Supporting the vulnerable: Increasing adaptive capacities of agropastoralists to climate change in West and southern Africa using a transdisciplinary research approach

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Supporting the vulnerable: Increasing adaptive capacities of agropastoralists to climate change in West and southern Africa using a transdisciplinary research approach

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Acronyms

AU–IBAR	African Union, Inter-African Bureau of Animal Resources
CBO	Community-Based Organization
CFTs	Crop Functional groups
CMIP3	Coupled Model Intercomparison Project phase 3
GCMs	General Circulation Models
GDP	Gross Domestic Product
GIS	Geographic Information System
GLC	Global Land Cover
HIV	Human Immunodeficiency Virus
IER	Institut d'Economie Rurale
IIAM	Instituto de Investigacoes Agrarias de Mozambique
ILRI	International Livestock Research Institute
IPPC	Intergovernmental Panel on Climate Change
LPJmL	Lund-Potsdam-Jena managed Land Dynamic Global Vegetation and Water Balance Model
NGO	Non-Governmental Organization
NPP	Net Primary Production
PCA	Principal Component Analyses
PM&E	Participatory Monitoring and Evaluation
PIK	Potsdam Institut fuer Klimafolgenforschung
SRES	Special Report Emissions Scenarios
SSA	Sub-Saharan Africa
WCRP	World Climate Research Program

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Summary

The world's climate is changing rapidly and Africa will be severely affected by this, not only because of the effects on ecosystems but also because of the low adaptive capacity of communities due to poverty and lack of infrastructure, services, and appropriate policies to support adaptation strategies. A large share of Africa's poor are dependent on livestock for some part of their livelihoods, most of these living in smallholder, rainfed mixed systems and pastoral systems, where livestock play a key role as assets providing multiple economic, social, and risk management functions. The goal of this transdisciplinary project is to increase the adaptive capacity of agropastoralists, who are one of the most vulnerable groups in Africa, to climate change and variability. The purpose of this project is to co-generate methods, information and solutions between local communities, local and international scientists, policymakers and other actors involved in climate change and adaptation programs, for coping mechanisms and adapting strategies to climate change and variability in West and Southern Africa, and more particularly in Mali and Mozambique.

To quantify the magnitudes of the effects of climate variability and change on the productivity of rangelands, crops and livestock and how these changes affect agropastoralists, spatial data layers were created, collated and documented related to climate variability and change, production systems, primary production, vulnerability and feed resources. First a generalized downscaling and data generation method was used to take the outputs of a General Circulation Models (GCM) to describe some future climatology and to allow the stochastic generation of daily weather data that are to some extent characteristic of this future climatology, that can then be used to drive impact models that require daily (or otherwise aggregated) weather data. Secondly a global livestock production system classification scheme that integrates the notions of crop and livestock interactions with agro-ecological zones was extended by including indicators of the major crops grown in the mixed crop–livestock areas. Next a dynamic global vegetation crop model was used for simulating crop and rangeland yields, water and carbon fluxes and water productivities under different climate and land use scenarios. Areas of reduced primary productivity were identified and characterized and overlaid with information on poverty and livelihoods, to identify hotspots where productivity reductions may have serious repercussions on smallholders' wellbeing.

Communities have been adapting to change and variability for centuries. Household surveys and in-depth narrative analyses were conducted with agropastoral communities to document, synthesise and help disseminate their past and present coping mechanisms and adaptation strategies, particularly those related to livestock, for which there is relatively little information. Several institutions are already working on promoting adaptation strategies in West and Southern Africa. We collated and documented the strategies promoted, and together with the indigenous information provided by agropastoralist communities we initiated dialogues between the different stakeholders to jointly prioritize adaptation strategies, to select a few for pilot testing. By doing this we can provide active learning opportunities and promote the co-creation of adaptation options between different stakeholders. Implementation and dissemination of technical adaptation options often fails due to the lack of support from the policy environment.

Together with key policymaking institutions and regional policymaking bodies we identified and promoted policy entry points to support the implementation of priority adaptation strategies, and we identified policy mechanisms that in themselves are an appropriate intervention to allow agropastoralists to buffer the effects of climate variability and change.

1 Introduction

1.1 Background

The world's climate is changing rapidly: model projections for this century suggest an increase in global average surface temperature of between 1.4 to 5.8°C to 2100 (IPCC 2007). Yet the impacts of climate change are likely to be highly variable, spatially. Precipitation increases are likely in temperate land areas, while the tropics and subtropical land regions will see decreases in some areas (IPCC 2007). At the same time, weather variability is likely to increase generally. Africa is likely to be particularly badly affected by climate change. Nearly a third of the planet's 1.3 billion poor people live there, and 60% of these poor people are dependent on livestock for some part of their livelihoods (Thornton et al. 2002). The great majority of these people live in smallholder, rainfed mixed and pastoral systems. Climate change is likely to have major impacts on poor livestock keepers and on the ecosystems on which they depend. These impacts will include changes in the productivity of rainfed crops and forage, reduced water availability and more widespread water shortages, and changing severity and distribution of important human, livestock and crop diseases. Overall, warming and drying may reduce crop yields by 10 to 20% to 2050, but there are places where losses in yield and net primary productivity may be much more severe (Jones and Thornton 2003). In addition, increasing frequencies of heat stress, drought and flooding events will have adverse effects on crop and livestock productivity over and above the impacts due to changes in mean variables alone (IPCC 2007). Many African countries are more vulnerable to climate change impacts than more developed countries, because of their often limited capacity to adapt (Thomas and Twyman 2005). Nevertheless, climate change is but one driver of change: human population will increase in Africa by nearly 1 billion people to 2050; rapid urbanization is expected to continue throughout the continent; and the global demand for livestock products will continue to increase significantly in the coming decades (Delgado et al. 1999). The development challenges that Africa faces are already considerable, and climate change can only add to these.

Livestock are key assets held by poor people in pastoral systems, providing multiple economic, social, and risk management functions. Livestock are a crucial coping mechanism in variable environments, and as variability increases they will become more important. There is a growing body of literature on the role of livestock in providing pathways out of poverty for poor households. Climate-induced shocks often result in negative coping strategies that deplete livestock assets (Freeman et al. 2007). For many poor people the loss of livestock assets means collapsing into chronic poverty with long-term effects on their livelihoods or ability to climb up the poverty ladder. Other studies show that diversification of income sources through livestock farming can be a key strategy for escaping poverty (Krishna et al. 2004; Kristjanson et al. 2004). This highlights the importance of securing the livestock assets of poor households in the face of increasing variability. Despite the role that livestock have been shown to play in coping with risk and providing livelihood options, there is only very limited knowledge about the interactions of climate with other drivers of change in livestock-based systems and on broader development trends. There is much more information available on cropping systems responses than on livestock systems' responses and this is reflected throughout the adaptation literature. This serious imbalance needs to be rectified.

A wide range of possible adaptation options exists, from technological changes to increase or maintain productivity, through to learning, policies and investment in specific sectors and risk reduction options, which may increase the adaptive capacity of poor livestock keepers. Farmers already have a wealth of indigenous knowledge on how to deal with climate variability and risk. However there is still a need to assess these adaptation options in relation to reducing vulnerability of humans and ecosystems, particularly options associated with livestock, with the object of maintaining or increasing food security, incomes and resilience while maintaining key ecosystem functions. Such assessment needs to be done in conjunction with well-targeted capacity building efforts to help farmers deal with changes in their systems that go beyond what they have experienced in the past. Farming systems, including smallholder and pastoral systems can be regarded as human activity systems (Jiggens 2000). The ways these systems are managed, and farmers' production strategies, are of importance not only for production success but also for system resilience (Brodt et al. 2006). The management practices used by farmers depend on their decision-making, which again is influenced by the kind of information they take into account and how they process this information for creating knowledge (Ondersteijn et al. 2003). Assessing the attitudes and knowledge of agropastoralists will therefore help in identifying their production and coping strategies. These coping strategies are context specific, and can be found at different levels, e.g. the management of soil, plant and animal resources, as well as social and institutional regulations. Recent studies (Heiß 2003; Kaufmann 2005, Beyene et al. 2006) have shown that agropastoralists make use of spatial heterogeneity to cope with temporal heterogeneity. Their ability to buffer climatic variation depends on the diversity in the production system. Furthermore, improving the learning process and learning cycles of agropastoralists is a critical element in increasing the adaptive capacity of agricultural systems (Woodhill and Röling 1998; Leeuwis and Ban 2004; Morriss et al. 2006).

1.2 Justification

Africa will be severely affected by climate change, not only because of the effects on ecosystems but also because of the low adaptive capacity of communities due to poverty and lack of infrastructure, services, and appropriate policies to support adaptation strategies (Thornton et al. 2006). Some 60% of Africa's poor are dependent on livestock for some part of their livelihoods (Thornton et al. 2002). Most of these people live in smallholder, rainfed mixed systems and pastoral systems, where livestock play a key role as assets providing multiple economic, social, and risk management functions. Some of the most vulnerable systems to climate variability and change are pastoralists and marginal mixed crop–livestock systems (agropastoral systems) in the Sahelian belt and in Southern Africa (Figure 1).

While these systems are highly vulnerable, most work on adaptation strategies relates to crops (IPCC 2007). Due to the importance of livestock in Africa and recent multi-donor initiatives to address adaptation to climate change in the region, it is essential to inform the development agenda by doing research on livestock-specific adaptation strategies ranging from technical options (e.g. feeds, breeds, food/feed crops, water management) to enabling policies that can support technical options and buffer the effects of climate variability, such as insurance-based schemes and market incentives to sell surplus animals in bad years. Key to this process is to understand and document the wealth of indigenous coping mechanisms employed by agropastoral communities and link this knowledge with information produced through other initiatives, to derive lessons of what works, what does not, and what the information gaps are. In this way, active learning by all actors will be fostered, and adaptation solutions co-developed to benefit vulnerable agropastoralists in Africa.

The selection of regions (West and Southern Africa) and areas of Mozambique and Mali as pilot regions was done on the basis of recent analyses at ILRI. A vulnerability assessment of agricultural systems in Africa was carried out in relation to climate change, and by combining information on the regions and systems where climate change impacts are likely to be most severe with information on current levels of physical and social vulnerability in these systems, identified 'hotspots' in which the livelihoods of natural-resource-dependent people may be seriously threatened in the coming decades (Thornton et al. 2006). Mozambique and Mali are hotspots of vulnerability to climate change not only because of the severity of the effects of climate change but also because of a substantial lack of adaptive capacity caused by poverty and lack of government investment in health, education, infrastructure, and supporting institutions. Additionally, they represent well the main types of agropastoral systems in Southern and West Africa, respectively. The local partners in this project are important institutions in their respective countries and have recently started to structure R&D programs in the area of climate change and adaptation strategies.

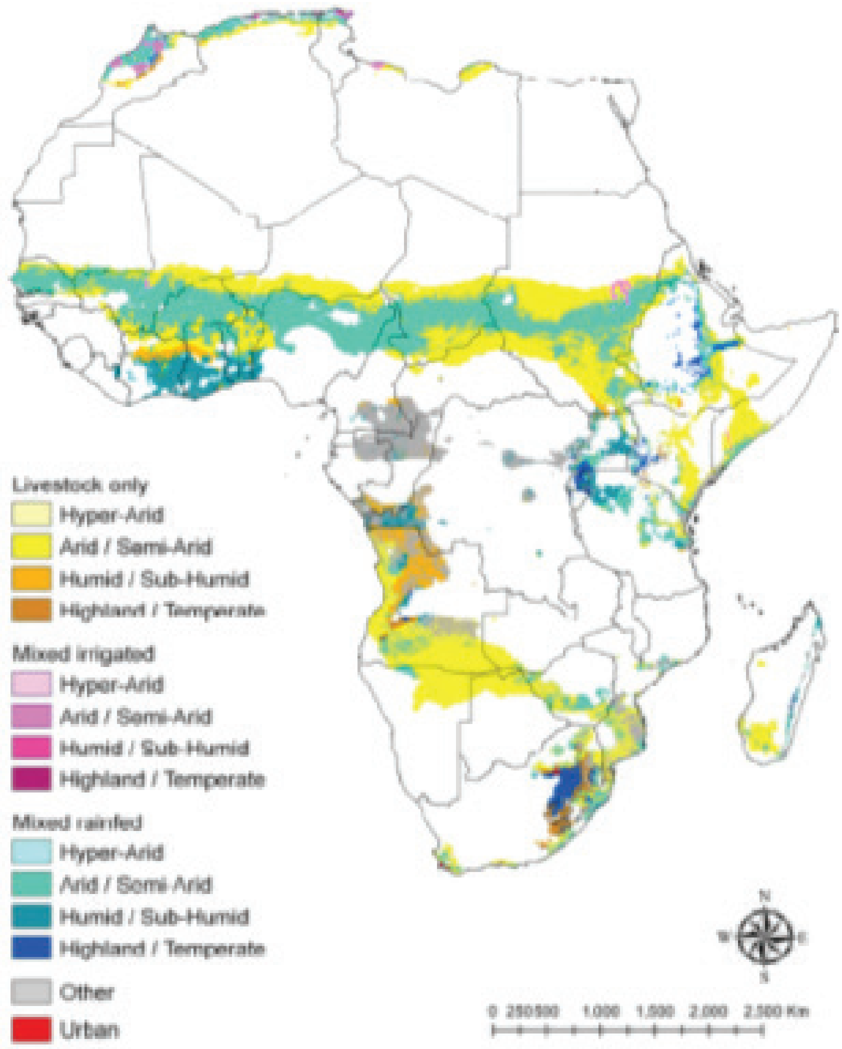


Figure 1. Livestock production systems in areas projected to undergo >20% reduction in Length of Growing Period to 2050: HadCM3, A1

1.3 Objectives

The goal of this transdisciplinary project is to increase the adaptive capacity of agropastoralists, who are one of the most vulnerable groups in Africa, to climate change and variability. The purpose of this project is to co-generate methods, information and solutions between local communities, local and international scientists, policymakers and other actors involved in climate change and adaptation programs, for coping mechanisms and adapting strategies to climate change and variability in West and Southern Africa, and more particularly in Mali and Mozambique.

Through this project we aim at a significant contribution to increasing the adaptive capacity of smallholders and pastoralists to climate variability and the expected effects of future climate change. This involves the identification and testing of options to increase the adaptive capacity of the system at different levels, including farmers, communities, institutions, and government. The work makes use of the natural synergies that exist between the expertise of the different partners: Potsdam Institut fur Klimafolgenforschung (PIK) on climate change modelling and impacts, the University of Kassel on innovative socio-economic data collection and analysis methods, the International Livestock Research Institute (ILRI) on vulnerability, livestock and poverty pathways, African Union, Inter-African Bureau of Animal Resources (AU–IBAR) on policy analysis, and Instituto de Investigaçoes Agrarias de Mozambique (IIAM) and Institut d'Economie Rurale (IER) in Mali who provide deep understanding of farmers and natural resource issues in both national and local contexts.

This project aims to contribute directly to these efforts through methodology development, particularly in relation to information dissemination and definition of policy entry points to support the dissemination of adaptation strategies.

1.4 Structure report

To quantify the magnitudes of the effects of climate variability and change on the productivity of rangelands, crops and livestock and how these changes affect agropastoralists, we collated and documented spatial data layers related to climate variability and change, production systems, vulnerability and poverty, land cover, natural resources, water and ecosystems services (Chapter 2). Household surveys and in-depth narrative analyses were conducted with agropastoral communities to document, synthesise and help disseminate their past and present coping mechanisms and adaptation strategies (Chapter 3). Several institutions are already working on promoting adaptation strategies in West and Southern Africa. We collated and documented the strategies promoted, and together with the indigenous information provided by agropastoralist communities we initiated dialogues between the different stakeholders to jointly prioritize adaptation strategies, to select a few for pilot testing (Chapter 4). Together with key policymaking institutions and regional policymaking bodies we identified and promoted policy entry points to support the implementation of priority adaptation strategies, and we identified policy mechanisms that in themselves are an appropriate intervention to allow agropastoralists to buffer the effects of climate variability and change (Chapter 5). Conclusions are given in Chapter 6.

2 Climate change impact projections

2.1 Climate change projections

The outputs from General Circulation Models (GCMs), climate models that project into the future, are almost never in a form that can be used directly to study the impacts of climate change on natural or human systems. GCMs model the atmosphere in stacks of cells that may have little to do with the detailed topography of the ground. They therefore do not model weather, which involves local effects, storms, and fronts, for example, but rather they model the average temperature of the cells in the stacks and precipitation is calculated from the latent heat balance as air is transferred from cell to cell. Downscaling refers to the process of taking GCM outputs and modifying their temporal and spatial resolution. There are several different downscaling methodologies (see the review of Wilby et al. (2009), for example), but all suffer from various disadvantages, and so considerable care is needed in utilizing and interpreting the results.

This section describes a generalized downscaling and data generation method that takes the outputs of a GCM that describe some future climatology, and allows the stochastic generation of daily weather data that are to some extent characteristic of this future climatology, that can then be used to drive impact models that require daily (or otherwise aggregated) weather data. The methods build on those outlined in Thornton et al. (2006).

2.1.1 Analysis of GCM outputs

A considerable amount of GCM data is available in the public domain, notably in the World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset. This dataset contains model output from 22 of the GCMs used in the IPCC's Fourth Assessment Report for three emission scenarios: A2, a high-greenhouse-gas-emission scenario; A1B, a medium-emission scenario; and B1, a low-emissions scenario. Model output data are not available for all combinations of GCM and scenario for the care variables of precipitation, maximum daily temperature, and minimum air temperature. This severely restricted the choice of GCMs that could be used here. We found appropriate data for the four GCMs shown in Table 1: CNRM-CM3, CSIRO-Mk3.0, MIROC 3.2 (medium resolution), and ECHam5.

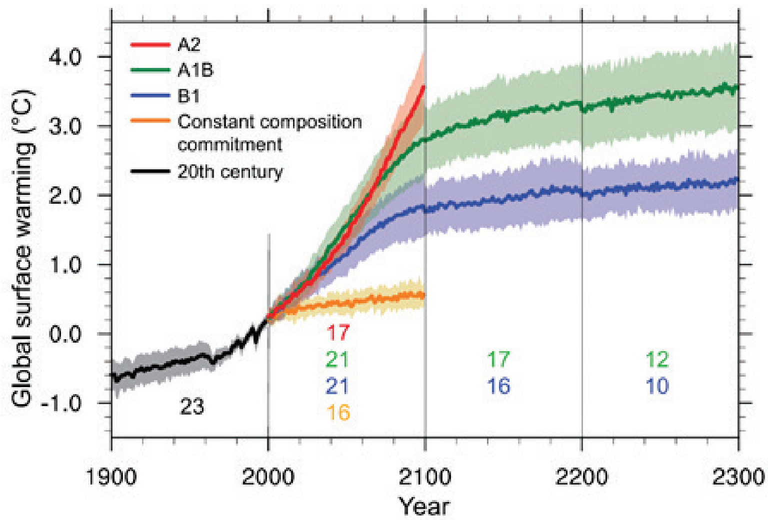
There are considerable differences between emission scenarios, in terms of projected changes in temperatures and rainfall for different regions. Figure 2 shows global multi-model means of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1 (Meehl et al. 2007). There is not that much difference between the three scenarios in global warming impacts to the 2050s, although thereafter the differences become considerable. There are also substantial regional variations in temperature shifts. Many GCMs project mean average temperature increases to 2050 for the East Africa region, for example, that are larger than the global mean—for scenario A2, of between about 1.5 and 2.5°C.

In addition to differences between the emissions scenarios used to drive the climate models, there can be substantial differences between the GCMs themselves. Some examples are shown in Figures 3 and 4 in relation to June temperature and precipitation anomalies, relative to the twentieth century control (1961–1990) 30 year normal, for the 2046–2065 time slices, for the A2 scenario and the four GCMs used here. Note that the scale for the temperature plots is the same for all GCMs, but there are slight differences between the scales for the rainfall anomalies.

Table 1. Climate models used in the work

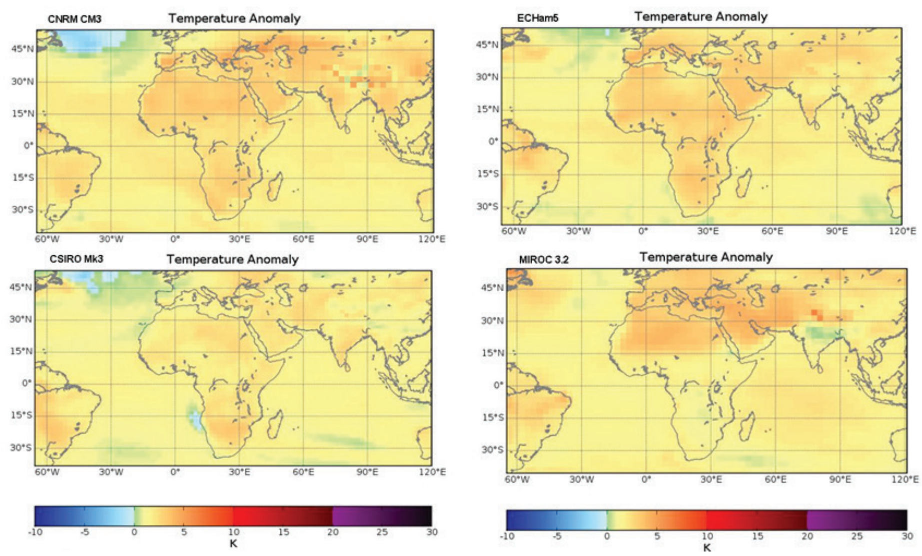
Model Name, Vintage	Institution	Reference	Resolution	Code
CNRM-CM3, 2004	Météo-France/Centre National de Recherches Météorologiques, France	Déqué et al. (1994)	1.9 × 1.9 degrees	CNR
CSIRO-Mk3.0, 2001	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia	Gordon et al. (2002)	1.9 × 1.9 degrees	CSI
ECHam5, 2005	Max Planck Institute for Meteorology, Germany	Roeckner et al. (2003)	1.9 × 1.9 degrees	ECH
MIROC3.2 (medres), 2004	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	Hasumi and Emori (2004)	2.8 × 2.8 degrees	MIR

Source: Randall et al. (2007).



Source: Meehl et al. (2007).

Figure 2. Multi-model means of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th-century simulation. Lines show the multi-model means, shading denotes the ±1 standard deviation range of individual model annual means



Source: Figures obtained from www.ipcc-data.org.

Figure 3. June temperature and precipitation anomalies (relative to the 20th century control 1961–1990 30 year normal) for 2046–2065 for SRES A2 and four GCMs, from IPCC Fourth Assessment Report simulations

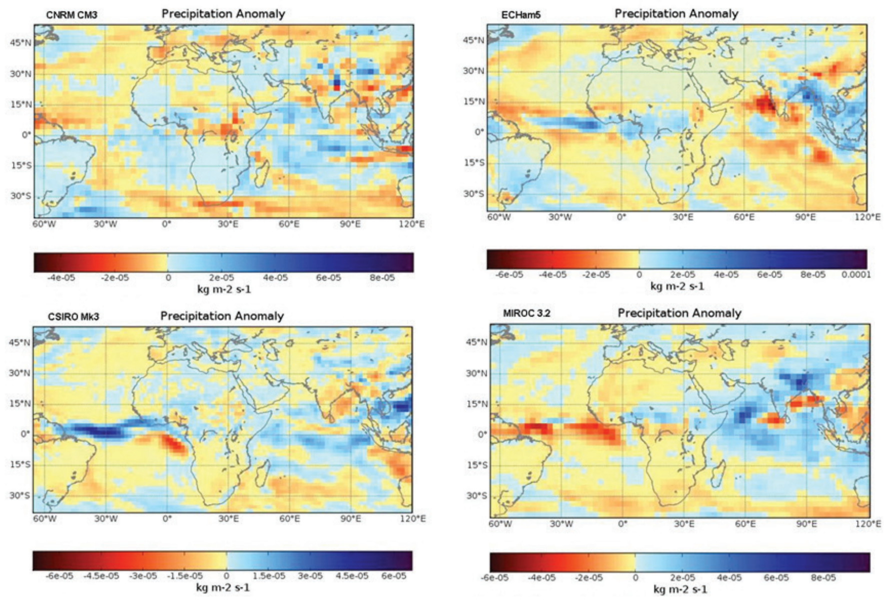


Figure 4. June precipitation anomalies (relative to the 20th century control 1961–1990 30 year normal) for 2046–2065 for SRES A2 and four GCMs, from IPCC Fourth Assessment Report simulations

The general scheme of the downscaling process is outlined in Figure 5. We obtained data for GCM deviations for five time slices: 1991–2010 (denoted '2000'), 2021–2040 (denoted 2030), 2041–2060 (denoted 2050), 2061–2080 (denoted 2070), and 2081–2100 (denoted 2090) for average monthly precipitation, and maximum (T_{max}) and minimum (T_{min}) temperatures. Processing of these data resulted in calculated mean monthly climatology for each time slice and for each variable from the original transient daily GCM time series. The mean monthly fields were then interpolated from the original resolution of each GCM to 0.5 degrees latitude-longitude using conservative remapping, a method that preserves the global averages. We then calculated monthly climate anomalies (absolute changes) for monthly rainfall, mean daily maximum temperature, and mean daily minimum temperature, for each time slice relative to the baseline climatology (1961–1990). The point of origin was designated 1975, being the mid-point of the 30-year climate normal.

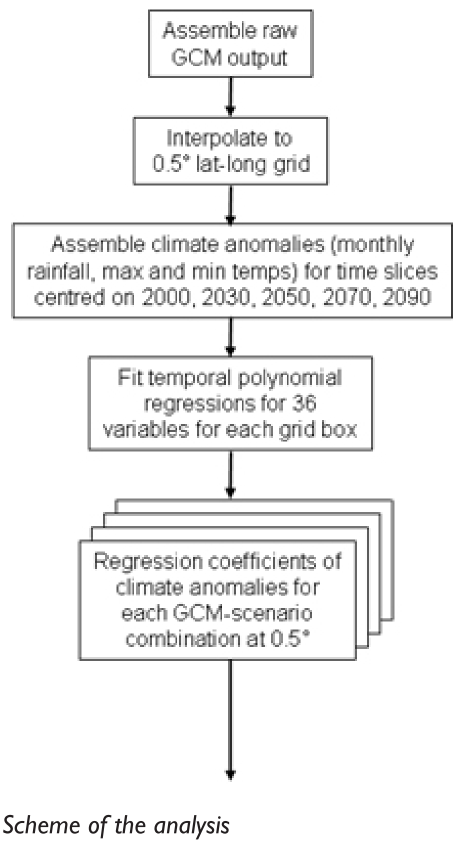


Figure 5. Scheme of the analysis

We made a preliminary investigation of the functional forms of the projections through time using cluster analysis. All pixels from each of the four models for scenario A1B were clustered for precipitation, T_{max} and T_{min} using the values of the five periods as clustering variates. We used a leader clustering algorithm (Hartigan 1975) to cope with the volume of data. The threshold was set to produce from 40 to 100 clusters which were ranked by the number of pixels and the cluster means were used to inspect the functional form. The first five clusters normally covered 80 to 90% of the pixels in for any given model. Polynomials were fitted through the cluster means by date (constrained through the origin) and showed that in many cases a quadratic fit over time would have sufficed, but there were numerous cases where only a fourth-order polynomial would suffice. We therefore decided to fit fourth-order polynomials throughout. Fourth-order polynomial fits were made for all models at all scenarios and another set was made for the average of the four models (the ensemble mean). The polynomial coefficients were condensed into a data file structure for ready retrieval on a pixel-by-pixel basis (at a resolution of 30 arc-minutes) for use in subsequent operations (Figure 3).

2.1.2 Generating daily data

We used a weather generator, MarkSim, to generate daily data from the GCM climate normals described above. The basic algorithm of MarkSim is a daily rainfall simulator that uses a third-order Markov process to predict the occurrence of a rainy day (Jones and Thornton 1993, 1997, 1999, 2000; Jones et al. 2002). The crux to the efficiency of MarkSim in simulating the actual variance of rainfall observed both in the tropical and temperate regions is its use of resampling of the Markov process parameters. MarkSim works from a large set of parameters; including those for rainstorm size, this totals 117 for any site. To make a globally valid model that does not need recalibration every time that it is used, we have constructed a calibration set of over 10,000 stations worldwide. These were clustered into 702 climate clusters using the 36 values of monthly precipitation and monthly maximum and minimum temperatures. Almost all except a small number of the calibration stations have more than 10 years of (almost) continuous data. Most stations have 15–20 years of data; a few have 100 years or more. The 117 parameters of the MarkSim model are calculated by regression from the cluster most representative of the climate point to be simulated. MarkSim estimates daily maximum and minimum air temperatures and daily solar radiation values from monthly means of these variables, using the methods originating with Richardson (1981). Monthly solar radiation values are estimated from temperatures, longitude and latitude using the model of Donatelli and Campbell (1997).

MarkSim guarantees that in the long run the values used as a starting point for a simulation series will be returned as the average of the simulated series. When GCM anomalies (the 'deltas') are added to the starting values, not only may the regression values for the coefficients change, but also they may completely change the climate cluster that is associated with that point. This means that the simulated climate has been shifted to a different type. Thus we have a form of 'climate typing'.

To utilize MarkSim, the estimated GCM anomaly for any pixel is added to a baseline climate record; inverse square distance weighting is used over the valid elements of the nearest nine GCM cells. The baseline climate database we generally use is WorldClim (Hijmans et al. 2005), which may be taken to be representative of current climatic conditions (most of the historical data in WorldClim cover the period 1960–1990).

An application, GCM4, was constructed to retrieve a current climate record and do the downscaling described above, to generate daily data for any year (more properly, any time slice, with the year the centre of the time slice), for any of the four GCMs and the three SRES scenarios described above. In recent months, this has been turned into a web-based application (available at gismap.ciat.cgiar.org/MarkSimGCM/), and this downsclaling and generation of daily weather data can be done for any point that is land on the surface of the globe. Two additional GCMs have been added, together with the ensemble mean of this new set of climate models. The application also allows the user to generate daily data that are characteristic of current conditions (i.e. using the base WorldClim dataset).

There are many ways in which these data can be used (with care). For example, daily data can be used to calculate lengths of growing period for current conditions and future climate scenarios (Jones and Thornton (2009) describe an example application). The software can also be used to generate daily weather for future climates that can be used by impact modelling software to drive various models, including the crop models that are part of the Decision Support System for Agrotechnology Transfer (DSSAT) ICASA (2007).

All downscaling activity is affected by considerable uncertainties of different types. First, even from the GCMs themselves, it is clear that present and future predictability of climate variability and climate change is not the same everywhere and those gaps in knowledge of basic climatology are revealed by a lack of agreement between climate models in some regions (Wilby 2007). While there is now higher confidence in projected patterns of warming and sea-level rise, there is less confidence in projections of the numbers of tropical storms and of regional patterns of rainfall over large areas of the planet. This highlights the importance of using different scenarios and different models to assess likely climate changes and their impacts. Second, our understanding is limited of what the local-level impacts of climate change are likely to be, which means that it is very difficult to evaluate the adequacy of different downscaling techniques. Third, there is a significant gap between the information that we currently have at seasonal time scales and the information we have at longer time scales—information about what is likely over the next three to 20 years is largely missing (Washington et al. 2006). This is problematic, as the medium-term time scale is vital for political negotiation, for assessing vulnerability, and for agricultural planning, for example.

2.2 Different production systems

2.2.1 Classifying livestock production systems

The characteristics and availability of the environmental and socio-economic assets that agricultural production is depending upon display distinct and heterogeneous patterns across sub-Saharan Africa. Some geographical areas are endowed with agro-ecological conditions suitable for rainfed cropping, while in others agricultural activities are limited to grazing, if irrigation systems are unavailable. Some regions have a well-developed road infrastructure, whilst others suffer from a lack of access to services and markets. Exposure to climate change impacts, institutional and policy environments and conventional livelihood and coping strategies all vary over space and are subject to changes over time.

This heterogeneity in conditions for agricultural production is reflected by the large variability in livestock production. There are huge differences in the ways in which livestock are kept in different places and in their roles for the livestock keepers' livelihoods. We need to develop a good understanding of the differences among production systems if we are to be able to help poor livestock keepers take advantage of the rising demand for animal-source foods, help livestock keepers adapt to a changing and more volatile climate, minimize the risk of disease emergence and spread, and to help all livestock keepers mitigate greenhouse gas emissions via a wide range of options.

One of the important pieces of information is therefore a spatial dataset of agricultural systems. As well as providing a simple stratification for impact assessment, a classification of livestock production systems can provide a framework within which to predict how the livestock sector is likely to evolve in response to changing demography and associated quantitative and qualitative changes in demand (for animal-source foods), land use and climate. Seré and Steinfeld (1996) developed a global livestock production system classification scheme that integrates the notions of crop and livestock interactions with agro-ecological zones. This classification can be extended by including indicators of the major crops grown in the mixed crop–livestock areas (Figure 6) (Robinson et al. 2011).

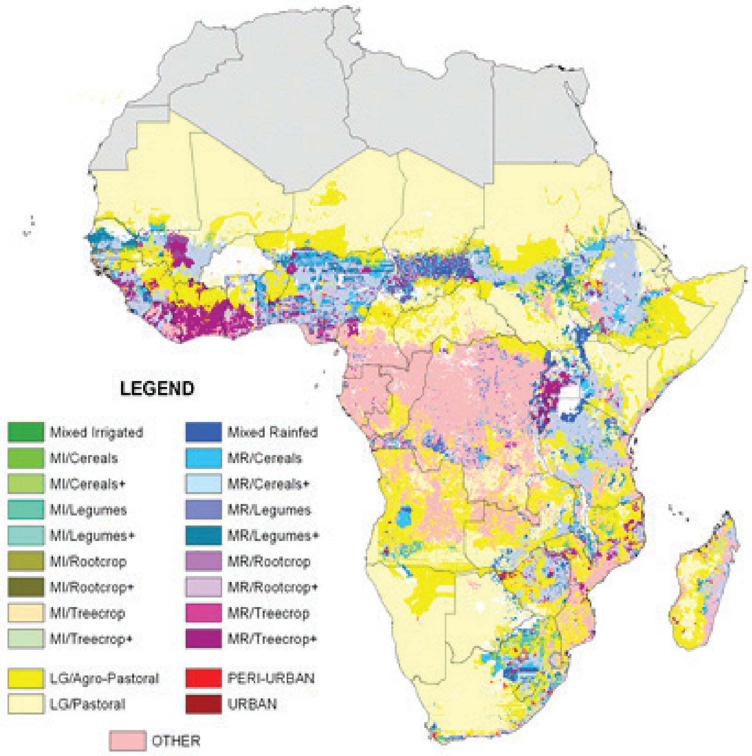


Figure 6. The livestock production systems extended to include crop data classes

2.2.2 A typology of the grazing lands in sub-Saharan Africa

The resulting classes are quite disaggregated for the mixed crop–livestock systems, but give very little detail about the pastoral and agropastoral areas. These grasslands, however, cover extensive areas of sub-Saharan Africa and support a lot of livestock production. Apart from livestock products, pastoral and agropastoral production systems also deliver a large set of environmental services, such as sustaining biodiversity, water regulating services, carbon sequestration, biofuels and food crop production. Adaptation options and alternative livelihood strategies as well as economic and environmental trade-offs will differ widely across these vast grassland areas as they are much more diverse than the original classification of Robinson et al. (2011) suggests. We therefore developed a more detailed stratification for the grazing lands too.

The extent of grassland, similarly to cropland, is generally derived from global land cover products. We therefore started off from the Global Land Cover map (JRC 2003) and reclassified it into grazing and other classes (Table 2). From the original 22 land cover classes 3 were reclassified in explicit crop land classes, 10 were interpreted as forest, and 6 as grasslands.

There is, however, a high degree of uncertainty in global land cover maps. Instead of simply reclassifying this dataset, we corrected the reclassification, based on the dataset of Ramankutty et al. (2008). This dataset gives an estimate of the percentages cropland and pasture in each pixel. We derived the average percentages of cropland and pasture for each of the landcover classes. Based on this data (and in accordance to the proposal by Ramankutty et al. 2008), we were able to identify GLC landcover classes that seemed to be dominated by cropland, i.e. have at least 3 times more cropland than pasture, and the ones dominated by pastures, i.e. have at least 3 times more pasture than cropping. The 'GLC grazing classes' that are dominated by cropland were then excluded, while the 'GLC crop or other classes' dominated by pasture were considered for inclusion. If more than 10% of the area was estimated to be under pasture, the class was added to the 'grazing lands of the world'. In a final step, we extracted the areas with a length of growing period of zero days (according to Jones and Thornton 2010) and the urban areas (based on the GRUMP urban extent dataset (CIESIN 2004)). The extent of the grazing land is shown in Figure 7.

Table 2. The 22 GLC landuse classes and their intuitive simplified classes

Intuitive class	GLC legend
Crop	Cultivated and managed areas
Crop	Mosaic: Cropland/Tree Cover/Other natural vegetation
Crop	Mosaic: Cropland/Shrub and/or grass cover
Forest	Tree Cover, broadleaved, evergreen
Forest	Tree Cover, broadleaved, deciduous, closed
Forest	Tree Cover, broadleaved, deciduous, open
Forest	Tree Cover, needle-leaved, evergreen
Forest	Tree Cover, needle-leaved, deciduous
Forest	Tree Cover, mixed leaf type
Forest	Tree Cover, regularly flooded, fresh water
Forest	Tree Cover, regularly flooded, saline water
Forest	Mosaic: Tree Cover/Other natural vegetation
Forest	Tree Cover, burnt
Grazing	Shrub Cover, closed-open, evergreen
Grazing	Shrub Cover, closed-open, deciduous
Grazing	Herbaceous Cover, closed-open
Grazing	Sparse herbaceous or sparse shrub cover
Grazing	Regularly flooded shrub and/or herbaceous cover
Grazing	Bare Areas
Other	Water Bodies
Other	Snow and Ice
Other	Artificial surfaces and associated areas
Other	No data

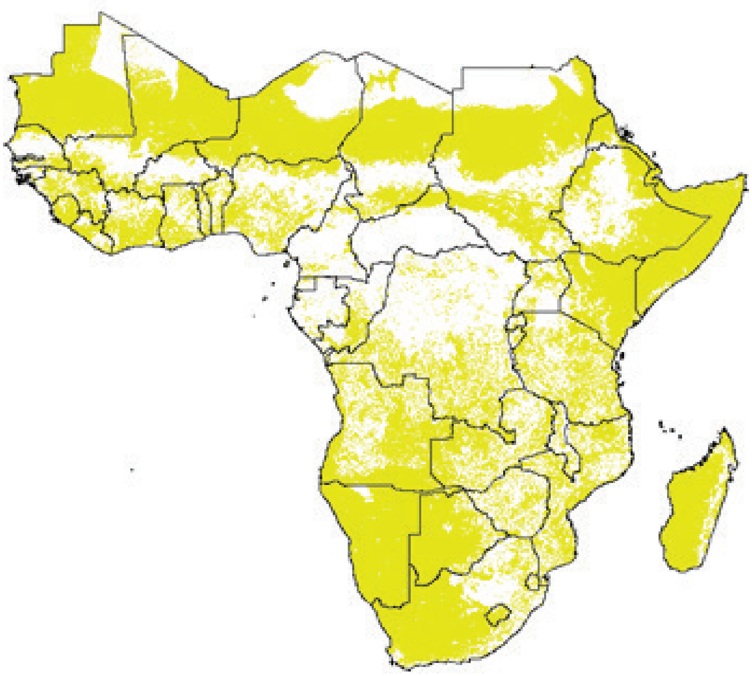


Figure 7. The grazing lands of sub-Saharan Africa

Figure 8 schematizes the procedure followed to stratify the grazing areas. The first step involves the identification of wetland areas. They are extracted from the Global Lakes and Wetlands database and include the floodplains. In many of the wetland areas water is abundantly available and the production potential generally high, but ecosystem services and biodiversity issues are important to keep in mind when considering alternative livelihood strategies. The floodplains often constitute key dry season grazing areas. Conversion of these grazing areas would negatively affect the ability of herders to access these key resources during periods of need, and make pastoralism over much larger areas less sustainable, as well as generate local disputes and destructive conflicts over these key resources (COMESA 2009).

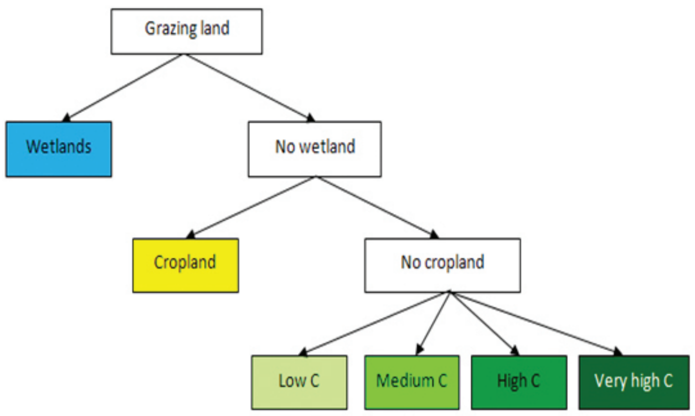


Figure 8. The procedure for stratifying the grazing lands of sub-Saharan Africa

The second step extracts from the Ramankutty et al. (2008) data those areas where there is currently already more than 10% of the area under crops. The remaining areas are subdivided in 4 classes based on the Ruesch and Gibbs (2008) data into grazing land with currently low, medium, high and very high carbon content. To a certain extent, the carbon content also reflects the productivity of the land. We made the subdivision in carbon content classes to emphasize the potential trade-off with ecosystem services such as carbon sequestration, firewood production, hunting, sustaining of biodiversity if these grazing areas were to be converted to for example crop or biofuel production.

Most of the land area is covered by low carbon rangeland. Most of the population lives in the areas where crop agriculture is already practiced (Figure 9).

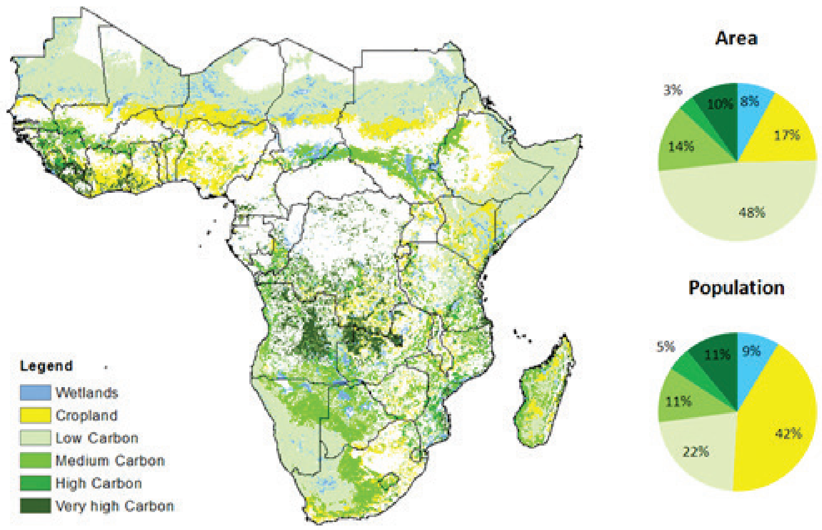


Figure 9. The stratification of the grazing lands

Some of the heterogeneity found in the grazing lands of sub-Saharan Africa is clearly reflected in this stratification. It provides a broad-brush spatial framework for targeting and evaluating potential alternative livelihood strategies and adaptation options.

2.3 Primary production

We employed the LPJmL model (Bondeau et al. 2007) to compute the effects of climate change and CO_2 fertilization on yields of major crops globally at a spatial resolution of 0.5° x 0.5°. Simulations of net primary production (NPP) are based on process-based implementations of gross primary production, growth and maintenance respiration, water-stress, and biomass allocation, dynamically computing the most suitable crop variety and growing period in each grid cell as described in more detail by Bondeau et al. (2007) and Fader et al. (2010), with improved sowing date algorithms (Waha et al. 2011).

We present percentage changes in agricultural productivity (NPP of 11 crops, wheat, rice, maize, millet, field pea, sugar beet, sweet potato, soybean, groundnut, sunflower, and rapeseed, as well as of managed grassland) between two 10-year periods: 1992–2001 (reference period) and 2042–2051. Management intensity has been calibrated to match national yield levels as reported by FAOSTAT[1] for the 1990s (Fader et al. 2010), assuming land-use patterns as described by Portmann et al. (2010) and Fader et al. (2010).

Future development of crop yields are subject to several uncertainties: (a) changes in climate (Solomon et al. 2007), (b) changes in atmospheric CO_2 concentrations and the subsequent impact on crop water use efficiency and CO_2 fertilization (Long et al. 2006; Tubiello et al. 2007), (c) changes in management/breeding, and (d) changes in cropping area. Here, we account for the first two drivers only: climate change and CO_2 fertilization by employing different scenarios.

We computed 30 different scenarios from 1950 to 2055 for 3 different emission scenarios (SRES A1b, A2, B1) (Nakicenovic and Swart 2000), each implemented by 5 different general circulation models (GCM): CCSM3 (Collins et al. 2006), ECHAM5 (Jungclaus et al. 2006), ECHO-G (Min et al. 2005), GFDL (Delworth et al. 2006), and HadCM3 (Cox et al. 1999). Climate data for these GCM-projections were generated by downscaling the change rates of monthly mean temperatures and monthly precipitation to 0.5° resolution by bi-linear interpolation and superimposing these monthly climate anomalies (absolute for temperature, relative for precipitation and cloudiness) on the 1961–1990 average of the observed climate (New et al. 2000; Österle et al. 2003). Since there was no information about the number of wet days in the future, these were kept constant after 2003 at the 30-year average of 1971–2000.

To assess the range of CO_2 fertilization uncertainty (e.g. Long et al. 2006; Tubiello et al. 2007), we computed each of the 15 scenarios twice: first, taking into account full CO_2 fertilization effects according to the prescribed SRES atmospheric CO_2 concentrations, and second, keeping atmospheric CO_2 concentrations constant at 370 ppm after 2000.

Mean changes in agricultural productivity and the variability of the NPP signal between scenarios are the basis for computing the climate impact on feed resources and vulnerability maps.

2.4 Impact feed resources

Rangelands cover about one-half of the landmass in Africa. Livestock are a central source of livelihoods in this region and the major way that pastoralists and agropastoralists generate income and build their 'asset base'. One of the major bottlenecks to livestock development in these areas is access to water and grazing resources. Livestock are recognized as essential assets for the livelihoods in the mixed crop–livestock systems throughout the tropics too, and feed resources have been identified as an important constraint to their productivity (Powell and Williams 1993). Farmers constantly have to make difficult choices between crops for human consumption, soil amendment or animal feed and, therefore, significant trade-offs exist in the use of resources. These trade-offs partly determine the livelihood status of smallholders (Giller et al. 2006).

Although the impacts of climate change on livestock production might be many fold (reduced agricultural productivity of crops and livestock, higher disease prevalence and reduced fresh water availability), we therefore focus in this study on the projected impacts on feed resources.

In the mixed crop–livestock systems stover comprises between 45–60% of the diets of ruminants (Blummel et al. 2006). Most of this is coming from the cereals. As we are looking across SSA where we encounter not only mixed crop–livestock systems but also pastoral/agropastoral systems, we assess feed availability by looking at both cereal stover and grasslands.

1. http://faostat.fao.org/default.aspx.

To assess the changing feed production, we started off with LPJmL model output. The data we are using is actually the mean of 30 model runs, i.e. 2 CO_2 assumptions, 3 SRES, 5 GCMs. (section 2.1). We used LPJmL output in the form of the per cent change in carbon for 5 different crop functional groups (CFTs):

- wheat
- rice
- maize
- temperate cereals
- tropical cereals
- managed grass,

The time periods we compared were:

- 1992–2001
- 2042–2051.

Since the carbon to dry matter conversion factor is constant (DM = C/0.45), we can also say that we used the mean % change of net primary productivity (NPP) in dry matter.

Based on the change in NPP of wheat, rice, maize, millet and grassland the change in feed supply was estimated using the following formula:

$$A = \frac{\Sigma \text{ NPP\_changei} * \text{fraction}_i * \text{c-facti} * \text{util}_i * \text{enerval}}{\Sigma \text{ fraction}_i * \text{c-facti} * \text{util}_i * \text{enerval}_i}$$

With

i:	wheat, rice, maize, millet, grass
NPP_change_i:	percentage change in net primary production of crop i
faction_i:	fraction of the area cultivated by crop i
$\text{c-fact}_{i:}$	conversion factor indicating how much straw is produced as compared to crop yield (derived from harvest indices)
util_i:	utilization factor—the fact that cereals are grown in a particular area does not mean that these are actually used as feed resources. Other competing uses are as soil amendments or as fuel for cooking
enerval_i:	energy value of the stover expressed in MJ/MT dry matter

The result of these calculations is an estimated change of metabolisable energy; as an intermediate product also the change in dry matter production (in MT DM/ha/year) is stored.

It is important to note that the analysis excludes cut and carry forages, small grazing areas found in mixed systems and purchased feeds (grain supplements, purchased fodder).

Table 3. Indices used

Crop	c-fact	Utilization (%)	Enerval (MJ/kg)
Wheat	1.3	85	9
Rice	1.4	75	7.5
Maize	2	95	8.2
Millet	2	95	7.4
Grass	1	50	8

Figure 10 illustrates the potential impact of climate change on local feed availability. With the exception of some areas in Southern Africa, Ethiopia, Kenya and Somalia, the stover availability is decreasing throughout SSA. In contrast with the stover, the impacts on grass seem much less pronounced. In a huge area we see less than 5% change. Impact in most of the Greater Horn of Africa and some of the Sahelian band from Mali all the way to Sudan seems positive. The same can be noticed in an area stretching from the West-Coast in Namibia going east the Zimbabwe. Negative impacts on grass availability are concentrated around Senegal and in Southern Africa, where Namibia, Botswana and South Africa meet. The change in overall feed availability, i.e. the combination of stover and grass, shows a similar pattern, with some extra decreases along the West coast, going quite a bit inland in e.g. Nigeria.

2.5 Coarse scale vulnerability maps

2.5.1 Conceptual framework

A wide variety of definitions and frameworks to assess vulnerability of households and ecosystems is used, described and applied throughout the scientific literature. For the purpose of this study, we will refer to (i) exposure to climate change impacts, (ii) sensitivity to those impacts and (iii) the capacity to cope with those impacts as the components of vulnerability. This can be mathematically denoted as:

Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)

In other words, the greater the exposure or sensitivity, the greater is the vulnerability. However, adaptive capacity is inversely related to vulnerability. So, the greater the adaptive capacity, the lesser is the vulnerability. Therefore, reducing vulnerability would involve reducing exposure through specific measures like building a dyke in case of sea level rise, or increasing adaptive capacity through activities that are closely aligned with development priorities.

As opposed to poverty, being a 'static' measure, vulnerability is a much more dynamic concept. It includes the notions of moving in and out of poverty, poverty traps and explicitly includes the element of risk or exposure. It is therefore an appropriate concept, forcing people to think about protecting and enhancing livelihoods in a context of a consistent threat of risks (Mude et al. 2007).

As we already mentioned, we define vulnerability as composed of exposure, sensitivity and adaptive capacity. These components vary significantly across space and time. We therefore propose to include a temporal dimension in vulnerability assessments to enable incorporation in climate change studies.

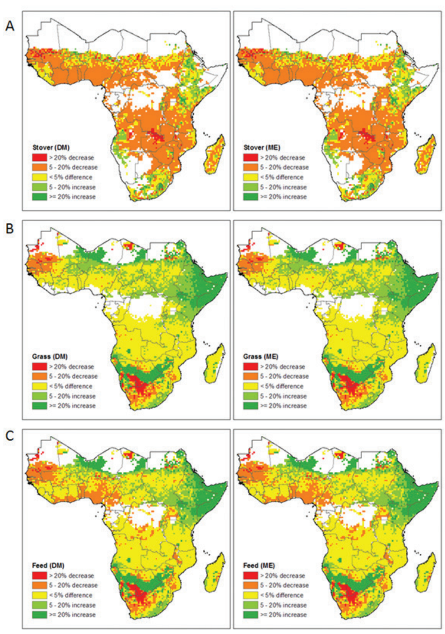


Figure 10. Projected change in feed availability (a. stover; b. grass; c. total)

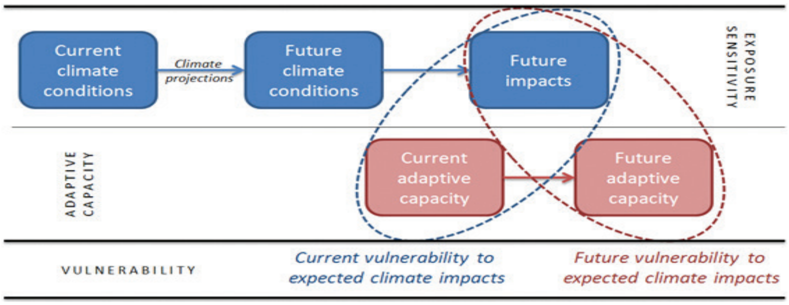


Figure 11. The dynamic nature of vulnerability and its components

In order to study vulnerability we have to look at each of its components: adaptive capacity, exposure and sensitivity and develop measures for each of them. As these metrics differ over space, we also develop maps depicting this spatial heterogeneity.

2.5.2 Adaptive capacity

In order to map adaptive capacity, we looked for those characteristics of livestock production systems that influence the capacity of the livestock keepers to prepare for, respond to, and recover from climate related impacts and disasters. In line with the approach described in Thornton et al. (2006), we chose the following 12 different indicators: human poverty index, governance, infant mortality, HIV/aids, agricultural GDP, crop suitability, soil degradation, water resources, malaria, malnutrition, health expenditure and market access. We mapped each indicator and combined them into one single index of adaptive capacity. The combination was performed in a GIS system through a weighted linear overlay. Different methods were tested for coming up with the weights. In this report we show the results for the year 2005 based on a simple Principal Component Analysis (PCA). Theoretically, the indicators of adaptive capacity can be projected into the future and undergo a similar mapping into one index.

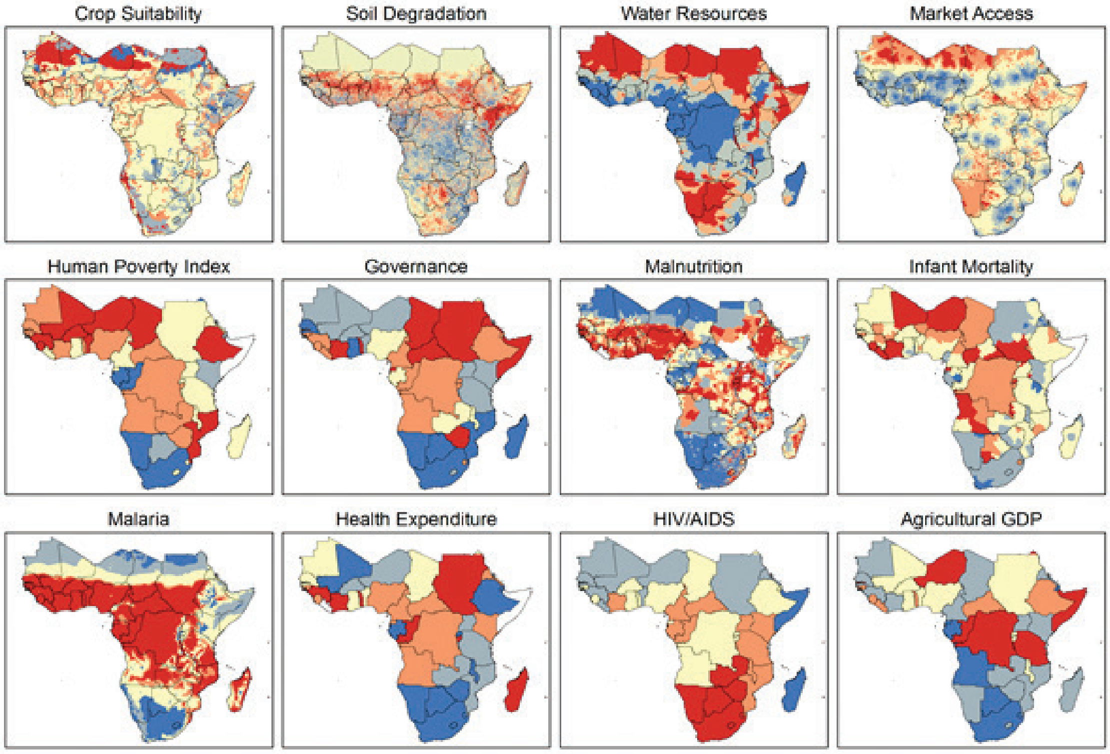


Figure 12. Indicators of adaptive capacity for the year 2005

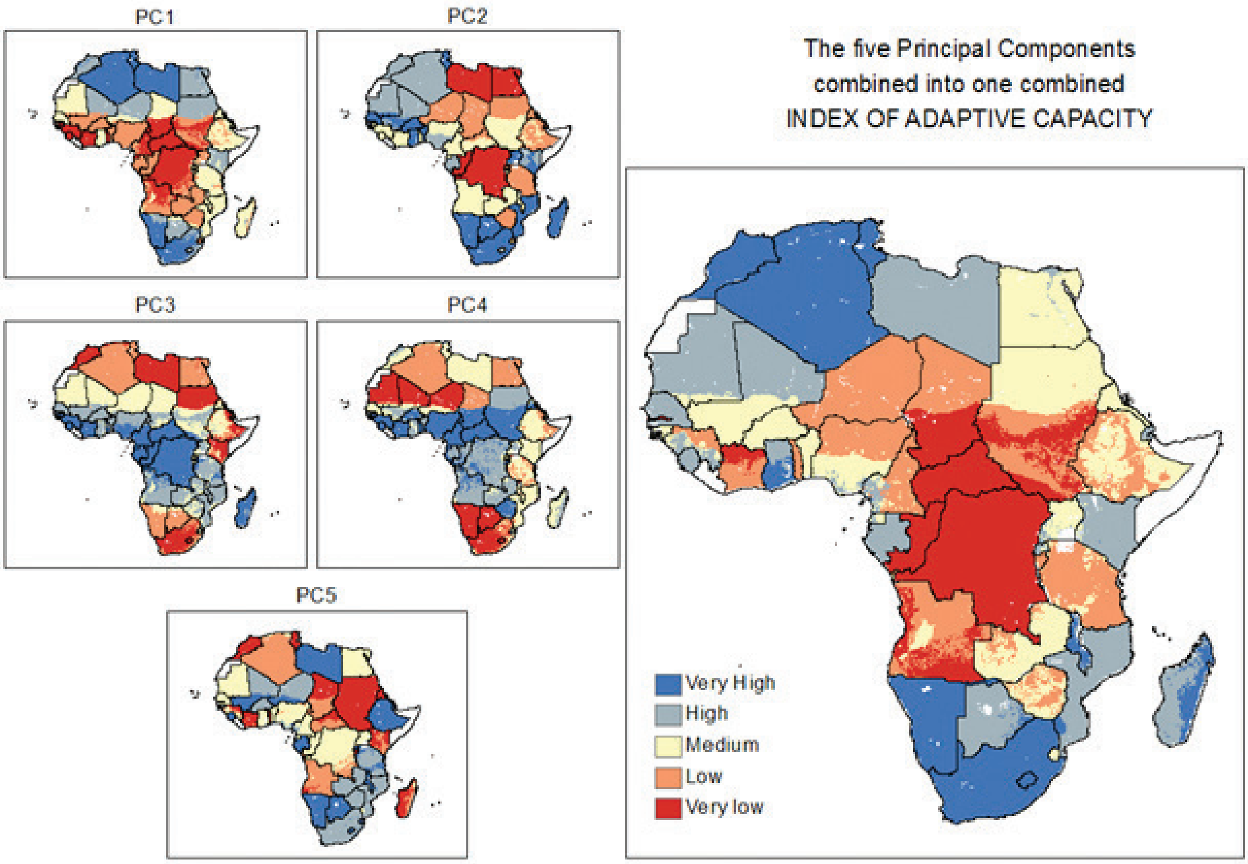


Figure 13. The index of adaptive capacity for the year 2005

Figure 13 shows the maps of the five principal components and the resulting index of adaptive capacity for the year 2005. The resulting index of adaptive capacity, classifies most of Central Africa as having a very low adaptive capacity (DRC, Congo Brazzaville, Central African Republic, big parts of Sudan, Chad and Angola). The North of Ivory Coast also shows up in the 'very low' class.

2.5.3 Exposure

The metric used for exposure is the projected change in feed supply. More details about this metric can be found in section 2.4.

2.5.4 Sensitivity

Sensitivity is the degree to which a system will be affected by, or is responsive to climate stimuli (Smith et al. 2001). Areas with more dependence on livestock are assumed to be more sensitive to a change in feed availability due to the changing climate. Therefore, the higher the economic dependence on livestock, the higher the sensitivity of that area is. Based data from the FAOSTAT country-level database we used the percentage of the total GDP sourced from livestock production as a proxy for sensitivity.

Throughout SSA livestock contributes a lot to the economy. In fifteen countries livestock contributes more than one third of the GDP. In Western Sahara, Sudan, Somalia, Namibia, Botswana and Lesotho this is even more than 45% (Figure 14). Clearly, a change in feed availability in these countries could have serious consequences.

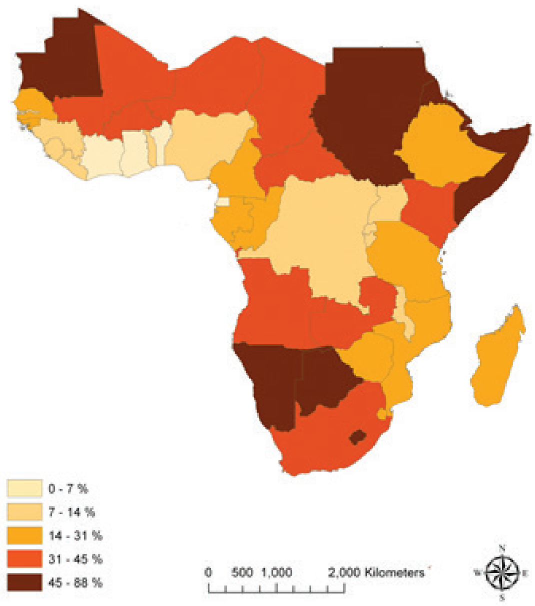


Figure 14. % Livestock contribution to GDP

2.5.5 Hotspots of vulnerability to feed resource impacts of climate change

In a second step, we combined these measures of exposure, adaptive capacity and sensitivity into vulnerability hotspots and domains. Hotspots of vulnerability to feed resource impacts of climate change are areas where high climate change impact on feed resources and 'low adaptive capacity/high social vulnerability' coincide. These hotspots highlight the areas where livestock keepers are likely to be mostly affected by climate change impacts and can be used for priority setting.

The hotspots are shown in Figure 15. The map for the year 2000 highlights those areas where expected impacts coincide with low level of current adaptive capacity. The priority areas for interventions increasing the adaptive capacity can be found around Mali, in Chad, the Central African Republic, Southern Sudan, Angola, Mozambique and a relatively narrow east–west band in Namibia and Bostwana. Assuming that the current trends in the indicators of adaptive capacity continue the hotspots or priority areas move into DRC, the whole of South Sudan, and in West Africa in Ivory Coast, Burkina Faso, Ghana, Benin and Togo.

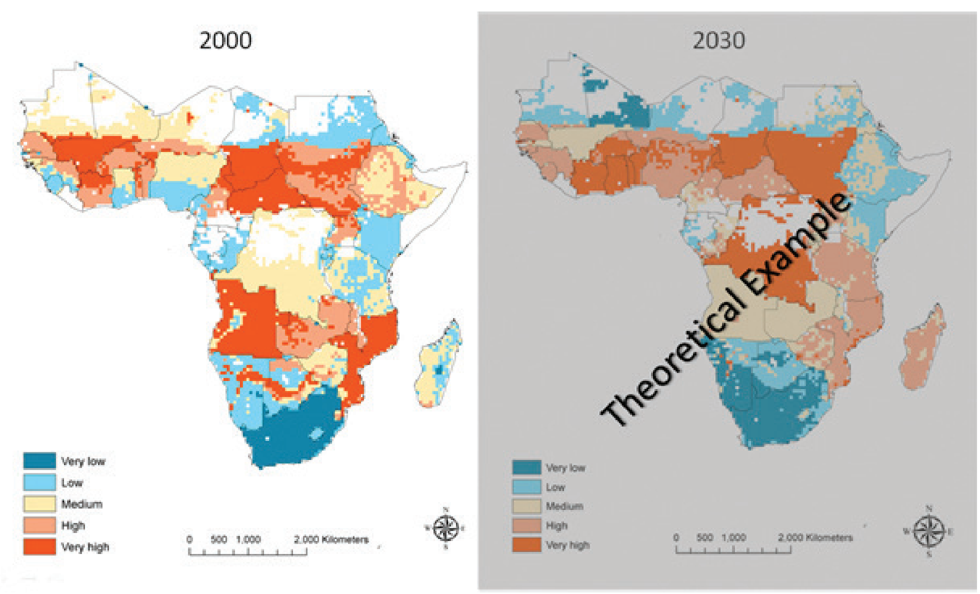


Figure 15. Hotspots of vulnerability of livestock systems to the impacts of climate change

2.5.6 Domains

The domain approach combines thresholds of adaptive capacity and exposure with a sensitivity threshold. The domain map (Figure 16) delineates areas in SSA according to their characteristics along the 3 vulnerability axes: exposure, sensitivity and adaptive capacity.

While hotspots highlight the areas where livestock keepers are likely to be mostly affected by climate change impacts and where adaptation action could be a priority, the domain approach yields maps subdividing SSA in domains with different vulnerability profiles and therefore different intervention needs.

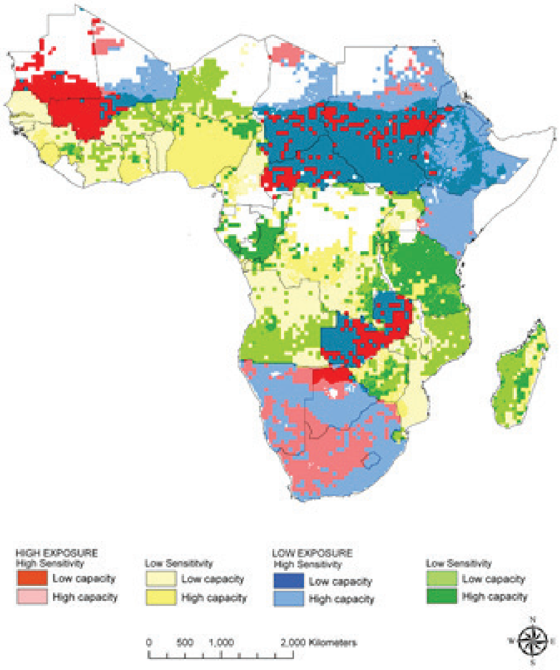


Figure 16. The domain map for sub-Saharan Africa

2.5.7 Discussion

Adaptation initiatives, as well as the ones associated with mitigation for that matter, are often dealing with scarcity of funds. The purpose of this mapping exercise is therefore twofold. First, it is to provide policymakers with a collation of baseline information on potential climate change impacts on livestock systems and the vulnerability of the livestock keepers making a living in these systems. We provide information on the type of stresses that might occur on feed production and identify geographical areas that are likely to be most affected by them. This can form the basis for initial resource allocation and the monitoring of progress by various interventions. The presented maps can inform policy discussions and eventually how best to target resource allocation. Secondly, we attempt to generate information that could be used to geographically target future research and eventually increase our understanding of the underlying processes of vulnerability. This is needed in order to design successful adaptation strategies.

The multi-dimensional approach is a response to the fact that there is not one solution for all problems. This study does not only identify regions under high exposure, but also looks at sensitivity and adaptive capacity. Clearly, certain interventions have more impact in certain targeted places; particular characteristics ask for particular, context-specific interventions.

As in any modelling work the accuracy of final outputs relies very much on the quality of input data to the analysis. Although there are several initiatives to generate GIS databases, there is still a lot of gaps in GIS data for agriculture and rural development in the SSA region. Even where the data exists, you find that some countries have more data while others have very limited or none, it is difficult to get detailed data for the whole region complicating regional level analyses. Availability of high resolution spatial data for the indicators of vulnerability mapping in the region was a major limitation in this study. To our knowledge, we worked with the best datasets available. Nonetheless, we still believe that the accuracy of the maps presented here would have been further enhanced if better data (both in terms of more indicators and higher resolution) was available. Continued effort from the growing number of data providers in the international arena and improved linkages and data sharing between them, however, will enable this type of analysis to be improved further in future.

The regional analysis undertaken in this study is limited by issues of scale as well as by the availability and quality of data. Whereas this report has the strength of providing a regional perspective, the lower level of the resolution for the data limits a provision of detailed picture for sub-national level interventions. In order to derive actionable, context-specific policy interventions aimed at reaching the vulnerable communities within SSA there is still a need to zoom in from the aggregated level of presented maps to access the necessary detail at sub national levels. This will provide information needed to identify investment options with the greatest potential impact for vulnerable communities. One way of achieving that is to conduct detailed cases studies in some selected sites within the hotspots to gather more information about the occurrence of the identified feed deficit in the areas and establish what would be the most appropriate interventions to suit a particular area and context. Some progress in this field is described in section 3.1 (Mali and Mozambique country studies).

There are also limitations to an analysis of livestock systems based on feed availability only. Future work on impacts on for example water and disease will be necessary.

2.6 Key messages

- Climate is changing
- The changing climate will have an impact on the primary productivity of the environment and therefore also on the feed availability
- The direction, as well as spatial and temporal distribution of impacts is uncertain
- Due to this uncertainty it is important to increase adaptive capacity
- Current data and model output suggest that the priority areas for interventions increasing the adaptive capacity can be found around Mali, in Chad, the Central African Republic, Southern Sudan, Angola, Mozambique and a relatively narrow east–west band in Namibia and Botswana.

3 Vulnerability and adaptation strategies in Mali and Mozambique

3.1 Household survey

The main objective of household surveys was to develop an inventory, documentation and dissemination of past, present and possible future coping mechanisms to deal with climate variability across agropastoralists households.

3.1.1 Survey design and implementation

The methodological approach included the following steps: choice of the benchmark sites, household sampling for the survey, training of investigators and field surveys. Selection of the district and the villages was made based on twin criteria of, first, representation of rural livelihood patterns in a broad sense and, secondly, the ability to capture the effect of livelihood 'gradients'. The key livelihood gradients that determined village selection were distance to the market (i.e. far from the market versus closeness to the market) and proximity to the river (i.e. close to the river versus far from the river) as shown in Table 4.

Table 4. The two by two design used in village selection

		Distance to market	
		Close	Far
Distance to water	Close	Cluster A	Cluster C
	Far	Cluster B	Cluster D

In addition, villages were selected in a balanced way that excluded influence emanating from development-oriented activities by other NGOs that could have effect household livelihoods. The sampling frame, from which villages were drawn, was developed with the assistance of government administrative area officers. In each selected village, the help of headmen or chiefs was sought to get the list of households for use as sampling frame. Finally, using systematic sampling, a total of 175 and 184 households were selected in Mopti region of Mali and Mabalane District in Mozambique respectively.

3.1.2 Data collection

Using a semi-structured questionnaire, which were administered with the help of trained enumerators, household interviews were conducted on March and May, 2009 in Mozambique and Mali respectively. The data collected comprised of: agricultural production at the plot level, household level data on livestock holdings and management, off-farm income activities and earning, household characteristics, household vulnerability context and the coping and adaptation strategies to climate change and variability.

3.1.3 Data entry and analysis

The data from the questionnaire were then entered into an access database during which time data entry and coding errors were checked and corrected. Data cleaning was then done using Microsoft EXCEL. Supervision and on the spot assistance during data cleaning was ensured throughout the process. Finally, STATA (release 10.0/SE) was used for descriptive and in-depth data analyses.

3.1.4 Results for Mali

Variable and low rainfall patterns and natural resource degradation linked to changes in climate have forced both agricultural and pastoral communities in Mopti region to transform their production systems and social relations on which they are based. To assess vulnerability factors and adaptive options of these communities to the consequences of climate change, a household survey was conducted within three major agro-ecological zones of the region: the Delta zone, the Seno zone and the Gourma zone. Investigations were made between February and May 2009 and were focused on 15 households per village representing 60 households per agro-ecological zone. This chapter reports the major results of this work.

Household related characteristics

The results of the survey showed that average age of household heads in the study area was 58.6 years with household sizes comprised between 1 and 32 people (Table 5). In this zone, male headed households were predominant with 96% compared to female for about 4%. Results also showed that no well-educated household heads was identified among the used samples of this study. Duration of the education varied between 0 and 13 years.

Table 5. Household related characteristics in the region of Mopti

Parameter	Mean	Std. Dev	Min	Max
Household age (Years)	58.6	13.2	22	89
Household education (Years)	0.8	2.9	0	13

Household revenues are generated from off-farm, crop and livestock incomes (Table 6). Crops constitute a main source of income generation for households with an average plot size of 5.4 ha/household. The importance of household's incomes varies according to the zones and the sources. The higher incomes generated from livestock was observed in the Delta zone, whereas crop revenues contributed the most in the Gourma zones and the Delta. This can be attributed to the availability of pasture in the Gourma and in the Delta. In the Delta and the Seno zones, off-farm revenues play an important role in increasing revenues of poor-resource agropastoralist households. In these areas, cereal cropping constitutes the major agricultural activities. Poverty and erratic rainfall conditions force households to send labour force elsewhere for off-farm employment to generate income.

Table 6. Average income generation sources of household per household head by zone (FCFA)

Agro-ecological zones	Off-farm	Livestock	Crop
Delta	13909	13572	132640
Gourma	5720	16101	139795
Seno	12542	9273	27447

Climate and vegetation

The study areas belong to the north Sahel-Soudanian bioclimatic zone characterized by a short erratic rainy season from June to September and a long dry season from October to May with average rainfall of 500 mm. The length of the growing period is shorter in the North than in the South mainly caused by an earlier end of the rainy season.

The natural vegetation consists of woody and herbaceous species mostly used for human needs and animal feeds. The highest total wood stock of the study areas is found in the Séno and the Gourma zones compared to the Delta. This is due to strong natural regeneration of trees on agricultural and fallow lands in the Séno and the difficult access of the Gourma zone for human pressure on trees. The lesser wood reserve in the Central Delta is a consequence of the annual flooding.

Infrastructures and services

Table 7 shows information on the agropastoralist villages about access to infrastructures. No market was reported in the investigation zones. The closest urban market is located at 5 km from households while the farthest is at 160 km. As for livestock markets, the interviewed households are 2 to 40 km away. All villages are connected to both urban and livestock markets by the dirt tracts only, which make difficult sale of animal products. No centre for health, public telephone and electricity exists in the investigation villages. Only access to available pure drinking water from drilling exists in some places. The closest location from these infrastructures is 0 to 5 km and the farthest is 25 to 60 km.

Table 7. Average distances (km) to infrastructures to the households in the Delta

Infrastructures and services	Delta	Gourma	Seno
Urban market	19.4	20.0	91.5
Livestock market	15.5	20.0	4.8
Water	6.5	7.5	1.3
Nearest electricity	20.5	20.0	4.8
Nearest clinic	5.0	20.0	4.8
Nearest public telephone	19.2	20.0	4.8

Farm size and land use

In the region of Mopti, land use consists of arable cropping animal husbandry, forestry and fishery. Farming systems always combine cropping and livestock systems. At this level, land belongs to the State. The pastoral code which rules access to common pastures is not well known and neither applied by the autochthonous population, nor by the transhumance herders.

At the village level, customary land right stipulates that only families who founded the village own the land and can decide on access. The decision related to access to land and solutions to conflicts are co-ordinated by the village chief, his counsellors and the lineage chiefs (Maïga et al. 1994; Samaké 2003). The administrative and juridical authorities interfere only in case of disagreement.

Results of the survey showed that households have an average plot size of 11.7 ha representing 11.4 persons/ha. Plot sizes vary from one agro-ecological zone to another. Maximum cultivated area per household head was observed in the Seno with about 8 ha (Table 8). In the Delta and the Gourma zones cultivated land represented 4.3 and 4.1 ha respectively.

Table 8. Average plot size (ha)/household head by zone

Agro-ecological zones	Sample size	Plot size	Std. Dev.	Min	Max
Delta	55	4,3	6	0	37
Gourma	60	4,1	4	0	20
Seno	60	7,9	8	1	50

In this study, 92% of the households said they owned their land without any title, 4% borrowed land with no payment, 2% rented the fields with payment in grain after harvest and 2% rented the land with cash payment. According to farmers, land is not sold but, can be allocated for cultivation to external people (other households and migrants). They are not allowed to plant trees or to carry out other long-term management practices (e.g. construction of stone-lines for soil and water conservation) without prior authorization from landowners.

Livestock asset

In the study zone, livestock activities are practiced in a very extensive way. They contribute to food security (meat, milk), animal traction and manure production and provide skin for households needs (clothing, containers, rope and many other valuable items). About, 87% of households raise cattle to produce milk for consumption, 86% for milk selling and only 5% for animal traction. In many areas, the cattle kept by the Fulani herders provide manure to farmers. The animals grazing on harvested stalks manure the land to keep the field fertile.

Indigenous breeds constitute livestock species in the zone. Milk production varies between 0.5 litre/cow per day during the dry season and 2 litres/cow per day in the rainy season. The first calving of cow is at the age of 3–5 years as it is for the Sahel zones of Mali as a whole (Breman and de Ridder 1991). Live weight gains during the rainy season are only 200–350 g/day, and for cows, it takes up to 4 years to reach the marketable weight of 150 to 200 kg. Average tropical livestock units (TLU) are 257.13 for cattle, 12.99 for sheep, 7.98 for goats and 2.42 for camels (Table 9).

Table 9. Tropical Livestock Unit (TLU) of local breed livestock in Mopti region

Livestock breeds	Mean	Std. Dev	Min	Max
Cattle (n = 175)*	257.1	163.8	26.6	669.2
Goats (n = 170)	8.0	11.9	0.3	84.8
Sheep (n = 173)	13.0	12.1	0.4	54
Camel (n = 46)	2.4	1.8	1.3	7.5

* n stands for the number of households; TLU refer to Tropical Livestock Unit (1 TLU = 250 kg).

Feed resources and feeding strategies

Analysis of the results of the survey (Table 10) indicated that 29.7% of households use crop residues for cattle folders whereas 28.7% leave them on farm. 19% cut and carry crop residues home for cattle and 16.4% for goats grazing. Only 4.0 and 1.9% of households use treated crop residues for cattle and for conservation of agricultural lands. Similar results were found by a multidisciplinary farming research team of IER (DRSPR/Mopti 1992) which reported that crop residues constitute the major source of forage for cattle during the dry season in the Seno zone.

Table 10. The use of crop residues among livestock keeping households

Use of crop residues	Frequency	Per cent	Cumulative
Leave on farm	123	28.7	28.7
For cattle grazing	127	29.7	58.4
For goats grazing	83	19.4	77.8
Cut and carry for cattle	70	16.4	94.2
Treated for cattle	17	4.0	98.1
Used for conservation agriculture	2	1.9	100

Types of crop residues used for animal varies according to agro-ecological zones. Experiences of farmers showed that residues of rice as well as sorghum, millet and cowpea are used as forage for animals in the delta zone that constitutes the inland valley of the region. In the upland zones of the Gourma and the Seno, residues of millet, sorghum and some leguminous crops (cowpea, groundnuts and bambara groundnuts) are consumed by livestock after harvest.

Feed supplements are rarely given to livestock except for animal used for traction and those particularly used for fattening and milk production. These animals receive a wide range of feed resources, including groundnut and cowpea residues, ABH, bran and kitchen wastes.

As for watering, animals get water at the rivers and at wells during the dry seasons whereas in the rainy season, they water themselves in temporary ponds existing in the grazed pastures, or at the rivers and wells.

Beside crop residues, herbaceous vegetation including some graminea species such as burgu *(Echinochloa stagnina* and *E. pyramidalis*), *Voscia cuspidata*, *Andropogon gayanus* etc. and woody vegetation (*Acacia albida, Ziziphus mauriciaca* etc.) are also used as animal feed in the region.

Among livestock feed, investigation showed variation between forage species over years. Some species were reported to be abundant in the pastures 10 years ago but, absent today. These species include *Andropogon gayanus* according to 12 out of 55 interviewed households, *Panicum sp* (7 households)*, Chloris prieurii* (6 households) *Cenchrus biflorus* etc. However, other species were rare 10 years ago and abundant nowadays. The most important among these animal feeds are cotton cakes (62 households), crop residues (15 households), *Zornia glochidiata* (10 households), etc.

Past and present diseases and constraints for treatment

The region is characterized by the low productivity of animal associated to the insufficiency of forage during the dry season, the poor nutritional quality of pastures, the lack of genetic improvement and poor animal health care management. According to the pastoralist people, the unfavourable climatic conditions lead to the reproduction and the dissemination of diseases and parasites especially, ticks and worms. Results of this investigation also showed that certain diseases were present 10 years ago and almost inexistent today. The most important were said to be contagious bovine pleuropneumonia according to 14 heads of households out of 55 asked, diarrhoea (22 households), pest (7 households). However, some were rare 10 years ago but, abundant nowadays. Among these, there are: mouth ache (15 households), foot and mouth disease (22 households), faciola (6 households) and black legs (5 households).

According to farmers, livestock vaccination and treatment against internal and external parasites are limited because of the high prices and availability of veterinary inputs and lack of sanitary infrastructures such as park of vaccination. The reason is also the privatization of veterinary profession.

Climate-related concerns

The major climate-related concerns of the agropastoral communities identified in the study areas are the insufficiency of pastures for livestock and food for the populations according to about 34 and 32% respectively of the 55 households interviewed. Animals' diseases and death (9%), crop failure (7%), human sickness (4.5%), lack of water for livestock (4%), insecurity including conflict and violence (4%), high prices of inputs (2%), low market prices of the products (1%) and loss of goods (houses and lands) due to natural disasters (0.5%) are also identified as other vulnerability factors in the region. In their investigation, Togola and Kéïta (1995) reported in the delta zone that lack of natural pastures as well as water supply for the livestock in the dry season constitutes the major constraints to animal production in the zone.

3.1.5 Results for Mozambique

Mozambique has a total land surface area of 799,380 km^2 with about 36 million hectares considered as suitable for agriculture. Only 10% of the arable land is currently being used. The Northern provinces have generally good soils and regular rainfall and usually produce a marketable excess of crops, while the dry south is drought prone and a food deficit area.

Mabalane district of Gaza province is situated in the southern part of Mozambique. The district falls in arid and semi-arid land (ASALs) and the majority of the households are agropastoralist. The district has a total population of 32,040 inhabitants, and the population density is 3 persons/km^2, far below the national average of 25 people/km^2.The district receives low and variable rainfall averaging 623 mm/year and mostly falling from November to March, high evapotranspiration (1413 mm/year) and frequent floods leading to high agricultural risk particularly in dry land farming areas. Traditionally households' livelihoods centre on livestock keeping and agriculture.

Farming system

Livestock kept in district comprised of cattle, sheep, goats, pigs and chicken. 68% of the households raise cattle extensively and grazing is the main form of livestock feeding. Following the harvesting season some farmers give crop residues to their animals. Off-farm income generating activities included: non-agricultural (salary and wage labour), remittances (values of items received in kind such as gifts and groceries) and income from other sources (fishing, hunting and gathering) and trading of forest products such as charcoal. The major crops grown include: cereals (Maize, Millet and Sorghum), pulses (Beans and Cowpeas), vegetables (Cabbages, Pumpkins, Tomatoes and Onions), fruits (Watermelon) and tubers (Cassava and Sweet potatoes).The main land tenure systems were: freehold (90%), farm owned with title deed (8%) and communal and rental land from individuals (2%). Households cultivate their own small arable plots, producing subsistence food crops.

Socio-economic characteristics of households

The average household size was 8 members in adult equivalent (SD = 3; range 2–16). The average household head age was 52 years. The average farm size was 4 hectares and the head of the household was recognized as the overall farm manager. Three major sources of household income were identified for each household: crop, livestock and off farm income. The highest level of education attained by the head of households was primary education. The women were less educated in that a relative high proportion (65%) did not receive formal education at all. The results also indicate dominance of household head by males (80%) compared to 20% female headed households.

Land tenure

The main land tenure system was freehold (90%) and less than a 10% of farmers possessed a title deed. However, the type of land tenure system did not seem to have any influence on the type of land improvement made on the farms. This was because out of the 60 household who had title deed as a form of land ownership, only 3 of them had improved land through fencing. Majority of the households (70%) has farms whose size range between 0–2 hectares.

Farmer infrastructure and transport

Most of the infrastructures (i.e. clinic, public telephone, electricity, livestock and urban markets) were far for the majority of the households.

Annual food security of households

The cereals (maize and rice, sorghum and millet) contributed significantly to the dietary energy and protein by 49 and 51% respectively. Other significant sources of energy were edible oils (17%), meat (15%) and pulses (10%).As expected meat and pulses was reported as important sources of protein in that they contributed approximately 27 and 17% respectively to the household protein dietary pattern. The severest period for household in terms of access to food for consumption was the period between March and July, as reported by 80% of the households.

Household health

Malaria was reported as the main disease affecting the majority of households. Seventeen % of the households reported to have had at least one person infected by malaria for an average period of 117 days (SD = 133 days; range 14–365 days). 72% of the malaria cases sought medical care from a medical doctor while the remaining 18% went to traditional healers.

Household labour information

All the households sampled used family labour solely. The dependence on family labour was reported to be particularly useful for all aspect of food crop production such as land preparation, planting, weeding, harvesting, winnowing and transportation, and livestock production.

Cattle production system and characteristics

The indigenous breed was the predominant cattle breed across the surveyed households. In general, women were responsible for the shoats and poultry and men for cattle. However, , in male-headed households, while women play a role in managing small stock in terms of feeding, breeding and disease control, they had to consult the head of the household whenever shoats and pigs had to be sold. In female headed households, women were obviously in control of everything including sales and consumption. Utilization of cattle for draught power is especially with indigenous breed. The majority of the households (67%) use crop residues to supplement their cattle (either through direct grazing or by feeding them through cut and carry) while 30% of the households leave the crop residues on the farm to decay or apply them as a mulch to conserve moisture. Only 2% of the households supplement shoats with crop residues.

This study analysed actual coping strategies used by agropastoralist based on a household survey of 184 households in Mabalane district of Mozambique. The main coping strategies adopted by agropastoralist households to circumvent the effect related to climate change were: storing food; saving money; preventive health care for animals; preventive health care for humans; the use of irrigation and increasing water storage capacity. A logit discrete choice model was used to analyse factors influencing the coping strategies of farm level adaptation measures. The results showed that geographic, demographic and socioeconomic factors could have a positive or negative influence on the specific coping strategies used by the household as adaption measures.

This study demonstrates the importance of government policies and strategic investment plans that support improved access to climate forecast awareness, research into the development of and information about appropriate farm-level climate coping strategies, access to credit, farmer education, market development and access to public infrastructures.

Climate-related concerns

The five major climate-related concerns reported by the agropastoral households are animal loss due to theft, insecurity/violence/fight, lack of enough food, crop failure and loss of access to land.

3.2 Review of adaptation options in Mali

The inlands valley and the upland zones of the region of Mopti are transitioning from traditional to intensified agriculture and animal husbandry. These primarily dominant sectors serve as the engines of sustainable economic development that provide food security and alleviate poverty in the region. However, uncertain, variable and low rainfall patterns and increasing population pressure leading to natural resources degradation have forced both agricultural and pastoral communities to transform their production systems and social relations on which they are based. To assess adaptive capacities of these communities to the consequences of climate change, a field participatory survey was conducted in the region between February and May 2009 within the three major agro-ecological zones of the region of Mopti: the Delta zone, the Seno zone and the Gourma zone. The investigations were focused on 15 households/village representing 60 households distributed in four villages/agro-ecological zone.

3.2.1 Options to cope with climate changes and variability

Results of the survey showed that strategies adopted by agropastoral households to cope with climate change vary according to concerns they're addressing. These concerns include the insufficiency of pastures for livestock, the insufficiency of food for people, animals' diseases and death, crop failure caused by erratic rainfall, human sickness, lack of water supply for livestock, conflicts related to the resource use, etc.

To solve problems related to the pasture insufficiency, reducing the number of animal was said to be the best option according to 46% of the interviewed agropastoralists. However, 36% thought that collection and storage of animal feed such as crop residues, herbaceous forages (*Echinochloa stagnina, Echinochloa pyramidalis, Voscia cuspidata, Andropogon gayanus,* etc.) and fruits of woody vegetation (*Acacia albida* and *Acacia nilotica*) for the crisis period (April to June) are more suitable to solve feed deficiency problems. Only 8% felt reduced morbidity of the herd was seen to be the most appropriate option.

Crop failure caused by biotic (pest, weed, diseases, grain eating birds, etc.) and/or biophysical constraints (erratic rainfall and unfavourable physical and chemical conditions of soils) results in food deficiency during the critical periods of the year, mainly in the rainy season. To prevent this situation, about 52% of the 175 sampled households chose to store food whereas 31% opted to reduce investment in animals, lands and houses. Results also showed that 7% would save money to buy food and 7% would make arrangement with families or friends for help.

Although not said during this survey, work done by Moore et al. (2005) showed that famine relief actions in the delta zone of the Mopti region, like in other area in the Sahel, consisted of providing food to pastoralists who lost their livestock or farmers who lost their crop after the drought or from other any natural disaster. In this situation, food is freely distributed to households in case of need.

As for the preventive action for animal's health care, vaccination of livestock against diseases was reported by 88% of the 175 sampled households to be best option to prevent loss of livestock. Only 2 to 5% households said that reducing morbidity by avoiding certain infested areas or reducing investment in animals would be a good strategy to cope with animal deaths.

3.2.2 Relation between influencing factors and households' strategies

Results of the investigation showed that adoption of the different strategies by the agropastoralist to cope with climate changes are influenced by numerous factors such as distance of the households to infrastructures and services (water, market, rangelands…), rainfall, household income, herd size, household size, diseases and death, education etc.

In this study, a multiple linear regression analysis was established to determine factors influencing the choice of the adaptation options to climate change and variability in the Mopti region. Results showed significant linear relationships between these factors and coping strategies. The best regression equation obtained for this relationship is:

$$Y = \alpha + \beta x 1 + \beta x 2 + \beta x 3 + \ldots + \beta x \nu$$

With

Y:	coping strategies adopted by households
x:	expresses the influencing factors
β:	defines the coefficient
α:	represent the constant.

Analysis of the results showed that the most influencing factors on adaptation options to climate changes vary according to the different agro-ecological zones:

- In the Delta, access to water resources and income diversification affect the strategy of saving money, whereas rainfall and crop value determine preventive health care for humans. The strategy of storing food seems mostly influenced by average rainfall variability. To solve problems related to food shortage and famine, income diversification indices were seen as the significant factor ($P < 0.05$) limiting to saving money.
- In the Seno zone, many factors were identified to significantly influence coping strategies of households. Distance to water resources, number of natural resources accessed by household and the length of the household illness were declared to be the most important factors influencing food storage. However, rainfall variability, and livestock diversification indices were identified as major factors that affect preventive health care for animals.
- In the Gourma zone, fewer factors were said to influence coping actions. Household income was declared to influence the strategies of saving money whereas herd size and household income were the major factors that affect preventive health care for humans.

This study of the agropastoral systems in the Mopti region has permitted a better comprehension of the adaptive capacity of the agropastoralist communities to climate variability and changes (Werner 2010). The results of the investigation indicated that 20 to 68% of the agropastoralists reduce the number of animal and collects and stocks feed for animals and grain cereal to prevent feed and food shortage. To prevent animal diseases and death, 3% of the herders reduce investment on animals and houses, 2% proceed to the vaccination of livestock against animal diseases, 2% avoid infested areas and 1% makes arrangement with families or friends to help.

Major factors such as the distance of the households to water resources, market, rangelands, average rainfall variability, household income, herd and household size, diseases and death, etc. were identified as influencing the most adaptation options to cope with climate variability and change. The multiple linear regression analysis established showed significant relationship between these factors and adaptation strategies.

3.2.3 Factors influencing households' vulnerability

For the purpose of this study the nature and degree of people's vulnerability to the climate change related issues were examined at the household level. That is, the degree of vulnerability of household was assessed in relation to other households within the same village, as either better than, worse than or same as other households. As households compare their vulnerability to households in the same villages (with the same exposure to climate change and variability) this reflects in this case differences in coping or adaptive capacity. We looked at the impact of concerns such as: food availability, water availability and supply, loss/theft of livelihoods assets, conflicts and human and animal sicknesses. Vulnerability indicators were identified and an index was developed, based on the above-mentioned areas of concern. This index was necessary for determining the factors influencing the households' vulnerability to climate change.

A number of factors were hypothesized to influence household vulnerability. There were demographic (age, gender, educational attainment, households size), socioeconomic (income, household assets, farm size, household practices, membership to community organization, membership to groups and access to loan), geographic (distance to the markets) and the number of constrains facing the household.

Below a summary of the main factors found to influence a household's vulnerability in Mali:

- Households with easy access to rangelands several are less vulnerable to climate change and variability.
- Being a member of a community organization enhances information sharing about available opportunities, reducing a household's vulnerability.
- Households, who are in a position to increase their herd size, increase their insurance, income and food base, hence lowering their vulnerability.
- Households are more vulnerable to the effects associated with climate change, when predisposed to an emergency situation during the last one year.

The results from a household's vulnerability in Mali have shown that for reducing vulnerability to climate change, for better or improved adaptive capacity there is need to evaluate factors which are important in different areas for the purpose of targeting. Although our findings clearly show the importance of different factors in determining household vulnerability, our model could only explain 28% of the variation; this implies that there is need for an in-depth study of other additional factors which makes households vulnerable to the effect of climate change and variability.

3.3 Review of adaptation options in Mozambique

3.3.1 Options to cope with climate variability and change

Mozambique as a country is very prone to natural disasters such as floods and cyclones. As such, loss of house or land due to natural disasters were reported as important concern with more than 90% of the households afraid that this could make them very vulnerable in the next 12 months. To reduce these risks and the vulnerability posed to the household, the following strategies were used:

- 25% saving money;
- 20% reduction on investing in land or houses;
- 10% reducing animal mobility or avoiding certain areas while grazing.

In terms of coping with lack of food, food storage is the most important strategy. Other strategies, in order of importance, include: making arrangement with family or friends for help (social networks), reducing the number of animals, introduction of irrigation, reducing investment in animals and houses and saving of money.

The households noted that though the idea of increasing water conservation could be successful in reducing the household vulnerability particularly during the dry season.

3.3.2 Relation between influencing factors and households' strategies

The result suggests that long distance to the market promotes storage of food and increase the water storage as coping strategy. The effect of long distances to the paved road had, as expected, a negative and positive influence (at 5% level of significance) on the use of saving and preventive health care for animals as a coping strategy. Implying that, when distances to a point/places where the banking facilities are situated are far, it become costly for farmers who are already resource constrained to access such services.

As expected, households were less likely to adopt the preventive healthcare for human if the distance to the local market was far. However, households had the tendency to adopt irrigation and increasing water storage coping strategies as distance from the households to the local market increased. This positive relationship could be due to households' inability to travel for long distance to buy food and water, during the periods when food and water are in shortage (i.e. during drought period).

The distance to the livestock market was important in that it influenced storage of food, saving money, preventive health care for animal and human beings, introduction of irrigation and increasing of water storage. Implying that livestock market were important avenue for generating income, which is essential to determine farmers' coping ability. Daily water availability is very important to household livelihoods. Consequently, lack of daily water availability had a negative influence on saving money and preventive healthcare for animal and human beings, implying that income that otherwise could have been saved, or used in preventive health care for animal and human being, was being utilized to secure daily water supply.

In their study, Kurukulasuriya and Mendelssohn (2006b), found that access to electricity was an important factor explaining household access to market access and technology. Accordingly, in this study lack of good access to electricity, had a negative influence on the ability to save money and introduce irrigation as a coping strategy. As expected, technology associated with banking sector function well where electricity is present, but lack of such technology, which is also influenced by access to electricity, could explain why farmer with poor access to electricity did not consider saving money as an important coping strategy to the effects associated with climate change.

Several studies have shown that improving education and knowledge dissemination as important policy measure for stimulating local participation in adoption decision (Dolisca et al. 2006; Anley et al. 2007). Similarly in this study, years spent in education had a positive influence on the adoption of preventive health care for household members as a coping strategy. This implied that educated farmers had more knowledge and information relating to climate change and its related effects, and were therefore willing to practice preventive health practice as an adaptation measure. Similarly, aged household heads have a lot of farming experience and are able to perceive when changes in production start to occurs, and as such are able to adopt such practices as storing food for the households as well as introducing irrigation as adaptation measures, as indicated by the positive relationship between age of the household head and the two coping strategies (i.e. storing of food and introduction of irrigation). This concurs, with similar observation made in Bayard et al. (2007) that age was positively related to the adoption of conservation measures as adaptation measures.

As hypothesized large household size was expected to take up labour intensive adaptation measures, in this study it was found that large household size in adult equivalent had a positive influence on the use of irrigation as a coping strategy against effect related to climate change.

High proportion of income from livestock was found to have a negative influence of storing food, coping strategy. This observation was as expected because, more than fifty per cent of the household interviewed revealed that they use livestock as a form of saving and only selling them only when a particular needs arise. This therefore implies that, with livestock such as cattle, goat and sheep, the household were not keen on storing food, since possession of livestock made them lack the motivation. However, higher crop value of crops per hectare was found to be an important in influencing the adoption of the following four coping strategies: saving of money, preventive health care for human, introduction of irrigation and increasing water storage, as adaptation measures.

For saving money, the results were as expected that, when the crop value per hectare rises farmers dispose most of the produce in favour of savings. Since, higher crop value per hectare is positively related to disposable income, when the crop value per hectare is high; the households are obliged to react positively in relation to their health, thus getting preventive health care (i.e. acquiring mosquito nets). Similarly, with more disposable income, the household easily acquires irrigation technology and water storage facilities (for example water tanks), which could have been un-affordable if the crop value per hectare was low.

The number of natural resources accessible to household were found exert a negative influence three coping strategies (household ability to store food, introduction of irrigation money and increasing water storage) and a positive influence on preventive healthcare for animals. This could be explained by the fact that more than 60% of the households studied reported that they gather forest fruits for use as food thereby lowering the motivation for storage food as a coping strategy.

Access to rangeland among the household interviewed households also had negative influence on all coping strategies, except the use of preventive health care for animals. Implying that free access to rangeland imply the cost related to livestock production is low and thus can keep large herd, and as was explained earlier, large number of livestock reduces the motivation to store food as a coping strategy among households. The negative influence to saving money by free access to rangeland can be attributed to the fact that majority of household regard livestock as a form of saving. Consequently, with less disposable income, since animal are sold only when a need arises, lowers the motivation for the introduction of irrigation, increase of water storage and preventive health care for the humans.

The results also suggest that low cost of accessing resources (i.e. rangeland, forest and water) have a positive influence on the adoption coping strategies such as: saving money, preventive health care for animal and humans, introduction of irrigation and increasing the water storage capacities. This implies that by the virtue of resources that the household access being free, a large portion of disposable income becomes available for saving, acquiring new technology to facilitate irrigation and water storage facilities as well as money for providing preventive healthcare to the animals and household members as well, hence the positive influence.

The free access to large number of natural resources, some of which are major sources of livelihoods (for example commercial burning and selling of charcoal as well as a source of food), implies that they act as a platform for household income diversification. Consequently, the motivation for saving money and preventive health care for animals Nevertheless, access to large number of free natural resources (for example fruits) which are free food, have the tendency to reduce crop diversification on the farm. Consequently, crop diversity index has a negative influence on introduction of irrigation as a coping strategy.

Awareness of the problems and potential benefits of taking action is an important factor in influencing farmers coping strategy to climate change. However, the effects of this awareness become pronounced when spread widely through social networks among households and communities (Birungi 2007). The result suggest that in Mabalane district, social networks through such forms as membership to community organization or group membership positively influenced the household in the use of preventive healthcare among household members, introduction or irrigation and increase the water storage capacities positively. This imply that social network is an asset that has the potential of making farmers in a group to influence each other in creating awareness and implementing appropriate coping strategy.

As expected the ability to save among household, had a positive influence on the saving, preventive health care for animal and preventive health care for humans. Implying that the ability to mobilize saving among households had potential of enabling farmers to cope well to the effects of climate change. This observation concurs with past studies that have shown that more financial resources at the farmers disposal, enables them to use all available information to change their management practice in repose to changing climatic condition (Kandlinkar and Risbey 2000; Tizale 2007). Nevertheless, a good access to credit or emergency loan whenever a need arises had a negative influence to the saving of money, implying that an easy access to credit reduces the motivation to save money.

Large herd size and high income per adult equivalent have a positive influence on the use of preventive health care for animals. Since, as was noted earlier cattle are used as a form of saving, and thus the large the herd size the more saving a household has. Consequently, the value attached to cattle is a motivation among farmers to adopt preventive health care for animal as an insurance against any risk (i.e. a disease outbreak).

3.3.3 Factors influencing households' vulnerability

Below a summary of the main factors found to influence a household's vulnerability in Mozambique:

- The closer the household farm is to the paved road and to the portable water; the less vulnerable they are to the climate change and variability;
- Households are more vulnerable to the effects associated with climate change if, the proportion of household income derived from livestock is low and also if the crop value per hectare is low.
- Access to several free natural resources is positively correlated with vulnerability, although the degree related with it is quite weak.
- Food aid was negatively correlated with household vulnerability, implying that the household less dependent on food aid were less vulnerable compared to those who were highly dependent on food aid.
- Female headed households were more vulnerable compared to male headed households. The higher vulnerability to climate change associated with female headed households could be attributed not only to their limited physical capacity but also to their overwhelming family burden.
- Among the postulated socioeconomic variables the access loans among households in times of emergency was an important factor influencing household vulnerability negatively at 10% level of significance.

In conclusion, diversification of income sources in the study district had the potential to reduce household vulnerability and was thus important. However, income diversification does not necessarily accrue to the reduction of household's vulnerability but may in fact in the long term, exacerbate it. For example, access to natural resources, such as forest enable the household to diversify income sources, through selling of firewood or charcoal, an economic activity that in the long run might exacerbate the effect of climate change causing the households to be even more vulnerable.

3.4 Key messages

The results show that a variety of geographic, demographic and socioeconomic factors have a positive or negative influence on the specific coping strategies used by the households.

1. The study has permitted a better comprehension on the adaptive capacity of the agropastoralist communities to climate change.
2. The results indicate that pastoralist communities in the region have adapted many adaptation strategies to prevent vulnerability factors.
3. This study gave us more certainty about some variables' influence on coping capacity; some of which are widely applicable.
4. The results from this study have shown that for reduction of vulnerability to climate change, for better or improved adaptive capacity there is need to evaluate factors which are important in different areas for the purpose of targeting.

4 Active learning mechanisms

4.1 Introduction

In order to conduct a collaborative learning approach, the collaboration with the agropastoralists was institutionalized by supporting them to form Community-Based Organizations (CBOs). The formation took place in the first trimester of 2010. In Mabalane District of the Gaza Province of Mozambique, two CBOs were formed; one in the village of Mabomo situated 30 km distance from the District headquarters Mabalane, and one in the village of Mungazi situated in a remote area 100 km from Mabalane (Levy 2010). In Mali, two CBOs were formed in the two neighbouring villages of Ouadiana and Degessagou in the Seno area of Mopti province (Kuete 2011). Facilitation of the group work was done by PhD and MSc students and, in their absence, by employed community facilitators.

All the four CBOs received an initial instalment of community funds worth 1000 Euro to test promising adaptation strategies in form of group activities. In Mali, efforts were made to select adaptation strategies through literature search, from local NGO's and through the identification of local innovations (Kuete 2011). After the group members conducted a problem analysis, adaptation strategies for pilot testing were suggested by the members and their feasibility and expected results discussed within the group. Finally the strategies were ranked according to their priority to form the basis for action plans for the CBOs.

In Mozambique, the priority activities conducted by the groups were: communal goat keeping, revolving loan scheme, construction of improved corral for goat keeping and construction of improved corral for confined pig rearing (Levy et al. 2010). The CBO in Mabomo conducted a visit to the zonal research centre (Levy 2011) where members learned improved production techniques and implemented selected ones e.g. improved pen for goats and pigs. In Mali, the group activities comprised: sheep fattening, collective purchase of concentrate feeds, afforestation, communal millet/groundnut cultivation (Werner 2011). Apart from these group activities, the group members gained experience from collaborative actions to various degrees: this ranged from member to member exchange to regular meetings and joint decision-making within the CBOs (Levy 2011).

After one year, the group performance was evaluated. In both countries, one group proved successful (Mabomo in Mozambique and Ouadiana in Mali), based on the following indicators (Levy 2011; Restrepo 2011; Werner 2011):

1. The CBO members collectively implemented at least one of the strategies they had previously selected;
2. Good management by the CBO officials (e.g. meeting records, financial records, communication);
3. Self-organized regular meetings and transparent decision-making process e.g. on how to proceed in one activity;
4. Benefits of the collective activities in the CBO were equally distributed among all members;
5. CBO members showed motivation towards the implementation of innovative strategies, and perceived the group work as promising.
5. After the evaluation, each of the successful groups received a final instalment of 2000 Euro in 2011 to expand the scope of their activities.

Equally in both countries, one group experienced difficulties, related to (Levy 2011; Restrepo 2011; Werner 2011):

1. Some disposition of officials towards self-gains;
2. Unclear accountability within the CBO due to the fact that meetings were not performed regularly and a controversial decision-making process;
3. No rule enforcing mechanisms within the CBO;
4. Low motivation of the CBO members due to their conflicting relations;
5. Unequal distribution of work-load within the CBO.

For the two problematic groups, solutions were sought in collaboration with the group members. In Mozambique, a member to member exchange among the two CBOs was conducted (Levy 2011) that was followed by the election of a new president and vice-president in the CBO in Mungazi. This meeting enabled the implementation of the activities previously selected by the group members (e.g. training of the community animal health workers (paravets), purchase of veterinary supplies, purchase of a communal goat herd) and fortification of the CBO management with regard to meetings and decision-making process. In Mali, the solution entailed the separation of the non-functioning group in Degessagou into a group of the livestock keepers (Fulbe) and the agriculturalists (Rimaibe and Dogon). The newly formed agricultural groups received 500 Euros to implement group activities.

4.2. PM&E

In 2011, a Participatory Monitoring and Evaluation (PM&E) system was installed in the CBOs. In Mali the purpose for monitoring was discussed in the frame of the evaluation mission (Werner 2011). In Mozambique, the objective of the development and implementation of a PM&E system was to increase the active-learning possibilities of agropastoralists for improving their livelihood strategies and the sustainability of the system (Restrepo 2011).

The process of development and implementation of a PM&E system was divided in five basic steps following Burke 1998; Estrella and Gaventa 1998; Woodhill and Robins 1998; Cramb and Purcell 2001; FAO 2003; Slocum 2003; Geilfus 2008; and Anandajayasekeram et al. 2008, as shown in Figure 17.

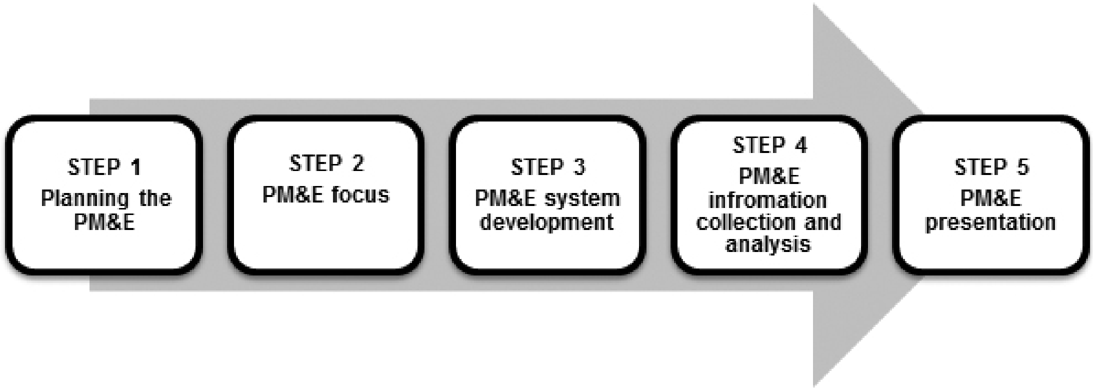


Figure 17. Steps used to develop and implement PM&E system in the CBOs in Mabomo and Mungazi, Mozambique

The PM&E was structured as an iterative learning process with cycles of exploration, analysis, decision-making, action, and reflection. Its development was based following a set of principles, which allowed CBO members to be the owners of their own process. All these principles were integrated into a flexible design, and applied during the process of development and implementation of the PM&E system in both CBOs, as show in Figure 18.

The five-step methodology is situated in the middle of the model. Principles attained in specific steps of the process are at the left side, while principles implemented during the five-step methodology are at the right side of the model. In the bottom stands learning and empowerment, which are objectives of M&E system, and outcomes.

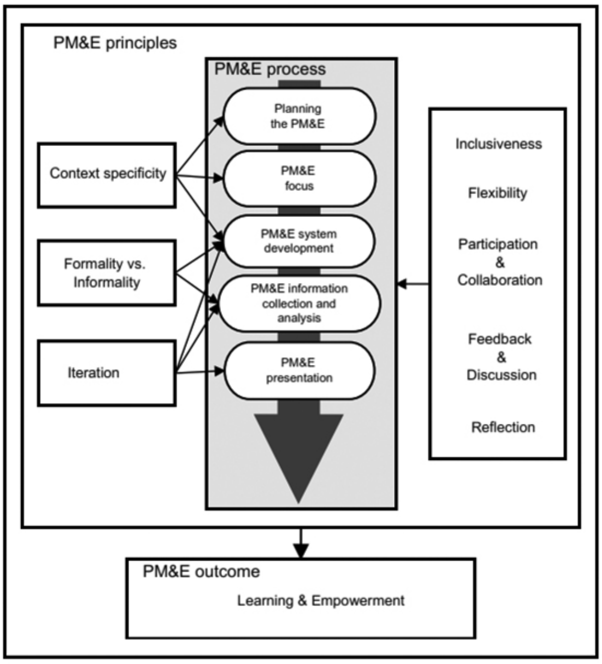
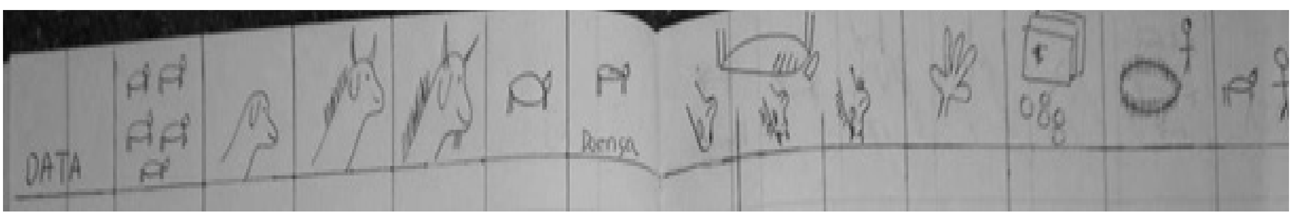


Figure 18. Model that integrates the PM&E principles to the development and implementation of the PM&E system

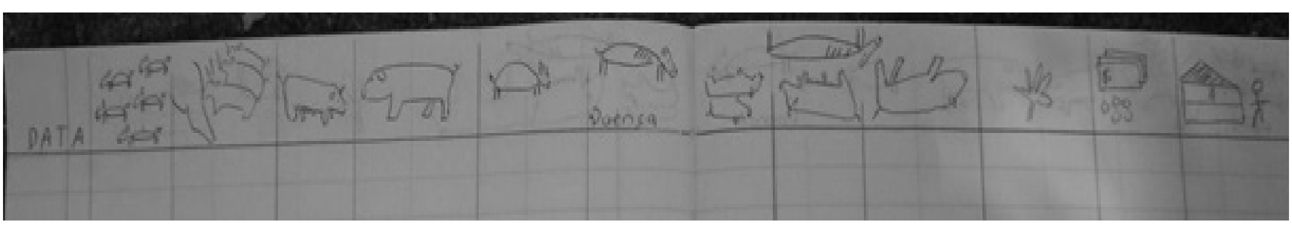
The five-step methodology is situated in the middle of the model. Principles attained in specific steps of the process are at the left side: context specificity; balance between formality and informality; and iteration. Principles implemented during the five-steps of the process are at the right side of the model: inclusiveness; participation and collaboration; feedback and discussion, and reflection. At the bottom of the model stands learning and empowerment, which are objectives of the M&E system (Guijt 1999; Hagmann et al. 1999; Estrella 2000; Mahanty et al. 2007), but also results from the process of developing it (Woodhill 2007; Guijt 2008).

For the goat keeping activity, a set of indicators for monitoring and evaluation were developed with the group members (Restrepo 2011). After the development and implementation of the PM&E, the monitoring and evaluation system was institutionalized in the CBO. The CBO members took over the PM&E process and continued collecting and analysing information by themselves and developed a monitoring scheme for the pig rearing activity, as seen in Figure 19 (Restrepo 2011).

A)



B)



Source: Restrepo (2011).

Figure 19. (a) Goat keeping and (b)pig rearing M&E instruments developed by the CBO members in Mozambique

4.3 Lessons learnt by the CBO members

The members of both CBOs perceived they have learned several lessons during the course of the CBO. The lessons learnt in both CBOs are different, as the processes have been different.

In the CBO in Mabomo regular members perceived they have learnt about the importance of collective action and learning, while official members claimed that they have improved their skills in the management of the group and its activities, as shown in Table 11 (Restrepo 2011).

Table 11. Lessons learnt by the members of the CBO in Mabomo

Lessons learnt	Members		
	Sum		(%)*
	R	O	
Awareness of the importance of collective action for the CBO functioning	4	2	56
Awareness of the CBO as a learning platform, things that can only be leaned in a group	2	1	27
Improvement of their skills in planning, implementing and PM&E an activity	0	2	18
About the activity	0	1	9

* % of respondents, n = 11; 12 answers; R: regular, O: official.

The following commentaries from CBO members in Mabomo represent the general perception regarding the importance of acting together, and their improved skills in planning and acting:

- 'I have learnt that together we can make great things that can't be done by one person individually. For example, because we are associated we were able to have money for the CBO, but alone, we will not have been able to have the money' (Frazao Lainane Simago, Mabomo CBO treasurer/herder).
- 'Together we can go far, individually is not so easy. For example if we continue working together, in the year 2013 we will have enough animals to help in reducing poverty among the CBO members' (Jose Cumbulela Mundlovo, Mabomo CBO secretary).
- 'We learnt to do thing in practice and in thinking. We have been planning and doing and that's the most important thing I have learnt' (Maria Mpungo Ngulele, Mabomo CBO Fiscal).

In the CBO in Mungazi, official and regular members learnt similar lessons as shown in Table 12 (Restrepo 2011). The most common reply (80%) refers to the importance of investing the money from the CBO in goats. Equally important, the members have identify problems within the activity implemented, and realized the importance of working together.

Table 12. Lessons learnt by the members of the CBO in Mungazi

Lessons learnt	Members		
	Sum		(%)*
	R	O	
Importance of investing the CBO money in goats (they have bought three)	4	4	80
Identification of problems in the community-based activity implemented	3	2	50
Awareness of the importance of collective action for the CBO functioning	3	2	40

* % of respondents, n = 10; 18 answers; R: regular, O: official.

The following commentaries represent the general perception from CBO members in Mungazi regarding lessons learnt from the revolving loan scheme, the importance of working together, and how to use the money repaid:

- ':.. we didn't knew then, now we know that we should have bought first animals, and then after with monetary gains implement a revolving loans scheme' (Antonio M Chauque, Mungazi CBO secretary).
- 'If all the members participate form the meetings and activities, once we have the money from the loans, we will be in the good path' (Elizabethe Chauque, Mungazi CBO regular member)
- 'It is important for us to work hard in order to rescue the CBO' (Paulo Pambule Chauque, Mungazi CBO regular member).
- 'For me, the CBO will be in a good path when the people with loan have returned the money, and with this money we will be able of buying animals, that would reproduce' (Piosse Samuel Chauque, Mungazi CBO treasurer).

4.4 Learning outputs

The PM&E system permitted the CBO members to learn: (1) from the PM&E process, and (2) about the outcome of the community-based activities implemented in the frame of the project, allowing the identification of possible improvement options (Restrepo 2011).

4.4.1 Learning from the PM&E process

Group members gained experience in the iterative cycles of exploration, analysis, decision-making, action and reflection. This learning finally led to empowerment of the group members (Restrepo 2011). In the CBOs, learning from the process can be seen by:

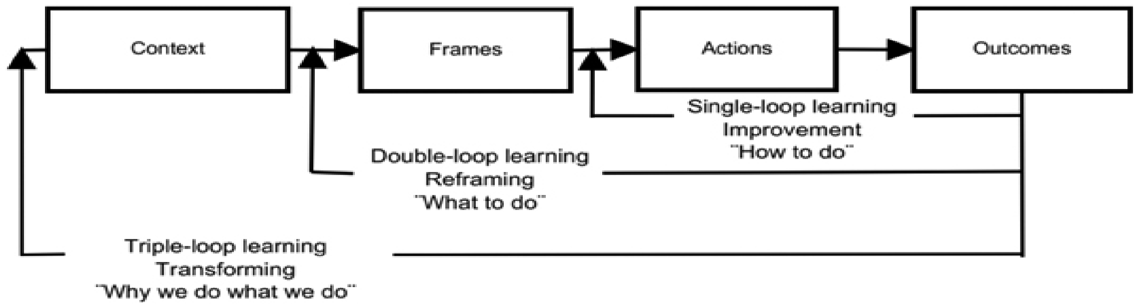
- Enhanced and fortified skills of CBO members to plan, implement, and follow a PM&E system (single-loop learning)
- Awareness of the importance of meetings and decision-making process, which in turn enhanced transparency and accountability (single-loop learning)
- Improvement in management skills (single-loop learning)
- Awareness of the importance of collective action (single-loop learning) and a change in the CBO governance to plan and implement collective action (triple-loop learning)
- Awareness of the importance of having plans (single-loop learning) and collectively establishing and implementing plans so that all members benefit (triple-loop learning)
- Establishing and implementing activities with short-term and long-term benefits (triple-loop learning) to maintain motivation among members.

4.4.2 Learning from the PM&E findings

- Systematization, analysis and reflection of innovative livestock management practices, which generates new contextualized knowledge (second-loop learning).

4.5 PM&E and social learning

Social learning is often conceptualized by the different cycles or loops of learning (Argyris and Schön 1978; Maarleveld and Dabgbagnon 1999), as shown in Figure 20. Single-loop learning (correcting errors form routines) involves the identification of alternative strategies and actions to resolve specific problems, and improve outcomes by increasing the effectiveness and efficiency (Argyris and Schön 1978; King and Jiggins 2002). It occurs at individual level, and involves little reflection (Maarleveld and Dabgbagnon 1999). This learning also includes the first improvement of the capacity to make and implement collective decision (Pahl-Wostl 2009). Double-loop learning (reframing) involves renewing or doing the right things (Argyris and Schön 1978; Maarleveld and Dabgbagnon 1999). It implies a reflection on how goals can be achieved (Pahl-Wostl 2009), as it incorporates feedback of experience into planning (Hiyama and Keen 2005). Improvement is achieved by experimenting with innovative approaches (Pahl-Wostl 2009). Thus, it is characterized by trust building efforts, and willingness to take risks (King and Jiggins 2002; Armitage et al. 2008). The implementation of innovative approaches may not be possible without modifying the context and factors that determine the frame of reference (Pahl-Wostl 2009). Triple-loop learning (transforming) occurs through the reflection of single and double-loop learning (Maarleveld and Dabgbagnon 1999; King and Jiggins 2002). It is a consideration of why we do what we do.



Adapted from Armitage et al. (2008) and Pahl-Wostl (2009).

Figure 20. A multiple-loop learning framework

Incorporating social learning principles and practices in M&E process promotes collective action, critical reflection, and increase knowledge sharing (Cundill & Fabricius, 2009; Measham, 2009). Clarifying and specifying learning goals is important if learning processes are to be linked to learning outcomes (Collins and Ison 2009; Cundil and Fabricius 2009), moreover if scaling up is to be based on promoting process of learning (Hagmann and Chuma 2000). CBO members in Mabomo and in Mungazi have learnt different lessons during the period in which they have implemented the community-based activities (Restrepo 2011). Table 13 presents examples extracted from the results of the present research of learning outcomes using evaluation parameters proposed by Plummer and Armitage (2007), and following the concepts of single-loop, double-loop and triple-loop learning (Agyris and Schön 1978; Maarleveld and Dabgbagnon 1999; King and Jiggings 2002; Armitage 2008).

Table 13. Assessment of learning outcomes for the CBOs in Mabomo and Mungazi, Mozambique

Parameter*	CBO in MABOMO	CBO in MUNGAZI
Shared actions are undertaken	Purchase of goats and construction of their corral; Cutting of poles for a traditional pig corral; Construction of an improved corral for pigs according to the new plans (currently under development)	Establishment of a revolving loan scheme; Construction of goat and pig corral
Modifications are made in an on-going process of re-ection	Designed and implement a PM&E system; Willingness to implement the PM&E system for other activities	Designed and implement a PM&E system; Willingness to implement the PM&E system for other activities
Single-loop learning Improvement/How to do	Re-adjustments and improvements in the PM&E system; Improvement of their skills in planning, implementing and PM&E an activity	Money from the revolving loan scheme is returning to the CBO; Identification of problems in the community-based activity implemented
Double-loop learning Reframing/What to do	Willingness to innovate in livestock management practices: construction of an improved corral for goats and improved confined pig rearing	CBO started buying animals to implement a second activity;
Triple-loop learning Transforming/Why we do what we do	Awareness of the importance of collective action for the CBO functioning; Awareness of the CBO as a learning platform; Awareness of the importance of having plans so that all CBO members can benefit; Awareness of the importance of having short-term and long-term benefit	Awareness of the importance of collective action for the CBO functioning; Awareness of the importance of having plans so that all CBO members can benefit

* Evaluation parameter based on Plummer and Armitage (2007).

4.6 Key messages

The PM&E system promoted learning among and empowerment of the CBO members, which in turn created opportunities for consensus building, collective decision-making and action (Restrepo 2011). At the same time, the PM&E process introduced a motivational aspect that acted as a positive feedback to community-based activities (Restrepo 2011). It motivated the community to continue with their activities and the PM&E system itself. The collection and dissemination of the PM&E information within the CBO and also between the CBOs, e.g. during the member-to-member exchange (Levy 2011) strengthened the decision-making processes, which in turn enhances community-based activities in the villages, showing that group members were facilitated to enter a learning cycle.

The implementation of promising strategies in a CBO supported moving from single to double and triple-loop learning, which proved to be important in increasing the adaptive capacity in a continued process of learning and development (Restrepo 2011).

5 Policy entry points

The studies conducted under the supervision of AU-IBAR strived to understand the current inter-institutional coordination in the context of establishing an enabling policy and institutional environment for the identification and implementation of adaptation strategies to climate variability and change in agropastoral systems in Mali and Mozambique. The studies looked through the lens of national climate change policies in Mali and Mozambique and described coordination and alignment of policies and actions that are central to achieving climate resilience.

5.1 Policy framework

The Government of Mali has a random response on climate change. Mali along with is technical and financial partners, has undertaken a number of actions that have had an impact on strategies, policies and programs for sustainable agricultural development and food security. The Ministry of Environment and Sanitation is the lead agency for the negotiations on climate change. In support of these negotiations, the Department of Meteorology has produced many of the early country communiqués on climate change, mainly focusing on reporting on the amount of greenhouse gas emissions. The Permanent Technical Secretariat's informal climate change committee is chaired by the Ministry of Environment, which with its political capacity is trying to make the committee function effectively on cross-sectoral issues. On adaptation, the government's response is uncoordinated and focused on sectoral interventions. The Ministry of Agriculture seems to be ahead of other ministries in terms of taking adaptation seriously and integrating climate change into its development strategies. However, there seems to be no clear mandate within the government for addressing larger, multi-sectoral issues, such as the potential for climate change to cause increased migration of populations or increased conflict over limited natural resources. Mali signed the United Nations Framework Convention on climate change (UNFCCC) in 1992, and the Kyoto Protocol in 1999. The country is also a signatory to the United Nations Convention to Combat Desertification and the Convention on Biological Diversity. Under the UN negotiations on climate change, developing countries put together National Adaptation Programmes of Action (NAPA, known in French as the 'PANA'). The first National Action Program of Adaptation to climate change was validated in Mali in 2009.

In Mozambique the policy support for the implementation of climate change adaptation options is still weak, particularly in pastoral and agropastoral production systems. A five year Government Plans (2010–2014) was developed to ensure that livestock continues to play a key role in reducing poverty and in helping rural poor families to deal with climate change and variability. In contrast to policies approved earlier, policies and legislation approved since 1999 such as the National Water Policy, Policy for the Management of Calamities, Policy and Strategy for the Development of Meteorology and the Master Plan for the Management of Calamities, indicate the need of considering the challenge that climate change represent for the development of the Country. In recognition of the climate change risk, Mozambique has as well adopted important policies on environment and climate change in the last few years, including the preparation of the NAPA which seeks to prioritize projects contributing to the national adaptation effort, as well as the implementation of a dedicated CC program that has led to the preparation of a suite of studies, including a comprehensive Climate Change (CC) risk and vulnerability assessment, which has led to the formulation of a draft national long-term adaptation program. The Government of Mozambique has ratified the Convention in 1994, and as part of the international process, has published its Initial National Communication (INC) to the UNFCCC in 2003. The document provided an assessment of vulnerability and adaptation to climate change impacts, and suggested policy options for mitigation and public awareness-raising. The Ministry for Co-ordination of Environmental Affairs (MICOA) was responsible for compiling the report and remains the focal point for the government's climate change response.

5.2 Institutional framework

In both countries, from an institutional and policy perspective, a concerted effort to support agricultural activities and favourable price policies is required. Strengthening the institutions of farmers is fundamental to guaranteeing access to inputs and necessary credits for increased productivity. The limited integration of climate change considerations into current development activities needs to be addressed by strengthening coordination among the country's relevant institutions. Responding to climate change requires that a significant effort is made to raise education activities and awareness regarding current and projected climate variability and change. Integrating climate change into formal education curricula as well as community awareness programs could help in meeting these goals.

The current policy framework shows that there is a weak policy support for the implementation of adaptation measures to climate change. The lack of specific legislation is more accentuated in agropastoral and pastoral production systems because most of the adaptation strategies supported by legislation are related to crop production, despite the important role played by livestock in the livelihoods of rural poor people. Therefore, one of the major challenges that the countries face in adapting to climate change is to review the policy framework and fill the prevailing gaps in coverage of climate change adaptation issues giving due attention to livestock and agropastoral production systems. Existing policies are mainstreamed into relevant sectoral legislation and regulation. However, due to limited coordination between institutions, during the planning of activities these legal instruments are generally only considered by the institutions that prepared them for endorsement. In addition, the implementation of the existing legislation by the institutions is very weak on the ground, mainly because institutions are understaffed and with no budgets and equipment necessary to disseminate and enforce legislation. Furthermore, legislation somehow restricting the use of natural resources by rural people is of more difficult enforcement due to lack of alternative means of livelihood. Therefore, apart from policy revisions and development of additional policies, there is a need to improve the interactions between policies and institutions, mainstreaming of environmental legislation into sectoral activity plans and the need to create mechanisms for implementation.

5.3 Activities

The institutional capacity, preparedness and coordination, identify gaps and duplication of activities among institutions involved in the implementation of climate change adaptation strategies were assessed. It came out that a number of climate change projects and activities have been carried out in Mali and Mozambique many of which are set to offer significant insights and experiences on current and potential adaptation strategies for addressing climate change risks in both countries. Various public and private institutions, development agencies and NGO's are active in adaptation to climate change.

Priority research topics include:

The important role of research and of the scientific community in generating information and knowledge base that would help in identifying, developing and implementing effective responses to enhance adaptive capacity and reduce vulnerability has not been included in the climate change adaptation priorities.

A number of institutions across Mali are actively engaged in activities that should address climate change considerations, but additional work needs to be done. Some key gaps in the areas of research, data, and information that need to be addressed in order to keep pace with projected changes in climate are:

- Increase understanding and ability to reproduce interannual and interdecadal rainfall variability
- Improve the derivative statistics calculated from these data and link them to critical sectoral thresholds in order to better understand how climate change is likely to impact these sectors
- Improve water use in agriculture
- Build and enhance the socio-economic capacity to adapt and to manage disaster risks.
- Conflict mitigation/prevention/resolution among pastoral societies caused by land use changes or limited availability and quality of forages due to drought
- Changes in rangeland species distribution, composition, patterns and distribution due to climate change with subsequent land degradation caused by overgrazing
- Increasing growth of industrial livestock production systems and GHG emissions due to poor or no waste management
- Deforestation for grazing or land use for biofuel production.

The research capacity in Mozambique is limited because there are few research institutions in Mozambique. Furthermore, the primary mission of these institutions is not to carry out research related to climate change adaptation strategies. The transfer of research results to livestock keepers is weak due to a restricted number of extension workers at the local level and weak collaboration among institutions.

5.4 Key messages

Mali

1. The Governments should improve the policy coherence, coordination, synergy and sectoral integration between national development goals, and diverse adaptation needs, incorporating climate risk across sectors
2. Apart from policy revisions and development of additional policies, there is a need to improve the interactions between policies and institutions, mainstreaming of environmental legislation into sectoral activity plans and the need to create mechanisms for implementation
3. A better coordination among institutions would create opportunities for the identification of cross-cutting issues, building of partnerships and reduction of overlaps and duplication of efforts
4. Donors should support the Government to base development planning and policies on climate risk information and analyses to identify other ways of strengthening people's climate resilience, such as through social protection measures and other forms of livelihood support and asset-building
5. Donors should support the Government with longer term, predictable funding arrangements to ensure adaptation and food security, by funding NAPAs and incorporating contingency plans.
6. National policies should focus on priorities for investment, including the implementation of innovative adaptation options to climate change, to ensure the maintenance of household food security in the face of increasing climate variability
7. Policies should guide institutions towards developing and disseminating technologies that integrate modern with traditional and cultural practices that seem effective as a mechanism to cope with climate change. This would increase the adherence of livestock keepers to the technologies promoted.

8. Research institutions should be strengthened in financial resources, qualified staff and adequate equipment and materials to develop and test innovative climate change adaptation technologies in agropastoral and pastoral production systems, which have been marginalized and are anticipated to be severely affected by climate change, particularly in arid semi-arid areas

Mozambique

1. Smallholder and subsistence farmers and pastoralists will suffer complex, localized impacts of climate change, due to constrained adaptive capacity. Accordingly, MICOA in coordination with INGC, MINAG, INAM and international development partners should conduct a detailed assessment of localized impacts as the baseline for an informed and appropriate action to help livestock keepers adapt to climate change.

2. Diversification of income sources through livestock farming and commercialization can be a key strategy for escaping poverty because livestock appears more tolerant to drought than crops. Therefore, national policies should support the relevant institutions in the identification of areas of the country where climate change and variability are likely to make any crop production increasingly difficult. In places such as semi-arid and arid areas livestock production has a comparative advantage over crop production. Therefore, it should be a priority for investment, including in the implementation of innovative adaptation options to climate change to ensure the maintenance of household food security in the face of increasing climate variability.

3. Policies should guide institutions towards developing and disseminating technologies that integrate modern with traditional and cultural practices that seem effective as a mechanism to cope with climate change. This would increase the adherence of livestock keepers to the technologies promoted.

4. Climate change predictions indicate that there will be an increasing demand and competition for water in many places. Accordingly, policies that can address water allocation and water use efficiency issues will increasingly be needed. As predicted in the Policy for the management of calamities and in the Master Plan for the management of calamities, this is currently being implemented by INGC, but only in few selected pilot areas and benefiting few people, hence need to be expanded

5. A strategy for livestock production in the country need to be prepared to fill the current gap. This should include the vision, objectives, roles of different institutions and mechanisms to adapt to climate change and other disasters affecting livestock production.

6. Research institutions should be strengthened in financial resources, qualified staff and adequate equipment and materials to develop and test innovative climate change adaptation technologies in agropastoral and pastoral production systems, which have been marginalized and are anticipated to be severely affected by climate change, particularly in arid semi-arid areas

7. Key institutions should sign an agreement for information sharing as well as clarification of divisions of responsibilities regarding the implementation of actions to adapt to climate change. This would reduce duplication of efforts and promote partnership in the implementation of adaptation options.

8. The extension services need to be strengthened and appropriately linked with research institutions producing innovative options to cope with climate change such as IIAM so that these options are transferred to and benefit poor agropastoralists and pastoralists

9. Specific activities to adapt to climate change in agropastoral systems need to be prioritized during the elaboration of annual activity plans and budgets in key institutions. The mainstreaming process should be led by MPD

6 Lessons learned

In this report it is demonstrated that there are considerable differences between emission scenarios, in terms of projected changes in temperatures and rainfall for different regions. There is not that much difference between scenarios in global warming impacts to the 2050s, although thereafter the differences become considerable. Moreover, there are substantial regional variations in temperature shifts. Many GCMs project mean average temperature increases to 2050 for the East Africa region, for example, that are larger than the global mean of between about 1.5 and 2.5°C.

Mean changes in agricultural productivity and the variability of the NPP signal between scenarios were the basis for computing the climate impact on feed resources and vulnerability maps. With the exception of some areas in Southern Africa, Ethiopia, Kenya and Somalia, the availability of stover is decreasing throughout SSA. In contrast to stover, the impacts on grass seem much less pronounced. In a huge area we see less than 5% change. Impact in most of the Greater Horn of Africa and some of the Sahelian band from Mali all the way to Sudan seems positive. The same can be noticed in an area stretching from the West-Coast in Namibia going east the Zimbabwe. Negative impacts on grass availability are concentrated around Senegal and in Southern Africa, where Namibia, Botswana and South Africa meet. The change in overall feed availability, i.e. the combination of stover and grass, shows a similar pattern, with some extra decreases along the West coast, going quite a bit inland in e.g. Nigeria. Overall, the direction, as well as spatial and temporal distribution of the climate impacts is rather uncertain.

Due to this uncertainty it is important to increase adaptive capacity. We combined measures of exposure, adaptive capacity and sensitivity into vulnerability hotspots and domains. Hotspots of vulnerability to feed resource impacts of climate change are areas where high climate change impact on feed resources and 'low adaptive capacity/high social vulnerability' coincide. These hotspots highlight the areas where livestock keepers are likely to be mostly affected by climate change impacts and can be used for priority setting. Current data and model output suggest that the priority areas for interventions increasing the adaptive capacity can be found around Mali, in Chad, the Central African Republic, Southern Sudan, Angola, Mozambique and a relatively narrow east–west band in Namibia and Botswana.

At a household level, a number of factors influence the nature and degree of people's vulnerability to the climate change. Among these are demographic (age, gender, educational attainment, households size), socioeconomic (income, household assets, farm size, herd size, household practices, membership to community organization, membership to groups and access to loan) and geographic (rainfall variability, distance of water resources, distance to the markets). The results show that for reduction of vulnerability to climate change, for better or improved adaptive capacity there is need to evaluate factors which are important in different areas for the purpose of targeting (say for sustainable development). This study gives us more certainty about some variables' influence on coping capacity; some of which are widely applicable. Income diversification, increasing access to infrastructure and saving, for example, are widely applicable and promoted adaptation options. Lowering the distance to the livestock market, on the other hand, only makes sense in settings where livestock provides a significant proportion of income to households. Still, our findings suggest that many pastoral and agropastoral regions can benefit from interventions increasing the access to livestock markets.

In order to conduct a collaborative learning approach, the collaboration with the agropastoralists was institutionalized by supporting them to form CBOs. After the group members conducted a problem analysis, adaptation strategies for pilot testing were suggested by the members and their feasibility and expected results discussed within the group. Finally the strategies were ranked according to their priority to form the basis for action plans for the CBOs. After one year, a PM&E system was installed in the CBOs. In Mali the purpose for monitoring was discussed in the frame of the evaluation mission. In Mozambique, the objective of the development and implementation of a PM&E system was to increase the active-learning possibilities of agropastoralists for improving their livelihood strategies and the sustainability of the system.

The PM&E system promoted learning among and empowerment of the CBO members, which in turn created opportunities for consensus building, collective decision-making and action. At the same time, the PM&E process introduced a motivational aspect that acted as a positive feedback to community-based activities. It motivated the community to continue with their activities and the PM&E system itself. The collection and dissemination of the PM&E information within the CBO and also between the CBOs, e.g. during the member-to-member exchange strengthened the decision-making processes, which in turn enhances community-based activities in the villages, showing that group members were facilitated to enter a learning cycle.

Social learning is often conceptualized by the different cycles or loops of learning. The implementation of promising strategies in a CBO, supported by single to double and triple-loops of learning, proved to be important tool in increasing the adaptive capacity in a continued process of learning and development.

The current policy framework of the two countries shows that there is a weak policy support for the implementation of adaptation measures to climate change. The lack of specific legislation is more accentuated in agropastoral and pastoral production systems because most of the adaptation strategies supported by legislation are related to crop production, despite the important role played by livestock in the livelihoods of rural poor people. Therefore, one of the major challenges that the countries face in adapting to climate change is to review the policy framework and fill the prevailing gaps in coverage of climate change adaptation issues giving due attention to livestock and agropastoral production systems.

Governments should improve the policy coherence, coordination, synergy and sectoral integration between national development goals, and diverse adaptation needs, incorporating climate risk across sectors. Apart from policy revisions and development of additional policies, there is a need to improve the interactions between policies and institutions, mainstreaming of environmental legislation into sectoral activity plans and the need to create mechanisms for implementation. Policies should guide institutions towards developing and disseminating technologies that integrate modern with traditional and cultural practices that seem effective as a mechanism to cope with climate change. This would increase the adherence of livestock keepers to the technologies promoted. Moreover, a better coordination among institutions would create opportunities for the identification of cross-cutting issues, building of partnerships and reduction of overlaps and duplication of efforts.

7 Recommendations

Climate is changing and this will have an impact on the primary productivity of the environment and therefore also on the feed availability. However, the direction of this change as well as spatial and temporal distribution of impacts is uncertain. Therefor it is important to increase the adaptive capacity of agropastoralists, who are one of the most vulnerable groups in Africa, to climate change and variability.

To do so, governments should improve the policy coherence, coordination, synergy and sectoral integration between national development goals, and diverse adaptation needs, incorporating climate risk across sectors. Apart from policy revisions and development of additional policies, there is a need to improve the interactions between policies and institutions, mainstreaming of environmental legislate on into sectoral activity plans and the need to create mechanisms for implementation. National policies should focus on priorities for investment, including the implementation of innovative adaptation options to climate change, to ensure the maintenance of household food security in the face of increasing climate variability.

Diversification of income sources through livestock farming and commercialization can be a key strategy for escaping poverty because livestock appears more tolerant to drought than crops. Therefore, national policies should support the relevant institutions in the identification of areas of the country where climate change and variability are likely to make any crop production increasingly difficult. In places such as semi-arid and arid areas livestock production has a comparative advantage over crop production. Therefore, it should be a priority for investment, including in the implementation of innovative adaptation options to climate change to ensure the maintenance of household food security in the face of increasing climate variability. National policies should guide institutions towards developing and disseminating technologies that integrate modern with traditional and cultural practices that seem effective as a mechanism to cope with climate change. This would increase the adherence of livestock keepers to the technologies promoted.

Donors should support governments to base development planning and policies on climate risk information and analyses to identify other ways of strengthening people's climate resilience, such as through social protection measures and other forms of livelihood support and asset-building. Moreover, donors could support governments with longer term, predictable funding arrangements to ensure adaptation and food security, by funding NAPAs and incorporating contingency plans.

Research institutions should be strengthened in financial resources, qualified staff and adequate equipment and materials to develop and test innovative climate change adaptation technologies in agropastoral and pastoral production systems, which have been marginalized and are anticipated to be severely affected by climate change, particularly in arid semi-arid areas. Moreover, key institutions should sign an agreement for information sharing as well as clarification of divisions of responsibilities regarding the implementation of actions to adapt to climate change. This would reduce duplication of efforts and promote partnership in the implementation of adaptation options.

The extension services need to be strengthened and appropriately linked with research institutions producing innovative options to cope with climate change so that these options are transferred to and benefit poor agropastoralists and pastoralists.

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