would vary depending on the resources available to the farmer and the likely impacts on yields.

Finally, agriculture is increasingly gaining attention in the UNFCCC negotiations and with regard to the post-2012 climate regime, many actors like the FAO, IFPRI und UNCCD, some African countries, Argentina und the USA (Smith et al. 2007; Nelson 2009; FAO 2009a/b; UNCCD 2009; UNFCCC 2009a; African Governments 2009; Paul et al. 2009) are proposing the admission of agriculture into carbon trading. However, going by past developments, it is unlikely that SSA smallholder farmers will benefit from such a scheme. Hence governments need to explore various options to compensate farmers for their contribution to environmental and climate protection and how to link these to the international climate regime. As earlier discussed, the certification standards for organic agriculture may provide an option, but governments need to take a more active role in this process than has hitherto been the case.

4.5 On-farm and off-farm diversification, migration and remittances

Often, dryland smallholders' income from crops and livestock is not enough to sustain their households. Thus, additional incomes, no matter how small, can improve their decision framework. Such additional incomes are often sought through seasonal migration to urban areas or areas with better agricultural potentials (Ifejika Speranza 2006b; Laube / Awo / Schraven 2008). Yet the low level of literacy and lack of skills are entry barriers into non-primary sectors and need to be addressed by the government and development partners, for example, through improving the skills of the local people so they can offer services in their locality (for example, repairing farm implements, manufacture of small implements, post harvest processing, extension services and auxiliary veterinary services).

For generations, labour migration has remained an adaptation strategy in Africa. Seasonal migration remains an important source of income in "normal" circumstances and in times of scarcity like drought (Ifejika Speranza 2006b; Laube / Awo / Schraven 2008). People migrate to earn income when the livelihood conditions in their home areas are not conducive, pushing them to look for alternative places and activities to earn income. However, improving conditions in the area of origin can encourage the people to stay at home and explore new possibilities to earn income and improve their livelihoods (cf. Laube / Awo / Schraven 2008). Still, if conditions in the receiving areas cease to be conducive to migrants, then the smallholders would rather remain at "home" because they feel more secure in their home area than in the receiving areas (cf. Laube / Awo / Schraven 2008). This suggests that adverse climate conditions is just one of the many factors that push people to migrate and that the conditions in the receiving areas must also be conducive before people decide to move to those areas. Another implication is that if conditions and employment opportunities are increased in the rural areas that migration can be reduced. Through migration, the migrants earn off-farm incomes which they reinvest in agricultural activities. Thus earning income outside the farm contributes to maintaining on-farm food security and production, especially in the aftermath of droughts and floods. Another important aspect is the issue of gender. Since it is mostly men (who are also household heads) that migrate or have multi-local livelihoods, wives are left at home to cater for the farms, grandparents and children, but the decision-making power mainly remains with the absentee husbands. This means that women must take on additional work but their spheres of influence in decision-making does not increase. This can adversely affect the effectiveness of adaptations as decisions to sell livestock in times of scarcity like drought must be delayed until the household head sends a message of his decision. Thus interventions in rural areas must be gender-sensitive in order to also improve the livelihood conditions for the wives left behind.

Contributions to resilience to climate change:

Contributions to ecological resilience

- Some of the income derived from off-farm activities are sometimes invested in soil and water conservation measures.

Contributions to economic resilience

- Participation in off-farm activities increases the incomes of the smallholders and provides them with capital to invest in farm production.
- Through migration, the migrants become exposed to other knowledge and technology and serve to diffuse innovations by testing what they have learned from their sojourn in their farms. In that way, they improve their adaptive capacities.

Contributions to social resilience

- Participation in off-farm activities makes social structures more flexible, since women (in the absence of the male household heads) become representatives of their households, but decision-making power remains with the absentee husbands in most cases.
- However, the off-farm engagement of the men reduces on-farm labour and increases the workload for the women both in the farm and in the household.

4.6 Farmer social networks and group-organisation

Self-organisation is one of the three main components of resilience that promises greater control and influence over farm activities and farm socio-economic environments than without. Traditionally, African farmers have organised themselves into various groups and this practice has evolved to the modern, with financial institutions taking advantage of this form of cooperation to disburse credit to farmers through group liability. In some places in SSA, these forms of self-organisation are much more pronounced than in others, while in some others it is absent. Such forms of collectiveness cover activity spheres related to farm production such as finance, labour, marketing, knowledge groups, or even multi-functional farmer organisations that offer extension services.

In order to increase their access to credit and savings, farmers organise themselves in *Self Help Financial Groups* (SHFG). The indigenous forms of SHFG include Esusu/Susu in Nigeria and Ghana, Ekub in Ethiopia, Tontines in Cameroon and Niger, and merry-go-round/Kielo in Kenya. The financial services that SHFG provide give farmers room to accumulate capital, increase their livelihood assets and invest in agricultural production. With time, these traditional SHFG have evolved into formalised forms such as Savings and Credit Cooperatives (SACCOs). In some rural areas more women organise themselves in SHFG than the men. This is because most men migrate to the urban centres to earn additional incomes while the women are left behind to cater for the farms and the household. Through membership in SHFG women improve their access to financial services, and thereby become more empowered to venture into small businesses (Seibel 2001). Some also invest the financial capital acquired in paying children's school fees and in farm production (Ifejika Speranza 2006b). However, SHFG without links to formal financial institutions tend to collapse during crisis like those triggered by drought, as their limited funds dwindle when their members default in their contributions. Those groups that maintain linkage with formal financial institutions have a sustained source of savings and credit (Lee 2006). Thus linking those stand-alone (traditional) SHFG to formal financial institutions is one way of stabilising the capital flows in such groups, thereby enabling such groups to provide financial services to their members in a sustained manner. Actors in development cooperation like CARE, Oxfam and IFAD have supported over 500,000 self-help groups in Africa to achieve greater rural outreach and to sustain their financial services (Lee 2006).

Farmers also organise themselves into *labour groups* to reduce the labour burden in farm work, for example, the *Mwethya* and *Mwilaso* groups in south-eastern Kenya. *Mwethya* is a group comprising relatives, friends and neighbours called upon by an individual who needs help with a definite short-term task, while *Mwilaso* traditionally consists of a group of friends who work on each other's farm on a strictly rotational basis (Tiffen / Mortimore / Gichuki 1994; Ifejika Speranza 2006b). However, such forms of group formation are disappearing with farmers now engaging in paid contracts for such jobs.

Natural resources users and management associations are in forms of Water Users Associations (WUA), irrigation management associations, forest users groups or fishery committees (Liniger et al. 2005; Neubert et al. 2007). As climate change reduces resources availability, efficient management of resources is one way to adapt to the impacts of climate change-induced resource scarcity and periodic resource abundance (for example, floodwater from torrential rains). Resource scarcity triggers tensions and conflicts among resource users. In the case of water, local communities organise themselves into WUA to address issues concerning water availability and access. The WUA have emerged out of the need of locals and government to improve resources governance. Thus in countries like Kenya and Tanzania, WUA help to diffuse tensions and resolve conflicts over water use. In Kenya, the WUA was formalised by being incorporated into the Kenya Water Act (GoK 2002; 2006), and giving the WUA the role to monitor water rights and distribution as well as to resolve equity issues and conflicts. Since their inception, such groups have resolved various conflicts and disputes over water (Liniger et al. 2005; Neubert et al. 2007).

Government and other external actors drive group formation, thus providing them with the leverage to address gender inequality in the management of irrigation schemes. Neubert et al. 2007 report that women were consistently underrepresented in water user groups and in irrigation projects, necessitating the World Bank to introduce a system of quotas designed to increase women’s participation. This increased the empowerment of women in their communities.

Marketing associations and cooperatives are not so successful like farmer organisations in other sectors. Compared to other sectors related to farm production, the marketing sector is the one area where farmers are not well organised in many African countries. The various cases of corruption and mismanagement of farmers' cooperatives (for example in Kenya) have made farmers wary of marketing organisations (Ifejika Speranza 2006b; Neubert et al. 2007). Consequently, traders continue to exploit farmers through low prices for produce and livestock, while the high costs of transportation to markets hinder farmers from directly selling their produce in the market. Thus, governments and development cooperation need to support the farmers by rebuilding trust amongst them by creating an enabling environment that enforces checks and balances as well as transparency, accountability and penalty.

Many farmer organisations have diversified into *providing multiple services* for their members ranging from extension to weather-based index insurance. Examples are the Uganda National Farmers’ Federation and the National Smallholder Farmers’ Association of Malawi. Such organisations have emerged to represent farmers’ interests and facilitate their access to extension services. However, such organisations tend to represent the interests of the small-farm businesses of innovative farmers. In this sense, poorer farmers may be left out.

Contributions to resilience to climate change:

Taking the components of resilience as analytical frame (see Table 4), the following section discusses how farmer organisations increase resilience and how development cooperation can support these processes.

Contributions to ecological resilience

- The WUAs contribute to protecting the environment by monitoring the equitable distribution of river water for various uses.

Contributions to economic resilience

- Establishing links with formal financial institutions has been one way that the SHFG adapted to the challenges of insecure funding base. Some have even gone further to diversify their activities – in addition to providing farmers access to credit, they now also provide farmers with weather-based index insurance as well as improved cultivars and high value seeds.
- The success of many formal micro-finance schemes depends on the basis that SHFG provide through *local leadership, local social capital and governance* (Lee 2006).

Contributions to social resilience

- Through self-organisation, the farmers themselves have ownership of the group formation process and define their own agenda, contrary to cases where the agenda is externally driven.
- Through cooperation the farmers increase their social capital, and their access to information, and through exchange with other farmers and their own experiences learn about new developments.
- As a member of a group, farmers gain the capacity for collective action or joint enterprise (WRI 2008), and through their group/organisations become a social force and actor that shapes development. This contributes to social capital and in effect to buffer capacity.

By facilitating access to livelihood capitals (financial services, technical information), farmer organisations play a critical role in increasing buffer capacity (to deal with risks, shocks and uncertainty) and by extension enhance environmental, economic and social resilience. Self-organisation thus contributes to the other components of resilience (buffer capacity and capacity for learning) and is equally self-reinforcing. It forms the basis for networks and institutions, which again reinforce self-organisation. Through participation and networking the farmers gain new tools to survive (that is increase their social capital; WRI 2008). By recognising the limitations of their organisational form, and linking up to formal rural finance and credit institutions (see Chapter 5.7), SHFGs have led to their own transformation to hybrids of the traditional forms (characterised by client proximity, flexibility, social capital, outreach to poorer clients), and to modern forms (characterised by risk pooling, provision of long-term investment loans). This linkage and adaptation demonstrate the resilience of self-organised groups (Zeller 2003). Self-organisation is thus a powerful tool for increasing farmers' adaptive capacities. However, while self-organisation may be an endogenous process, there may be strategic roles for external involvement to support this process. Depending on how external actors like development cooperation act, they can impede or facilitate these processes (Lee 2006).

With climate change, farmers will need to acquire new knowledge on the management of new crops and dealing with unaccustomed weather/climate conditions. In addition, the expected trend of rising agricultural prices means they will need access to cash and going by the current procedure of group-liability by the rural finance institutions a poor farmer will have to be a group member to be able to source such credit. Finally, it needs to be mentioned that badly-managed farmer groups have also undone positive contributions to resilience through mismanagement of funds and sowing mistrust among members. Rebuilding trust should thus be the goal in such situations.

4.7 Implications and conclusion

The foregoing highlights that there are several ways to adapt to climate change at farm-level. These different ways are mainly complementary as they address different components of the smallholder farming system. It also shows that adaptation is a continuum that ranges from activities that are predominantly developmental to those that focus on reducing climate change impacts.

No one single measure is sufficient to adapt to climate change. Rather, *a mix of measures* is needed which targets the various farm variables – water, soil, micro-climate, seeds and crops as well as labour and capital. The integrated approaches discussed can offer desired pathways to achieving adaptation. Achieving a balance between efficiency of resources use, environmental integrity and social and economic viability hints at a system shift in agricultural production, but in the SSA context, such a shift must not be at the expense of sustained food production.

This chapter also illustrated the *close link between climate change adaptation and mitigation* in the agricultural sector. Many of the adaptation practices like mixed cropping, green manures that fix nitrogen, agro-forestry and improved range land management sequester carbon, thereby reducing greenhouse concentrations in the atmosphere. Other measures like rain water harvesting and soil conservation measures reduce soil erosion and the silting of rivers. Considering these *environmental services* and the pecuniary circumstances of the smallholders, providing smallholders incentives or compensation for good land management practices holds potentials for poverty reduction, environment and climate protection. Development policy and development cooperation need to exploit these potentials.

A challenge remains regarding *how to manage the competing uses of biomass* in drylands. Competition for crop residues remains a challenge to using crop residues for soil and water conservation in the drylands of SSA. A possible solution could be in planting trees which produce a lot of biomass that can be used for fodder.

There is a need to *examine the trade-offs and synergies between international climate and trade policies* as these can impede or enhance adaptations. Such tradeoffs frame the conditions of adaptation. They contribute to "double exposure" (O'Brien / Leichenko 2000; O'Brien et al. 2004; Eakin 2005) and are part of the "dynamic pressures" (Wisner / Blaikie / Cannon 2004), and "vulnerability context" (Chambers 1989; Watts / Bohle 1993; DFID 2000) that smallholders face. This means that any introduced *adaptation measures should be tested through the whole chain* from smallholder producers to consumers in order to ensure that adaptation practices are really providing layers of resilience against climate change.

The elaborations also highlighted that the continuum from conventional to organic agriculture shows that mechanisation, though not a direct adaptation response but a development action, should be considered. If smallholder farmers are to increase productivity despite climate change, mechanisation is one key to achieving this goal. However, it must be ensured that the mode of mechanisation has a low net energy balance and not overtly increase GHG emissions. In this sense, the transfer of appropriate technology is an adaptation strategy that development cooperation should address and support the climate policy to implement.

Generally, the drylands have lower agricultural potential compared to the more humid areas. Within these low potential areas, islands of high resource potential exist. The contextual conditions also vary. This means that the appropriateness of farm management such as organic production, integrated crop management, conservation agriculture or conventional agriculture has to be evaluated based on the contextual conditions. Discussions in this chapter have shown that irrespective of the type of farm management chosen, that *resource use efficiency* is critical both for maintaining or increasing production in the face of climate change as well as for protecting the environment and mitigating climate change. In many cases, an integrated management approach, in which farmers choose bundles of practices applicable to their context, is key to improving adaptation actions.

The resilience check developed in Chapter 3 was used to analyse the contributions of the adaptation practices to climate resilience (as defined in Chapter 3). The resilience check was fully used in two examples for illustration and analysis. In other cases, only results using the resilience-check were discussed. This was done to save space as displaying the resilience check for each practice would cover several pages and reduce the reader-friendliness of this chapter. The analysis showed that it is possible to capture the contributions of adaptation to climate resilience. Each adaptation practice contributes to the resilience of smallholder farming to climate change in one or several dimensions (ecological, economic and social). Notable is the fact that building resilience in one dimension may have significant positive (mostly) or negative effects in other dimensions. Thus, using the resilience check in field data collection and analysis will provide more detailed and differentiated data and insights about the contribution of adaptation practices to resilience at farm-level.

Table 8 provides a summary of the benefits and costs of adaptation and related mitigation benefits based on the discussions carried out in Chapters 4.1 to 4.4. Ordinarily, not all adaptation measures would be found within the same farm and at the same time. Rather, farmers will adopt certain adaptation measures based on their utility at the point in time and may switch to others as opportunities arise.

From Table 8, it is evident that some adaptation practices contribute to mitigating climate change. Many practices sequester carbon. However, the contributions of the few adaptation measures and strategies to reducing nitrous oxide emissions are only partial and depends greatly on good management practices, whether for organic agriculture or for rangeland management. The few studies on methane emission in SSA agriculture did not provide an adequate basis for an assessment in Table 8.

In addition, the time and labour costs of each adaptation practice or strategy is estimated to provide an overview. While some adaptations are relatively quick (several weeks to one year) to be established, others require longer periods or continuous adjustments. For example, assuming that heat-tolerant crops or varieties are available to the farmer, the farmer will gradually test these seeds over a period of two to six seasons (ca. 3 years) and will successively increase the acreage covered depending on their performance and social acceptability. Similarly, the generic costs (labour and capital) of each adaptation practice or strategy is estimated. Compared to capital, smallholder farmers have better access to labour (own and social network). It is likely that smallholders will be slower to adopt those adaptations that are cost-intensive compared to those that are labour-intensive, although labour is also a constraint and motivation to adopt certain adaptation practices also plays a role. Table 8 also offers a framework that can be validated and improved on through empirical data collection.

- Many of the farm practices analysed are dependent on local knowledge, which makes important contributions to resilience. Local production should not be primarily reliant on external inputs as this is one factor that already spells the failure of adaptations. Input in this sense covers both factors of production as well as the knowledge and skills needed to run the agricultural system. This does not mean that all the knowledge should remain with the farmers at the local level but, for adaptation to be sustainable, *local knowledge should be combined with other knowledge systems*. As will be discussed in the following chapter on policy, and institutional level adaptations, a system of cascading and overlapping knowledge systems, in which the various national to local

Table 8: Summary of adaptation and mitigation benefits and costs

	Farm-Level Adaptations of Agriculture to climate change	Rainwater management practices	Irrigation management practices
Adaptation benefits	Stabilises on-farm water supply	x	x
	Reduces runoff	x	x
	Increases soil water content/infiltration	x	x
	Increased resilience to heat/high temperature	x	x
	Increased resilience to high evaporation	x	x
	Increased resilience to drought	x	x
	Increased resilience to flood	x	
	Increased resilience to rainfall variability	x	x
	Increased yields	x	x
	Increases soil fertility	x	x
	Reduces input costs		
Mitigation benefits	Sequesters carbon		
	Reduces N_2O emissions		
	Reduces CH_4 emissions		
Time and labour costs	Time to establish	Several weeks to 1 year	1 year
	Labour / capital costs	Labour intensive; requires initial investments in implements	Labour intensive; requires initial and continuous investments

Source: Author / Based on literature

Legend: x :significant contribution, ~: partial contribution, empty cells: no contribution

Table 8 continued

	Soil management practices				
	Farm-Level Adaptations of Agriculture to climate change	Mulching	Organic manure and composts	Planting pits and stone lines	Terracing
Adaptation benefits	**Stabilises on-farm water supply**			x	x
	Reduces runoff	x	x	x	x
	Increases soil water content/infiltration	x	x	x	x
	Increased resilience to heat/high temperature	x	x	x	
	Increased resilience to high evaporation	x	x	x	
	Increased resilience to drought	x	x	x	
	Increased resilience to flood		~		x
	Increased resilience to rainfall variability	x	x	x	x
	Increased yields	x	x	x	x
	Increases soil fertility	x	x	x	x
	Reduces input costs	~	x		
Mitigation benefits	**Sequesters carbon**	x	x	x	
	Reduces N_2O emissions				
	Reduces CH_4 emissions				
Time and labour costs	**Time to establish**	4 months	1 week	1 year	1 year
	Labour / capital costs	Labour intensive	Labour intensive	Labour intensive	Labour intensive

Source: Author / Based on literature

Legend: x :significant contribution, ~: partial contribution, empty cells: no contribution

Table 8 continued

		Seed management practices		
	Farm-Level Adaptations of Agriculture to climate change	Heat-tolerant crops/ varieties	Drought tolerant crops/ varieties	Early maturing crops/ varieties
Adaptation benefits	**Stabilises on-farm water supply**			
	Reduces runoff			
	Increases soil water content/infiltration			
	Increased resilience to heat/high temperature	x	x	x
	Increased resilience to high evaporation	x	x	x
	Increased resilience to drought	x	x	x
	Increased resilience to flood			
	Increased resilience to rainfall variability	x	x	x
	Increased yields	~	~	~
	Increases soil fertility			
	Reduces input costs			
Mitigation benefits	**Sequesters carbon**			
	Reduces N_2O emissions			
	Reduces CH_4 emissions			
Time and labour costs	**Time to establish**	2–6 seasons	1–2 seasons	1–2 seasons
	Labour / capital costs	Requires capital for seed purchase	Requires capital for seed purchase	Requires capital for seed purchase

Source: Author / Based on literature

Legend: x :significant contribution, ~: partial contribution, empty cells: no contribution

Table 8 continued

		Crop/trees management practices		
	Farm-Level Adaptations of Agriculture to climate change	Crop rotation and mixed cropping	Agro-forestry/ live fences/ hedges	Reforestation and avoiding deforestation
Adaptation benefits	**Stabilises on-farm water supply**			
	Reduces runoff		x	x
	Increases soil water content/infiltration	x	x	x
	Increased resilience to heat/high temperature		x	x
	Increased resilience to high evaporation		x	x
	Increased resilience to drought	x	x	x
	Increased resilience to flood		x	x
	Increased resilience to rainfall variability	x	x	x
	Increased yields		x	x
	Increases soil fertility	x	x	x
	Reduces input costs			
Mitigation benefits	**Sequesters carbon**	x	x	x
	Reduces N_2O emissions			
	Reduces CH_4 emissions			
Time and labour costs	**Time to establish**	1–2 years	1–2 years	1–many years
	Labour / capital costs	Labour intensive	Labour intensive	Labour intensive

Source: Author / Based on literature

Legend: x :significant contribution, ~: partial contribution, empty cells: no contribution

Table 8 continued

	Farm-Level Adaptations of Agriculture to climate change	Conser-vation Agri-culture	Organic Agri-culture	Livestock, pasture and range-land ma-nagement practices	Integrated/ biological pests and diseases manage-ment
Adaptation benefits	Stabilises on-farm water supply				
	Reduces runoff	x	x	x	
	Increases soil water content/infiltration	x	x	x	
	Increased resilience to heat/high temperature	x	x	x	
	Increased resilience to high evaporation	x	x	x	
	Increased resilience to drought	x	x	x	
	Increased resilience to flood		x		
	Increased resilience to rainfall variability	x	x	x	
	Increased yields	x	~	x	
	Increases soil fertility	x	x	x	
	Reduces input costs	x	x		x
Mitigation benefits	Sequesters carbon	x	x	x	
	Reduces N_2O emissions		~	~	
	Reduces CH_4 emissions				
Time and labour costs	Time to establish	1–3 years	1–3 years	1–many years	1–2 years
	Labour / capital costs	Cost intensive	Labour intensive	Labour intensive	Cost intensive

Source: Author / Based on literature

Legend: x :significant contribution, ~: partial contribution, empty cells: no contribution

institutional frameworks and actors play their expected roles, is needed. Thus, the following chapter analyses adaptation practices at the levels of institutions and policies, with the aim of elucidating how they build or support farmers to build the resilience of smallholder farming systems.

Contributions to ecological resilience

- Farmers use information and advice from the extension services to improve their land and resources management strategies, which often result in improved soil fertility and higher yields. Thus, farmers derive benefits from the extension services and through use of this information protect the environment from soil erosion and degradation. In this way, extension services contribute to increasing the resilience of smallholder farming systems to climate change impacts.

Contributions to economic resilience

- The extension services promote the spread of farmer-based innovations, thereby empowering farmers. For example, through farmer-exchange visits, farmers observe the adaptations practised by fellow farmers first hand and are more likely to adopt them. Reviews of the diffusion of new technologies show that access to extension services is one of the major determinants of adoption (Maddison 2006). Since extension services disseminate information and knowledge to farmers, free extension advice specifically related to climate change shapes farmer perception of climate change and positively influences farmer adaptation processes and resilience (Maddison 2006; CEEPA 2006).

The information and advice (for example information on new crops) that the extension services provide to the farmers increase farmers' livelihood options.

5 Policy and institutional level adaptation frameworks and instruments

In the previous chapter, several farm-level adaptation practices were identified and analysed. However, to practice such farm-level adaptations, sustained policy and institutional level support and adaptations are required. In the following, adaptations at policy and institutional levels are analysed, starting with the international environmental regimes of the Rio Conventions. This is because international policies provide frameworks that considerably influence the manner in which adaptation is addressed at national and sub-national levels.

5.1 Adaptation under the Rio Conventions and national policy frameworks

Given the magnitude of the climate change problem and the differing adaptive capacities and vulnerabilities of countries, coordinated action is crucial between international, regional, national and local-level initiatives to identify adaptation options and to provide adequate resources to implement them.

At the international level, the Rio Conventions – the United Nations Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention to Combat Desertification (UNCCD; see Annex 16) – provide for such a multi-level approach to addressing adaptation to climate change in their activities. These conventions are crucial for adaptation because they address global environmental problems and provide resources for the developing countries to enable them to address these problems.

The three conventions are interlinked as they address similar issues. Biodiversity contributes to the provision of many ecosystem services, which climate change and desertification can adversely affect, leading to biodiversity loss. Biodiversity loss in turn reduces ecosystem services. Conserving biodiversity is thus an adaptation option that can positively reduce the adverse impacts of climate change and desertification on smallholder agriculture. In turn, smallholders depend on natural resources (including biodiversity) for their livelihoods. Combating desertification in drylands, for example through improving soil organic content, can restore the productive potential of drylands and protect climate through sequestering soil carbon. Charcoal production which is a widespread coping and adaptation strategy of smallholder farmers destroys forests, ultimately leading to ecosystem degradation and loss of biodiversity.

The planning instruments of the conventions (see Annex 16) also address similar activities. Soil conservation and reforestation, improved water management for use in agricultural production to deal with dry spells and maintain production in the dry seasons; support for monitoring and early warning systems, promoting activities that contribute to livelihood and food security, harmonization of environmental and public policies; promoting environmental mainstreaming (UNFCCC-JLG 2009).

The recognition of these overlaps, potential synergies as well as trade-offs between these Multilateral Environmental Agreements (MEA) (cf. UNFCCC 2005b) led to increased coordination aimed at improving efficiency and effectiveness through exploiting synergies and reducing trade-offs. A Joint Liaison Group (JLG) between the secretariats of the CBD, UNCCD and UNFCCC was established in 2001 with the aim of enhancing coordination between the three Conventions, including cooperation on adaptation. Together with the CBD Ad Hoc Technical Expert Group (AHTEG) on biodiversity and adaptation to climate change, and the UNCCD's Group of Experts, these groups address the synergies and approach adaptation to climate change as a cross-cutting issue since activities that promote adaptation to climate change also contribute to conservation, sustainable land management and biodiversity. Among the three foci (climate change, desertification, and biodiversity conservation), climate change currently receives more attention and offers a key to undertake activities that would also address desertification and biodiversity conservation.

The inclusion of the Land Use, Land-Use Change and Forestry (LULUCF) sector in the Kyoto protocol also highlighted the environmental linkages between the three conventions, while certain Clean Development Mechanism (CDM) projects offer a means of achieving biodiversity conservation and sustainable land management, which are also goals of the CBD and the UNCCD (Yamin / Depledge 2004). However, depending on how the Kyoto Protocol's CDM is implemented, trade-offs with biodiversity plans of the CBD might occur. For example, large-scale planting of fast growing exotic species to increase carbon sinks may destroy traditional forest ecosystems and lead to biodiversity loss (Velasquez 2000).

The foregoing highlights a close relationship between agriculture and the Rio Conventions. While agriculture depends on natural resources and ecosystem services, it also affects the state of natural resources and the ecosystem services they can offer. Degraded soils imply low soil fertility and low yields. Lack of or reduced agro-biodiversity reduces the resilience of agricultural systems to various risks, prominent among them reduced soil fertility, pests and diseases (Thrupp 1997). Climate change through various climatic hazards like droughts, floods or frosts or increased variability and shift in seasons not only affect biodiversity. Through changes in ecosystems and biological resources climate change may also lead to the extinction of various biological species and to desertification (SCBD 2003; Boko et al. 2007). The above interactions between biodiversity, climate, desertification, agriculture and development can translate into reducing or increasing agricultural production. For the predominantly poor smallholder farmers in Africa, maintaining biodiversity and avoiding soil degradation can therefore forestall food and livelihood insecurity.

The *dominance of agricultural projects* in the National Communications (NC) and the National Adaptation Programmes of Action (NAPA) submitted to the UNFCCC, as well as the attention the sector receives in the Technology Needs Assessments (TNA), the UNCCD National Action Programmes (NAPs) and the CBD National Biodiversity Strategies and Action Plans (NBSAPs) (Annex 16) reflects the importance of agriculture in the economy and thus also for adaptation. Agriculture, food security and sustainable management of natural resources feature prominently in the proposed projects of the NAPAs (for example Chad, Niger 2006, Burundi 2007, Benin 2008, Central African Republic 2008, Cape Verde 2007, Eritrea 2007). *Capacity building for adaptation and improving early warning systems* are also high on the criteria listings of the NAPAs (see for example RoK 2002; UTC 2006; URT 2007).

Through promoting synergies, the conventions improve the way adaptation is addressed. From the outset, the preparation and implementation of the NAPAs built on the UNCCD NAPs, the CBD NBSAPs and on national sectoral policies through the Decision 28/CP.7 of the UNFCCC seventh COP in 2001. As such, "synergy with other MEAs was a criterion for prioritizing identified adaptation measures" (UNFCCC 2005b, 4). At the national levels, this synergy was accounted for in the participation of the UNCCD and the CBD focal points in the NAPA process, for example through membership in the NAPA country team (UNFCCC 2005b). In some countries, this integration was enhanced by the fact that the same ministry (for example the Ministry of Environment) manages all three MEAs.

Lessons and Challenges to exploiting the full potentials of the Rio Conventions

Although the Conventions support adaptation in various ways, various limitations to their full potential remain. These include, at the international level, the need for "enhanced cooperation, strengthening of planning and reporting processes, outreach and awareness-raising activities, as well as collaboration on scientific matters" (Djoghlaf 2009a, 2). At the national levels, the lack of information and awareness about the gravity and impact of biodiversity loss and climate change pose a barrier to mainstream biodiversity and climate change effectively into development strategies and processes (cf. SCBD 2009; Djoghlaf 2009b, c).

The potential barriers to the implementation of the NAPA-projects is the present lack of basic development – as manifested by poor health, limited knowledge, education and skills, endemic poverty, poor infrastructure, weak institutions and institutional capacity (cf. Republic of Malawi 2006, 5 ff; Government of Sierra Leone 2007, 17 ff.; Republic of Sudan 2007, 8 ff.; URT 2007, 20 ff.). The implications are that if these underlying core problems are not addressed, the success / sustainability of the NAPA projects are likely to be compromised. This also emphasises the importance of development interventions in infrastructure which should underpin adaptation to climate change. Further, the means and ways to ensure the mainstreaming of NAPA projects in national development plans and strategies are not yet clear in many countries (Osman-Elasha / Downing 2007).

Despite the foregoing limitations, the Rio Conventions contribute to building the adaptive capacities (a component of resilience) of developing countries and in particular, the Least Developed Countries (LDC) to enable them to address climate change:

1. Through their establishments and their instruments, the UNFCCC NCs, NAPAs and TNAs; the CBD NBSAPs and the UNCCD NAPs provide international reference frameworks for national governments to address and mainstream climate change into national policies and programmes. In that way, they build the adaptive capacity (a feature of resilience) of the developing countries.
2. Through providing funding for the preparation of the national planning instruments (see Box 13), they made it possible for developing countries to actively address the climate change, desertification and biodiversity-loss problems.

3. The planning instruments were elaborated at different degrees of consultations with various stakeholders, from local to national levels. They thus contributed to network building and feedbacks between the various involved actors. The participatory process that followed brought with it not only the challenges of building consensus among the various stakeholders but also the benefits of considering various opinions (cf. Burundi 2007).

4. By providing expertise (for example the LDC expert group) in the elaboration of the NAPAs, the UNFCCC improved the capacities of LDC professionals to address the climate change problem. Because it involved consultation of various stakeholders, it provided those participating in the elaboration of the NAPAs the opportunity for learning. The NAPA-process offered the LDCs, many of which are African, the possibilities to practice adaptation planning. Many of the countries' personnel who participated gained additional expertise (learning effect) on adaptation planning (Osman-Elasha / Downing 2007).

5. Through its bottom-up approach and the wide consultations, the NAPA-process provides an example of an inclusive policy formulation process to emulate (although, in some cases not all stakeholder categories were consulted due to limited funds).

6. Through meeting the costs of adaptation (see Box 13) by having mechanisms that provide funding for the implementation of adaptation projects and other activities to meet the conventions goals, in both developing and in particular in the LDCs, the Rio Conventions actively support adaptation to climate change. In that way, they contribute to building the resilience of the communities and countries where the projects are implemented.

7. The UNFCCC NAPAs give the LDCs the advantage of having already prepared proposals that can be presented to other development partners like NGOs, bilateral and multilateral donors for funding.

8. The Convention instruments provide a basis for mainstreaming climate change adaptation, desertification and biodiversity conservation into national development policies.

9. The synergies between these environmental concerns have led to harmonising legal frameworks for all the MEAs (for example Uganda NAP). This can improve the efficiency of adaptation projects.

Box 8: Mechanisms for funding adaptation to climate change in developing countries

Funding adaptation to climate change in developing countries is mainly through two sets of mechanisms. The official development assistance (ODA), which focuses on activities to reduce poverty and the dedicated multilateral adaptation funds that focus on climate change adaptation.

The Global Environment Facility (GEF) is designated to operate the financial mechanisms for the Rio Conventions. Besides funding activities aimed at combating desertification and biodiversity conservation, the GEF also funds adaptation measures or related activities through the following funding mechanisms established under the UNFCCC and the Kyoto Protocol:

1. The Global Environment Facility (GEF) Trust Fund finances the "incremental" costs of producing "global environmental benefits."
2. The Special Climate Change Fund (SCCF) funds support activities complementary to those funded by the GEF trust fund,
3. The LDC Fund (LDCF) supports the preparation and implementation of the NAPAs and other components of the LDC work program. To date, financial support has been provided for the preparation of 44 NAPAs and two global support projects. The total costs of these activities are around US$ 12 million.
4. The Adaptation Fund established under the Kyoto Protocol receives 2 percent of the Certified Emission Reduction (CERs) issued for projects of the Clean Development Mechanism (CDM) and funds from other sources. The Adaptation Fund will finance concrete adaptation projects in developing countries. Contrary to the other funds, the Adaptation Fund is supervised and managed by the Adaptation Fund Board (AFB). The Global Environment Facility (GEF) provides secretariat services to the AFB while the World Bank serves as trustee of the Adaptation Fund on an interim basis. According to the UNFCCC these interim institutional arrangements will be reviewed in 2011.

Sources: Mace 2005; McGray et al. 2007; UNFCCC 2009b – FCCC/KP/CMP/2008/11/Add.2.; Horstmann 2008; http://unfccc.int/cooperation_and_support/financial_mechanism/adaptation_fund/items/3659.php (accessed 11 Sept. 2009)

While some level of harmonisation may have been achieved, a more important goal is the actual planning and implementation of the conventions action plans at the national and local level. Thus synergy in implementation is crucial and this requires close cooperation among the MEA national focal points. Where this is inexistent, promoting synergy among MEAs during the NAPA implementation phase is important (UNFCCC 2005b). This would also require explicitly providing funds for the implementation of identified synergies.

Although, international and national policies provide the framing conditions for adaptation, actual services offered, whether by the government or the private sector, also shape the framing conditions for adaptation in smallholder agriculture. In the following the contributions of various services in enhancing the adaptation of smallholder agriculture to climate change are analysed.

Participatory approach is critical in elaborating projects but some of the prioritized projects beg for more explanation in their reporting. For example, what is the weight given to the problem of diffusion of technology in such cases like the development of drought resistant crops and seed varieties? Did the crop scientists participate in the NAPA process? How well could the farmers articulate their aversion to growing drought resistant seeds that are generally known for lower yields in the NAPA process and their reasons for this aversion? Developing drought resistant crops and seed varieties as an adaptation measure is well and just, but what lessons from past developments of drought resistant crops are we taking along with us as we develop these new seeds? That is the critical point that needs to be addressed in such adaptation projects. It also sends confusing messages considering that ICRISAT and CIMMYT (two research institutions that work on the major grains of the drylands) suggest that drought-tolerant varieties are already developed and only need to be diffused. Such prioritized projects and the way they are presented hint that we may not be learning from past mistakes. It may also be that the proponents plan to do so but this information is not explicit in the reporting format of the NAPA documentations.

Finally, a fundamental question that needs to be posed is this: Can the three conventions not be adequately addressed at the national level within a common framework of action programmes at that level? Instead of having NAPA, NAPs and NBSAPs, will it not be enough to have one action programme instead of spending resources to ensure that the synergies are addressed? The process has been piecemeal: first the NBSAPs, then the NAPs, and then the NAPAs. Then, along the way, one realises there are synergies that need to be addressed. A more viable way would be to take the synergies as the departure point and address these environmental problems together in one national action plan.

5.2 Climate monitoring and early warning systems

Information on climate can inform the design of appropriate adaptation policies, support adaptation planning and choice of strategies provided climate data is of adequate quantity and quality. With information on impending drought or storms, farmers can adapt their strategies accordingly. In this way climate monitoring and Early Warning Systems (EWS) contribute to better responses to climate change.

Data

Climate services comprise climate data collection, the monitoring, prediction and dissemination of climate information. Climate-based EWS comprises the assessment of risk, the technical warning service, the communication needs, and the preparedness of those at risk (ISDR 2006). An effective EWS thus provides information on impending climatic hazards early enough to enable actors to take action to prevent injury and loss of life as well as to reduce socio-economic impacts.

Various meteorological departments and regional climate prediction centres (for example the Intergovernmental Authority on Development (IGAD) Climate Prediction and Application Centre – ICPAC) in Eastern Africa focus on broad ranging issues from seasonal forecasts, attributing climate change and monitoring climate.

From a cross-scale perspective, climate hazards like floods affect whole river basins. Often, heavy rainfall in one part of the basin that belongs to another country determines the development of floods in neighbouring countries (Hellmuth et al. 2007). In such cases, *regional cooperation* in climate monitoring and predictions is necessary (Hellmuth et al. 2007). For example, the African Centre of Meteorological Application for Development (ACMAD) provides weather and climate information as well as capacity building for the National Meteorological and Hydrological Services (NMHS) of its member states. At sub-continental levels the Southern African Development Community (SADC) Southern African Regional Climate Outlook Forum (SARCOF) provides various climate services to its member states. The IGAD-ICPAC covering the Greater Horn of Africa regions provides the IGAD subregion with weather and climate advisories and early warnings on extreme climate events. In response to the coarse spatial and temporal resolution of climate change scenarios derived from GCM outputs, ICPAC is downscaling GCM outputs to improve their resolution and provide information for regional level adaptations (Oludhe 2009).

At national and sub-national levels, the National Meteorological and Hydrological services (NMHS) are the major providers of climate services and act as a link to the World Meteorological Organisation (WMO). However, while climate (specifically, droughts and floods) is mentioned in national agricultural policies, it is almost absent in most other national policies (Eriksen 2000; Ifejika Speranza 2006b). Yet, these institutions provide valuable services to the farmers but face several limitations (Box 13) as will be discussed below.

Challenges

Some of the major challenges to monitoring and forecasting weather and climate are listed in Box 13. While some progress in climate monitoring and predictions were made in the last decades, much room for improvement remains (Patt / Ogallo / Hellmuth 2007). Limitations in climate data, in sharing data, in the dissemination and use of climate information have restricted the benefits that Africa can derive from current climate science (IRI 2006; Hellmuth et al. 2007).

Climate data from developing countries is often *limited, in terms of both quantity* and quality. Many African governments have failed to invest in equipment and trained personnel resulting in insufficient climate data. The density of meteorological stations in Africa is estimated to be eight times lower than the minimum recommended by the World Meteorological Organization (WMO) causing a gap in global climate data (Giles 2005). In addition, the uneven distribution of stations, especially in the rural remote areas where climate information is needed most (cf. Hellmuth et al. 2007) increases this deficit. As a result, missing climate data, which cannot be easily interpolated, are common. Thus available data in many regions cannot fully reflect current climate variability. Often, satellite data is used to compensate for missing data but the limited technological development in Africa restricts the use of this data. Hence, the scarcity of data constrains the uptake of weather-based index insurance in Malawi (Hellmuth et al. 2007) and reduces *the accuracy of Early Warning Systems (EWS) and climate forecasts.* In recognition of this limiting condition, several SSA countries in the framework of the NAPA projects prioritise strengthening their climate services (UNFCCC 2008d).

Limited climate data affects the credibility of the climate information and restricts its use for decision-making. Hence, the *spatial and temporal accuracy* of weather forecast itself needs to be improved. Seasonal forecasts are available at *coarse spatio-temporal scale* but farmers are more interested in when the rains would start and end, and in the dry spells during the season (O'Brien et al. 2000; Ingram / Roncoli / Kirshen 2002; Luseno et al. 2003). Ziervogel et al. (2005) analysed the impact of using seasonal forecasts among smallholder farmers in Lesotho and found that unless the forecast accuracy is 60–70 percent or above, positive impacts from using forecasts are unlikely. The authors also found that the level of forecast accuracy determines the level of trust, the lack of which leads to longer adoption timescales for forecast use. Thus, more investments in data and human resources are required to improve accuracy. A viable way of improving efficiency of such investments is to define areas of similar weather patterns and to reduce the number of stations in such homogenous areas while increasing weather stations in pockets that reflect different weather patterns from their surrounding areas. This will improve the efficiency of investments in weather stations and accuracy of generated data.

Improving Early Warning Systems (EWS) is not only an adaptation to climate change but also crucial for the success of other adaptation measures in agriculture. EWS can be primarily for weather monitoring and predictions (as is the case of Meteorological departments), but there are also combined forms that model the potential effects of forecasts on food production (e. g. USAID Famine Early Warning Systems Network –

Box 9:	**Challenges to climate monitoring and prediction for informing adaptation**
Some of the major challenges to monitoring and forecasting for informing adaptation are the:	
1.	Lack of historical data with a few exceptions, limiting the use of climate data to develop adaptation instruments like index-based micro-insurance.
2.	Coarse spatial and temporal resolution of the forecasts.
3.	Sparse distribution of stations, especially in the marginal areas (also areas of low rainfall).
4.	Limited interaction between the producers and users of climate information in some countries. The inadequate knowledge of the public about climatic hazards, climate variability and climate change.
5.	Lack of calibration for point rainfall estimates to enable real-time monitoring.
6.	Inadequate communication facilities.
7.	Limited resources for research (special equipment and computers for climate monitoring, diagnosis and prediction).
8.	Lack of resources for further training of the available skilled personnel.
9.	Low number of staff.
10.	Mismanagement and abuse of climate information.
11.	Timely availability of climate products and services from global climate centres.
Sources:	Ogallo 2000; Boulahya et al. 2005

FEWS-NET in Africa). FEWS-NET uses the climate outlook of the National Meteorological Services as one input variable to develop seasonal food security outlooks, monitor food conditions physically like in the Drought EWS and the Livestock EWS in Kenya.

Of importance to agriculture is also the dissemination of seasonal climate outlooks (seasonal climate predictions or seasonal-averaged weather predictions) that provide indication of rainfall 3 to 6 months in advance and short-term weather forecasts of impending climatic hazards.

However, forecasts contain some degree of uncertainty that needs to be communicated to the farmers. Farmers need to know that when the Meteorological Department forecasts early or late rains that the rains might turn out to be not so early or late in the farmers' judgements. Thus, to improve weather forecasts and their dissemination to farmers, Meteorological Departments and scientists must understand the cultural context of the target audiences, communicate in a "language" that farmers understand and remind farmers that the forecasts are probabilities so that farmers respond to the weather forecasts bearing these limitations in mind (Kenya, Ifejika Speranza 2006b). In other areas, pastoralists in the Horn of Africa were found to comprehend the probabilistic nature of forecasts (Luseno et al. 2003). The authors argue that building confidence in forecasting, improving forecast skill or dissemination are of lesser priority than *promoting the economic advancement* of pastoralists so they are able to use current forecasts to adjust their resource allocations (migrating to grazing grounds) before the forecasts becomes reality. For farmers, access to seasonal forecasts may help maintain production, but addressing other production constraints can help farmers benefit more from the forecasts (Ingram / Roncoli / Kirshen 2002).

To ensure that the farmers get the weather information in ways that inform farming decisions means tailoring the information to particular regions and target groups. Seasonal forecast information is oriented more toward crop cultivation than to pastoral production systems (Luseno et al. 2003). Hence, the importance of targeting – targeting particular regions addresses the problem of adapting the spatial scale to fit the audience. Adapting it to the farmers in the region means answering questions like, what do the forecasts mean for the maize crop, for the cowpea crop, for millet, or for sorghum? Adapting it temporally means providing answers to farming practices, on timing of planting, and on crop-specific measures.

Since climate information is one part of the set of information needed in agriculture, Hellmuth et al. (2007) suggest that climate information is most effective if *integrated with other information* into a decision-making framework. This would mean involving other actors like extension officers and the media in disseminating early warning information and advising farmers accordingly. Since the media are mostly contacted after a disaster has occurred, a behaviour shift is needed from a rather reactive approach to managing climate risks to a more proactive approach, that involves preparedness measures the dissemination of early warning information and advising farmers accordingly.

The *periodicity of forecasts* needs to be adapted to the periods when climate information is critical – during sowing, dry spells during critical periods in crop growth (Amissah-Arthur 2003; Ziervogel 2004). Due to limitations in data and human resources, many African meteorological departments cannot provide weather forecasts on a temporal scale needed by the farmers. On the other hand, there have been cases where farmers were aware of forecasted drought or abundant rains but very few modified their farming practices in response. Those that intended to modify their practices could not do so due to limited financial and labour resources (in Kenya, Ifejika Speranza 2006b). Others that had the information but did not change their strategies are wary of forecasts because they have experienced forecasts not to come true.

However, studies show that although a larger proportion of farmers may be aware of climate hazards, increased variability and climate change, very few actually change their practices to fit the changing climatic conditions. Limited access to credit, lack of access to climate information and limited adaptation options are major reasons for not translating perception into action (cf. Ifejika Speranza 2006b).

The inability of climate forecasts to influence farmers' decisions depends in part on the lack of fit between farmers' needs for climate information and the forecasted information. Yet, Phillips et al. (2002) observed that farmers in Zimbabwe reduce area planted in years with forecasts of below normal rainfall, and increase area when they expect rainfall to be optimal for yields to avoid losses. Thus, *production volatility may potentially increase* with the use of seasonal climate forecasts and need to be addressed.

Contributions to resilience to climate change:

The contributions of climate information to building resilience at the community level have been recognised as being crucial to reducing climate-related risks (Hellmuth et al. 2007). However, considering the limitations of current climate services discussed in this section, the question of how they *contribute to the resilience* of smallholder agriculture, in terms of building or maintaining buffer capacity, self-organisation and capacity for learning (see Chapter 3.5), is a difficult one to answer. This is more so considering that the target is the smallholder and not the extension officers. Perhaps one way of reaching the smallholders is to also improve the outreach to extension officers who are often in direct contact with the smallholders. The collection of climate data and the monitoring of climate provide information on which adaptations can be based. In this sense climate services contribute to the buffer capacity of their audience in that they give actors time to adapt their strategies. However, in terms of self-organisation, the high dependence on external foreign resources – financially, technologically and in terms of human capital, hints at a low level of buffer capacity and self-organisation. Similarly, the continuing disasters caused by droughts, floods and cyclones suggest that adaptive learning, feedback and coordination among actors needs to be improved both horizontally and vertically.

5.3 Crop research and improvement

Crop research is crucial for adaptation to climate change because climate change will bring about changes in certain areas, in the length of growing seasons, increased droughts and periodic water logging, increased temperature (heat) and salinity as well as new pests and diseases. These changes will increase the stresses on crops.

Crop research institutes such as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Institute of Tropical Agriculture (IITA), the West African Rice Development Association (WARDA; newly renamed Africa Rice Center), and the International Maize and Wheat Improvement Center (CIMMYT) have already developed improved varieties that address most of the above challenges. ICRISAT (2009) shows that predicted temperature increases have greater negative impacts on crop production than relatively small (plus or minus 10 percent) changes in rainfall. Therefore, crop research needs to breed crops that respond to a range of production environments, for instance, crops that still produce under drought and temporary flooding conditions. This would serve better than crops that are adapted to specific climate conditions since uncertainty about future climate provides no specific information on the localities and time periods to expect certain climate impacts. Research on improving livestock breeds, for example dietary changes to reduce methane emissions, are also essential (Upadhyaya / Gowda / Sastry 2008; ICRISAT 2009).

In the following, the resilient characteristics of improved varieties of same major staples are discussed.

Dryland crops – pearl millet, sorghum, chickpea, groundnut and pigeon pea

Various research centres, for example ICRISAT and the CIMMYT with National Research Centres (NARS) are developing new crop varieties and hybrids that are more drought tolerant than previously existing varieties and also do well under good rainfall conditions.

The crops on which ICRISAT works – pearl millet, sorghum, chickpea, groundnut and pigeon pea – are by themselves hardy and drought tolerant. According to ICRISAT these crops have several natural evolutionary advantages for the global warming scenarios. Thus areas that are becoming dryer can already adopt these crops.

ICRISAT also has a genetic resources unit "for assembly, characterization, evaluation, maintenance, conservation, documentation and distribution of germplasm of sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), chickpea (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), groundnut (*Arachis hypogaea*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), barnyard millet (*Echinocloa crus-galli*), kodo millet (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*) and proso millet (*Panicum miliaceum*)" (Upadhyaya / Gowda / Sastry 2008, 3). These collections contain a wide range of crop genetic diversity that can be used in developing improved varieties that address the impacts of climate change as well as new pests and diseases

ICRISAT reports that the improved crops it developed with its partners,

> *"are able to withstand severe droughts, tolerate higher temperatures and mature early, enabling the farmers to be ready to meet the challenges of climate change. Both pearl millet and sorghum have high levels of salinity tolerance, and hence are better adapted to areas that are becoming saline due to global warming. Some of the pearl millet varieties and hybrids, developed from ICRISAT's germplasm, are able to flower and set seeds at temperatures more than 42 degrees centigrade, in areas such as Western Rajasthan and Gujarat in India. Improved*

> *sorghum lines have also been developed that are capable of producing good yields in temperatures of 42 degrees C, and have stay-green traits that can enhance terminal drought tolerance"* (ICRISAT 2009).

A bonus of these crops is that they already grow in marginal lands and can serve for areas that become marginal due to climate change. Since climate change will modify the length of the growing period across the semi-arid tropics of Asia and sub-Saharan Africa, ICRISAT suggests that re-targeting and re-deploying the existing crop varieties can address this problem. By climate-proofing these crops ICRISAT and its partners make the crops able to withstand more adverse environmental conditions (warmer temperatures) than is currently known in the drylands.

In a position paper presented to the UNFCCC, ICRISAT (2009, 1) argues that:

> *"The impact of climate change on the yields under low input agriculture is likely to be minimal as other factors will continue to provide the overriding constraints to crop growth and yield.*
>
> *The adoption of currently recommended improved crop, soil and water management practices, even under climate change, will result in substantially higher yields than farmers are currently obtaining in their low input systems.*
>
> *The adaptation of better 'temperature-adapted' varieties could result in the almost complete mitigation of climate change effects that result from temperature increases."*

The above arguments suggest that farmers could improve yields by adopting simple and affordable recommendations in variety choice and in crop, soil and water management practices. Thus, government with support from development cooperation needs to invest more resources in promoting these practices which many smallholders in SSA have not adopted.

Information available hints that ICRISAT has solutions to many prioritised NAPA projects that aims to develop improved varieties of crops to withstand the potential impacts of climate change (for example Burundi, Comoros, Eritrea, Mauritania and Zambia).

Maize

To ensure food security, maize which is the most important cereal in Africa, needs to be adapted to climate change, for example by becoming drought tolerant. CIMMYT and IITA are drawing on the global maize genetic resources to develop drought tolerant maize. In alliance with national research and extension programmes, local seed companies, and non-governmental organizations, CIMMYT / IITA (2009) aim to disseminate drought tolerant maize faster to the farmers. The CIMMYT and the IITA report that more than 50 new drought-tolerant varieties and hybrids have been developed and released for dissemination by private seed companies, national agencies and non-governmental organizations.

> *"The new varieties yield 20–50 percent more than others under drought. The Drought-Tolerant Maize for Africa (DTMA) Initiative of the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA) expects to provide over the next decade 30–40 million farmers with improved maize varieties that will help to boost maize productivity on small farms by 20–30 percent. It is working in 13 African countries where maize is particularly important"* (CIMMYT / IITA 2009).

Improved crops are of no use if the farmers cannot access them as many farmers continue to grow very old maize varieties simply because they have no access to information on newer, better performing varieties. To address this problem, information about drought tolerant maize varieties are spread on radio, television, brochures, demonstration trials, field days, and farmer field schools to reach many farmers.

Despite the availability of improved varieties, many farmers do not have access to them. Thus, improving access to seeds is important for adaptation to climate change. The CIYMMT and IITA focuses on getting the seed to farmers faster through capacity building and partnerships with national agencies for rapid farmer-participatory varietal testing and release and through informing farmers, extension officers and NGO groups of the new varieties.

Through developing drought tolerant open pollinated varieties (OPVs) and hybrids adapted to sub-Saharan Africa (SSA), the institutions address the various needs of African farmers. According to the institutions, "to be useful to farmers in SSA, drought tolerance needs to be built into locally adapted, high-yielding varieties that do well under farmers' conditions and are popular with seed producers and consumers".

Improving the policy environment for disseminating seeds so that seeds are traded across borders is also a strategy followed by the research institutions to ensure that the improved seeds get to the farmers. Consequently, plans are underway by national governments to harmonize regional seed regulations with the aim of improving rates of variety release, lower costs in dealing with regulatory authorities, increase trade in seed of improved varieties and, ultimately, adoption by farmers (CIMMYT / IITA 2009).

Through building up indigenous seed enterprises CIMMYT/IITA aim to reach out to farmers in drought-prone regions with inadequate access to seeds. Supporting small seed enterprises is expected to catalyze their growth and sustainability in meeting farmers' seed requirements, many of whom are so far inadequately supplied.

Rice – The New Rice for Africa (NERICA)

The NERICA developed by the West African Rice Development Association (WARDA; newly renamed Africa Rice Center) targets upland or dryland rice farmers. This improved variety addresses many challenges associated with climate change and agriculture in Africa: the NERICA varieties have higher yields, higher protein content, grow faster, resists pests, tolerate drought, infertile soils and low input conditions better than the African *Oryza glaberrima* and Asian *Oryza sativa* rice varieties from which it was derived.

According to Kormawa (2008, 127) "WARDA member countries together account for nearly 17 percent of total world rice imports, amounting to an annual USD 1.4 billion in scarce foreign exchange". Thus NERICA has the potential to contribute to food security and reduce the dependence of African countries on rice imports. However, adoption is still low due to insufficient dissemination, training, and extension (Kijima 2008; WARDA 2008).

Cassava

Cassava is a drought tolerant crop that can address the impacts of climate change in the SSA context – it grows on marginal lands, is drought-tolerant, early maturing, high yielding, can store for a long period and has high market integration. Cassava is one of the few staple crops where Africa accounts for slightly more than half of total world production, with Nigeria being the world's largest producer. The IITA has been instrumental in developing such improved breeds that also have low cyanide content. Since cassava grows in marginal lands, there are potentials to introduce it to the drier regions of SSA that are chronically food insecure. World Bank (2007a, 160) argues that since cassava is "a staple of the poor, the impacts of productivity gains are especially pro-poor". However, governments need to spend resources to promote exposure to the crop and its adoption.

Various other agricultural research centres like the – The World Vegetable Center – Regional Center for Africa, the International Potato Center (CIP) regional programme for sub-Saharan Africa have improved varieties of vegetables, potatoes and sweet potatoes that can increase agricultural production if widely adopted. However, they also face similar challenges like the other crops in their diffusion and adoption.

The foregoing indicates that improved crop technologies that address many climate change impacts on crops already exist but with modest farmer exposure to the technologies. The existence of improved crops is good news that needs to be spread to the relevant actors. By maintaining the genetic resource units, the research centres increase the buffer capacity of cropping systems. Through their inclusive approach in diffusion they increase their outreach and contribute to the resilience of smallholder farming. However, the limitations in diffusion and farmer adoption compared to their potentials hint that governments need to provide more funding for extension and to improve the socio-economic conditions framing production conditions and value-addition.

5.4 Agricultural extension services and outreach

Agricultural extension services are expected to continue to play a key role in agricultural development in Africa through the diffusion of innovations and by extension in adaptation to climate change in the field of agriculture. The lack of a functioning market for agricultural information (apart from private extension services for high-value products) indicates that extension services for the food crops sector will retain a largely public good character. This public-good nature of extension services reflects its importance for agricultural development (Anderson 2007; World Bank 2007a). Providing services that facilitate adaptation to climate change adds to the range of tasks (advice on cropping techniques, post-harvest management, nutrition, marketing, emerging products etc.) that extension services currently address. However, in order to meet the demands associated with adaptation to climate change extension services need to improve their efficiency and effectiveness. Since the *lack of information* continues to be an important constraint to agricultural development and to adaptation to climate change in particular (Gautam 2000; World Bank 2007a), extension services will need to acquire new knowledge on how climate change impacts agriculture and rural livelihoods.

To be able to improve efficiency of services, the working conditions of extension officers need to be improved. Extension services chronically lack resources (e. g. human, budget allocations, and transport) to carry out outreach to the farmers. This is even more difficult in some agro-pastoral and pastoral areas where settlements are far apart. The poor working conditions of the extension agents (Belay / Abebaw 2004) do not augur well for adaptation to climate change. Low income, work overload, inadequate transport facilities, limited resources, little or no incentives – relative to the NGO-extension sector means that many extension officers who have received regular in-service training become more attractive for the NGO-sectors and as a consequence get employed in the NGO-sector with better remunerations (cf. Hanyani-Mlambo 2002). In that way, the government-run extension services lose their stores of knowledge, an important aspect for adaptation.

Bureaucracy and long hierarchical lines of communication delay communication process and weaken linkages within and between organisations (Hanyani-Mlambo 2002). In many SSA countries, ministries at the headquarters, which are miles away from the local areas, or district headquarters regulate the extension services. This distance is not only in geographical terms but also in terms of information exchange and dissemination, quickness to act, and the freedom to adapt services without consulting the top. Because extension is mostly top-down, it focuses on the government agenda, whose policies mainly target cash crops and single staples. This does not augur well for farm-level resilience where mixed-cropping is the norm. Thus, there is a need to extend focus beyond input distribution schemes for major crops like maize to include initiatives on diversifying smallholder cropping patterns by including non-maize staple inputs (Mano /

Isaacson / Dardel 2003; Ifejika Speranza 2006b). In view of the limitations of the dominant top-down approach, a participatory extension approach (i. e. scientists, extension staff and smallholders) in which the site-specific knowledge of the farmers is combined with the external knowledge of the scientists and extension personnel can enhance the efficiency of extension through group learning and action (cf. Belay / Abebaw 2004).

In order to effectively provide services that support adaptation, long-term field presence and field knowledge of extension officers is necessary. This will allow extension officers to follow up a project from the beginning to the end and to evaluate the success or failure factors (Aw / Diemer 2005). However, the model of public extension services in many countries is such that extension officers cannot serve in only one location. Government often transfers them from one part of the country to another, leading to loss of knowledge for the local communities and delays in promoting certain adaptations, as the new officers first have to get acquainted with their new locations before advising farmers. According to Hanyani-Mlambo (2002, 24), in Zimbabwe

> *"the policy of frequent lateral transfers for field staff and the resultant high turnover of extension agents present one of the major causes of rather weak institutional linkages. The high turnover has led to the failure of extension personnel in some organizations to understand the local context thoroughly, the failure of organizations to gain each other's trust (a failure to enter each others' circles of confidence) and, ultimately, a failure to establish sustainable linkages among extension service providers".*

This scenario is similar for many SSA countries and does not augur well for adaptation as "stores of knowledge" become lost. Thus, this model of extension service needs to be reformed. A complementary approach would be (in addition to the classical extension employment model) to recruit locals and train them as auxiliary extension workers. That way the knowledge remains with the people when government transfers the extension officers to other locations.

Some climate change impacts will likely be similar to the impacts of climate variability and extreme climate events as they are known today. However, the likely temporal and geographical shift in weather and climate characteristics as a result of climate change implies that extension services need to have the ability to identify and manage the opportunities and constraints that climate change pose for natural resources management and agricultural production. To be able to facilitate adaptation, *extension personnel need to be trained* in the various dimensions of adaptation to climate change. Although, early or late onsets, dry spells and droughts as well as wet spells and floods are long recognised constraints in agriculture, climate change is not yet an issue in many public extension departments in Africa. In order to address this *perception- and knowledge gap*, various new adaptation and development programmes have an extension component whereby they focus on increasing the awareness of extension personnel on climate change and related issues (cf. World Bank 2008a; CIAT 2009). Because government resources are limited, ongoing efforts to train extension personnel on emerging issues like climate change depend significantly on donor funding.

Climate change and its associated uncertainties implies that extension services need to regularly access new knowledge and extend it in an adequate and timely manner to the farmers. It also entails harnessing the local knowledge of the farmers who constantly observe their environment and using the two sources of knowledge (extension and farmers) to improve adaptation practices. However, in many SSA countries there is no regular in-service training for extension officers. The low levels of education of some extension officers adversely affect the quality of extension services (Belay / Abebaw 2004). Yet to comprehend and communicate climate change, extension officers need regular training to upgrade their skills and be able to advice and work together with smallholders on how to adapt to climate change. As training models differ from country to country, a context-specific review of the curriculum to integrate climate change training into agriculture-related fields is crucial (cf. Chakeredza et al. 2009).

Since climate change will bring about the development or spread of improved technologies that enhance resource use efficiency, extension needs to take the opportunity to use and disseminate the new technologies. However, in a project on improving internet access to world scientific literature in Ghana, the International Institute for Communication and Development (IICD 2009), report that while the service became popular with researchers and students, surveys showed minimal use by extension services and farmers.

Yet, the capacity to learn contributes to resilience against risks, those arising from climate included, hence there is need to establish cross-scale and multi-actor feedback mechanisms currently lacking in extension services. While it is institutionalised that extension agents prepare regular reports for their superiors, it is not institutionalised that superiors in the headquarters send regular reports to the field level. Even when they do, the various levels of management filter the information before it reaches the field level.

Furthermore, smallholders have very marginal contribution in designing and formulating extension activities and should be able to determine the extensions services that they need (Belay / Abebaw 2004). In order to improve efficiency of public spending, more attention must be given to demand-led extension as with the advance of communication tools; farmers in many areas are no longer as isolated from innovations as before. In areas with access to various sources of agricultural information, more emphasis should be given to farmer-led approaches such as farmer's associations, co-operatives and self-help groups. However, demand-driven extension only succeeds where the crops have market value (cf. Aw / Diemer 2005) and the extension crop does not compete for farm resources with other farm enterprise like livestock which farmers in the drylands value more than crops (Ifejika Speranza 2006b).

Thus collaboration and coordination between public and private extension is another way of increasing efficiency of extension services. Considering that many private extension services are externally driven, collaboration of public extension with private extension services ensures that the knowledge generated during a project remains within the institutional structure in the country and locality. Involving local research institutions is also another sustainable way of building capacity yet many externally funded projects are implemented without their involvement. The implications are that knowledge gained through such projects are difficult to access by local experts and remains elusive for integration into existing local knowledge. Further, the collaboration between various Ministries in change of natural resources management, for example Ministry of Water and Irrigation, Ministry of Agriculture, Ministry of Livestock, needs to be improved. Often these ministries work on similar issues with little or no coordination.

The duplication of duties among organisations is thus a key issue. This arises from the plurality of extension services, their different administrative structures and organisations, varying institutional mandates and organisational cultures, as well as compartmentalisation of duties and responsibilities. Considering also that farmers get information from various sources, coordinating activities with other extension service providers (private agro-technology companies, NGOs, research institutions, credit institutions, farmer organisations, other government ministries) can increase efficiency in adaptation to climate change. Hanyani-Mlambo (2002) reports that in Zimbabwe, pluralism and lack of coordination among extension service providers at the grassroots level are causing lower outputs and confusion at the farmers' expense. Similar conditions abound in Kenya (pers. communication with extension officers in March 2009). This calls for coordination and collaboration to improve effectiveness and avoid the duplication and wastage of scarce resources. Collaboration in response to the needs of the organisations involved (demand-driven) rather than donor-driven collaboration is essential. Hanyani-Mlambo (2002) recommends a thorough understanding of institutional and organizational politics in order to establish effective linkages. Since collaboration needs coordination, donors need to consider funding coordination platforms. However, there are mixed results from establishing organizations/institutions for coordination purposes: some have failed to fulfil this role while others have succeeded (cf. Hanyani-Mlambo 2002, 25). The author notes that formal institutional linkages and informal networks characterized by joint planning, joint implementation (including field visits), division of tasks, and sharing of information and resources tend to be more pronounced at the district and local levels (the operational levels) than at the head office or provincial levels. Few formal linkages exist at the administrative (head office) level.

Depending on context, *multiple providers of extension* may be a viable option to expand and improve extension services (see Box 13) but this may compromise extension services to marginal areas. An option could be to leave the cash crop extension sector to the private sector because cash crop farmers are willing (able) to pay for extension services. They also prefer other advisory services to the public extension (for example Zimbabwe; Hanyani-Mlambo 2002). Another option is to *incorporate smallholders to offer extension services*. In this sense, it is important to change the attitudes of some extension agents, who perceive that they are more knowledgeable than smallholders (cf. Belay / Abebaw 2004). The advantage of doing so is that knowledge (internal as from the farmers and

Box 10: The National Smallholder Farmers' Association of Malawi
An example of a farmer based organisation that offers extension services is the National Smallholder Farmers' Association of Malawi (NASFAM). Its membership comprises close to 100,000 Malawian smallholders, most of whom farm less than one hectare of land. It engages in policy advocacy and outreach, offers information services, on HIV/AIDS, gender and other cross-cutting issues. It offers training services that cover various agronomic issues, from production to post-harvest management and marketing. It also has its own supply outlet for seeds and fertiliser primarily for its members. According to NASFAM (2009), the realisation that its dependence on government extension was neither viable nor practical led it to engage in the provision of its own extension services. The government's policy on pluralistic extension system that is demand driven and allows private sector participation made this choice possible. The organisation together with the World Bank and national partners has improved access to financial services in the rural areas and pioneered index-based weather insurance for farmers in Malawi. Worthy to note is that the NASFAM has its roots in the 1994 USAID-funded Smallholder Agribusiness Development Project. USAID has remained its largest donor-supporter since that time, and is working with NASFAM on improving market linkages and developing information systems under a three-year co-operative grant. NASFAM also collaborates with and receives support from the Norwegian Agency for Development Cooperation (NORAD).
Source: NASFAM 2009

external as gained through extension work) remains in the locality. This can contribute to long-term positive effects as the knowledge remains with the people, contrary to current extension models whereby the extension officers serve for a few years in one area and are posted / transferred sometimes to a totally different social-ecological setting. To facilitate continuity in place-based knowledge accumulation, farmer groups that provide extension services seem promising. In Kenya, an example is the common interest groups approach, used to promote exchange among farmers with similar enterprises. Farmer field schools also seem to offer a more effective way to reach the farmers than other previously tried extension approaches, yet the challenge is to train the facilitator-farmers to ensure effective dissemination.

To be able to carry out extension effectively, there is a need to *improve efficiency of public spending on extension* in order to have adequate resources to deal with the problems arising from climate change. In the past, policy reforms resulted in removal of subsidies for agricultural inputs and reduced public sector funding leading among others to limiting/curtailing the spheres of activity of the public extension services in some African countries (Amanor / Farrington 1991; Woodhouse 1994). Yet, Gautam (2000) in an empirical assessment of the impact of Kenya's World Bank-financed National Extension Projects that ran from 1983 to 1998 found that an overwhelming proportion (80 percent) of the operational budget was consumed by staff salaries. Hence depending on context and available options, the radio can be used to disseminate certain extension services.

However, Maddison (2006) points out that the differences in climate change from location to location limits the extent to which costs can be saved by combining extension services. This means that a mix of extension services is required – those that are user and area specific, those that require face-to-face communication, and those that can be combined and transmitted through the mass media.

Extension services in the face of climate change will require even more targeting or tailoring than before. This is because apart from the fact that smallholders are a heterogeneous group in terms of income and gender, the various crops grown have varying vulnerabilities to climate change (increasing drought intensities and frequencies, heat conditions) and thus, need to be given relevant attention. The aim of targeting is to ensure that the most vulnerable to climate change – subsistence farmers, women and the poor, get the right services and are thereby empowered. However, extension tends to promote uniform packages despite its heterogeneous audience and to work more closely with higher income farmers and pay little attention to the marginal areas and resource poor farmers (e. g. Kenya: Gautam 2000; Malawi: Harrigan 2003; Ethiopia: Belay / Abebaw 2004; Biratu 2008).

The role of extension in brokering knowledge and information between farmers and other actors in the agricultural sector means that extension services have to evaluate the impacts of their services on the resilience of the farmers, which they actually aim to build. Extension services tend to create and/or increase the wealth gap between farming households (Biratu 2008). Furthermore, many SSA countries follow the global trend of adopting high yielding varieties that better suit high input agriculture, and thereby neglect the traditional varieties, which farmers have used for generations (Asfaw 2000). Adopting improved varieties on the advice of extension, has led to increased productivity but also to loss in crop species diversity (landraces) in Ethiopia (Biratu 2008). According to Biratu (2008, 43 ff.) the impact of extension is direct replacement of traditional varieties by improved varieties, for crop types that are under extension, and competition for farm land for crop types that are not under extension coverage. Yet to achieve resilience and sustainability, conserving and maintaining crop diversity is crucial because it limits widespread adverse impacts of climate change, as different varieties are drought-tolerant to different degrees. Bringing crop diversity into balance (trade-offs) with increasing productivity is thus a challenge to researchers and extension services.

Contributions to resilience to climate change:

Based on the resilience check developed in Chapter 3, Table 9 shows the various ways that extension services build the resilience of smallholders to cope with and adapt to climate change. The assessments in Table 9 on which the following arguments are based, are derived from literature, but are not comprehensive. They are thus generic and would require field work to address the contextual specificity of a study area.

Contributions to ecological resilience

- Farmers use information and advice from the extension services to improve their land and resources management strategies, which often result in improved soil fertility and higher yields. Thus, farmers derive benefits from the extension services and through use of this information protect the environment from soil erosion and degradation. In this way, extension services contribute to increasing the resilience of smallholder farming systems to climate change impacts.

Table 9: A resilience check of support services: Assessing the contributions of extension services to the resilience of smallholder agriculture to climate variability and change

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
		In what ways and how much does the service offered in respect to an adaptation …			
Buffer capacity (robustness to uncertainty)	Spheres of action	Increase livelihood-/ activity options?	VH	VH	H
	Human capital	Promote human capital (endowments)?	VH	H	H
	Access (rights)	Promote entitlements (access)?	NA	NA	NA
	Income	Improve incomes?	NA	H	NA
	Climate protection	Promote climate protection?	H	NA	M
	Site-specific knowledge	Require or use site-specific knowledge?	VH	H	VH
	Incentives	Promote (at least not hinder) the adaptation option (incentives)?	H	M	H
	Diversity	Promote diversification or diversity?	H	H	H

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 9 continued

Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
		In what ways and how much does the service offered in respect to an adaptation …			
Buffer capacity (robustness to uncertainty)	Stewardship	encourage stewardship (in contrast to exploitation/mining resources) rather than just management?	VH	NA	M
	Environmental protection	benefit the environment?	H	NA	H
Self-organisation	Local resources use	use locally available resources?	H	M	M
	Cooperation and networks	promote cooperation and networks among farmers?	H	H	H
	Farm resources use	How much can/does the farmer relies on own resources in using/ practising the services (e. g. advice, tools) provided?	H	H	H

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 9 continued					
Components of Resilience	**Indicators**	**Resilience check**	**Ecological**	**Economic**	**Social**
Self-orga-nisation	Farmer knowledge	In what ways and how much does the farmer rely on own knowledge in practicing the adaptation?	M	M	M
	Flexibility	In what ways and how much are farmers flexible in using the services provided (e. g. sequencing of farm activities like farm preparation, planting/ sowing, spraying, and weeding)?	H	H	H
Adaptive capacity	Knowledge combination	In what ways and how much do the services support/provide incentives for farmers to combine different sources of knowledge on an adaptation?	VH	H	VH

Source: Based on literature / own design
Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 9 continued					
Adaptive capacity		**In what ways and how much does the service promote/provide incentives**			
	Feedback among stakeholders	for feedback among various stakeholders?	H	H	H
	Feedback among peers	among farmers?	VH	VH	VH
	Feedback farmer-extension	between farmers and extension officers?	VH	VH	VH
	Feedback farmer-policy-makers	between farmers and policy makers?	L	L	L
	Feedback extension-policy-makers	between extension and policy makers?	L	L	L
	Feedback farmers-researchers	between farmers and researchers?	H	H	H
	Power differentials	In what ways and how much does the service narrow power differentials?	M	L	L

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Table 9 continued

Components of Resilience	Indicators	Resilience check	Ecological	Economic	Social
Adaptive capacity	Local ecological knowledge	In what ways and how much does the service build on or transmit local ecological knowledge?	M	NA	M
Other adaptation criteria					
Efficiency	Costs-benefits (Market values)	How favourable is the cost-benefit ratio of the service provided to the farmer in respect to the adaptation?	H	H	H
	Costs-benefits (Non-market values)	How favourable are the social costs relative to the benefits of supporting farmers to practice various adaptation options?	NA	NA	M
	Right timing of adaptation	Is the timing of the services with respect to the adaptation practice right?	H	H	H
Gender	Gender positive / negative	In what ways and how much does the service reduce existing gender inequalities?	VH	M	M

Source: Based on literature / own design

Legend: NA: Not Applicable; N: None; VL: Very Low; L: Low; M: Moderate; H: High; VH: Very High

Contributions to economic resilience

- The extension services promote the spread of farmer-based innovations, thereby empowering farmers. For example, through farmer-exchange visits, farmers observe the adaptations practised by fellow farmers first hand and are more likely to adopt them. Reviews of the diffusion of new technologies show that access to extension services is one of the major determinants of adoption (Maddison 2006). Since extension services disseminate information and knowledge to farmers, free extension advice specifically related to climate change shapes farmer perception of climate change and positively influences farmer adaptation processes and resilience (Maddison 2006; CEEPA 2006).
- The information and advice (for example information on new crops) that the extension services provide to the farmers increase farmers' livelihood options.

Contributions to social resilience

- Public extension services serve as a direct link between government and the farmers and thus implements government policies and provide feedback from the farmers to higher levels of government.
- Extension also observes emerging innovations in agriculture and informs the farmers accordingly.
- Extension plays an important bridging function between scientists and farmers by disseminating innovations from research to farmers, and by helping to articulate for research systems the problems and constraints faced by farmers (Anderson 2007). In these ways, extension facilitates both the adoption and adaptation of technology to local conditions (Belay / Abebaw 2004).
- Extension services also support farmers in group formation thereby contributing to their social capital.

In conclusion, the foregoing hints at the need to reform extension services. This is in terms of mainstreaming climate change issues and addressing the underlying issues besetting the extension services as discussed above. Issues such as ineffective institutional arrangements for delivering services, inefficient resources allocation, poor targeting and sustainability related to the foregoing as well as the heavy dependence on donor funding (Gautam 2000) need to be evaluated. In a climate change resilient social-ecological system, more participatory approaches are needed, farmers' indigenous and experience-based knowledge are needed, feedback systems across scales of management and actors are crucial, and timely and competent climate-sensitive knowledge and inputs are needed. For extension and its agents to meet these and other challenges posed by climate change, flexible decision making is required. To start with, development interventions should enhance the participation of local actors in providing extension services to ensure that knowledge on climate change adaptation remain with the rural people.

5.5 Rural radio services

The potential of radio services for adaptation to climate change is yet to be fully exploited in SSA. Rural radio services also hold the potential to complement extension services. The lack of information and the concentration of available information on climate change in certain government departments have been proffered as the reason why much information on climate change does not reach other government ministries and the public. In the causal chain of factors for this information gap, "*inadequate resources*" is often given as a main reason. Radio services can address this limitation as it offers a medium to provide climate information to a large number of people at low cost. The fact that most rural households own at least one radio (cf. Gautam 2000; Ifejika Speranza 2006b) makes it attractive for disseminating information. It can therefore complement extension services and provide farmers information on agricultural practices for adapting to and mitigating climate change through:

- Conveying what climate change is and its implications for society and development,
- Discussing possible adaptation and mitigation measures,
- Providing a platform for knowledge exchange on adaptation and mitigation practices among farmers, and between farmers and other actors, as well as
- Reducing the amount of resources needed for extension services on adaptation to climate change.

Climatic hazards such as droughts, floods, cyclones and frosts receive wide public attention but there seems to be a lack of awareness about the link between these climatic hazards and climate change, and about climate change itself. Yet, the social construction of climate change risk depends in part on the information that people have access to, how they digest and interpret the information. Therefore, mass communication of climate change will raise awareness about climate change and inform on what can be done to mitigate and adapt to it. Because information is transmitted orally, it provides smallholders a platform to speak in their own languages and exchange information and knowledge with their peers. Besides educational goals, rural radio can become more effective by adopting an interactive strategy and methodology that give rural radio stations a role of facilitating dialogue between communities (Ilboudo 2003; 2005).

Several rural radios exist in SSA countries that focus on public education, on the environment and on raising public awareness about various issues (cf. URT 2001, 15 and 70; FAO 2006d). These programmes can be extended to cover climate change issues in order to raise awareness about climate change, its mitigation and adaptation. Other reports acknowledge the benefits of using radio, bulletins, internet and similar technologies to provide crop and livestock information services (cf. RoK 2004, I.29). Of interest is the work of Farm Radio International (FRI), which focuses exclusively on communicating information for agricultural production and rural development through its farm radio network. FRI produces own script packages and disseminates these to partner radio broadcasting institutions across the world, which adapt the scripts to local contexts and transmit to listeners. In return, FRI receives feedback and suggestions from their African radio partners on how to improve the scripts.

In recognition of the importance of radio for development, FAO, World Bank and The Communication Initiative organised the first World Congress on Communication for Development (WCCD) (cf. World Bank 2007b). Mainstreaming adaptation to climate change through radio is also an approach that the Farm Radio International, in collaboration with the Technical Centre for Agricultural and Rural Cooperation (CTA), and the German Organization for Technical Cooperation (GTZ) adopted. Through input competition from fifty-one African radio presenters, scripts were prepared on climate change adaptation strategies. The organisations are in the process of transforming selected scripts into various programs that will be transmitted to rural audiences by approximately 500 radio organizations across sub-Saharan Africa.

While many radio projects and programmes have been functioning for years there are no systematic evaluations (to the author's knowledge) on the impacts of many radio projects and programmes (cf. FAO 2003). Already in 2003, FAO noted that the omission of collecting data for monitoring and evaluation of impacts of Information and Communication Technologies' (ICT; including radio) programmes is still one to be addressed. The current study also found little information on the impacts of radio, hinting at the lack of monitoring and evaluation. Hence, there is need for more empirical studies to evaluate the impact and provide insights on how communities and groups make use of ICTs (FAO 2003).

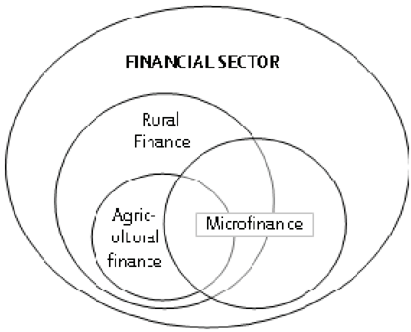
In addition, information available does not show how much radio programmes provide farmers with platforms to exchange information with other farmers. It seems that farmers are more on the passive end of receiving information and not contributing to programme content. While the success registered with information on market prices is encouraging, it would be insightful to evaluate the impact of programmes on other agricultural topics, whether they have such rates of success and whether the rate of adoption or success is comparable to that achieved through classical extension services.

Contributions to resilience to climate change:

- Rural radio services foster adaptive capacity in ecological, economic and social dimensions through promoting knowledge combination and feedback among peers and between various actors.
- Because access to the information disseminated is not restricted, rural radio services reduce power differentials between various actors. For example, an evaluation of a radio programme showed that before the radio programme farmers were exploited but with knowledge on market prices provided by radio the farmers improved their bargaining power (cf. Farmradio International 2008, 2 f.). Accordingly, the most popular programmes among those farmers are those on market prices.

In conclusion, the potential of radio for disseminating information and knowledge on climate change is little explored. There are few studies on how radios enable smallholders to improve agricultural productivity. Climate change is yet to find its way into the few existing programmes. Therefore this low exploitation and the potential benefits call for a focussed support of projects and programmes that propose to use radio to advance adaptation to and mitigation of climate change.

Box 11: Rural finance, agricultural finance and microfinance



"*Rural finance* comprises the range of financial services (e. g. loans/credit, savings, payment transfers and insurance) offered and used in rural areas by people of all income levels. *Agricultural finance* is the part of rural finance that focuses on financing agricultural related activities like input supply, production, distribution, wholesale, processing and marketing. *Microfinance* provides financial services for the poor and low-income people by offering smaller loans and flexible savings services where permitted, while accepting a wider variety of assets as collateral" (CGAP Donor Brief No. 15, October 2003, 1).

Source: CGAP Donor Brief No. 15, October 2003

5.6 Rural finance, agricultural finance and micro-finance

Adaptation to climate change means being able to cope with climate change and its impacts as well as having the capacity to take advantage of the opportunities arising from climate change. Access to financial capital allows farmers to implement adaptation measures. Thus Rural Finance Services (RFS), Agricultural Finance Services (AFS) and Micro-Finance Services (MFS) will continue to play a crucial role in buffering farmers from climate shocks by providing them with alternative sources of finance. Henceforth all parts of the three that fall into rural financial services (Box 13) will be referred to as RFS, except where a differentiation is necessary.

Access to RFS could help households retain their productive assets despite a disaster. Because farmers do not have access to credit and off-farm income is limited, they often sell their produce immediately after harvest at "throw-away" prices. Faced with climatic disasters like droughts and floods, many farmers also lack alternatives to access cash and must sell their productive assets like livestock and farm equipments at low prices to acquire cash to meet other livelihood needs. With the projected increase in intensity of extreme climatic events, farmers are likely to have lesser assets to liquidate. Many smallholders indebt themselves with their neighbours or with traders and usually repay after harvests (that is assuming that no droughts, floods or pests strike). This cycle of indebtedness and repayments means that such households cannot accumulate capital and are likely to perpetually remain at the same levels of poverty. Climate change is likely to exacerbate the situation through more intensive extreme climatic events like droughts and floods. However, with access to RFS, many of these limitations can be addressed.

According to Daley-Harris et al. (2002, 26 and 37), 970 programmes in SSA offer micro-credit services reaching roughly over 8.4 million people in 2006, out of which 48 percent are women in the bottom 50 percent of the population living below their country's poverty line. In SSA, 27 countries have developed specific regulatory frameworks for microfinance while in 15 countries microfinance falls under other financial sector regulations (CGAP 2008). Such policies encourage the establishment and spread of Micro Finance Institutes (MFI) but reports highlight that regulatory disparity still remains on private MFIs and NGO-MFIs (cf. Millinga 2007; Gobezie 2008). Because the three finance services (RFS, AFS, MFS) mentioned earlier address the same clientele group, Rural Financial Programmes (RFP) and those MFIs that rely on donor funding may have the un-intended effect of distorting the financial markets and crowding-out MFIs that generate their own incomes (e. g. Ethiopia: Gobezie 2008). However, Millinga (2007) recommends that since microfinance is still at its infancy in Tanzania, the regulatory system need to be progressive and developmental with graduated standards and a framework that encourages institutional development and creation of new MFIs.

An example of an integrated financial service is the Warehouse Receipt System (WRS) (IFAD 2007a; cf. Coulter / Onumah 2002). Warehouse receipt lending enables farmers to use stored product as collateral. Farmers are thus able to secure cash at the time of harvest and sell their product at a more favourable price later in the year. Such a tailor-made measure is in the IFAD financed programmes of the WRS in Tanzania (IFAD 2007a). To access the services of the WRS farmers have to become members of a cooperative/group. The cooperative runs a warehouse where the farmers deposit their produce. In return, the farmers receive a receipt, which they can use as collateral to apply for loans of up to 75 per cent of the value of the stock deposited in the warehouse, from the bank through the cooperative. Supporting self-managed financial associations to manage their own resources through the WRS had immediate and positive impact on incomes and livelihoods of farmers (IFAD 2007a).

Microfinance in SSA has a two-way relationship with climatic hazards like drought. Many MFIs were established in West Africa as a response to drought disasters, to provide post-disaster assistance to the poor (Chao-Beroff 1999), but droughts also affect the operations of MFIs. Many traditional self-help-based micro-savings and micro-credit groups tend to fold up during droughts, while some MFIs have difficulties to recover debts during droughts (Ifejika Speranza 2006b).

Another link of microfinance to climate change is the evolution in the microfinance sector on the understanding of sustainability (Rippey 2009). According to Rippey (2009, 1), "Responsible finance" is now being considered a measure of success for microfinance institutions, whereby "maintaining financial viability while advancing the social interest of stakeholders and protecting the environment" is a goal (also referred to as the "triple bottom" line of economic, social and environmental returns" Hammill et al. 2008, 120). Rippey (2009), reports that MFIs elsewhere have begun to address certain "aspects of climate change, including the need to reduce emissions". Thus sustainable microfinance builds resilience as it aims to meet the needs of the present without compromising the ability of future generations to meet their own needs (cf. WCED 1987).

Lessons so far and challenges

Although contextual specificities shape the degree of contribution of rural financial services to climate change adaptation, a review of lessons so far in servicing the agricultural sector provides insights into how the rural finance sector can increase its contribution to poverty and vulnerability reduction as well as to climate change adaptation and mitigation:

Multilateral and bilateral donors such as USAID, SIDA, DFID and IFAD finance several Rural Finance Programmes (for example in Zambia, Uganda, Sierra Leone, Lesotho). The RFPs are *integrated approaches* that include the development of community-based financial institutions, rural banking services, contracted smallholder production and other financial services. What makes *RFPs seem better than the MFI* is that various financial services are integrated and are thus better able to serve the demands of a varied clientele. In contrast to MFI, RFPs adopt pro-poor principles.

With regard to the current global financial crisis, Littlefield and Kneiding (2009) argue that the savings-led rural MFIs in Africa seem to be relatively well-cushioned compared to others elsewhere in the world, which depend on international donors and investors. Yet it must be noted that many RFIs and MFIs in Africa are dependent on international banks. Furthermore, the large share of rural finance programmes financed by international organisations implies that the credit squeeze that affects such institutions will also extend to SSA. This means that rural finance in SSA cannot be decoupled from happenings in the global financial markets.

Farmers gain access to microfinance through membership in producers associations or self-help-groups (group liability). However, ensuring that farmers can maintain their membership in credit groups under adverse climate conditions is not a primary focus of MFIs. Rather, some elements of this pro-poor approach are found in agricultural and rural finance programmes, which are mainly run, by the government and international donors. Little or no studies (to the author's knowledge) have analysed how farmers maintain their access to credit (membership of credit-groups) under crises conditions. Rather, evidence exists that poorer smallholders usually cannot maintain their membership under conditions of drought and crop failure (Ifejika Speranza 2006b).

Although it is widely acknowledged that micro-credit is an effective tool to reduce poverty (cf. Daley-Harris et al. 2002) there is contrasting evidence on net positive impact on poverty alleviation and on the level of financial self-sufficiency that the MFIs have attained. The typical target audience of MFI in agriculture tend to be the medium scale farmers and those that focus on export markets and international trade and much less the very poor small-scale farmers. Hence, Pitamber (2003) contends the ability of micro-credit to achieve sustainable poverty reduction. The author argues that the use and supply of micro-credit does not always lead to a sustainable impact on poverty reduction as the small size of the loans does not allow for making a lasting impact, hence earning a higher income does not equal empowerment, which the author argues can only be achieved through negotiation and change in gender relations.

Under "normal" climate conditions farmers must cope with dry spells, floods and droughts and sometimes widespread crop infestation. Even when the crops are harvested, the harvest can be decimated by pests (Ifejika Speranza 2006b). This situation can worsen under climate change. Thus, the risky nature of agricultural production makes farmers an economically unattractive clientele for MFI. Many of the loan products are thus unsuitable for farm production and farmers' needs for seasonal finance for food crop production remain unaddressed (Marr 1999; Dorward et al. 2001). This is because the micro-credits require immediate repayment and operate based on group liability. This does not suit agricultural production conditions whereby crops need at least four months and up to 12 months to mature before the output (which may also be at risk of storage pests) can be sold to acquire income. Flexible repayments (weekly or monthly basis) are thus needed when dealing with farmers (IFAD 2001).

Micro-credit needs to go hand in hand with enterprise choice and development as women in rural areas tend to establish the same enterprises (for example, petty trading) thereby saturating the markets and causing the prices to fall and reducing their own incomes (Pitamber 2003; Ifejika Speranza 2006b). Often, the recipients' lack of business orientation, acumen and entrepreneurial drive contribute to the ineffectiveness of credit projects (Temu et al. 2001). This calls for an extension of RFS to training in managing financial investments.

The high operational costs of MFIs (Nissanke 2002), the danger of borrowers to slip into debt (Snow / Buss 2001; Daniels 2004), the high interest rates (Hossain 2002), the exclusion of the very poor (Pitamber 2003), the misfit of offered financial products compared to the demanded products by borrowers and the rigidity of services, free-riding and conflicts, as well as achieving gender equity (Hossain 2002) remain major challenges. Based on these limitations, Nissanke (2002) reiterates that micro-credit may not be the best instrument to address the very poor.

Thus, RFS need to take account of the constraints and demands of the different clientele (Diagne / Zeller 2001) as this can limit the impacts of FS on smallholder income or cause negative impacts. While the rural poor are in need of credit, Diagne and Zeller (2001) suggest that rural financial institutions should focus primarily on high-potential agricultural areas in order to meet the demand in these areas and ensure repayments.

However, such a shift will exclude the poorer farmers and areas from financial services. Dealing with marginality (remote areas and the poorest) thus remains a challenge to rural financial services. Most of the services also tend to concentrate in easily accessible rural areas while there is a lack of services in remote areas (Marr 1999; Kherallah et al. 2000; Dorward et al. 2001). The fact that many rural infrastructures such as roads are in poor conditions also increases the operational costs of reaching the poor or for the poor to reach the financial institutions.

Due to heterogeneous groups (in terms of mixed income levels), free-riding becomes a problem (Hietalahti / Linden 2006). In some cases in Ethiopia, non-targeted people benefit more from rural credit programmes than the poor and vulnerable people initially targeted due to ineffective supervision of implementations (Gobezie 2008).

Maintaining efficiency and self-sustainability remains a challenge. At the organisational level, most MFI do not rely on local funds but obtain most of their lending from donors (Ghatak / Guinnane 1999; Nissanke 2002). This does not augur well for independent and long-term existence. While most MFIs achieve high outreach, achieving self-sustainability remains a major challenge. Gurgand et al. (1996) reviewed six RFIs in Cameroon, Togo, Rwanda, Benin, Malawi and Burkina Faso. They found that the RFI had extended financial services to smallholder farmers, women and the poor, that are usually excluded from formal financing but that in many cases (in Cameroon, Togo and Rwanda) self-sustainability (that is, non-dependence on external funding and high repayment rates) remained a challenge.

There seems to be a significant dependency on donors in the rural finance sector. For example, in addition to the country cases discussed above, IFAD also supports various rural finance programmes in Tanzania (IFAD 2000a), Chad (IFAD 2000b, 2003a, 2005), Uganda (IFAD 2002a), Eritrea (IFAD 2002b), Djibouti (IFAD 2002c), Mozambique (IFAD 2003b), Zambia (IFAD 2004), Nigeria (IFAD 2006) and Sierra Leone (IFAD 2007b).

In addition, appropriate institutional framework is lacking in some cases. According to IFAD (2003b, 3) "standard MFI operations are often costly to implement in rural Mozambique and tend to result in unsustainable institutional arrangements with very limited outreach and impact". The author suggests that if the right institutional framework is created, the government can play an important role in rationalizing donor support and make it more effective. Despite the success stories on the positive impacts of MF and RF their efficiency needs to be improved. This means that more emphasis needs to be put on monitoring and evaluation.

As there is no one single solution to improving the efficiency of MFI, different approaches are used in various SSA countries. For example, based on lessons from previous programmes, IFAD is supporting RFS in Zambia through development of Community-Based Financial Institutions, strengthening the capital structure; improving management and operating systems; expanding the branch network; developing new financial products; and manpower (IFAD 2004).

Climate change will likely change the economic and institutional environment but it may also occur under rapidly changing economic environment. This necessitates responsive and flexible programme design including built-in feedback mechanisms that enable programme management to regularly take stock of progress and modify as necessary (cf. IFAD 2003a).

Through public-private partnerships, the impact of financial services can be increased. An example is a credit facility for contracted small-scale production (IFAD 2004), which provides access to credit to smallholders and other rural producers by linking them with companies involved in contracted small-scale production. The potential of MFIs to participate in carbon markets holds potentials for allowing smallholders access such markets. Rippey (2009) suggests that the distribution channels of MFIs, their clientele and organisational resources, management information systems, linkages to local governments and international partners, credibility and transparency through annual audits and external evaluations, as well as efficiency and standardization in conducting large numbers of small transactions (a potential for carbon offset payments), makes them ideal partners in climate change adaptation and mitigation, in particular carbon trading.

Contributions to resilience to climate change:

Contributions to ecological resilience

- Some loan conditions provide incentives for sustainable soil and water management practices.

Contributions to economic resilience

- RFS improve access to and accumulation of financial capital. A major link between climate change adaptation and financial services is that financial services provide the poor access to financial capital which tends to be the least available asset for the poor (cf. DFID 2000). Since financial capital is versatile, it can be converted into other types of livelihood assets (human, social, natural, and physical capital) or it can be used for direct achievement of desired livelihood outcomes (e. g. purchasing of food to reduce food insecurity; cf. DFID 2000). Thus, an assets bundle and its combinations is positively linked with livelihood strategies – the more assets people have at their disposal, the wider the range of adaptation options available to them in their strategies to secure their livelihoods (DFID 2000; Ellis 2000). Hence access to RFS can increase the livelihood assets of farmers, thereby enabling them to take measures to reduce their poverty and vulnerability to livelihood risks (climate change included).
- Loans for agricultural equipment and infrastructure enhance physical capital and increase production. With regard to climate change and agriculture, RFPs positively influence production and social development. IFAD (2000a) reports that loans given to Savings and Credit Cooperatives (SACCOs) in Tanzania contributed to increase the production of the major crops two- to threefold and increased farmers' net returns more than 200 percent. Enabling the poor access to financial services and participation in the management of the SACCOs brought about fundamental changes within Tanzanian society and increased the voice and power of the poor in the governance of civil society organisations.
- The Warehouse Receipt System increases the spheres of action and the incomes of the farmers. It provides the farmers with a facility to store their produce until the market prices are more favourable. In that way, it not only allows farmers to obtain higher prices for their agricultural

produce because they do not have to sell immediately after harvest when the prices are down, but also provides them with the opportunity to access affordable financial services at the appropriate time. Such integrated products also buffer farmers from consumption shocks that usually arise in rural areas as a result of drought-induced hikes in food prices.

- The success of the SACCOs as manifested in increased farmers' incomes led to a diffusion of innovations as other farmers outside the IFAD programme adopted and implemented the innovation with their own funds (IFAD 2007c).

Contributions to social resilience

- Through group formation to access RFS, a contribution is made to creating and strengthening social networks and empowering women.
- Another resilience-building feature of such programmes is that they build on existing successful institutions. For example, by establishing and rehabilitating warehouses in areas where Savings and Credit Cooperatives (SACCOs) have considerable experience it also expanded the spheres of action of the SACCOs from "savings groups" into self-help organizations, with farmers as members. Through this system, IFAD (2007c) addressed the reluctance of banks to finance agricultural activities as the WRS provides the collateral that banks require to finance agricultural activities.

The key messages for building resilience and for development policy and cooperation are as follows: there is concern that the MF sector is taking over roles and responsibilities that are actually those of the national governments. This means that the goals of establishing appropriate safety nets and good government policies pale in the background of the emphasis on providing the poor access to credit. Many of the underlying obstacles to effective credit provision lie in inadequate basic technical and socio-economic infrastructure. In this sense, Hammill et al. (2008) ask whether MF actually provides a sustainable pathway out of poverty, whether it keeps people at the same level of poverty or prevent them from falling further below the poverty line. There is a dearth of evidence to substantiate either direction of argument, but to address the concerns in development circles; development cooperation needs to quite plainly discuss these issues with their government partners.

Since the clientele of the RFS are likely to be one of the most affected by climate change, Rippey (2009) suggests that MFIs need to diversify their portfolios, for example, by going into partnerships with other institutions that address climate change adaptation and mitigation through promoting clean energy products, forestry projects, low-carbon agriculture and participation in carbon markets. Such a move will also diversify the MFI portfolios and reduce the institutions' exposure to climatic hazards.

In the face of climate change and considering that a large proportion of the rural clientele are poor, RFIs need to *diversify their portfolio* to reduce risks attributable to climate change impacts. There is need to improve the robustness of RFS and MFI so they do not collapse under conditions of widespread impacts due to climate change. How to build in checks and balances, as most of the clientele in SSA are farmers, who upon losing their crops due to climate change may become unable to repay loans, remains an unanswered question in several cases.

The high dependency on donor and external funding in the rural finance programmes or in the MFIs contributes little to building the resilience of the finance institutions and by extension those they serve. Self-organisation is an important component of resilience which needs to be tapped more, for example by building on and further developing the indigenous forms of microfinance and involving the local communities in the management of RFS. Admittedly, the RF and MF sector seem to be learning from their experiences as proponents in the sector are already integrating aspects of sustainable resources management into their service conditions. This holds potentials to motivate and reward farmers for agricultural practices. In terms of increasing the buffer capacities of farmers (including economic resilience), findings on poverty reduction and increasing farmers' spheres of action are promising. However, a crucial question is to understand how farmers maintain their access to credit under crises conditions and how rural finance services can continue to provide such services under a changing climate that not only holds risks but also opportunities.

5.7 Weather indexed crop insurance

Insuring farmers against climatic risks is a viable way to build their resilience to climate change. Until recently, farmers had limited opportunities to secure their crop production against droughts or floods. Mostly they had to rely on relief aid, which governments and international NGOs have had to spend unbudgeted amounts to provide. This can disrupt financial plans and reverse the level of development achieved. In recognition of this situation, Article 4.8 of the UNFCCC identifies insurance as one mechanism to support developing countries to adapt to climate change (UNFCCC 2006b). Article 3.14 of the Kyoto Protocol also calls for the implementation of Articles 4.8 and 4.9 of the UNFCCC to fulfil obligations of the Kyoto Protocol, and through the consideration of the "establishment" of insurance (Linnerooth-Bayer / Mace / Verheyen 2003). Insurance thus continues to take a prominent position in the UNFCCC discussions (UNFCCC 2008b; IISD 2009).

However, the use of insurance as a tool for managing crop production is still in its infancy in SSA. Linnerooth-Bayer, Mace and Verheyen (2003) report that Asia (excluding Japan) and Africa only represent 6.3 percent of the world insurance market and that of all natural catastrophes in 2002, only 1.1 percent were insured in Africa (Swiss Re 2003). Thus, the potential of using insurance as an adaptation instrument is high. Insurance can improve adaptive capacity by providing beneficiaries buffer capacity against climate impacts thereby breaking the poverty spiral. In addition, it also makes people more aware of climate risk management and may bring about behavioural changes as people become more aware of the risky outcomes of their decisions choices.

Index-based weather insurance is an emerging instrument introduced in many parts of SSA (Mali, Malawi, Kenya, Tanzania, and South Africa) to improve risk management of farmers. The insurance pays out money to farmers based not on the yield they lost but on predefined weather (rainfall) benchmarks (Osgood et al. 2007). Pilot projects have been conducted in Ethiopia (in 2006) in the form of crop loss micro-insurance, and in Malawi, Kenya, and Tanzania through a World Bank initiative (cf. Hess / Syroka 2005; Osgood et al. 2007). There are also ongoing initiatives in South Africa. Because of differential vulnerabilities and cropping prac

Box 12: Macro-insurance : The UN World Food Programme pilot project on drought / index-based weather insurance against the Ethiopian famine

The Ethiopian government in its National Food Security Programme (NFSP) adopted a long-term risk management approach to addressing the chronic food insecurity besetting the country and the associated dependency on food aid (Government of Ethiopia 2006). A Productive Safety Nets Programme (PSNP) and national weather risk insurance are two major pillars.

Under the PSNP, targeted households (8 million people, mostly smallholders) receive cash or food in exchange for participation in public works schemes. Those unable to work such as pregnant women receive direct support. Through cash provision, the poor recipients have more control over how they spend the money received. This is expected to contribute to development through purchase by the benefactors in the local markets and ensuring that farmers retain their productive assets. Households participate in the PSNP until they cover their food gap; they then graduate into the food security programme until they acquire a critical level of income/assets, after which they become only eligible for regular government programmes and services (Government of Ethiopia 2006).

Building on the PSNP, the WFP in 2006 contracted AXA Re, the reinsurance division of France's AXA Group to underwrite a weather derivate transaction, whereby the WFP pays a premium of US$ 930,000 to insure against drought and famine in Ethiopia. In return, if rainfall falls below certain thresholds (extreme drought) during Ethiopia's 2006 agricultural season (March – October), indicating the likelihood of widespread crop failure, AXA Re would provide up to US$ 7.1 to Ethiopian farmers (310,000 beneficiaries). The policy is based on a calibrated index of rainfall data from 26 weather stations across Ethiopia and is designed based on the losses 17 million poor Ethiopian farmers would incur in event of an extreme drought. The insurance is part of an Early Livelihood Protection Facility (see Hess et al. 2006; Wiseman / Hess 2008). When all the facility's instruments are "triggered" by the index and funds exhausted, a flash appeal would be launched.

Sources: WFP 2006b; Hess et al. 2006; Insurance Journal 2006; Devereux et al. 2008; Wiseman / Hess 2008 tices, each crop has its own insurance scheme. In Malawi, two crops were addressed, namely groundnuts and maize, while maize was addressed in Kenya and Tanzania.

Such index-based weather insurance can be at the local level (in terms of micro-insurance) or at larger spatial scales like national (referred to as macro-insurance). An example of a macro-insurance, which covers broader areas, is described in Box 13. Another example of a micro-model of insurance, which offers protection to weather risks that have direct impact on an individual farmer's agricultural production, is provided in Box 13.

The WFP (2005; 2006b) hopes that with an insurance approach (Box 13) to reduce the time it takes to acquire sufficient emergency relief funds, thereby pre-empting the need to provide emergency food and reducing the threat of starvation. The likely developmental impact of the safety net provided by such insurance is that farmers can retain their productive assets. According to WFP (2005), an appeal usually takes four to five months to access funds for emergency aid. By this time, the Ethiopian farmers have sold their productive assets making them unable to cultivate their farms in a following season. This cycle appears to have perpetuated their dependency on aid.

While the PSNP (Box 13) protects the people (enhanced food and livelihoods security) and their assets, evaluation reports show that the public work schemes often coincide with peak periods of agricultural production. Although targeting was improved in the course of the programme it still remains a challenge (see Sharp / Brown / Teshome 2006 for a comprehensive report). However, the pilot promoted the use of contingency plans and showed that it is feasible to use market mechanisms to insure drought risks, and to develop objective, timely and accurate indicators for triggering assistance (WFP 2007).

Since the signing of the contract in 2006, no extreme droughts occurred to trigger the payment of the insurance funds. According to the WFP (2007), the Ethiopian drought index performed well in accurately reflecting local weather shortfalls where they occurred, but the calibration of crop sowing periods and the length of the growing cycle of the crops needs to be refined. In addition, a danger remains in that if droughts increase in intensity as projected by climate models, the insurance would regularly be claimed, thereby making underwriting the risk unattractive for the reinsurance industry. Yet such disaster insurance "could offer a basis for a rights-based approach to climate change" which could be linked to carbon compensatory schemes for adaptation in countries affected by climate change and managed through the UNFCCC's Adaptation Fund (Pierro / Desai 2008, 126).

In a similar move, the World Bank with the UK Department for International Development (DFID) plan a weather derivative for Malawi that requires an upfront premium and is designed to *manage the risk of low probability but high severity events,* like severe droughts, rather than the risk of events that occur more frequently, like minor or normal droughts. According to World Bank (2008b), the first weather derivatives transaction for Malawi will test the market with a small contract that is expected to pay out a maximum of approximately US$3 million if a severe drought occurs. The World Bank will act as intermediary, and the premium is being paid by the UK Department for International Development (DFID) (World Bank 2008b). A similar framework is also in the making for the Southern African Development Community (SADC) region (Hess / Syroka 2005).

The following analyses the contributions of the micro model of index-based weather insurance to climate change adaptation using a Malawi case (Box 13) as an example.

Lessons so far and challenges

The Malawi index insurance is an example where *public-private partnership* spanning global (World Bank, reinsurance companies) to local (farmer associations) actors seems to be effective. The stakeholders comprise insurers, credit companies, seed producing companies, the Malawi meteorological services, farmer associations and the World Bank. There also seems to be gains for all involved – for the farmers because it provides them credit for crop production and insures their production against drought conditions, for government because it saves them higher costs of ex-post recovery measures after drought; for the business community because it offers them an opportunity to make business with reduced risks compared to the micro-finance product alone, for the seed company

Box 13: The National Smallholder Farmers' Association of Malawi index-based weather insurance

The National Smallholder Farmers' Association of Malawi (NASFAM), an outcome from the 1994 USAID-funded Smallholder Agribusiness Development Project, in partnership with the Insurance Association of Malawi and the World Bank, designed a pilot index-based weather insurance scheme (2005/6 and 2006/7). Payments would be made to farmers if the rainfall needed for groundnut production was insufficient. Recognising that such an insurance scheme reduces the risk of payment defaults, "Opportunity International Bank of Malawi and Malawi Rural Finance Corporation lend the farmers the funds necessary to purchase higher-yielding seeds provided the farmers bought weather insurance as part of the loan package. These loans stipulate that the bank will be the first beneficiary if there is a payout from the insurance. NASFAM served to identify the participant farmers, provide training to farmers on the products (in conjunction with the banks), and provide marketing services at the end of the season" (Bryla / Syroka 2007, 7).

In the Malawi Groundnut contract bundle a farmer gets a loan to cover the cost of seeds, the interest rates, insurance premium and tax (Osgood et al. 2007). In case of weather failure, the farmer receives at maximum the loan size. Index rainfall measurements are used as benchmarks to trigger payments. The farmers are compensated for unfavourable weather conditions that adversely impact crop growth and similar to the micro-finance sector, liability is jointly borne by farmer groups. The rainfall index is valid for farmers in a 20km radius of a weather station. If there are no weather disturbances, at harvest the farmer presents yields to the farmer association, which markets the yields. The farmer association then uses the proceeds and insurance payouts to pay off the loan, while the rest is returned to the farmer. This way the farmers pay the full cost of the insurance program and the only subsidy is data and contract design assistance (Osgood et al. 2007). The rapid growth in participants from 900 farmers in 2005 to 5500 farmers in 2006 (Syroka 2008) hints at the success of the project.

Sources: Hess / Syroka 2005; Osgood et al. 2007; Bryla / Syroka 2007; Syroka 2008 because it offers them a "guaranteed" market for their seed products and for the World Bank because it increases the effectiveness of poverty-reduction interventions.

Index-based crop insurance has two advantages over traditional crop based insurance: Index insurance insures for a specific event or risk, such as rainfall deficits, so there is no need for in-field assessment of damage because weather data directly trigger payouts. Index insurance also addresses two problems associated with traditional crop insurance: (a) *moral hazard*, a situation in which farmer practices cannot be observed so that a farmer may let a crop die in order to get an insurance payout; and (b) *adverse selection* referring to a situation in which insurance is priced based on the risks of the entire population but only the most vulnerable farmers purchase insurance (Osgood et al. 2007). Since no measurement of actual loss is required, rapid payments can be realised with index-based products.

Further, micro-insurance loan package bundle as used in Malawi has *advantage over micro-credit*. Since farmers pay their premiums upfront, the micro-insurance organisations are guaranteed their income, in contrast to micro-credit loans where high default in repayment by farmers during widespread droughts have been experienced (e. g. in Kenya).

In another case, Duchrow (2007), reporting on the Mali-Nord Programme of the GTZ, notes that although small agricultural producers with little capital assets are the most vulnerable, a severe drought would affect all sectors hence the target of such insurance instruments should be the rural population as a whole organised as shareholders in micro-finance institutions. Duchrow (2007) also suggests that the best immediate impact can be achieved by insuring micro-finance institutes, which have a crucial role for the economic development of the region.

As a result of its success, market demand in many places in Malawi overwhelmed administrative capacity to serve clients. For many farmers, enrolment in the insurance programme became "their primary strategy for adaptation to climate change". This success demonstrates the feasibility of weather insurance for farmers in developing countries (Osgood et al. 2007, 10). However, it is still premature to call for market-based prices based on the initial success reported, considering that the farmers and the service providers fixed the prices for insurance packages in a participatory process (cf. Osgood et al. 2007).

Despite its seeming success, various challenges to a fully sustainable and scalable product remain. These are *the need to build local capacity and transfer technology* for continuous improvement of the insurance contracts, the danger of imbalance between the pace of product up-scaling and the pace of capacity development and project improvement, the need to fine-tune the insurance and extend to other crops.

Another major gap is to *improve the quality of climate data* used (Osgood et al. 2007; Chavula 2007). Since the index-insurance programmes are still in their infancy there is not much evidence for evaluation. The 20 km radius is too wide, as the areas do not belong to the same homogeneous rainfall regions (Chavula 2007).

A major challenge is *how to bring about long lasting local ownership*. Will there be a local replacement if World Bank pools out? Is their danger of over reliance on the World Bank? The documents available tend to confirm so. Chavula (2007) also notes the need for Governments to put in place appropriate policies and allocate adequate financial and human resources for meteorological services to carry out their mandate effectively. What is also striking is that the extension services are not involved in the pilot projects and their follow-ups. The position of extension is taken by the farmer organisation, which functions as an intermediary between the farmer groups and the credit/insurance and seed providers (see also Box 13).

A question that arises is *how well such programmes reach the poorest* since a form of targeting is carried out in which those farmers who are perceived to be able and willing to pay for insurance premiums are targeted. Studies show that even at such minimal levels some actors, especially female household heads find it difficult to participate in self-help-groups (cf. Ifejika Speranza 2006a). The answer to this question is not yet clear. Based on analyses of the pilots, Giné and Yang (2008) report that *insured loan take-up was positively correlated with farmer education levels,* implying that the very poor may have been left out.

Based on climate change projections, Hochrainer et al. (2008) indicate that *climate change impacts will likely decrease the financial robustness* of micro-insurance in Malawi in the period 2008–2017. In addition, the predicted stronger changes in rainfall patterns will further decline the financial robustness of the Malawian insurance pool from 2070–2080. However, the authors caution that there are large uncertainties in the estimates and projections, and further research is needed to refine the methodology of impact assessment. Hence, farmers must be informed that index insurance *only provides partial protection* and is therefore *only one component of a risk management package* (Osgood et al. 2007). However, since inception, no major drought has occurred so the full impact of the weather insurance cannot yet be tested.

In view of the *possibilities of widespread adverse climate impacts,* there are limitations to micro-insurance and other market-based instruments as poor countries can ill-afford to pay the reinsurance premiums alone. Hence, a coordinated action is needed to *pool global and regional risks* (cf. Hess / Syroka 2005; Hochrainer et al. 2008). Also, in the event of widespread drought national governments have to spend a lot of money for relief aid and recovery, thereby disrupting their financial plans. For example in 2005, the drought response cost for the Malawi government was more than US$ 200 million. In order to ensure that such widespread disasters do not gulp much of the national finances, plans are underway to upscale index-based insurance to national levels. The World Bank plans to offer Index-based Weather Derivative Contracts as part of its strategy to reduce the impact of drought in developing countries (see also Box 13). Malawi will be the first country to enter into such a contract with the World Bank whereby the World Bank will serve as an intermediary between client countries and a financial market counterpart. In the event of a severe weather event, client countries, such as Malawi, would receive a payout from the Bank, the total value of which would be based on an index used as an estimate of the financial impact (Hess / Syroka 2005).

Contributions to resilience to climate change:

Contributions to economic resilience

- Insurance offers farmers security against climatic risks like drought.
- Macro-insurance programmes ensure that the national governments are able to support farmers in cases of production failure.
- By receiving insurance payouts, farmers no longer have to sell their farm implements to access cash to buy food.

Contributions to social resilience

- Taking out insurance hinders the deterioration of living conditions and contributes to social security.
- Through taking out the insurance, farmers increase their social security from livelihood pressures of which climate change and climate variability are major ones.

Although the contributions of insurance to building resilience are rather economic and social, the benefits extend to the environment as having such an option is likely to hinder farmers from harmful practices like charcoal production.

The foregoing shows the potentials of micro- and macro-insurance as adaptation instruments for farmers and national governments. The micro-insurance model fits sub-national areas known to or expected to suffer more from droughts while countries that have similar food security challenges like Ethiopia could integrate such safety net programmes into their national planning.

While insurance provides short-term relief, it depends on the availability of historical and continuous weather data of good quality and reliability to be able to function (Hess / Syroka 2005). Whether the existing network of weather stations is actually enough requires empirical research that provides evidence on the coverage of all homogenous rainfall regions within the area of operation. Development policy and development cooperation should therefore support partner countries in assessing the distribution of weather stations in such countries and support the collection and appropriate management of such data.

From a resilience perspective, the dominant role of the World Bank and the WFP puts to question the establishment of long-lasting ownership to carry such instruments through once these international partners pool out. The question then is how to prepare for and manage transition so that once they pool out that index-based weather insurance will flourish and spread in SSA. Development policy and development cooperation need to incorporate ownership into such interventions from the outset. A mechanism or checklist of criteria for fostering ownership and for successful transfer of interventions to local actors can help to address this challenge.

5.8 Paying farmers for ecosystem services

Paying farmers for ecosystem services can act as an incentive that promotes the adaptation of resources management and agricultural practices to climate change. It can also contribute to poverty reduction. Ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystems Assessment 2003, 3). These include provisioning services such as food, water and forest products; regulating services such as regulation of climate, floods, drought, land degradation, and disease; supporting services such as soil formation, photosynthesis and nutrient cycling; and cultural services such as recreational, spiritual, religious, aesthetic and other nonmaterial benefits. An important ecosystem service is the mitigation of GHG emissions in agriculture through carbon sequestration. Smith et al. (2007) report that soil carbon sequestration is the mechanism responsible for an estimated 89 percent of the mitigation potential in agriculture while CH_4 emissions and N_2O emissions from soils account for 9 percent and 2 percent respectively of the total mitigation potential (Smith et al. 2007, 499).

Payment for Ecosystem Services (PES) describes arrangements whereby beneficiaries of ecosystem services pay those that engage in measurable activities to provide such services. FAO (2007b, 6 ff.) defines PES transactions as "voluntary transactions where a service provider is paid by, or on behalf of, service beneficiaries for agricultural land, forest, coastal or marine management practices that are expected to result in continued or improved service provision beyond what would have been provided without the payment". PES can be in form of monetary payments, incentives or in kind.

However, the limitation of the definition by FAO (2007b) to refer only to externalities (that is "unintended consequences") is not adopted here. Hence PES in this study covers payment for the intended and unintended positive outcomes. The logic is that to adapt to climate change farmers have to carry out these activities anyway (see Chapter 4) and the benefits although intended, do not cease at the farm boundaries and should be acknowledged. Hence, spatial differentiation may be one way to define who pays for what Ecosystem Services (ES) – local, watershed, regional, or global.

According to (WOCAT 2007) payment for ecosystem services are a promising policy and management approach with two options:

1. Payments or tax concessions by the government for ecosystem services rendered (e. g. through direct payments as in Europe).
2. Payments or compensation by users of an ecosystem service to those who ensure that service. The idea is that such a payment could be sustainable and would economically underpin investments in soil and water conservation.

Therefore, the activities of farmers can be assessed for such services. PES thus provides one way to support the farmers in their efforts to shift to sustainable land management and can serve as an incentive to choose this development path. In that way, it holds potentials for reducing poverty and enhancing the uptake of adaptation measures.

To be able to explore the potential of PES for agriculture and agricultural practices for ES, one must seek to answer the question of values. What is the value of the ecosystem services associated with agro-forestry, terracing, or organic farm production practices to beneficiaries? How do the beneficiaries (public, the decision makers, the private industries and individual stakeholders) perceive these values? Having such information can inform decisions on PES programmes in agriculture. In addition, an analysis of the use of PES in agriculture or related sectors can offer insights into its actual and potential contributions to adaptation practices and for reducing vulnerability to climate change.

While PES is an established tool for agricultural and landscape management in the OECD countries (FAO 2007b, 8), *PES is a relatively new concept in most of SSA*. Although many rural development programmes in SSA could qualify for PES (for example, cash for work and food for work) their main focus is on reducing poverty and food insecurity which are rather development objectives. Recently, PES is being explored for carbon sequestration, biodiversity conservation, eco-tourism, water and eco-labelling in Uganda (cf. Ruhweza / Biryahwaho / Kalanzi 2008), in South Africa (Blignaut 2008), in Tanzania (Scurrah-Ehrhart 2006), in Madagascar (cf. Randimby / Razafintsalama 2006), and in Kenya (cf. Mutunga 2006; Mwangi 2008).

Lessons so far and challenges

Since many PES programmes in SSA are still on a small scale, at the scoping or pilot stage, the effectiveness of PES as an adaptation and poverty reduction instrument in the SSA context is yet to be proven. Important for such an evaluation is the establishment of mechanisms for collecting data so that future evaluations of the effectiveness of PES are at all possible. Nonetheless, preliminary findings indicate that like in other interventions in agriculture, *land ownership and security of tenure* are factors that define how benefits are distributed hence this is an aspect that needs to be addressed in any PES programme (cf. Mutunga 2006; Smith et al. 2007; Tschakert 2007).

PES does not always result in a win-win situation. Tschakert (2007) analysed the extent to which different farmer groups are able and willing to participate and benefit from potential carbon offset programmes and found that no real win-win options exist as "trades-offs between global benefits (increase in carbon uptake) and local benefits (profitability, estimated in net present values) will be inevitable" (Tschakert 2007, 79).

Since poorer smallholders have *limited capital to invest*, higher advance payments can help alleviate this limitation (cf. Pagiola et al. 2005). Tschakert (2004) argues that without such payments, poorer households in the old peanut basin of Senegal would not be able to afford a single improved management practice while richer households could at least adopt a few options.

Inadequate information and knowledge including limited understanding of the Kyoto Protocol's Clean Development Mechanism (CDM) guidelines, lack of awareness of ES and the value various stakeholders attach to them, especially by policy makers and government agencies, lack of knowledge about PES markets, shortage of skilled capacities to push PES-schemes forward and lack of institutions responsible for PES-mechanisms have been identified as barriers to PES programmes in Africa (Scurrah-Ehrhart 2006; Randimby / Razafintsalama 2006; Mutunga 2006; The Katoomba Group 2007; Ruhweza / Biryahwaho / Kalanzi 2008). The challenges specific to the adoption of carbon sequestration adds to this list. These include for instance achieving and maintaining the maximum storage capacities of the soil for carbon; changing agricultural management in ways that do not reverse sequestered carbon; the selection of appropriate base-lines to measure changes in soil carbon; the uncertainties about the complex biological and ecological processes involved in GHG emissions and carbon storage; the temporal and spatial variability in agricultural conditions that affect carbon storage, unclear property rights, and the rather high transaction costs which may create entry barriers for smallholders (see Smith et al. 2007, 525 for details). The implication of these challenges is that each farm management practice being promoted should have an *educational component* that addresses the use of new technologies by farmers as well as by those engaged in offering farmers support services.

The *challenge of reaching the poor* also holds true for PES. A crucial question that must be answered for any PES in SSA is whether it compromises poor people's access to natural resources. Which PES accounts for the needs of poor smallholders for example, by providing them access to start-up capital, cooperative institutions for bundling and bargaining of contracts and access to training? Because resource endowments and entitlements differ even among the poor, analysing and differentiating the costs and benefits of various farm management practices for a PES programme need to be carried out for the different wealth categories of smallholders (Tschakert 2007, 78). Actors with wealthier natural resource bases in terms of quality and quantity (land, labour and capital) stand to gain more in PES than the poor hence there is the *danger of increasing rural inequalities* rather than decreasing it (Tschakert 2007). Carefully designed pro-poor measures are thus crucial. Possible solutions could be flexible management and payments mechanisms that allow farmers to mix and bundle various farming practices, training to enhance participants' skills and providing access to credit so that the very poor can access capital for the initially high investments in farm management practices that provide ES. In a PES programme, the ability of the poor to participate depends on the design of the programme. Pagiola et al. (2007) in an analysis of PES in a silvo-pastoral project in Colombia found that transaction costs may pose greater obstacles to the participation of poorer households in PES projects than household-specific constraints such as labour and limited assets.

Understanding the *local context* is therefore crucial to designing robust PES mechanisms as activities that provide PES might be suitable to one area but not to another (cf. Tschakert 2007). *Institutional barriers* such as the lack of "certification bodies, financial intermediaries, national registries for ES" (The Katoomba Group 2007, 6), increase the transaction costs for PES. For example, for smallholders in organic production to access export markets, an export company, which contracts a large number of smallholder farmers as out-growers and ensures the produce meet the specifications for organic certification and for valuing the ES, is required. Tschakert (2007, 84) argues for support for institutional structures since "without reliable, accountable, and legitimate local and regional institutions, a more equitable and pro-poor system of environmental service provision among marginal smallholders is not viable". This could be in form of supporting formation of cooperatives and implementing measures that ensure that the better placed do not hijack PES schemes by establishing, monitoring, and enforcing rules and regulations.

In many instances, *policy frameworks* do not account for PES (maybe because it is still a new instrument) and sometimes rather hinders the use of PES. For instance, the Kenya National Forestry Bill is in conflict with the use of certain resources for PES (Mutunga 2006, 12). In some PES cases in Tanzania, landowners do not have a clear and legal right to sell ES (Scurrah-Ehrhart 2006). Moreover, The Katoomba Group (2007) reports that there is contention between delivery of ES as "private goods" or as "public goods" and debate on, who should claim the benefits. Although policies establishing rights to buy and sell ES were not essential for the pilot phase of a scoping project, they become crucial in the expansion stage (The Katoomba Group 2007).

At the international level, *trade rules and regulations* can affect what practices might qualify for PES and what not. Considering that PES can contribute to increased production and that it can be misused as subsidy and distort trade conditions, the World Trade Organization (WTO) Agreement on Agriculture (AoA) under the Green Box provisions permits payments to enhance environmental services if the instrument is decoupled from "agricultural production, from post-base period prices and from factors of production" (FAO 2007b, 79 ff.). Paragraph 12 of the Green Box also permits direct payments under environmental programmes if payments are restricted to extra costs or compensating loss of income involved in complying with environmental programmes. Other activities allowed under the AoA include structural adjustment assistance where land is removed from agricultural production or regional assistance programmes involving payments to producers in disadvantageous regions (FAO 2007b, 79 ff.).

A common characteristic of PES in SSA is that it is largely *externally driven*. Many PES-programmes are donor-driven and run by NGOs whereby pilot projects are used to evaluate the potentials of PES in the SSA context. These activities depend on substantial donor support and care must be taken that the ownership of PES is rooted among the local communities at the latest when the pilot programmes are expanded into full programmes.

Despite the dearth of studies on PES in SSA, the foregoing offers insights on some factors to consider when using PES as an adaptation-enhancing tool. Since PES is an instrument that has been extensively used in Latin America (cf. Pagiola et al. 2005; Grieg-Gran et al. 2005) and in the OECD, studying the PES process and mechanisms in these areas can offer insights on how PES can be effectively used in SSA. The factors identified above show that adopting a resilience lens (see Chapter 3.5) can be useful in analysing the sustainability of PES in SSA.

Contributions to resilience to climate change:

Contributions to economic resilience

- PES provides poor farmers with the necessary financial resources to maintain their shift to more-environmentally friendly practices.
- Eco-labelling promotes smallholders' access to international markets for organic products. Through eco-labelling, smallholder farmers in Uganda receive premium prices that are 25 percent to 50 percent higher than those of conventional produce, in return for keeping to organic production principles (Ruhweza / Masiga 2005).

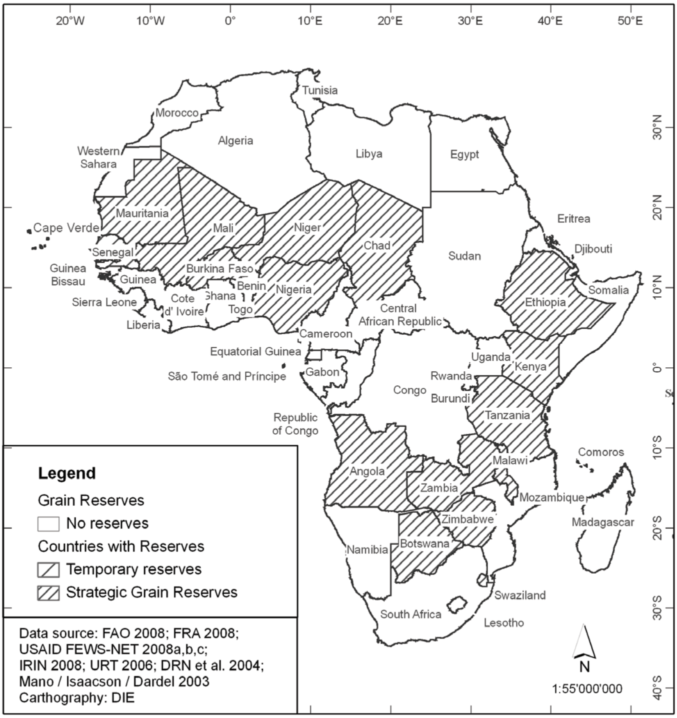
The relevance of PES for farmers' adaptive capacity lies in the additional income smallholders can earn through PES. Farmers depend on and generate a wide range of ES but they may also impact negatively on the environment. To adapt to climate change farmers must change or modify their practices (see Chapter 4). Most of the adaptation practices analysed in Chapter 4 will not only benefit the farmers themselves but will also produce various positive externalities, such as decreased erosion, increased soil carbon, increased biodiversity, increased ground cover and less river sediments. However, from the perspective of poor farmers, some of the investments needed for adaptation may not be available or affordable and since the general public benefits from the change in farming practices, (e. g. enhanced river flows, increased soil carbon, scenic beauty), paying farmers for changing to more sustainable farming practices will not only meet the goal of ES provision but also act as an incentive. Governments together with development policy and development cooperation should therefore explore pathways through which PES can be promoted in the public and private sector. This could be through reviewing the ongoing pilot projects or initiating one with the aim to upscale the pilot into a regular programme.

5.9 Strategic grain reserves

Holding Strategic Grain Reserves (SGR) can be a viable measure to address climate-triggered food shortages. In anticipation that food will not always be available in the quantity needed, several SSA national governments hold Strategic Grain Reserves (SGR) as a way of buffering/offsetting shortfalls in food supply or in order to stabilise prices with the goal of maintaining food security (see Figure 12). Considering that food purchase in the international market takes months to arrive while an appeal usually takes four to five months to access funds for emergency aid (WFP 2005), having some grain reserves can moderate the severity of food shortages, until other measures take effect.

SGRs can be in the form of physical or financial reserves. Physical reserves of certain quantity aimed to meet national food shortfalls for a certain duration (usually days to months, but varies from country to country) are held on storage in the country. Financial reserves, which could be complementary to the physical reserve or the single national food security measure, are set aside to meet the purchase of a pre-defined amount of food should the need arise. Some African countries hold both types of reserves while others rely on their financial reserves. The following analysis focuses on the physical grain reserves.

Figure 12: Sub-Sahara African countries holding strategic grain reserves



Lessons so far and challenges

In some countries (for example Nigeria and Kenya) the SGR also feature as Buyers of Last Resort (BLR) allowing farmers to sell grains directly to the SGR in their locality at a minimum guaranteed price thereby providing a ready and accessible market for locally produced items (Olajide / Oyelade 2002). Whether or not to have an SGR is controversial and highly politicised (cf. Devereux 2002; Harrigan 2003; Tschirley et al. 2004). This is partly due to the *rather poor performances of the SGRs* (World Bank 2007a) in guaranteeing fast and adequate response in food crises situations and their possible distortion of market prices.

Still, a well managed SGR could be a relevant instrument for adaptation to climate change. Extreme climate events like drought and floods have triggered the use of SGR as a response and planning instrument for coping with food shortages. The Tanzanian and Kenyan SGR were established as a response to climate-triggered food crises (for example Tanzania in 1974/75 and Kenya in 1985). Where SGRs exist, the minimum stock requirements have been increased also in response to food crises as in the case of Malawi after the 2002 drought-triggered food crises. Going by projections of climate change-induced increase in drought and flood frequencies and intensities, having food reserves to bridge periods of national food deficit can contribute to maintaining food security – that is if managed correctly. However, the costs of maintaining an SGR (purchase, transport, storage, logistics and distribution) can be very high and need to be weighed against the costs of importing food when needed or liberalising the market and providing framing conditions so that the private sector can take over this role.

The rather poor performances of SGRs (World Bank 2007a) questions the role of SGR in ensuring food availability and stabilising food prices under conditions of food crises. The role that the SGR played in response to the 2002–2003 South African Development Community (SADC) food crises is contested. While Devereux (2002) hints that the SGR could not play its role due to mismanagement, Tschirley et al. (2004, 22) find that the SGRs played "no role in what has to be considered a successful response to the 2002/03 crisis" and as such may not be needed to ensure food security. Whether or not to let the markets decide on national food availability and the degree of intervention by government into market mechanisms through the SGR has been a bone of contention between some African countries and the World Bank/IMF (cf. Devereux 2002; Harrigan 2003; Tschirley et al. 2004). However, in recent years, it has been realised that in countries where chronic poverty is high and foreign exchange rare, that SGR can contribute to national food security until food imports or food aid, which take time to transport, arrive. Tschirley et al. (2004, 23) argue that "in principle, a small and well managed stock could provide "degrees of freedom" in responding to crises, allowing quick sales or emergency distribution as needed until commercial imports and food aid can arrive".

The debate about the effectiveness of SGR to contribute to food self-sufficiency and food security is continuous: it seems that the SGR have sometimes achieved the goal of contributing to national food availability but evidence shows that in most other times, it has not (cf. Malawi famine of 2002: Devereux 2002; Mano / Isaacson / Dardel 2003). NEPAD (2004, 34) reports that "in most cases, experience with strategic grain reserves in Southern Africa has been less satisfactory". Mano, Isaacson and Dardel (2003) highlight that those countries in SADC (Lesotho, Mozambique, Namibia, and South Africa) which do not have any SGR and have delegated this duty to the private sector are also countries that are food secure, hinting at the capability of the private sector to maintain food reserves. On the other hand, the importance of SGR was realised by its absence in the 2002 food crises emergency in the SADC region. Mano, Isaacson and Dardel (2003) attribute the low stocks in SGRs to different factors in the various countries: one factor was that the SGRs were at a low level due to the production shortfalls in the preceding year indicating a high dependence of SGR on national production and lack of imports to replace missing stocks. The low stocks also imply that the rules or operational guidelines governing stock levels and replenishments (cf. Trueblood 1997) were either inexistent, unclear or were not adhered to.

The assumption that Early Warning Systems (EWS) are able to provide adequate information to allow governments to import food may not be the case for many SSA countries (see for example Chapter 5.2). However, Tschirley et al. (2004, 24) advise against focussing on SGR in Southern Africa and suggest that "government and donor time and money are likely to be better spent on continuing improvements to market information and EWS, on improved infrastructure for domestic food marketing, on more transparent policy towards external trade, and on market facilitating mechanisms that can be deployed when needed during crises". In contrast, Devereux (2002) reporting on the same crises in Malawi hints at "the imposition of economic liberalisation policies that have undermined the institutional capacity of the state to deliver food security to its citizens" as a contributory factor.

Devereux (2002) reports that due to the low capitalisation of the Malawian National Food Reserve agency (NFRA) the IMF advised it to sell off part of the reserves in order to repay its loan. Although in retrospect the IMF admitted that the policy advice it gave to the Malawi government in 2001 was based on "wrong information" about crop production. Otherwise the advice to sell would have been correct if the information (on which the advice was based) was correct (IRIN 2002; Devereux 2002, 73); it was already too late to make amendments.

In view of the above contestations, viable alternatives to SGR could be to hold foreign currency reserves, implement insurance mechanisms and participate in futures markets. Yet each of these options has its limitations and risks. To hold foreign currency reserves instead of physical grain reserves may not be feasible for many countries due to chronic balance of payment problems. While South Africa and Namibia uses futures and options (cf. Mano / Isaacson / Dardel 2003), many SSA countries are not at the same level of economic development as South Africa and may thus be less able to depend on market mechanisms. Even Mano, Isaacson and Dardel (2003) forewarn that the introduction of insurance schemes (as planned for Botswana) requires careful analysis, especially within the context of an unfavourable business environment in some countries.

I argue that totally depending on imports is risky and presupposes that a country has enough foreign currency reserves to purchase food, that food is available at that particular moment in the world market, that a loan request can be granted and that the ordered food arrives in good time. The cases of Malawi and Kenya show that this is not always so (WFP 2000; Devereux 2002). Suggestions to spread the risk of food emergencies by establishing an SADC regional grain reserve was not supported by some SADC countries, given their different national strategies and food security status (Trueblood 1997; Mano / Isaacson / Dardel 2003), so the responsibility remains at the national level.

The often-critical shortage of stocks when they are needed indicates an issue of mismanagement. Actual official cereal reserve levels normally fall far short of policy guidelines (Mano / Isaacson / Dardel 2003). There is also a lack of a transparent policy on the management of SGR as in the case of Malawi in which relevant officers were not informed of the low stock levels. In contrast, stock levels of the Botswanan SGR were regularly monitored through monthly early warning reports (Mano / Isaacson / Dardel 2003). The reserves of the National Cereals and Produce Management Board (NCPB) of Kenya were short of requirement during the 2000 drought in Kenya (WFP 2000). More recently, in reaction to three consecutive failed harvests due to inadequate rains in the marginal agricultural production areas of Kenya, stocks in the Kenya national emergency reserve were little over 10 percent of their legal requirement, necessitating the WFP to consider increasing its food aid to the affected populations in Kenya (WFP 2009).

Corruption also played a part. It was reported that those who knew beforehand the decision of the Malawi government to increase the price of the NFRA maize, bought the remaining stocks from the NFRA and resold it after the government increased the maize price (Devereux 2002). Indirect sale and price hikes by middlemen are also a problem elsewhere in Africa, as in Nigeria. As producers cannot sell directly to the SGR sometimes due to low quantities, they lose out on middlemen, who are also contractors to the SGRs (Olajide / Oyelade 2002). The intermediary effect of middlemen is a factor that discourages farmers from increasing production.

Untimely sales / disposal contributed to famine in the Malawi 2002 example. Often the management of SGR sell their stock prematurely. Devereux (2002) reports that the NFRA sold its stocks in 2001 and some months later, Malawians were suffering from food scarcity. This was also the case in Kenya during the 1999–2000 climate-triggered food crises.

However, the wrong information base on food availability given by the authorities responsible for early warning led to wrong decisions to sell off food reserves as the decision to sell or not, depended on this information (Devereux 2002). Yet the case of Malawi highlights the lack of inclusiveness in managing food situations. While organisations working at local levels such as the NGOs and churches already had information about the looming food crises and informed the government and donors, their message was not taken seriously, as they were not the "official sources" to provide such information. Even worse, their information was not validated (cf. Harrigan 2003). By the time information came from the relevant authorities, the food crisis had broken out and it was too late to organise response measures. Other countries, like Kenya, specifically have agents on the ground that monitor food situation to complement the information coming from the EWS. Yet this activity can as well be carried out by extension workers and does not need an expansion of government apparatus. This has to be considered for other SSA countries.

Another argument is that SGR tend to distort prices to the disadvantage of smallholders, thereby discouraging them from producing more (NEPAD 2004, 34). The prices at which SGR offers to buy produce are usually lower than market prices; hence they benefit the traders rather than the farmers or consumers.

That reforms are needed to address the identified limitations is uncontested (Olajide / Oyelade 2002; Devereux 2002; Harrigan 2003; Mano / Isaacson / Dardel 2003; Tschirley et al. 2004). To diversify resources, joint commercial ventures with the private sector (Olajide / Oyelade 2002) or complete privatisation may be viable options. Implementation should be monitored to ensure that SGR policy guidelines are followed – this could be through introducing checks and balances into the decision frame. Farm and community-level storage could be improved so that farmers have longer access to food. Instead of having one national SGR, the management could be decentralised so that each local government area can decide over its own food reserves and is responsible for any shortages. Such a system decreases the distance to the decision makers and improves responses as those at the local level have more information about the evolving situation on the ground. The national level could then take over coordination duties. Learning from history is also an aspect of a resilience approach and this bears on any planned reforms of SGRs. Tschirley et al. (2004) argues that any review of anticipated costs and benefits of SGR needs to analyse their past management history, make realistic assessments of the prospects for improved management, and requires an in-depth understanding of the strengths and weaknesses of local and regional EWS. Following the failure of the Malawi SGR to deliver, reforms have led to decreasing the level of stocks held by the SGR, changing the management approach, and guidelines and defining certain conditions attached to food sales (cf. Mousseaui 2004). The national reports submitted as follow-up of the implementation of the World Food Summit plan of action (cf. URT 2006; RoK 2008) illustrates the persisting importance of SGR as a strategic instrument for food security.

The foregoing indicates that a constellation of various factors that can be different for various SSA contexts are the underlying causes of the food emergencies, which climate events trigger. Vulnerability to climate related impacts as in the case of SGR is thus to a great extent mediated by management factors and these management deficiencies need to be ironed out before climate change impacts increase in frequency and intensity. The identified limitations also make a case for a resilience-based approach to climate change adaptation in SSA since well managed SGRs can be understood as buffers against adverse climate change impacts like large scale harvest failures (see Chapter 3). Climate change adaptation thus offers an opportunity to reassess the pros and cons of SGR and to assess how it can be improved.

A peculiar feature of the SGR is that it is the only institutional instrument that is predominantly driven by national governments. All other institutional services for adaptation analysed in this chapter are largely donor-driven and controlled. There is also a dearth of information on the current state of SGRs in Africa. What is available is scattered over various sources, is incomplete and provides little room for presenting the few available detailed information using a common frame (see Figure 12). This calls for an in-depth review and empirical research to collect relevant data on SGRs, how they are currently managed, and provide further evidence on their relevance for addressing food scarcity and stabilising food prices. Such data would also provide a basis for assessing the contributions of SGRs to resilience to climate change.

Considering the pros and cons, whatever policy or management changes is deemed fit to the context of individual SSA countries should not lead to a drastic and complete shift (without competent alternatives: see Harrigan 2003), but should be gradual and partial, allowing for adjustments along the way to desired results as in adaptive management.

Contributions to resilience to climate change:

The potential of SGRs to contribute to resilient adaptation is in their nature as a solution of last resort that aims to avoid the degeneration of food scarcity conditions into widespread crisis. Access to SGR increases thus the sphere of action of the government and increases national buffer capacities, that is, if well managed.

However, the discouraging management record of SGR in Africa (cf. Tschirley et al. 2004) should not be taken as an argument for ignoring SGR as a tool for maintaining food security and adaptation to climate change. SGR still holds promises of maintaining at least some quantity of food at national levels, especially in the context of global food crises and supply shortages. Development policy and development cooperation should support national governments to focus on (1) dealing with the various mismanagement issues reported; (2) ensuring that the SGR mechanisms does not distort food prices and discourage farmers from production; (3) addressing the problem of misuse by traders and those that have access to government information; (4) decentralising SGRs to sub-national levels to improve response and accountability, and, (5) introducing measures that ensure that the food gets to the intended targets – the poor and people in very remote rural areas whose food security is jeopardised by both climatic and non-climatic stressors.

5.10 Implications and conclusion

The foregoing analysed the various adaptation measures that can be undertaken at policy and institutional levels and their contributions to resilience. Their benefits and limitations were also highlighted. Where well managed, these measures can enhance adaptation to climate change.

The Rio Conventions provide international reference frameworks for national governments to address and mainstream climate change into national policies and programmes. In that way, they build the adaptive capacity of the developing countries. Most action plans have significant relevance and potential synergies in relation to country priorities, and are in a few cases, integrated into regular country planning processes. Thus they have made their mark in country planning frameworks.

While some level of harmonisation may have been achieved, a more important goal is the *actual planning and implementation* of the conventions action plans at the national and local level. Thus synergy in implementation is crucial and this requires close cooperation among the MEA national focal points as well as explicitly providing funds for the implementation of identified synergies.

Participatory approach is critical in elaborating projects but some of the prioritized projects in the NAPAs beg for more explanation in their reporting. For example, what is the weight given to the problem of diffusion of technology in such cases like the development of drought resistant crops and seed varieties? Did the crop scientists participate in the NAPA process? How well could the farmers articulate their aversion to growing drought resistant seeds that are generally known for lower yields? Developing drought resistant crops and seed varieties as an adaptation measure is well and just, but what lessons from past developments of drought resistant crops are we taking along with us as we develop these new seeds?

That is the critical point that needs to be addressed in such adaptation projects. It also sends confusing messages considering that research institutions that work on the major grains of the drylands suggest that drought-tolerant varieties are already developed and only need to be diffused. Such prioritized projects and the way they are presented hint that we may not be learning from past mistakes. It may also be that the proponents plan to do so but this information is not explicit in the reporting format of the NAPA documentations.

Crop research is a crucial area for adaptation to climate change to deal with changes in the length of growing seasons, increased droughts and periodic water logging as well as increased temperature and salinity. This message of the crop research institutes about the availability of improved germplasm that address the various impacts of climate change is good news that needs to be spread to the relevant actors. Thus, efforts should be concentrated to bring these improved varieties of maize, rice, cassava, pearl millet, sorghum, chickpea, pigeon pea and groundnut to the farmers. National Agricultural Research Centres and the private sector in areas that are likely to expect more droughts in future should be supported to re-deploy and retarget the existing germplasm of the crop research institutes.

Analyses have revealed the interdependencies between various services. This means that limitations in a base service leads to limitations in the depending services, which cannot always be compensated by other means. For example, effective decisions in providing extension services or managing strategic grain reserves depend significantly on the correctness of the weather and other information provided by Early Warning Systems (EWS). Thus, the basic services on which others build, in this case the EWS, need to be improved first before other depending services can profit from their potentials.

Various services can be used to support smallholders to adapt to climate change. However, reaching the poor remains a challenge for many of these services. For example, farmers need to have the financial resources to become members in farmer groups as membership determines access to financial and insurance services. Inadequate extension resources imply that the poorer farmers cannot be adequately targeted. A solution would be to shift the focus of public extension services to the poorer farmers and marginal areas, while allowing the private extension to service the cash crop sector and the high potential areas.

Some of the services discussed are new, for example, index-based weather insurance. This means that a monitoring and evaluation will be necessary in a few years to ascertain how effective they are in supporting adaptation to climate change.

Perhaps, associated with the foregoing, a prominent feature of most of the services is the high level of external dependence. This donor-driven and donor-controlled feature raises the issue of ownership and sustainability of interventions. How to ensure that such projects and programmes continue after the donors have left is not highlighted. Available information does not provide enough information to arrive at conclusions at the moment. However, the issue of the sustainability of interventions is fundamental for development policy and cooperation and should therefore be given more attention or prominence in the reporting.

In this light, the foregoing analyses shows that building capacity should not be an add-on in the establishment of these services but should be explicitly accounted for from the outset, especially for those areas that require special knowledge and skills. Perhaps, a tool for measuring the contributions of development/adaptation projects/programmes to capacity building needs to be developed and used. This also holds for the mechanisms of the international environmental regimes.

While some services are predominantly donor-driven, the Strategic Grain Reserve is the only service analysed where donors are generally absent. This reflects the divergences in the understandings of international development policy and national development policies on the importance of holding a physical grain reserve for the SSA countries. In principle, holding an SGR is good because it gives countries a manoeuvring space to address short but acute food shortages and time to moderate widespread food shortages before food imports arrive. Food is also a political issue as a country (regime) that cannot provide its inhabitants food is seen by the hungry to have failed them and thus loses legitimacy. However, the poor performances of the SGRs so far do not speak for their further existence. Considering that the principle is good but the practice bad, corruption and mismanagement need to be addressed by improving the guidelines and having the political will to penalise corruption.

Finally, the resilience check was used to analyse the contributions of the services to a resilient adaptation to climate change in smallholder agriculture. Results show that most of the services contribute to economic resilience, in some cases to social resilience, but hardly directly to ecological resilience. This is plausible because the direct benefits of most services are an increase in financial capital, as well as in human and social capital. However, these benefits extend to ecological resilience in that with improved financial, social and human capital, smallholders are able to invest in farm production and improve their farm management practices, thereby building their adaptive capacity.

6 Conclusions and recommendations

6.1 Main findings

6.1.1 Underlying development deficits

Many non-climate factors determine the success and failure of smallholder agriculture. Some key factors at the national level are the neglect of investment in agriculture, increasing land degradation, inadequate infrastructure to promote agricultural marketing and processing, the deficit food production and resultant dependency on food imports. At local levels, major factors include the widespread poverty among smallholders, their risk-averse strategies and the low agricultural intensification and adoption of technologies. Although the recent improvements and prospects in agricultural growth, propelled by the commitments of many SSA countries to allocate 10 percent of their respective budgets to agriculture, will likely lead to growth in the sector, access to resources remains a constraint.

Overlapping land tenure regimes, access to land and conflict potentials

Land tenure remains a key determinant factor in smallholder farming and is crucial for various adaptation practices. With climate change, certain areas will become un-conducive for farming. Smallholders will need manoeuvring space to shift their cropping areas. However, the recent leasing out of agricultural lands in some African countries to countries outside Africa to produce food for export back into the investor countries reduces smallholder access to such lands. Such leasing arrangements (at least under the mostly disadvantageous terms for locals) are odd considering that many of those African countries that lease out land do not produce enough food for own consumption. The overriding claims of the national governments that lease out the land and the communities that perceive the land to be theirs hold potentials for conflict considering that land has been at the root of many social upheavals in SSA. Such lease agreements highlight the need for an international reference framework, national land reforms, the imperative to protect and secure local (community) property rights and the unaddressed tension between customary and modern state land rights.

6.1.2 Predominantly adverse climate change impacts

Climate change will overlay and interact with these factors to further worsen the crop production conditions in most of SSA. Precipitation amounts will decrease for most parts of SSA while rainfall variability and intensive rainfall events will increase. The observed changes in climate give a picture of increased variability, of decrease as well as increase of rainfall and temperature. Future climate change is expected to intensify the already observed changes considering the implications of committed warming and if no remedial actions are taken to reduce emissions. Projected changes indicate that temperatures will continue to increase in a "business as usual" development pathway. There will be shifts in rainfall seasons, highland areas will be won for agriculture but also affected by malaria, and "new" diseases and pests will be manifest in areas where they were hitherto unknown / uncommon.

"Accounting for uncertainty in climate" as a major focus for adaptation

Currently, climate projections for SSA do not fit the spatial and temporal scales of agricultural processes, practices or planning, and cannot yet produce the details needed for impacts assessments. These limitations of climate change projections need to be understood and accounted for in research, policy and planning that departs from or aims to account for climate change impacts. Thus "accounting for uncertainty" becomes a major focus for adaptation. This means that adaptations need continuous adjustment and require periodical evaluations to establish whether they are still beneficial under the evolving circumstances.

Misfit of projection timescales with political realities

From the perspective of political regimes, projections are provided for the distant future but politicians are more interested in impacts within their rather short political regimes. Thus downscaling of climate models and projections remains crucial.

Difficult to differentiate development activities from adaptation actions

It remains difficult to differentiate development activities from adaptation actions and in many cases adaptation actions will be the same as development action. In this tension between development and adaptation, it is prudent to build adaptations on robust foundations. This is why adaptation essentially has to be developmental and the issue of additionality in adaptation while important is rather political as it does not reflect the real realities. Still, tools are needed to identify the additionality of adaptations.

6.1.3 Resilient adaptation as a guiding principle

Considering the challenges of dealing with uncertainties, the widespread poverty and lack of capacities, the resilience concept offers a superior entry point to analyse adaptations to climate change under conditions of uncertainty compared to vulnerability. Adaptations to climate change need to be resilient, by building buffer capacities, enhancing self-organisation as well as the capacity to learn and adapt. A resilience approach focuses on underlying causes as well as long-term capacity to deal with change. The concept of resilient adaptation can thus serve as a guiding principle for decision makers to plan adaptations that account for uncertainties in future climate change. It was shown that resilience underpins adaptive capacity without which adaptations will not be possible.

6.1.4 Agricultural adaptation practices and instruments

Existing improved crop varieties address most climate change impacts known in the medium-term (2010–2050).

The good news of improved climate change robust crop varieties needs to be spread to the relevant actors. Crop research reports the development of crop varieties that are robust to changes in the length of growing seasons, increased droughts and periodic water logging as well as increased temperature and salinity. Thus efforts should be concentrated to bring these improved varieties of rice, maize, cassava, pearl millet, sorghum, chickpea, pigeon pea and groundnut to the farmers. National Agricultural Research Centres and the private sector in areas that are to expect more drying in future should be supported to re-deploy and retarget the existing germplasm.

The seeming success of weather indexed insurance

Index-based weather insurance is an emerging instrument in many parts of SSA (Mali, Malawi, Kenya, Tanzania, and South Africa) to improve risk management of farmers. Examples include the National Smallholder Farmers' Association of Malawi Index-Based Weather Insurance and the Ethiopian drought / index-based weather insurance under its Productive Safety Nets Programme. At the national level such insurance reduces the time it takes to acquire sufficient emergency relief funds, thereby pre-empting the need to provide emergency food and reducing the threat of starvation. At the local level, farmers can retain their productive assets. Thus insurance can break the dependency on aid and its fast spread indicates its success among the farmers. The insurance schemes are examples where public-private partnership spanning global to local actors seems to be effective. Despite its seeming success, various challenges to a fully sustainable and scalable product remain. These are the need to improve the quality of climate data, to build local capacity and transfer technology for continuous improvement of the insurance contracts. Other challenges are how to bring about lasting local ownership and how to reach the poorest. Since the index-based insurance is a new instrument, there is not much evidence to be used for evaluation. Hence their performance should be assessed after some years to ascertain their effectiveness.

High level of external dependence and their implications

A prominent feature of most of the services is the *high level of external dependence*. This donor-driven and donor-controlled feature raises the issue of ownership and sustainability of interventions. How to ensure that such projects and programmes continue after the donors have left is not highlighted. *External support can sometimes be harmful to the existence of self-help groups* (Lee 2006). Therefore development or adaptation inputs to make in order to enhance self-organisation should be considered carefully. The issue of the sustainability of interventions seems to be consciously addressed and should therefore receive more attention or prominence in reporting.

The politics of strategic grain reserves

While some services are predominantly donor-driven, the Strategic Grain Reserve (SGR) is the only service analysed where donors are generally absent. This reflects the divergences in the understandings of international development policy and national development policies on the importance of holding a physical grain reserve for the SSA countries. In principle, holding an SGR is good because it gives countries a manoeuvring space to address short but acute food shortages and time to moderate widespread food shortages before food imports arrive. Food is also a political issue as a country (regime) that cannot provide its inhabitants food is seen by the hungry to have failed them and thus loses legitimacy. However, the poor performances of the SGRs so far, do not speak for their further existence. Considering that the principle is good but the practice bad, governments need to address corruption and mismanagement by improving the guidelines and having the political will to penalise corruption.

The persisting challenge of reaching the very poor and very marginal areas

How to reach the *very poor and very marginal areas* remains a challenge. While interventions may reach the poor generally and contribute to poverty alleviation, the very poor remain shut off from participating in development activities, due to entry barriers like payment of membership fees of a farmer group which is crucial to be able to access farm support instruments like micro-finance or micro-insurance. Even in the adoption of recommended improved technologies, it is those who have the money to invest that do so and succeed. Therefore, the danger of increasing the gap between the rich and the poor has to be accounted for in interventions that aim to promote climate change adaptation. Specifically targeting the very poor is a key to achieving a sustainable adaptation, but since this group is not economically interesting to the private sector, it remains in the hands of governments and NGOs to specifically target the very poor. Inadequate extension resources imply that the poorer farmers cannot be adequately targeted. A solution would be to shift the focus of public extension services to the poorer farmers and marginal areas, while allowing the private extension to service the cash crop sector and the high potential areas. In order not to keep on perpetually targeting the poor, it might be worthwhile to invest in human capital. By educating and training the very poor in relevant skills (like health workers, extension officers, entre-preneurs, teachers, technicians); the chance that such poor will remain in poverty is slim.

6.1.5 International and national policy integration

Coherence between international and national policies is crucial for planning and implementing adaptations. While a certain level of coordination among the three Multilateral Environmental Agreements (MEAs) has been achieved at international levels, there is little information on the level of linkages between the various national focal points of the conventions. Where the focal points are under different ministries, the level of interaction may be limited. Close cooperation among national MEA focal points is paramount, especially with regard to the implementation of adaptation-related action plans.

In line with exploiting the synergies and providing guidance on how to deal with trade-offs and barriers, some SSA countries like Djibouti and Lesotho have integrated environmental protection and the promotion of sustainable development into various development plans and programmes. However both countries recognise that their NAPAs need to address the gaps in current scientific knowledge in terms of integrating adaptation concerns into specific sectoral development plans. Burkina Faso plans to mainstream its NAPAs through "increasing consistency and leveraging synergy between various projects and programmes while addressing specific constraints encountered in prior planning frameworks" (UNFCCC 2005b, 5).

Many African LDCs from the outset analysed the inter-linkages and (where not already existing) acknowledged the importance of integrating climate change into national policies. It remains to be seen how this will be done in practice as only Lesotho (cf. Lesotho 2007, 30) proposes a NAPA-project on policy reform to integrate climate change in sectoral development plans. Similar problems also face the non-LDC SSA countries in the options identified in their National Communications (cf. Orindi / Murray 2005). The poor institutional framework in many African countries foster the duplicity of services and areas of jurisdiction, the plurality of institutions as exemplified in the traditional and state laws and regulations, bureaucratic processes and corruption. These factors interact to cause low adaptive capacity.

An evaluation for UNEP of the preparation of the NAPAs in 13 countries showed that most NAPAs have a "high degree of relevance and potential synergies in relation to country priorities. In a few cases, evidence of NAPA integration into regular country planning processes was found". The selected adaptation options were also found to be "highly relevant as compared to development priorities and needs, but presented varying degrees of relevance in relation to climate change" (UNFCCC 2008c, 10).

The links between the Rio conventions and poverty reduction have brought about efforts to mainstream climate change and biological diversity into development cooperation (SCBD 2006; 2009). However, although the NAPAs took account of the national Poverty Reduction Strategy Papers (PRSPs), the disconnect between the ministries of finance or planning, which prepare the PRSPs, and the environment ministries that mostly coordinate the NAPA process makes mainstreaming adaptation into development agendas as described in the PRSPs difficult (McGray et al. 2007). Osman-Elasha and Downing (2007) note that "the practical means of integrating climate change into sectoral and structural planning decisions are largely lacking", also partly because experience from implementing the NAPA projects is still to be made. Thus, the integration of environmental objectives and sustainable development into the PRSPs is low, with exceptions of Zambia and Mozambique (UNFCCC 2005b). Eritrea's NAP plans to mainstream desertification, climate change and biodiversity into various ministries while Gambia's NAP is part of the Gambian Environmental Action Plan and its Vision 2020 strategy and objectives (UNFCCC 2005b).

However, institutional reform is not a priority in the NAPAs. This could be because of its very sensitive and political nature, which requires impetus from other actor categories (e. g. the politicians themselves) rather than from government officers (who prepared the NAPAs), who could lose their job in attempts at addressing such sensitive topics. Institutional barriers such as bureaucratic structures in some partner institutions hindered the free exchange of information among the different team members during the NAPA process (Osman-Elasha / Downing 2007). Hence, political will and institutional barriers also need to be addressed because even in conditions of low development, these two factors are fundamental to the success of adaptations. Some countries highlight "inadequate support and involvement of critical stakeholders" and "inadequate support and involvement of local communities" (for example Lesotho 2007, 38 and 43), as a risk and barrier to implementing prioritized NAPA projects. Such conclusions pose the question of "how participatory the NAPAs were?"

Participatory approach is critical in elaborating projects but some of the prioritized projects in the NAPAs beg for more explanation in their reporting. For example, what is the weight given to the problem of diffusion of technology in such cases like the development of drought resistant crops and seed varieties? Did the crop scientists participate in the NAPA process? How well could the farmers articulate their aversion to growing drought resistant seeds that are generally known for lower yields? Developing drought resistant crops and seed varieties as an adaptation measure is all well and good, but what lessons from past developments of drought resistant crops are we taking along with us as we develop these new seeds? That is the critical point that needs to be addressed in such adaptation projects. It also sends confusing messages considering that crop research institutions that work on the major grains of the drylands suggest that drought-tolerant varieties are already developed and only need to be diffused. Such prioritized projects and the way they are presented hint that we may not be learning from past mistakes.

6.2 Recommendations

Since adaptation is a broad field with various actors, an adaptation action might require different complementing inputs from national governments, climate policy, development policy and cooperation, the private sector, and the research community. Therefore coordinated action is a key to implementing adaptations. In this sense the following recommendations are not structured according to roles of the above actors but according to what needs to be done. Within such recommendations, the primary actor responsible and the division of labour in implementing adaptations are discussed.

6.2.1 Recommendations to African governments

National governments bear the primary responsibility for implementing adaptation actions and development programmes. It is at the national level that the different strands of international policy (development, trade, climate, biodiversity, migration) converge. From this vantage position, it is to be expected from the African governments that they know the synergies and trade-offs of the various policy strands and how to manage these.

Since African governments have the primary responsibility for development and for implementing adaptation actions in their countries, they need to define

1. Their adaptation needs.
2. The strategies they plan to follow to adapt to climate change.
3. The kind of support they require from the international climate policy, development policy and cooperation.
4. The role of various actors at national and sub-national levels.
5. Re-examine their roles so far.

Without this identification, adaptations and development are likely to be haphazard and uncoordinated. Currently, the predominance of donor interventions at national levels masks this primary responsibility and poses the question of who is responsible for development and adaptation at national level.

The following is used to illustrate the proposed strategy above: the interdependencies between various private and public support services mean that limitations in a base service leads to limitations in the depending services, which cannot always be compensated by other means. For example, effective decisions in providing extension services or managing strategic grain reserves depend significantly on the correctness of the weather and other information provided by Early Warning Systems (EWS). Thus, the base services on which others build, in this case the EWS, need to be improved first before other depending services (adaptations) can profit from their potentials.

The limitations in adaptation in the agricultural sector indicate that apart from funding and implementing adaptation projects (which is not a primary function of ODA but that of the climate regime) development interventions still need to invest in classical development issues (for example, poverty reduction, health, education, energy and road infrastructure development) and indeed, in a coordinated way. This will forestall the multiplier effect of low development plus high climate change risks and avoid building adaptations on fragile foundations. Such an approach is crucial to achieve progress in the near future. African governments should realise their responsibility for basic development in their countries. Development cooperation can only act in support of government initiatives.

Many African governments have already identified their adaptation needs. Through the support of the international climate policy, the governments have developed their NAPAs and the national communications. However, financial resources are required to implement the identified adaptations.

The international climate policy thus needs to provide adequate resources for adaptation to climate change. The financial resources for adaptation have to be additional (however defined) to those of the ODA because the resources from the ODA are needed for development. The financial mechanisms for development and adaptation stem from different considerations (ODA: aid principle; climate change adaptation: polluter pays principle). However, funds for adaptation are currently insufficient and all actor categories (governments, climate policy, development policy and cooperation) need to harness additional funding sources (for example from the private sector).

In recognising that the primary responsibility for implementing adaptations lies with the national governments, African governments need to re-examine international policy and agreements to determine and use the flexibility that these already offer. The governments will have to use own resources or source for funds for achieving this goal.

There is a need for coordination at national level in order to ensure that adaptation is integrated into national policies and planning. However, the governments not only need to identify adaptation options but also how such adaptations fit with their aims to increase agricultural production. It is only after the governments have defined what for them a resilient adaptation strategy is that mainstreaming will bring about long-term benefits.

The progress achieved by coordination at regional level to arrive at a common position in international climate negotiations hints at the potentials African countries have to steer climate policy. This political will should also seep down to the national and sub-national levels.

A question that the governments must answer is: why is it that of all services analysed the national strategic grain reserves, despite their quality as a national food security insurance measure, have been and are still wrought with corruption and mismanagement and often fail when they are most needed? Regional organisations like the Africa Union NEPAD need to re-examine this case and advise their members accordingly.

African governments need to promote farmer social network and group organisation over several years to ensure that such organisations pick up. Farmers' and local users' organisations are effective in regulating the use of natural resources such as in water users associations or forest users' associations. Such group organisations offer an effective governance instrument to deal with the conflicts that are likely to increase as a result of climate change triggered resource scarcity. Examples from Malawi show that farmers' organisations can effectively offer extension services to their members. Such innovations need the support of the African governments.

Finally, climate policy requires the support of development policy and cooperation. While international climate policy is primarily responsible for climate change adaptation at international levels, the overlap of adaptation with development calls for coordination with the development community. Development policy and cooperation thus have years of experience that climate policy and the emerging adaptation community do not have. In this sense, it is prudent for climate policy to draw from the experiences and expertise of the development community through policy coordination and joint implementations.

6.2.2 Responsibilities and roles for adaptation practice at national level

Adopt an integrated approach to adaptation

Due to the broad nature of adaptation, various spheres of knowledge, various actors and scales interact to define adaptation outcomes. For adaptation to be sustainable, local knowledge should be combined with other knowledge systems. Local production should not be mainly reliant on external inputs as this is one factor that already spells the failure of adaptations. Input in this sense covers both factors of production as well as the knowledge and skills needed to run the agricultural system. This does not mean that all the knowledge should remain with the farmers at the local level but, a system of cascading and overlapping knowledge whereby the various national to local institutional frameworks play their expected roles is needed.

Responsibilities and roles:

- Governments need to coordinate adaptation strategies and programmes between their organs, research institutes, the extension services, private sector actors, other government bodies, NGOs, civil society and not the least the farmers to promote adaptation practices.

Improve climate monitoring and early warning systems

Early warning systems still struggle with collecting data of adequate quantity and quality for monitoring climate and for early warning. Despite positive examples of the use of climate information (Hellmuth et al. 2007: flood management in Mozambique), regional networks require further strengthening – politically, legally, institutionally, operationally, or technically to increase their effectiveness (Hellmuth et al. 2007). A remarkable factor in climate services offered so far is the high dependence on donor funding for projects aimed at improving climate services. Considering the poor financial state of many African countries, the frequent exposure to extreme events and the recent global financial crisis, it is likely that the *dependence on foreign aid for improving climate services will persist*. The questions then are how to improve EWS and reduce this dependence.

Responsibilities and roles:

- Since most of the countries lack the necessary resources to improve climate services on their own, sustained long-term support from donors still remain necessary.
- Governments need to train more African scientists in climate science, the transfer of technological innovations in climate monitoring and prediction.
- Development cooperation needs to encourage institutional coordination so that best use can be made of the available information and resources.

Direct agricultural development towards low carbon intensification paths

Adaptation planning offers an opportunity to reconcile low-carbon development with high agricultural productivity. Any shift of farm management in the context of adaptation must not be at the expense of sustained food production. Already most SSA smallholders practice various shades of organic farming by default – meaning their pecuniary circumstances force them not to use fertiliser, pesticides, high yielding seeds, and mechanisation. Thus, their management approaches do not (yet) pollute the environment as would be the case if they were to intensify their production with chemical fertilisers and mechanisation. Yet these two factors belong to the core factors for increasing food production. A low carbon path is also important considering the close link between climate change adaptation and mitigation in the agricultural sector. Thus, an adaptation strategy for smallholder farming systems in Africa is to ensure that they keep to a low carbon path but at the same time increase production – an integrated approach that combines the merits of organic practices with those of low carbon intensification.

Responsibilities and roles:

- Governments and climate policy, with support from development policy and cooperation need to guide the development pathway of SSA agriculture towards a low-carbon intensification path. This can be achieved through promoting smallholders' access to new and affordable farm technologies that are environmentally-friendly and which also allow them to practice integrated nutrient management.
- Research needs to develop and modify technologies to the smallholder contexts and needs. It also needs to examine and show how adopting a low carbon path can still maintain and increase agricultural production in Africa.
- Governments need to increase the capacity of extension in organic and conservation agriculture: although organic and conservation agriculture are promising development paths for smallholder agriculture, this arena is dominated by private commercial farms, pesticide companies, private NGOs and foreign certification bodies. In many countries, extension services for the sub-sectors are generally lacking. Thus, development cooperation and the research community need to first make deciding actors in governments aware of the potentials of these farming approaches to maintain agricultural production and their contributions to

climate and environmental protection. With awareness raised, governments and development cooperation can direct resources to building up extension capacity in these spheres.

Promote an actor-differentiated programme on awareness creation

Awareness and perceptions of a problem shapes action or inaction on the problem. Currently, many actors at various levels do not have an in-depth understanding of the climate change problem and its implications. Deciding actors need to be aware of and understand the ramifications of climate change. It is therefore crucial to disseminate and explain relevant climate change information as well as tailor these to the various audiences. In addition, the use of many farm technologies (such as rain water harvesting, improved germplasm) remains modest. Yet widespread adoption is needed for existing improved technologies to effectively contribute to climate change adaptation and development.

Responsibilities and roles:

- Governments, with the support of climate and development policy should introduce awareness programmes tailored to various actor categories in agriculture, which can be aired on radio. Airing on radio will reduce the costs of using face-to-face extension services and the time it takes to disseminate information.
- Development policy and development cooperation can support rain water harvesting through creating awareness in campaigns on the benefits of this practice. It also needs to support research that examines the barriers to diffusion and adoption of technologies and how to address them.

Introduce policy instruments and measures that address resource use efficiency

Extension services need to focus on promoting farm resource use efficiency. Organic agriculture, conservation agriculture and integrated crop management approaches contribute to ecological resilience more than conventional agriculture. However, each of these systems has its merits and demerits in the context of adaptation but also in the context of food production. Irrespective of farm management chosen, resource use efficiency was found to be a challenge in all systems.

Responsibilities and roles:

- Governments (extension services), with the support of climate and development policy, should establish programmes that promote farm resource use efficiency.

Implement the NAPA projects

Many adaptation projects in agriculture are proposed in the NAPAs. However, too much delay in the implementation of the NAPA projects compromises their validity as the social-ecological conditions from which they were designed are also changing. The question of funding is still paramount as the costs of adaptation needs are still higher than the funds set aside for adaptation (UNFCCC 2008c). The LDCs themselves suggest various measures to expedite the NAPA process. These include reducing the requirements for the additionality criteria of proposed projects, suggestions for the LDC Expert Group (LEG) to provide templates for common projects so as to reduce the project proposal preparation phase, to conduct training workshops on project development and project management. Broadening the LDC Work programme in Decision 5/CP.7, to include more work on adaptation, increasing capacity building efforts, and creating a possibility to update the priorities in the NAPA regularly, were found to be crucial (UNFCCC 2008c). The NAPAs could thus be introduced as pilot programmes.

Responsibilities and roles:

- Considering the supposedly urgent nature of the NAPAs, climate policy and governments have the primary responsibility but need the support of development cooperation and the private sector to implement the NAPAs in a timely manner.
- The LDCs should actively source for additional funding sources (philanthropy, bilateral and multilateral) instead of totally depending on and waiting for the decisions of the Global Environment Facility (GEF) or Adaptation Fund Board.

More tools are needed to evaluate adaptation options and progress

The "Resilience Check", developed for assessing adaptation and resilience to climate change, highlighted the need for more tools that can be used for evaluating adaptations. Considering the danger of mal-adaptation and the fact that this feature cannot be easily identified at the initial stages of an adaptation action, tools are needed that screen adaptations. In this sense, research needs to examine existing tools for incorporation of climate change issues.

Responsibilities and roles:

- Policy makers should communicate to the research community the kind to tools they need for evaluating adaptations.
- Policy makers and practitioners should try to use available tools and provide feedback to research.

Promote diffusion and adoption of existing agricultural technologies

The NAPAs, NCs and TNAs recognise technology as an important adaptation instrument. However, the diffusion and adoption of existing agricultural technologies that adequately address some climate change impacts is still modest. Technologies such as rain water harvesting, drought and heat tolerant crop varieties, those that can withstand water-logging and those with improved yields exist. Small-scale mechanisation is also available. Thus the barriers to diffusing and adopting such technologies such as lack of credit, low market integration, weak processing sub-sector, need to be addressed. If smallholder farmers are to increase productivity despite climate change, mechanisation (a development factor) is one key to achieving this goal. However, it must be ensured that the mode of mechanisation has a low net energy balance and does not overtly increase GHG emissions.

Responsibilities and roles:

- Climate policy needs the support of development policy and development cooperation to ensure that the past mistakes in crop development and diffusion are not repeated.
- Development cooperation can integrate these aspects into the relevant strategic development plans after due consultations with development partners.
- Development policy and development cooperation should thus support good crop management practices through inclusion in strategic planning with partner countries and increase support for needed agricultural extension services.

- *Research should* review literature to identify the major determinants of diffusion and adoption, and how to promote these.
- Governments, with support of development cooperation and climate policy promote the diffusion of appropriate (climate-friendly) mechanisation technology. Considering the large proportion of women farmers, such mechanisation should be adapted so women can use it.
- Governments should promote secondary industries in the rural areas by training people in fabrication of farm tools that save labour.
- Governments should promote the establishment of more micro-finance services in the rural areas and ensure that their service conditions motivate smallholders to access cash for acquiring existing farm technologies.

Promote the location of secondary industries in the rural areas

A major factor contributing to food insecurity in SSA is the lack of industry-level post-harvest processing. As rainfall variability is the norm rather than the exception, bumper harvests in one season need to be preserved for consumption and for trade. However, post-harvest processing remains a challenge and cannot yet be fully exploited as an adaptation option.

Responsibilities and roles:

- Governments with support of development policy and cooperation need to promote the location of secondary industries in rural areas to provide the rural inhabitants (including farmers) opportunities to earn off-farm income.
- Government should improve the skills of rural inhabitants so they can establish small-scale secondary industries.

Introduce pilot programmes on paying farmers for ecosystem services

Considering the *environmental services* (carbon sequestration, soil erosion control, maintenance of water quality) that farmers offer and the pecuniary circumstances of the smallholders, providing smallholders incentives or compensation for good land management practices holds potentials for poverty reduction, environment and climate protection.

Responsibilities and roles:

- Governments should promote agro-forestry for a programmatic CDM of small-scale afforestation and reforestation whereby the district, provincial or national government (or even private entities) offer farmers incentives through a CDM programme to promote agro-forestry.
- Governments should examine the place of smallholder agriculture in carbon trading and the post-Kyoto climate regime.
- Climate policy should in addition recognise paying smallholders for ecosystem services as an adaptation instrument.
- Public-private partnerships, through investments in corporate social responsibility by large firms could also be one way to improve farmers' capacity for such adaptations. In that way, the firms gain social prestige, while farmers get compensation for adhering to good land management practices.
- Development policy and development cooperation need to exploit these potentials and support governments and climate policy.
- Research should provide tools for valuing environmental services in Africa, not only for paying farmers, but also for the Ministries in charge of environment and relate issues to be able to quantify the value of maintaining a forest reserve (for example). Such a tool brings such environmental ministries on the same language basis (economics) as the ministries of finance and planning.

Explore the potentials of certification bodies from the non-climate sector

While it is evident that smallholders provide ecosystem services, it remains a challenge for them to derive benefits from these. The fact that SSA has gained very little from the current carbon trading schemes (in contrast to large commercial farms in Asia) hints at the inadequate know-how and resources required to establish such schemes as well as the disadvantageous structures of the CDM scheme of the UNFCCC whereby most certifying companies are located outside Africa.

Responsibilities and roles:

- Governments need to develop regional standards through the African Union for certification or explore the potentials that other certification bodies provide. For example, certification bodies from the organic agriculture sub-sector could be one such alternative.

- Climate policy, development policy and cooperation need to support SSA governments to set up the necessary infrastructure at country or regional levels to simplify access to the carbon markets.

Introduce one action plan and one coordinating national body for the MEAs

Based on the wide reaching synergies identified among the MEAs, it will be more effective to have one single action plan that integrates the three action plans of the convention. Each of the conventions aims to mainstream biodiversity, desertification and climate change-related issues into development policies and development cooperation (cf. UNCCD 2005; UNFCCC 2005c). However, having to mainstream separately biodiversity, desertification, climate change and many other issues of common concern into government development policies and activities or development cooperation holds the danger of mainstreaming overload or fatigue. One way of addressing this mainstreaming fatigue could be by focussing on mainstreaming sustainable development, which can then be interpreted flexibly, where relevant by the implementing organisations and government departments. In recognition of this potential, the UNFCCC JLG (2009, 9) suggests that, "from the perspective of environmental management, linking adaptation activities under the UNFCCC to the activities of the UNCCD, rather than designing, implementing and managing climate policy separately, augurs well for fostering a holistic approach to identifying and creating the necessary tools, resources and conditions for effective adaptation. Synergies also respond to the present orientations of international environmental governance, as it makes sense from an efficiency and mainstreaming perspective". However, much remains to be done to promote synergies between biodiversity, climate change and desertification and the climate change agenda (SCBD 2009).

Responsibilities and roles:

- Governments with the support of climate and development policy need to bridge the divide between development and environment communities by creating one action plan at the national level for implementing the MEAs.

6.2.3 Responsibilities and roles for adaptation practice at international level

Coordinate financing of development and adaptation actions

Development is the basis for adaptation. With limited development, adaptation lacks a solid basis to achieve its goals and it makes little sense to build adaptations on fragile foundations. Admittedly, the crux of the matter is the differing sources of funds for the two interlinked spheres of climate change and development. While ODA primarily focuses on funding development activities, funding from the international climate regime focuses on funding activities that address climate change (for example mitigation and adaptation). Various options need to be explored for coordinated funding and action. For example, some form of weighting to determine which funds should be from the regular ODA or from the adaptation funds could be used. While this study is not about financing adaptation or development aid, the findings show that pragmatic solutions are needed because the real-life manifestations of impacts and vulnerabilities due to climate change or lack of development do not manifest as two different things (and cannot be easily detached) but they manifest as one phenomenon of high vulnerability.

Responsibilities and roles:

- Climate policy should give national governments the freedom to decide whether the funding received for adaptation can be used for development.
- Research needs to develop a method of debiting adaptation funding contributions of industrialised countries from their financing responsibilities in adaptation, in order to address the issues of responsibility to finance adaptation by industrialised countries.
- To ensure that ODA is not used in such cases, national governments and development policy and cooperation could follow the following procedure:
    1. Identify the development basis (for example road infrastructure, health improvement, energy development, market infrastructure) that would ensure the effective implementation of a NAPA project or adaptation programme.

2. Governments and development cooperation should prioritize the identified development base (factor or process).
3. Governments with the support of development cooperation to invest funds and resources to implement the identified development base in lieu of implementing the adaptation or enter into a /an (*ad hoc*) consortium with actors implementing adaptations for a simultaneous implementation of development and adaptation projects.

Such a coordinated but differentiated approach ensures that ODA resources are used for development needs while funding from the climate regime focuses on adaptation. This way governments and development policy take on the responsibility of providing the solid developmental basis needed for adaptations.

Promote capacity building by integrating it as a component in projects and programmes

Capacity building should not be an add-on, but a core component of any adaptation activity with the goal that local actors gain the expertise needed to independently implement various tasks in the adaptation sphere. Some limitations, such as the low diffusion of technologies, the minimal participation of Africa in the CDM, the dependency on external support to identify adaptation actions can be traced back to inadequate skills capacity. The LDCs attribute the lower than expected capacity building-effect of the NAPA process to the fact that only international agencies like the UNDP or UNEP implement various activities associated with the NAPA. To address this situation, the LDCs call for the participation of local institutions in the implementation of NAPA projects in order to enhance local capacities. Such a strategy would increase available local capacity and in addition, hinder that the limited expertise in existing activities in the LDCs are not drained to new projects. Malawi for example, requested a more explicit capacity building approach in all GEF and NAPA projects (UNFCCC 2008c). Further, the high level of technical capacity required to develop follow-up project was perceived as an obstacle by many LDCs.

In addition, each of the adaptation strategies at farm-level needs a capacity building component whose aim should not only be to disseminate knowledge and skills but also to do so in such a way that this leads to the empowerment and self-organisation of smallholders. Since in some drylands agriculture may no longer be a viable alternative, enhancing human capital to be able to earn livelihoods in other economic sectors becomes a prerogative to adapting to climate change.

Responsibilities and roles:

- Climate policy should establish capacity building as an independent verifiable component of adaptation support.
- All development partners should define a proportion (for example 30 percent) of adaptation and development resources to be spent on capacity building.
- Research should develop a tool for measuring the contributions of development/adaptation projects/programmes to capacity building.

Examine the trade-offs and synergies between international climate and trade policies and act on these

There is a need to examine the trade-offs and synergies between international climate and trade policies as these can impede or enhance adaptations. Smallholders are exposed to global environmental change and economic globalisation leading to competition between smallholder produce and highly subsidized produce from industrialised countries. Such trade-offs frame the conditions of adaptation as they can worsen the conditions for adaptation. This means that any introduced adaptation measures should be tested through the whole chain from smallholder producers to consumers to ensure that adaptation practices are really providing layers of resilience against climate change. It does not make sense to improve productivity and not have a market for the produce thereby leaving them to waste – this does not also contribute to poverty alleviation in the long-term.

Responsibilities and roles:

- Actors in international climate, development and trade policies should ensure that trade policies do not impede adaptations. While addressing these interconnections has been difficult, unfair competition between unequal local smallholders and powerful international competitors will reduce the contributions to poverty reduction and adaptive capacity.

Finally, implementing these recommendations will go a long way to increase adaptive capacities and reduce poverty in a sustainable manner. To achieve this, dedicated long-term action, over decades, is necessary for adaptations and developments to take hold.

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APPENDICES

Annex 1: Observed climate change and impacts using Africa as spatial reference

Observation period	Observed CC	Reference, cited from	Reference
btw 1950-1954 and 1983-87	Southward shifts of JJA rainfall zones just under 3° latitude (330 km)	Hulme 1992	Sivakumar / Das / Brunini 2005
btw 1931-60 and 1961-90	Southward shifts of JJA rainfall zones of over 1° latitude (120 km)	Hulme 1992	Sivakumar / Das / Brunini 2005

Annex 2: Observed climate change and impacts using North Africa as spatial reference

Sub-Region	Observation period	Observed CC	Reference, cited from	Reference
Tropical	1961-90 (in comparison to 1931-1960)	Rainfall decline up to 30%	Sivakumar 2005	Sivakumar / Das / Brunini 2005
	Not specified	Temp increase up to 2°C		Hulme et al. 2001

Annex 3: Observed climate change and impacts using West Africa as spatial reference

Sub-Region / Country	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
	1931-1960; 1968-1990	Rainfall decline 20-40%		Nicholson / Some / Kone 2000; Chappell / Agnew 2004; Dai et al. 2004	Boko et al. 2007

Sub-Region / Country	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
Western Regions /	since late 1960s	Pattern of continued aridity		Nicholson / Some / Kone 2000	Sivakumar/ Das / Brunini 2005
Tropical rainforest zone /	1960-1998	Rainfall decline 4%		Malhi / Wright 2004	Boko et al. 2007
Semiarid, subhumid West Africa /	1968-97 in comparison to 1931-60	Rainfall 15-40% lower		Nicholson et al. 2000	Sivakumar/ Das / Brunini 2005
Sahel / Sudan, Guinea	1970-1990	Rainfall decline	25-35 km southward shift of Sahelian, Sudanese, Guinean ecological zones; loss of grassland and acacia, loss of flora, fauna, shifting sanddunes in Sahel	Gonzalez 2001; ECF / Potsdam Institute 2004	Boko et al. 2007
Sahel / Sudan, Guinea		Desertification	25-30 km southwest shift of vegetation zones	Davis / Zabinski 1992; IPCC 2001	Zhao et al. 2005
Sudan	during 1950s	DTR increase during July-Sept wet season		Nicholls et al. 1996	Hulme et al. 2001

Sub-Region / Country	**Observa-tion period**	**Observed CC**	**Observed impacts**	**Reference, cited from**	**Reference**
Sudan	since the 1950s	DTR decrease Oct-June		Brooks 1999	Hulme et al. 2001
Sahel-Sahara, Sahel, Sudan /	1968-97	Mean August rainfall 55, 37, 26% below average of 1931-60		Nicholson et al. 2000	Sivakumar/ Das / Brunini 2005
Sahel	1900-1996	Precip: large multi-decadal variability with recent drying		Hulme 1996	Hulme et al. 2001
Sahel	1961-90	Rainfall: annual average 371 mm, that is, mi-nus 25% in comparison to earlier decades		Hulme 1996	Hulme et al. 2001
Sahel	1990s	Temp increase 0.2-0.3°C			Hulme et al. 2001
Sahel	btw 1931-60 und 1961-90	Rainfall decline JJA, 0.4 mm/day		Hulme 1992	Sivakumar/ Das / Brunini 2005
Sahel		Rainfall anomalies		Hulme 1992	Sivakumar/ Das / Brunini 2005

Sub-Region / Country	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
Sahel	during 1980-90	Southward shift of JJA rainfall zones up to 2.2° latitude (240 km) in position of 200 mm annual isohyet		Tucker et al. 1991	Sivakumar/ Das / Brunini 2005
Some Western / Eastern parts of Sahel	1901-1995	Precip: decrease 25%		Hulme 1996	Hulme et al. 2001
Guinean cost	last 30 years	Rainfall increase 10%		Nicholson et al. 2000	Boko et al. 2007
Niger, Burkina Faso	after 1969		Reduction in mean annual rainfall	Sivakumar 89	Sivakumar/ Das / Brunini 2005
Niger	since 1966	Rainfall decline: annual and in August		Sivakumar 1992	Sivakumar/ Das / Brunini 2005
Nigeria / Cameroon area; coastal margins of Senegal / Mauritania	1901-1995	Temp decrease 0.1-0.5°C		Hulme 1996	Hulme et al. 2001

Annex 4: Observed climate change and impacts using East Africa as spatial reference

Sub-Region / Country	**Observation period**	**Observed CC**	**Observed impacts**	**Reference, cited from**	**Reference**
	during recent decades	Intensifying dipole rainfall; increasing rainfall over northern sector, declining amount southern sector		Schreck / Semazzi 2004	Boko et al. 2007
East African highlands	ongoing	More rain between Sept and November (warm period)	Increase in malaria transmission, reduction in larval development duration	Schreck / Semazzi 2004	Boko et al. 2007
Central Highlands of Kenya / Kenya	ongoing	More rain between Sept and November (warm period)	Spread of malaria vector	Chen et al. 2006	Boko et al. 2007
Highlands of western Kenya / Kenya	ongoing	Micro climate change, deforestation	Spread of malaria vector	Pascual et al. 2006	Boko et al. 2007

Sub-Region / Country	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
Western Indian Ocean region	1997 / 1998	ENSO	Coral bleaching, 30% loss of corals resulted in reduced tourism in Mombasa and Zanzibar, financial losses of about US$ 12-18 million	Payet / Obura 2004	Boko et al. 2007
	1900-1996	Long-term wetting		Hulme 1996	Hulme et al. 2001
	1990s	Temp increase 0.2-0.3°C		Hulme 1996	Hulme et al. 2001

Annex 5: Observed climate change and impacts using the Horn of Africa as spatial reference

Country	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
Ethiopia	past 10 years	Decline in rainfall during growing season	Serious agricultural damages	Slingo et al. 2005	Fisher et al. 2005
Sudan, Ethiopia	since 1950s	Mean annual diurnal temp range (DTR) decrease 0.5-1°C		Nicholls et al. 1996	Hulme et al. 2001

Annex 6: Observed climate change and impacts using Central Africa as spatial reference

Sub-Region	Country	Observation period	Observed CC	Reference, cited from	Reference
North Congo	Congo	1960-1998	Rainfall decline 3%	Malhi / Wright 2004	Boko et al. 2007
South Congo	Congo	1960-1998	Rainfall decline 2%	Malhi / Wright 2004	Boko et al. 2007
	Parts of Cameroon	1901-1995	Temp decrease 0.1-0.5°C	Hulme 1996	Hulme et al. 2001

Annex 7: Observed climate change and impacts using Southern Africa as spatial reference

Country	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
	post 1970-period	Rainfall increased interannual variability, anomalies	More intense and widespread droughts	Richard et al. 2001; Fauchereau et al. 2003	Boko et al. 2007
	1901-1995	Temp increase up to 2°C			Hulme et al. 2001
South Africa	since 1960s	Temp increase 0.1 to 0.3°C		Krueger / Shongwe, 2004	Boko et al. 2007
Angola, Namibia, Mozambique, Malawi, Zambia	n.s.	Rainfall: significant increase in heavy rainfall	Change in seasonality, weather extremes	Usman / Reason 2004; Tadross et al. 2005; New et al. 2006	Boko et al. 2007

Sub-Region / Country	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
Zimbabwe	n.s.	DTR increase 0.5-1°C		Nicholls et al. 1996	Hulme et al. 2001
South Africa	during 1950 and 1960s	DTR decrease		Nicholls et al. 1996	Hulme et al. 2001
Mediterranean coast, Botswana, Zimbabwe, Transvaal in SE Africa	1901-1995	Precip: decrease 5 to 15%		Hulme 1996	Hulme et al. 2001
South Africa	btw 1931-60 and 1961-90	Increased intensity of extreme rainfalls over 70%		Mason et al. 1999	Sivakumar/ Das / Brunini 2005
Botswana, Zimbabwe	n.s.	Rainfall decline DJF >0.4 mm/day		Hulme 1992	Sivakumar/ Das / Brunini 2005

Annex 8: Observed climate change and impacts in areas of Africa

Sub-Region	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
Equatorial Africa, Red Sea coast	1901-1995	Precip: increase up to 10%		Hulme 1996	Hulme et al. 2001
Semiarid regions	n.s.	Persistence of rainfall deviations		Hulme 1992	Sivakumar/ Das / Brunini 2005

Sub-Region / Country	Observation period	Observed CC	Observed impacts	Reference, cited from	Reference
Dry sub-humid areas	n.s.	Rainfall decline	Decreased soil fertility/range, decreased forest production		Zhao et al. 2005
Tropical land areas	20th century	Precipic. increase 0.2-0.3% per decade			Zhao et al. 2005

Annex 9: Projected climate change and impacts using Africa as spatial reference

Projected period	Projected CC	Projected impacts	Reference
By 2050	Temperature increase; 5-10% increase evapotranspiration	Reduced soil moisture and runoff	Sivakumar / Das / Brunini 2005
2080-2099	Temperature increase 3-4°C		Fischer et al. 2005
By 2080s		Arid and dry semi-arid land will increase by about 5-8%; loss of agricultural GDP about 2-9%	Fischer et al. 2005
By 2080s		Land for wheat production disappears	Fischer et al. 2005
2080s		Decreased production, increased risk of hunger	Gitay et al. 2001
		Consistent expansion of arid lands	Fischer et al. 2005

Annex 10: Projected climate change and impacts using North Africa as spatial reference

Projected period	**Projected CC**	**Projected impacts**	**Reference**
By 2050	Rainfall decrease 10-20%, March-Nov		Sivakumar / Das / Brunini 2005
By 2080s	Precipitation decrease in JJA		Hulme et al. 2001
2070-2099	Temp increase 9°C		Boko et al. 2007
By 2055		Increased number of people who could experience water stress	Boko et al. 2007
By 2100		Agricultural losses 0.4-1.3%	Mendelsohn / Dinar / Dalfelt 2000
		Significant losses of potential agricultural land	Fischer et al. 2005

Annex 11: Projected climate change and impacts using West Africa as spatial reference

Country	**Projected period**	**Projected CC**	**Projected impacts**	**Reference**
			Length of growing season reduced by 20%	Thornton et al. 2006
	By 2080s	Precipitation decrease 5-10% in JJA		Hulme et al. 2001
		Increase of extreme events		Fischer et al. 2005

Country	Projected period	Projected CC	Projected impacts	Reference
			Crop yield reduction up to 40%	Fischer et al. 2005
			Growing periods less	Fischer et al. 2005; Thornton et al. 2006
			Increased soil-surface temperature up to 60°C	Sivakumar / Das / Brunini 2005
		Significant drying vs. progressive wetting		Boko et al. 2007
Niger, Chad	By 2080s	Precipitation increase 15-25% in DJF und JJA		Hulme et al. 2001
Nigeria, Senegal, Mali, Burkina Faso, Sierra Leone, Niger	By 2080s		Loss of cereal production potential	Fischer et al. 2005
Côte d'Ivoire, Benin, Togo, Ghana, Guinea	By 2080s		Gain in cereal production potential	Fischer et al. 2005

Annex 12: Projected climate change and impacts using Central Africa as spatial reference

Country	Projected period	Projected CC	Projected impacts	Reference
		Wetting, rain-fall increase, precipitation increase		Boko et al. 2007

Country	Projected period	Projected CC	Projected impacts	Reference
Cameroon	by 2100	Rainfall increase 15%		Boko et al. 2007
	2050-2081		Malaria expansion, contraction of suitable areas	Boko et al. 2007
	By 2100		Agricultural losses 2-4% of GDP	Mendelsohn / Dinar / Dalfelt 2000
Sudan, Chad	By 2080s		Loose of cereal production potential	Fischer et al. 2005

Annex 13: Projected climate change and impacts using East Africa as spatial reference

Sub-Region / Country	Projected period	Projected CC	Projected impacts	Reference
	By 2080	Precipitation increase (5-100%) in DJF; precipitation decrease 5-10% in JJA		Hulme et al. 2001
Highland perennial systems in Great Lakes region, parts of E. Africa			Growing periods shorten	Thornton et al. 2006; Boko et al. 2007
Kenya	By 2030	Temp increase 3,5-4°C		

Country	Projected period	Projected CC	Projected impacts	Reference
Rainfall decrease 20%	High potential zones 1% gain (3,54 US$/ha); low / medium potential zones 21,5% loss (US$ 54/ ha)	Kabubo-Mariara / Karanja 2006		
Kenya, Highlands	By 2080		More suitable conditions for transmission of malaria	Boko et al. 2007
Kenya, Highlands		Temp increase 2.5°C	Agroecological suitability increase by 20%	Sivakumar / Das / Brunini 2005
Kenya, East		Temp increase 2,5°C	20% decrease in calorie production	Sivakumar / Das / Brunini 2005
Kenya, Uganda	In 2050		Increased length of growing season by 5%	Thornton et al. 2006
Zaire, Tanzania, Kenya, Uganda, Madagascar	By 2080s		Gain cereal-production potential	Fischer et al. 2005

Annex 14: Projected climate change and impacts using Horn of Africa as spatial reference

Country	Projected period	Projected CC	Projected impacts	Reference
	By 2080s	Precipitation decrease significantly in JJA and DJF (15-25%)		Hulme et al. 2001

Ethiopia, highlands	In 2050	Temperature increase; rainfall changes	Increased length of growing season	Thornton et al. 2006
Somalia, Ethiopia	By 2080s		Loose of cereal production potential	Fischer et al. 2005

Annex 15: Projected climate change and impacts using Southern Africa as spatial reference

Country	Projected period	Projected CC	Projected impacts	Reference
	2080-2100	Rainfall decrease by 30%-40%		Boko et al. 2007
	By 2050s	Temperature increase 1.6°C		Hulme et al. 2001
	By 2050s	Rainfall decrease 5-15% during Nov-May (growing season)		Sivakumar / Das / Brunini 2005
	2070-2099	Temperature increase 3.7-7°C		Boko et al. 2007
	By 2055		Increased number of people who could experience water stress	Boko et al. 2007
	By 2100		Agricultural losses 0.4-1.3% of GDP	Mendelsohn / Dinar / Dalfelt 2000
			Crop yield reduction up to 40%	Fischer et al. 2005

Country	**Projected period**	**Projected CC**	**Projected impacts**	**Reference**
	By 2080s		Environ-mental constraints, expansion of land areas with severe constraints/ risks for crop agriculture	Fischer et al. 2005
			Southward expansion of malaria transmission zone	Boko et al. 2007
	By 2100		Crop revenues likely to fall by 90%	Boko et al. 2007
Zimbabwe, Mozambique	In 2050	Temperature increase, rainfall change	Increased length of growing season	Thornton et al. 2006
Namibia	By 2080s	Precipitation decrease 15-25% in DJF		Hulme et al. 2001
Angola, Namibia, Zambia, Botswana			Reduced length of growing season (20%)	Thornton et al. 2006
Zimbabwe, Angola, Mozambique			Loose of cere-al production potential	Fischer et al. 2005

Annex 16: The Rio Conventions and their planning instruments

The Rio Conventions are part of the Multilateral Environment Agreements (MEA).

The **Convention on Biological Diversity** (CBD) aims at "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits of genetic resources" (UN 1993).

The **United Nations Framework Convention on Climate Change** (UNFCCC) is an overall framework for intergovernmental efforts to address climate change. The UNFCCC aims to achieve the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (UN 1992).

The **United Nations Convention to Combat Desertification** (UNCCD) aims to combat land degradation in arid, semi-arid and dry sub-humid areas (desertification) and to mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa (UN 1994).

The three conventions have various planning instruments that contribute to adaptation to climate change:

The CBD National Biodiversity Strategy and Action Plan (NBSAP)

- The National Biodiversity Strategy and Action Plan (NBSAP) of the CBD concerns developing national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapting for this purpose existing strategies, plans or programmes which shall reflect, inter alia, the measures set out in the CBD relevant to the Contracting Party concerned. The NBSAP also aims to integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies (Article 6 of the CBD). Tools available for mainstreaming biodiversity into development cooperation include the strategic environmental assessment and the environmental impact assessment.

Instruments of the UNFCCC

- The **National Communications** (NC), the **National Adaptation Plans of Action** (NAPA) and the **Technology Needs Assessment** (TNAs) are some instruments to implement the UNFCCC (UNFCCC 2000). The **NC** refers to the report of the Parties on the steps they are taking or plans to implement UNFCC Articles 4.1 and 12. The **NAPA** is one of the instruments of the UNFCCC to support the Least Developed Countries (LDC) to evaluate their vulnerability and identify priority adaptation actions to be implemented to reduce their vulnerability and enhance their adaptation to climate change (see UNFCCC Paragraph 9 of Article 4; decision 5th of the 7th Conference of the Parties: 5/COP.7; UNFCCC 2002a, 32; Decision 28/COP.7; UNFCCC 2002b, 7). The NAPA is only a short-term instrument, which may also serve for long-term planning, as the GEF does not finance all priority projects identified. The **TNAs** are a set of country-driven activities that assist in identifying and analysing priority technology needs, which can be the basis for a portfolio of environmentally sound technologies (ESTs) projects and programmes in the implementation of Article 4.5 of the Convention.

The UNCCD National Action Programme (NAP)

- The National Action Programmes (NAPs) are a key instrument in the implementation of the UNCCD. The NAPs identify factors contributing to desertification and practical steps and measures necessary to combat desertification as well as to reduce the effects of drought. The efficiency of NAPs is enhanced through support from action programmes at sub-regional and regional levels.

Sources: http://www.cbd.int/nbsap/introduction.shtml; http://unfccc.int/ttclear/jsp/TNA.jsp; http://www.unccd.int/actionprogrammes/menu.php (all accessed 2 June 2009); others mentioned in the box

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