Adapting East African ecosystems and productive systems to climate change; An ecosystems approach towards costin...

Joseph Maitima

Adapting East African ecosystems and productive systems to climate change

An ecosystems approach towards costing of climate change adaptations in East Africa

Report for the Economics of Climate Change Adaptations in Africa.

By

Joseph M. Maitima
Patrick C. Kariuki
Simon M. Mugatha
Lea W. Mariene

September 2009

Introduction

Climate change is affecting bio-physical systems worldwide. Variabilities in precipitation is altering water budgets and affecting the amounts and quality of water available for growth and support of life. Increasing temperatures are reducing the ability of ecosystems to retain water for growth. Soils are degrading as they loose water and microbial biodiversity. The spatial extent and intensity of these effects vary geographically from one place to another depending on location in the global atmospheric systems, regional settings on: land cover, land use, topography and weather patterns. The two most important climate stressors are changes in rainfall and temperature

For quite some time the focus on climate change issues has been vulnerability assessments to determine the areas which are more at risk from impacts of climate change. Recently however, there is a shift from vulnerability to adaptation. The shift needs metrics of impacts that focus on the direct effects on community or household assets: what is at risk and how much is potentially lost. On the other hand adaptation solutions need to relate to the livelihood assets capitals that characterize the [Sustainable Livelihoods Approach]. Moving the debate from vulnerability assessments to adaptation requires the application of different set of tools and methodologies that allow for the integration of various pieces of information and concerns. The shift from vulnerability to adaptation requires the design and implementation of appropriate channels for linking data and information to the decision/policy making process.

Adaptation and Development

The consequences of an adaptation strategy may influence and affect sectoral policies, livelihoods and so on. Therefore, adaptation strategies should be integrated into a broader context of development. Transition from impact to vulnerability assessments and then to adaptation, is a critical step in moving economies and livelihoods towards more resilient positions. A successful adaptation-development agenda could substantially reduce the cost of emergency disaster assistance. Self-reliance realised through effective pre-disaster and adaptation planning, as an integral part of development and aimed at capacity building for the most vulnerable, is a more effective means of disaster risk reduction.

Integrating adaptation into development planning broadens the metric of impact beyond direct effects (e.g., economic damages, lives lost) to health, social and economic effects (e.g., morbidity, livelihood security, economic investment and growth). the impacts of climate extremes such as droughts, floods and heat waves are measured not only by how much is lost but also by the effects on development and livelihoods. Climate factors are not the only factors that stress subsistence systems. Issues of markets, subsidies, access and cultural norms add to the challenge of assuring food security and alleviating poverty. To facilitate interactions and interplay between development and adaptation both bottom-up and top-down approaches are needed. Both approaches highlight the fact that adaptation is a multi-scale process that can interact with development efforts at different levels.

While linking adaptation and development, it is important to analyze both primary and off-farm non-primary production activities, as off-farm income is critical to livelihoods and overall adaptive capacity. Integration of adaptation measures needs to nest within national socio-economic considerations. To make progress in this regard, cross-sectoral analysis is necessary to assess the interactions of multiple adaptation strategies and their implications in national development policies. This fully integrated approach is the most effective means of minimizing maladaptation, where actions in one sector can have negative impacts in another.

There is potential for spontaneous and assisted adaptation in Africa. Many options will need to involve a combination of efforts to reduce land degradation and foster sustainable management of resources. This section highlights options for forestry and woodlands, rangelands, and wildlife.

A number of adaptive processes designed to prevent further deterioration of land cover already are being implemented to some degree. Some of these measures involve natural responses when particular plant species develop the ability to make more efficient use of reduced water and nutrients under elevated CO_2 levels. Other adaptive measures involve human-assisted action programs (such as tree planting) designed to minimize undesirable impacts. These strategies will include careful monitoring and micro-assessment of discreet impacts of climate change on particular species. Low-latitude forest adaptation options, especially in west Africa, must include active vegetation and soil management. For example, Gilbert et al. (1995) have indicated that silvicultural practices, endangered species habitat management, watershed manipulation, and anti-desertification techniques could be applied. These adaptive measures will help reduce climate change impacts on forest watersheds and semi-arid woodlands. Genetic diversity provides an assurance that benefits provided by forests are not lost forever and is particularly relevant to the maintenance of the forests in the Sahel and other extremely sensitive regions of Africa where 20 years of recurrent drought have degraded the forests.

Ecological settings

The varied spatial topographic patterns of east Africa's landscapes have resulted in vegetation and the associated biodiversity that reflects the wide variety of climatic regimes. From the mangrove forests of the coastal lowlands to the moor lands of Mt. Kenya, Kilimanjaro and Elgon, a wide range of vegetation cover follow varieties of soil types hosting different species of biodiversity in the terrestrial and aquatic environments. The most significant determinant of this variability however, is the pattern of rainfall and temperature regimes that very closely define the distribution of these fauna and flora. Land use follows the same pattern except for the areas protected as national parks and nature reserves. The wetter higher altitudes are largely cultivated and the higher the higher the altitudinal elevation the more likely that precipitation is also higher and the land use is also more likely to be monocultures of commercial cropping. The lower attitudes are dominated by savannah ecosystems and with the low rainfall and higher temperatures the best form of land use is livestock keeping.

Vegetation productivity (primary productivity) defined as the amount of vegetation matter in an area simply referred to as vegetation cover is a function of all the environmental conditions in the area. Rainfall and temperature are the main driving forces that trigger production. While all the other environmental conditions play part in determining the amount of productivity, it is the amount of rainfall and the atmospheric temperatures that determine the suitability of an area for a particular land use.

As rainfall and atmospheric temperatures change, land use potential and productivity will change mainly in response to changes in primary productivity. The change may come in altered vegetation cover (less or more depending on the direction change in respect to the amount of precipitation or temperatures) or may come in altered plant species composition.

Environmental pressures in East Africa

Across the African continent an increase in average and extreme temperatures can be expected over the coming decades. On an aggregate country level Kenya average daily rainfall amounts to 2.02mm/day based on the observation period from 1960 to 1990 (Obunde et. al. 2004). However, rainfall is unevenly distributed across space and time. Along Kenya's coast a humid tropical climate predominates. By contrast, inland areas are largely arid with two thirds of the country receiving less than 500 mm of rainfall per year. In general inter-annual climate variability is high. Two rainy seasons can be distinguished: The Long Rains (March to May) and Short Rains (October to December). The El Nino Southern Oscillation (ENSO) strongly influences interannual rainfall variability. El Nino events are associated with above normal rainfall conditions and floods, while La Nina events are linked to prolonged dry conditions. The strong predictive capacities of ENSO events represent an opportunity for disaster preparedness and vulnerability reduction. There is increasing observational evidence of changing precipitation patterns, including shifts in the timing and duration of the rainy season over parts of Kenya.

The annual average rainfall between 2070– 2099 is projected to increase to 2.19 mm/day (Obunde et. al. 2004). This is supported already by growing observational evidence. However, precipitation gains are uneven across the country and future increases in temperature will also increase evaporation rates.

The high altitude of Rwanda provides the country with a pleasant tropical highland climate, with a mean daily temperature range of less than 2° C. Temperatures vary considerably from region to region because of the variations in altitude. At Kigali, on the central plateau, the average temperature is 21° C. Rainfall is heaviest in the southwest and lightest in the east. A long rainy season lasts from February to May and a short one from November through December. At Gisovu, in the west, near Kibuye, annual rainfall averages 160 cm (63 in); at Gabiro, in the northeast, 78 cm (31 in); and at Butare, in the south, 115 cm. Despite its proximity to the equator, the climate in Rwanda is cooled by the high altitude. It is warm throughout most of the country but cooler in the mountains. There are two rainy seasons: mid January to April and mid October to mid December.

Burundi is not far from the equator, and in the capital Bujumbura and the lower areas near the lake, it can be hot and humid. The higher altitudes are generally comfortable year round (usually in the 22-27^{0}C during the day and the 16-21^0 C at night. The year is broken up into one distinct dry season and two rainy seasons. A short rainy season begins in October and ends in December. A long rainy season begins in February and continues through mid May. The long dry season extends from mid May to early October. During the rainy seasons, heavy downpours are not uncommon, but after the shower is over, the rest of the day may be sunny. Take rain gear and a sweater or light jacket year round.

Historical trends

Similar to global trends, along with other parts of Africa warmed by about 0.5°C in the 20th century with the most rapid warming occurring between 1910-1930 and after 1970, particularly in southern and northern Africa (Hulme et al., 2001; Christensen et al., 2007). Rainfall trends and patterns are more difficult to determine and significant regional differences are evident. For example, the alternating wet and dry periods in the Sahel, particularly the dry period after 1970, have been studied in detail (Brooks, 2006; Boko et al., 2007). There is some evidence that rainfall increased in parts of eastern Africa during the 20th century (Hulme et al., 2001; Christensen et al., 2007). Other areas of the continent, such as Southern Africa have experienced marked inter-decadal variability (Christensen et al., 2007) which adds to the difficulty of managing complex risks in several African environments.

Detailed local-level analyses of the historical rainfall record have indicated that the patterns are spatially complex, particularly in mountainous terrain, and the scale of observation and density of climate stations can influence the outcome significantly. For example, Mackellar et al. (2007) have shown from the relatively comprehensive historical rainfall record for rangelands in Namaqualand, South Africa, that some areas, which have exhibited a significant increase in rainfall since 1950, are next to areas only 50 km away, which have shown a significant decrease.

Furthermore, the biological composition and functioning of rangelands are not only influenced by climate. Local land use practices such as cultivation, heavy grazing, resource extraction (e.g. firewood use) has a profound influence on African rangelands (Hoffman and Ashwell 2001) with significant feedbacks on some important drivers of climate (Christensen et al., 2007). A closer alignment of historical climate data with comprehensive land use histories is urgently needed to understand the full extent of changes that have occurred in African rangelands over the course of the 20th century

Future climate projections

Atmospheric concentrations of CO^2 have increased by more than 100 ppm since industrial times and will increase further from the current 380 ppm to about 520 ppm by 2100 if 2000 emission rates continue (Meehl et al., 2007). Atmospheric CO2 concentrations measured in 2005 have not been experienced on Earth for 650,000 years (Bernstein et al., 2007), and will influence significantly the physiology and competitive interactions of rangeland plants.

Temperature will increase by between 2-6°C by the end of the 21st century (Conway, 2008) depending on the region and SRES emission scenario used (Christensen et al., 2007). Increases will very likely be greater throughout Africa and in all seasons than the global average with the drier northern and southern Africa subtropical regions warming more than the moister tropical regions of western, central and eastern Africa as well as the coastal environments (Christensen et al., 2007).

Annual rainfall is likely to decrease in southern and northern Africa with the Mediterranean areas of both regions being particularly badly affected. It is likely, however, that rainfall could increase in eastern Africa. Model projections for the Sahel, the Guinean Coast and the southern Sahara have returned mixed results and are considered unclear at present (Christensen et al., 2007).

Changes in variability (e.g. periods of extended dry spells, wet spells, pattern of rainfall including numbers of rain days, etc) is an additional area of concern. While limited by the number of studies and data to support very conclusive statements on trends at present, emerging research shows that droughts are likely to increase in total area affected and that heavy precipitation events are likely to increase generally beyond that expected from changes in the mean (Boko et al., 2007; Christensen et al., 2007). More than 250 million Africans live in drought-prone areas (Elasha et al., 2006). Changes in the frequency and magnitude of drought may add to the complex risk-management portfolios that many people use to sustain their livelihoods and such changes will make recovery more difficult as periods between significant events will be shortened.

There is considerable uncertainty associated with these projections. This uncertainty has arisen in part because a growing, but nonetheless limited understanding of the key drivers of African climates (Conway, 2008) that is frustrated by poor data and monitoring sources and further complicated by trying to understand the web of interaction between climate, land cover/atmospheric feedback processes (Christensen et al. 2007) and dust and biomass aerosols (Hulme et al., 2001). There is uncertainty as to whether the Sahara is going to get wetter or drier or what the impact of climate change is likely to be on the Nile River system and on African agriculture in general (Conway, 2008). A comparison of the maps of projected climate change impacts on the vegetation of Africa produced by Thornton et al.

(2006b) and Fischlin et al. (2007) is a sobering reminder of the high degree of uncertainty in environmental responses to global warming.

Over view on climate change impacts

Highlights of climate impacts in Africa

About 250 million people in Africa will be exposed to increased water stress by 2020. This will cause problems for health, food production and increase conflicts. Agricultural production in many African countries will be severely compromised. This will reduce food security and increase malnutrition. In some places yields from rain-fed agriculture could reduce by 50% by 2020. Fishing resources in large lakes will reduce due to rising water temperatures, made worse by over-fishing. Towards 2100, sea-level rise will affect low-lying coastal areas with large populations. Mangroves and coral reefs will be further degraded, with consequences for fisheries and tourism [Editor: they should have mentioned reduced defenses against tsunamis]. Africa is particularly vulnerable to climate change because of multiple stresses and few resources to adapt.

Impacts on selected sectors and eco regions

Impacts on Fresh Water

Water availability will increase at high latitudes and in some wet tropical areas. Water will decrease over some dry regions at mid-latitudes and in the dry tropics, some of which are already water-stressed. Drought will affect more areas. Heavy rain will increase leading to more floods. Water stored in glaciers and snow will decline, reducing water availability. According to FAO estimates (FAO 1994) 1992 global inland fisheries catch from wild sources was around 6000 mt. This was less than one tenth estimated total marine catch from wild sources (around 80,000 mt) and less than total inland aquaculture production (around 9000 mt). Globally therefore they are of much lesser importance than marine fisheries. Locally they may be of great importance, both ecologically and economically.

As with marine fisheries, management of inland fisheries increasingly entails analysis at the ecosystem level. This is because these fisheries are affected at least as much by habitat modification as by fishery regimes. Important factors include pollution, siltation, canalization, damming and abstraction of water. Inland waters are much more susceptible to most of these factors than marine waters, with land-locked or nearly land-locked seas occupying an intermediate position. A major factor in many inland fisheries which is as yet of minor importance in marine fisheries is the presence of introduced species. These have often come to dominate fisheries production and have had far reaching and sometimes devastating impacts on aquatic biological diversity.

According to the Initial National Communication, Kenya is already suffering from water stress. Kenya has numerous rivers, though a relatively small number are permanent, such as the Tana, Athi, Nzoia, Yala, Sondu, Nyando and Mara. Several of the rivers have been dammed upstream to provide hydroelectric power, irrigation water and water for domestic use. Fresh water lakes include Lakes Baringo, Naivasha and Victoria (Africa's largest fresh water lake shared with Tanzania and Uganda). Water-quality problems in lakes, including water hyacinth infestation in Lake Victoria, have contributed to a substantial decline in fishing output and endangered fish species most other lakes are within the Rift Valley and many of these are alkaline and valuable tourist attractions. The levels and volumes of these lakes fluctuate seasonally. Lake Magadi in the southern part of the Rift Valley is saline/alkaline and is mined for soda ash. Water resources are under pressure from agricultural chemicals and urbanization

Impacts Mountain Regions

Mountains usually are characterized by sensitive ecosystems and regions of conflicting interests between economic development and environmental conservation. In Africa, most mid-elevation ranges, plateaus, and high-mountain slopes are under considerable pressure from commercial and subsistence farming activities (Rogers, 1993). Mountain environments are potentially vulnerable to the impacts of global warming. This vulnerability has important ramifications for a wide variety of human uses-such as nature conservation, mountain streams, water management, agriculture, and tourism.

There is a general picture of continuing ice retreat on the mountains. On Mount Kenya, the Lewis and Gregory glaciers have shown recession since the late 19th century. Changes in climate could reduce the area and volume of seasonal snow, glacier, and periglacial belts-with a corresponding shift in landscape processes. The retreat of some glaciers on Kilimanjaro and Mt. Kenya would have significant impacts on downstream ecosystems, people, and their livelihoods because of moderation of the seasonal flow regimes of rivers upstream. Further reduction of snow cover and glaciers also could reduce the scenic appeal of African high mountain landscapes for tourists and thus have a negative impact on tourism.

Forest fires would increase in places where summers become warmer and drier. Prolonged periods of summer drought would transform areas already sensitive to fire into regions of sustained fire hazard. Mt. Kenya and mountains on the fringes of the Mediterranean Sea already subject to frequent fire episodes could be affected.

Impacts on Ecosystems

Many ecosystems will be overcome by an unprecedented combination of climate change and linked events, such as flooding, drought, wildfire, insects, ocean acidification, land-use change, pollution, over-exploitation of resources. Net carbon uptake by land-based ecosystems will peak before mid-century and then weaken or reverse, thus amplifying climate change. If global temperature rise exceeds 1.5-2.5°C, 20-30% of plants and animals assessed so far will be at increased risk of extinction. There will be major changes in ecosystems with mainly negative consequences for biodiversity and ecosystem services eg, water and food. The acidification of oceans will have negative impacts on marine shell-forming organisms (eg, corals) and the species that depend on them.

Impacts on Coasts and low-lying areas

Coasts will be at risk from erosion and sea-level rise. Corals are vulnerable to small changes in temperature. Sea temperature rise of 1-3°C will cause coral bleaching and widespread mortality. Coastal wetlands including salt marshes and mangroves will be damaged by sea-level rise. Many millions more people will be flooded every year due to sea-level rise by 2080. Densely-populated low-lying areas which face tropical storms or coastal subsidence (eg, small islands and the mega-deltas of Asia and Africa) are especially vulnerable.

Impacts on Terrestrial Animals

Globally, harvest of wild terrestrial animals is far less significant than fisheries, both in terms of its ecological impact and its importance to humanity. Locally this may be far from the case.

Uncontrolled hunting, usually for food, has been implicated as the main, and sometimes only, cause of a large number of extinctions, particularly of mammal and bird species. There is growing evidence that hunting by local peoples is having a greater impact than habitat loss on wildlife populations in many parts of the world, particularly tropical moist forest regions in Africa, South-east Asia and South America (Bennett, 1994). In these areas wild-caught animals ('bush-meat') may make up a significant proportion of animal protein intake in the diet. In addition, hunting may be a culturally important activity which continues to be undertaken even when not necessary from the point of view of food-provision.

Wild animals are harvested for a wide variety of reasons. By far the most important is food, but clothing (eg. leather, fur), medicines (eg. bones for oriental medicines), ornaments (eg. tropical fishes for aquaria), companion animals (eg. parrots as pets), sport (eg. trophy hunting), building material (eg. coral) are also sometimes important, as are a range of minor products such as dyes and wax. As with any commodity, products from wild animals may be used locally, transported within a country or traded internationally. They may be for subsistence use (consumed by those who harvested them), bartered or they may enter the cash economy. An overview of the various uses that wild animals are put to is provided in, while a detailed treatment of the international trade in wildlife and wildlife products (excluding large-scale fisheries).

As noted above, the harvest of fin fishes and aquatic invertebrates is by far the most important type of harvest of wild animals. In principle, methods for assessing sustainability and developing management techniques are much the same as when dealing with terrestrial species. In practice the two tend to be different. In particular control of marine (as opposed to inland) fisheries is very different from control of terrestrial resources. This arises for a number of reasons, including the sheer scale of fisheries operations, differences between marine and terrestrial ecosystems and legal and practical differences between the control of extra-territorial (i.e. international) waters and terrestrial and inland water areas which are strictly under national jurisdiction.

Assessment of the impact of harvest on wild animal species is usually problematic. It is difficult, expensive and time-consuming to census populations of most animal species, especially over wide areas. Wild populations of all animal species invariably fluctuate owing to environmental variation and stochastic processes. These variations may be extremely marked. Disentangling such variation from that caused by human actions is problematic, and as with fisheries, generally requires time-series data running over many years and usually decades. Even then it is unlikely that unambiguous causal relationships can be established without experimental manipulation of environmental conditions.

Assessment of sustainability of harvest of terrestrial animal species is in one important respect less problematic than assessment of use of trees or aquatic animals. This is in the broad context of ecosystem health. This is because terrestrial animals are in general less important components of the ecosystems in which they occur than are trees or marine animals of their ecosystems. Trees are essential structural components of the ecosystems they occur in, and they provide essential resources for a host of smaller organisms; their removal self-evidently has far reaching effects. Plants (with few exceptions) are also primary producers and therefore fundamental to the productivity of almost all ecosystems. Marine animals are the major components of most marine ecosystems, particularly those outside the photic zone (the surface layers of the sea which receive enough sunlight to allow photosynthesis and thus the existence of phytoplankton); harvest of these is therefore very likely to have far-reaching consequences. To this extent, therefore, it is more justifiable to examine sustainability of use of particular species or populations independently.

Care must be taken, however, not to neglect the impact that terrestrial animals do have on ecosystems. In some cases this may be very important (e.g. the role of grazing herbivores in maintaining grasslands; the role of insects, bats and birds in pollination; the role of many species in seed dispersal). Harvest of some animal species may therefore have far-reaching impact on ecosystem dynamics. In addition many forms of wildlife harvest can have destructive effects on habitats (e.g. tree-felling to collect wild honey; many fishing techniques).

Impacts on Agriculture

Agriculture is the main sector of the Kenyan economy and performance influences overall economic performance, but livestock production is central to livelihoods and food security in arid and semi-Arid lands. The small-scale farm sector accounts for about 75% of the total output in the agricultural sector. Over 75% is mostly smallholder agriculture, characterized by low farm inputs, low yields and low-level crop and land husbandry. Fertilizer usage is low, at an average of 25 kg per hectare. Irrigation development only accounts for less than 3% of the country's agricultural produce3. Food security has had frequent adverse impacts from current and historical climate variability according to the

National Communication: In Kenya, coastal agriculture losses for three crops (mangoes, cashew nuts and coconuts) could cost almost US$500 million for a 1 m sea-level rise (IPCC 2007)

Impacts on Energy

In Kenya, nearly all rural households use wood for cooking and over 90% of urban households use charcoal (EIA 2002). Electricity is the third source of energy in Kenya after fuel wood and petroleum products, but is second to petroleum fuel as a source of commercial energy (National Communication) The Government of Kenya has recognized the potential for exploitation for solar, wind, small hydros, biogas and municipal waste energy due to their potential for income and employment generation, over and above contributing to the supply and diversification of electricity generation sources

Impacts on Human Needs

Impacts on Food

Crop productivity away from the equator will go up slightly if the temperature rise is less than 1-3°C, then decrease if it gets hotter. Near the equator, especially dry and tropical regions, crop productivity will decrease for even small local temperature increases (1-2°C). This will increase the risk of hunger. Globally, food production may increase with temperature rises of 1-3°C, but above this it will decrease. More droughts and floods reduce crop production, especially for subsistence farmers near at low latitudes. Continued warming will change the distribution of some fish species, which will reduce fishing.

Impacts on Social Systems

Impacts of climate change on society will vary widely by location and scale. Overall, net effects will be more negative the bigger the change. The most vulnerable societies are those in coastal and river flood plains, those who rely on climate-sensitive resources, and those in areas prone to extreme weather events. Poor communities will be especially vulnerable. They have limited capacity to adapt, and are dependent on climate-sensitive resources such as local water and food supplies. More extreme weather events will have substantial economic and social costs in the areas directly affected. These impacts will spread to other areas too.

Impacts on Health

Climate change will impact the health of millions of people. Malnutrition and linked disorders will increase, with particular implications for children. There will be more deaths and disease from heat waves, floods, storms, fires and droughts. Diarrhea (water-related) and cardio-respiratory diseases (due to ground-level ozone) will rise. Insects that carry infectious diseases may change their range. It is difficult to predict some impacts, e.g on the range and transmission of malaria in Africa. Changes will bring some benefits (e.g, fewer deaths from the cold), but overall the impact on health will be negative worldwide, especially in developing countries.

Kenya is not likely to meet the child mortality and maternal health MDGs, but it has already met the target of halving the prevalence of HIV/AIDS, which has fallen by about one-half to about 6.0 percent in 2006 (Kenya CAS). Progress towards the MDGs on health outcomes will be hampered by the impacts of flood and drought, as well as climate change related health impacts. Previously malaria-free highland areas in Kenya could also experience modest incursions of malaria by the 2050s, with conditions for transmission becoming highly suitable by the 2080s. The IPCC has noted the recent observations of malaria vector Anopheles *arabiensis* in the central highlands of Kenya, where no malaria vectors have previously been recorded. There is new evidence of micro-climate change due to land-use changes, such as swamp reclamation for agricultural use and aforestation in the highlands of western Kenya, suggests that suitable conditions for the survival of Anopheles *gambiae* larvae are being created and therefore the risk of malaria is increasing. The average ambient temperature in the deforested areas of Kakamega in the western Kenyan highlands, for example, was 0.5°C higher than that of the forested area over a 10-month period. Mosquito pupation rates and larval-to-pupal development have been observed to be significantly faster in farmland habitats than in swamp and forest habitats. Floods can also trigger malaria epidemics in arid and semi-arid areas (IPCC 2007).

Climate change over Africa’s rangelands

Implications of climate change for Africa’s rangeland resources and ecosystem services

The changes in climate outlined above will have a range of impacts for people, particularly those who derive a large portion of their livelihoods from rangelands. Such changes in climate may also compound other changes that are already taking place (e.g. changes in access in to resource use, urbanization) and in some areas, may also enhance livelihoods. Some of the likely impacts, arising from changes in Arica’s climate, are outlined below.

Change in water resources

The impact of climate change on Africa's hydrological resources has been shown using a range of GCM projections (de Wit and Stankiewicz, 2006). Three main hydrological regions (dry, intermediate, wet), based on their perennial drainage densities (total perennial stream length per unit area), were identified in this analysis. The results show that it is in the intermediate region receiving between 400-1000 mm of rain per year that the impact of climate change on surface drainage will be greatest. The impact will also be felt non-linearly and drier areas within this range will experience significantly greater losses in surface drainage with a decrease in rainfall than wetter areas. For example, a 10% drop in rainfall (which is well within the bounds projected for southern Africa) in a region of 1000 mm per year will result in a decline in surface drainage of only 17% while in areas of 500 mm per year the same decrease in rainfall will result in a 50% decline in surface drainage. Such a dramatic response in surface drainage to decreasing rainfall could have devastating consequences for this intermediate hydrological zone which covers 25% of the continent, affects 75% of the 48 mainland countries in Africa and includes most of the densely populated savanna rangelands of southern and eastern Africa and a significant part of the Sahel (de Wit and Stankiewicz, 2006). The decrease in surface drainage coupled with an increase in water demand by livestock and people, as a result of increased temperatures will challenge traditional coping strategies and likely increase tensions around already scarce water resources.

Change in rangeland productivity

Rainfall and temperature are key determinants of rangeland productivity. The effect of future climate change projections on the length of the growing period (LGP), which integrates the influence of temperature and rainfall on productivity, results in a number of potential impacts, including changes in the length of the growing season for certain agricultural activities. Using the downscaled outputs of the HadCM3 and ECHam4 under a range of SRES scenarios, changes in LGP to 2050, relevant to current conditions, were computed for Africa. While there was considerable variation in the outputs, generalized findings were that the combined impact of changes in temperature and rainfall will result in a decrease of LGP in much of sub-Saharan Africa and in some cases this decrease will be severe. Areas where decreases in LGP >20% are predicted consistently include large parts of southern Africa, particularly where cropping is marginal, as well as a broad swathe in the Sahel, in the ecotone between the savanna and desert biomes of the northern African sub-tropics. A significant reduction in LGP by 2050 was also predicted in most models for the more arid parts of eastern Africa .

Fischlin et al. (2007) used a similar approach in their analysis of "projected appreciable changes in terrestrial ecosystems by 2100 relative to 2000…" While there are clear similarities between their map and the map of Thornton et al. (2006b) there are also appreciable differences. In general, Fischlin et al. (2007) suggest a far more benign future for Africa's rangelands with considerable portions of the subtropics showing an increase in forest, woodland and herbaceous cover. Even the more arid southern African region is predicted to experience conditions described as "desert amelioration". Reasons for the discrepancies in the two outputs are worth investigating and underscore the high degree of uncertainty associated with future projections.

The links to other climate phenomenon, particularly those most often associated with climate variability, such as El Niño-Southern Oscillation (ENSO), have also been examined for agro-pastoral production in Africa (Stige et al., 2006). Results here suggest reduced food production including the productivity of crops, livestock and pastures in Africa, if the frequency of ENSO-like conditions increases.

Change in forage quality and rangeland composition

Temperature, rainfall and atmospheric CO2 concentration interact with grazing and land cover change to influence rangeland quality and composition. Increased temperature, for example, not only increases drought stress in plants but also increases lignification of their tissues which affects both its digestibility as well as its rate of decomposition (Thornton 2006a). Increased temperature and lower rainfall also increases vegetation flammability (Fischlin et al., 2007) resulting in a shift in species composition as a result of an increased fire frequency. The amount and timing of rainfall on its own, also has an important influence on rangeland species composition in both the short- and long-term, primarily through its differential effect on the growth and reproduction of key forage species. An extended drought can result in the mortality of perennial plants and the switch to an annual-dominated flora (Hein, 2006).

Atmospheric CO2 is fundamental to the efficient physiological functioning of plants primarily through its influence on photosynthesis and nutrient absorption. Because of this, any change in CO2 concentration affects the performance and competitive ability of plants. Plants generally use less water at higher CO2 concentrations and a reduction in transpiration means that more water is available in the soil. Bond et al. (2003) suggested that a doubling of CO2 could nearly double the effectiveness of rainfall.

While C3 grasses should benefit more from increased CO2 concentrations than C4 grasses, experimental results are far from conclusive (Wand et al., 1999). Both pathways appear to benefit from CO2 enrichment and growth rate is more important than a plant's biochemical pathway in predicting its response to CO2 (Poorter and Navas, 2003). Just to complicate matters, recent findings suggest that warming and CO2 could have opposite effects on C3 and C4 plants with the former favored by CO2 and the latter by increased temperature (Fischlin et al. 2007).

Bush encroachment occurs as a result of the invasion of shrubs and trees into previously grassy rangelands. It is a common phenomenon in Africa and usually results in an increase in biomass but a decrease in rangeland productivity. The projected increase in the concentration of atmospheric CO2 could enhance the process of bush encroachment in two important ways. Firstly, less transpiration could result in more plant available water, particularly at depth, where deeper-rooted trees and shrubs have their roots. Greater access to water could increase the length of their growing season and increase their competitive dominance to the exclusion of shorter growth forms such as grasses and perennial herbs. Another mechanism for the increase in bush encroachment suggests that an increase in CO2 results in faster growth rates of saplings (Bond and Midgley, 2000). This enables them to more quickly escape the height at which fire usually kills young trees. Bond et al. (2003) have modeled the wider implications of this process and suggest that changing CO2 concentrations over the last 12000 years could explain the expansion and contraction of southern African savannas over this period.

Change in land use systems and rangeland-based livelihoods

The general reduction in productivity which is projected for Africa's rangelands will have important negative consequences for the development potential of an area and will likely result in a shift in sectoral activities (Hulme et al., 2001; Easterling et al., 2007). Some projections suggest that in marginal crop production areas the decrease in the length of the growth period (LGP) and an increase in rainfall variability will render cultivation too risky and will result in a switch to more rangeland-based, livestock production systems (Thornton et al. 2006a). There is also likely to be a switch to breeds and species (e.g. from cattle to sheep, goats and camels) which are better adapted to more marginal conditions (Hulme et al. 2001; Easterling et al., 2007). Other changes include a greater frequency of loss of livestock assets particularly through drought and through an expansion of vector-borne (e.g. ticks) diseases into cooler areas (Thornton et al., 2006a), a reduction in income and increased income inequalities and a general reduction in livelihood security for people who derive their livelihoods primarily, or even in part, from Africa's rangelands (Easterling et al., 2007).

However, reducing all changes in rangelands only to climate change as a 'driver' of change is well known as being a gross over-simplification. Recent assessments in parts of Africa (e.g. Archer, 2004 and Herrmann et al., 2005), for two contrasting areas, showed that land cover changes in both cases was not only determined by rainfall changes but also by complex rangeland management decisions. Climate (e.g. temperature and rainfall) is important but the combined impact of grazing and stocking strategies, and other factors influencing decision making, are also key in shaping rangelands (Batterbury and Forsyth, 1999; Brooks, 2006). Rather than singular stresses shaping and dominating the environment a range of other factors also need to be understood including the interaction of human settlements and changes in land use as well as how various policies impact on land use change. Much more work is also required on how policy and understandings of rangeland changes are framed, reproduced and mainstreamed into practice (e.g. Batterbury and Forsyth, 1999; Homewood, 2004, Rohde et al., 2006). These various interactions can act as critical drivers of rangeland bringing with them potential changes including conflicts between different land use sectors.

Vector-borne diseases sensitive to climate change Vector: Diseases

Table 1 Vectors and diseases they transmit

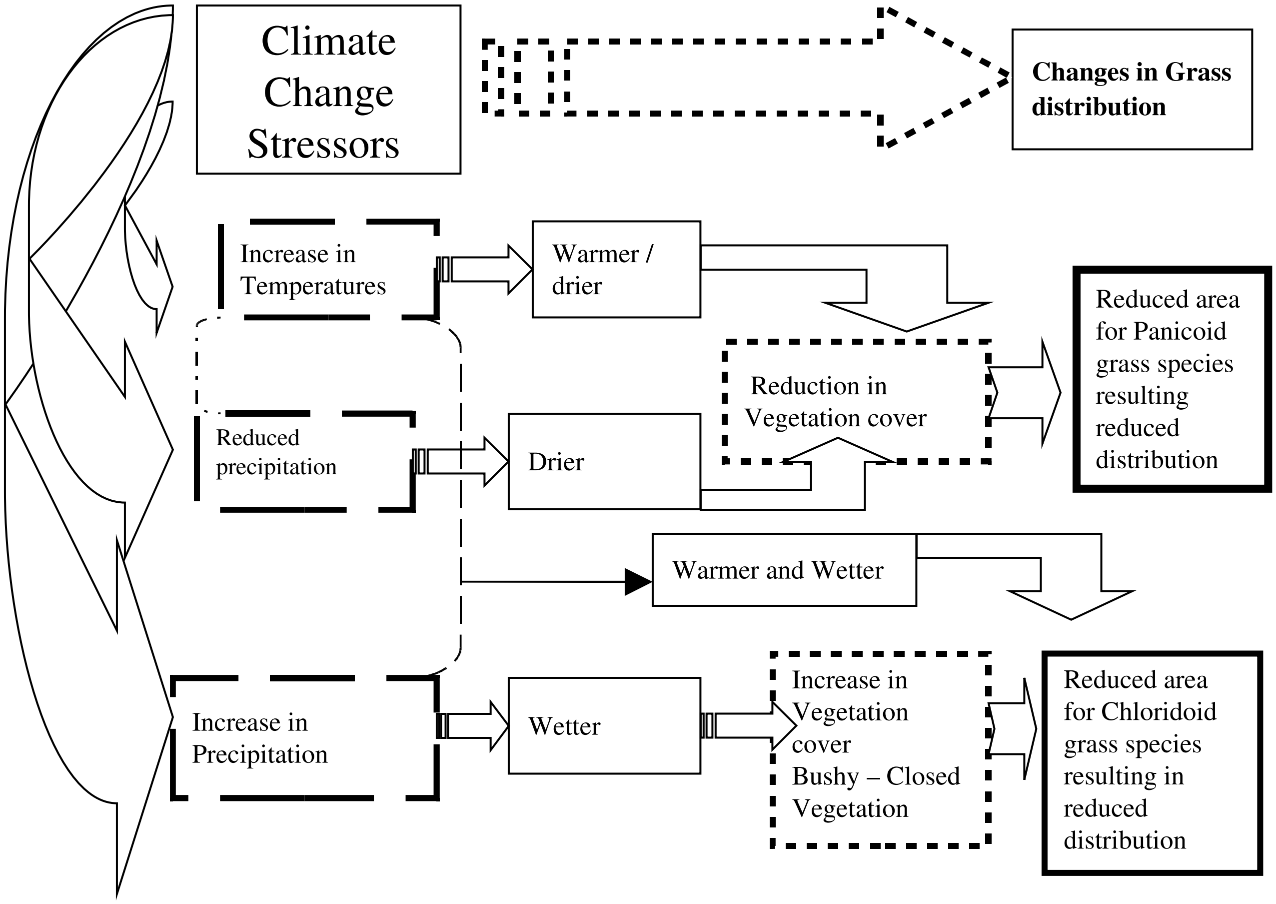
Vector	**Disease transmitted**
Mosquitoes	Malaria, filariasis, dengue fever, yellow fever, West Nile Fever
Sandflies:	Leishmaniasis
Triatomines	Chagas' disease
Ixodes Ticks	Lyme disease, tick-borne encephalitis
Tsetse flies	African trypanosomiasis
Blackflies	Onchocerciasis

Source: WHO, 2003, "Methods of assessing human health vulnerability and public health adaptation to climate change", Geneva: WHO

Climate Change Causal Chains and Human Responses

Climate change primary causes are the changes in atmospheric temperatures and variability in rainfall. Effects of these changes on biophysical processes trigger reactions on all the systems that depend on them.

Figure 1 An illustration of how climate change affects distribution of grass species



Climate and productivity of natural systems

The energy from the sun is absorbed by the green vegetation in the process of photosynthesis that manufactures carbohydrates as by products of primary productivity. The efficiency of photosynthesis process depend heavily on temperatures and water availability such that changes will alter this efficiency. If these change as persistent over a long period of time they may result in altering the composition of plant communities depending on the prevailing conditions.

*E*ffects of climate change on natural systems

Climate change will alter the distribution and composition of plant and anima species (flora and fauna). Places which will get wetter are likely to have more vegetation cover or become more productive. According to the Intergovernmental Panel on Climate Change (IPCC) working group II's fourth assessment on the impacts of climate change on natural, managed and human systems, around 20-30% of plant and animal species are likely to be at increased risk of extinction if global average temperatures rise by more than 1.5-2.5 ° C. The impacts of climate change on natural systems will be far ranging. For example, the impact on the water cycle includes changes in the size of fresh water reservoirs as seen by the melting of glaciers, ice caps, and permafrost and the evaporation of lakes; and increased amount of water vapour in the atmosphere, which affects the amount of solar energy that is reflected back into space or absorbed within the atmosphere and increases the amount of precipitation. Changes in temperature and precipitation patterns lead to shifts in the timing of seasons and thus reproductive timing of plants and animals as well as length of growing season. Shifts in water availability and temperatures affect species distribution (e.g., location or range where found) and abundance (e.g., numbers of individuals in populations) due to loss/expansion of suitable habitat (e.g., melting permafrost in arctic). Some species may become extinct if they cannot adapt at a similar rate to the changes occurring, resulting in a loss of biodiversity, loss of pollinators and seed dispersers, and biological control of pests.

How these effects affect human livelihoods

As a result of the many and varied effects of climate change on natural systems, there will also be many ways in which human systems are impacted. Many resource industries, food and health systems, production and manufacturing systems, and infrastructure all will be affected. Although humans will respond and adjust their lifestyles to fit with the changing environments over time, the changes that will trigger immediate response are those that affect their livelihoods. These include; changes in food availability and quality, changes affecting shelter, health, energy, and cash flow. Changes in food availability for example will be as a result poor harvest or crop failure due to lack of adequate precipitation. These and others that directly reduce availability or quality of life support resources. In this report we take these to be secondary causal effects in the chain of climate change impacts, primary causes of change being those on biophysical characteristics.

Primary human responses to impacts of climate change

Primary human responses to climate change will be triggered basically by the change in ecosystems services. People will respond to either increasing or reducing quality or quantity of a particular ecosystem service. Here we provide an inventory of what is the most likely possibility of human responses based on possible scenarios. Our assumption is that there are two possibilities: 1) either warmer and drier, 2) or warmer and wetter with of course the third option of warmer and no change in precipitation. The other factor that will influence choice of human responses is ecological and socio-economic potential of a particular place. To this we have based our inventory on agro-ecological zones. Agro-ecological zones are the basic government planning areas in developing land use activities. Appendix I, give an outline of the impact causal chains. Human responses to similar impacts may vary geographically depending on how the impact affects their livelihoods. To be able to capture this variability we have analysed the causal chains by agro-ecological and land cover types. This analysis does not take into account the coupling effects of increased CO^2 where there may be increased water use efficiency wi9th possible changes on the length of growing period.

Exposure Units and Vulnerability Analysis

Climate change impacts vary from place to place based on the regional variabilities on weather patterns and the bio-physical characteristics. These considerations are important especially while considering vulnerability are the land use activities in the area. We have analyzed climate exposure units of east Africa based on the current land cover and land use types. We have adopted land cover and land use categorization developed by Afri-cover, and adapted to East Africa regional situations. We have limited ourselves to landscape units we consider are functionally liked either in energy flow or can prescribe a type of unique utilization.

Appendix II gives an outline of exposure units based on the following land cover analysis: grasslands, forests, agriculture, swamps, bush land, woodland, plantations, water bodies, urban settlements and bare ground. For each of this we have analyzed are covers at national level.

Since climate change will affect different areas differently we have assessed how each of the areas will be affected by comparing land cover with climate projection data from the Climate Land Interactions Project (CLIP). CLIP data comprises of a map of east Africa showing temperature and precipitation modelling results projected from 2000 to 2020 and 2050. Areas that are projected to undergo significant changes are the hot spots. We have assessed vulnerability based on ecosystem services provided by a land cover type and the placed a value. These values are presented in the table below. The values were assigned by three person visual assessment and making a common agreement.

Table XX below gives some expert opinions (based on three expert agreements) on the relative importance of exposure units in terms of services they provide to the ecosystem

Table 2 Experts opinion on the relative importance of ecosystem services per exposure unit

Relative importance of exposure units in terms of services they provide to the ecosystem										
	EXPOSURE UNITS									
ECOSYSTEM SERVICES	agriculture	barren land	bush land	forest	grassland	plantation	swamp	town	water body	woodland
PROVISIONING										
Biomass fuel	5	0	5	5	2	4	3	1	1	5
Timber	5	0	2	5	1	4	1	1	1	5
Medicine	2	0	3	4	2	2	2	1	1	4
Food	5	0	4	3	2	4	4	1	2	3
Fiber	5	0	3	4	2	4	5	1	1	5
Shelter	3	0	3	3	3	2	4	5	1	3
Freshwater	0	0	3	5	3	1	5	1	5	4
Genetic resources (Biodiversity)	2	1	5	5	4	2	5	1	5	5
Biochemicals		1	3	4	2	1	3	1	4	3
Pasture	4	0	4	4	5	1	2	1	1	3
REGULATING										
Carbon sequestration	2	0	3	5	4	2	5	1	4	5
Climate regulation	2	0	2	5	4	2	5	1	3	5
Coastal protection	0	0	3	4	3	1	5	1	4	5
Flood protection	0	0	3	5	4	1	5	1	5	4
Wind control	1	0	2	5	2	2	4	1	1	4
Water quality (water purification)	0	0	3	5	4	1	5	1	5	4
Pest regulation	0	0	2	4	3	1	5	1	3	3
Sediment retention	0	0	3	4	4	1	5	1	5	3
Polution control	0	0	2	4	4	1	5	1	5	3
Water regulation	0	0	3	5	4	1	5	1	5	4
CULTURAL										
Recreation	0	3	2	5	4	1	5	4	5	3

Spiritual enrichment	0	2	3	5	3	1	5	3	4	3
Tourism	1	3	2	4	5	1	5	4	4	3
Aesthetic value	1	1	2	4	4	1	5	5	5	4
Education	3	3	3	4	3	3	4	5	4	4
Trade (goods and services)	5	4	3	5	3	5	4	5	5	5
Cultural heritage	1	3	1	5	3	1	4	4	5	3
SUPPORTING										
Nutrient cycling	3	0	3	5	3	2	5	1	4	5
Atmospheric Oxygen	3	0	3	5	4	2	5	1	4	5
Primary production of biomass	5	0	4	5	4	2	5	1	3	4
Soil formation	4	2	4	5	4	2	5	1	1	4

Key: 0- Not applicable; 1- 5 where 1 is least important and 5 is most important

In every exposure unit there may be opportunities brought about by climate or risks. Depending on how climate change occurs we have assessed the possible opportunities and risks based on main land cover types in an ecological or agro-ecological zone. The table below gives results of this assessment.

Table 3 Risks and opportunities

RISKS AND OPPORTUNITIES MATRICES

A. Risk and Opportunities in the Agricultural Sector

AEZ	Climate Classification	Main Vegetation Type	Average Annual Rainfall (mm)	Average Annual Potential Evaporation (mm)	Main Livelihoods in addition to Subsistence	Opportunities		Risks	
						Warmer & Drier	Warmer & Wetter	Warmer & Drier	Warmer & Wetter
I	Humid	Moist Forest	1100 - 2700	1200 - 2000	Dairy, Sheep, Coffee, Tea, Maize; Sugarcane	***Emerging habitat: Dry forest*** Better Coffee Maize and Sugarcane yields	***Emerging habitat: Moist Forest*** Better Dairy, and Tea	***Emerging habitat: Dry forest*** New crop and Livestock diseases Loss of Tea	***Emerging habitat: Moist Forest*** More floods, landslides More water borne diseases for humans

II	Sub Humid	Moist and Dry forest	1000 - 1600	1300 - 2100	Maize, Pyrethrum, Wheat Coffee, Sugarcane	***Emerging Habitat: Dry Forest*** Less cold related health problems	***Emerging Habitat: Moist Forest*** Better crop yields	***Emerging Habitat: Dry Forest*** New diseases	***Emerging Habitat: Moist Forest*** Increased soil erosion Crop damage by floods More disease
III	Semi Humid	Dry Forest and Moist woodland	800 - 1400	1450 - 2200	Wheat, Barley, Coffee Maize Cotton, Coconut, Cassava	***Emerging Habitat: Moist Woodland*** As above	***Emerging Habitat: Dry Forest*** Better production of wheat, barley and maize	***Emerging Habitat: Moist Woodland*** New diseases	***Emerging Habitat: Dry Forest*** Poor performance of Cotton and poor quality Cassava
IV	Semi Humid – Semi Arid	Dry woodland and Bush land	600 - 1100	1550- 2200	Ranching, Cattle Sheep, Barley Sunflower, Maize, Cotton Cashew nuts Cassava	***Emerging Habitat: Bushland*** More pastures	***Emerging Habitat: Moist Woodland*** Better performance of Barley, Maize and Cashew Nuts	***Emerging Habitat: Bushland*** As above	***Emerging Habitat: Moist Woodland*** Better for all crops for the zone

V	Semi Arid	Bush land	450 - 900	1650 - 2300	Ranching, Livestock Sorghum, Millet	***Emerging Habitat: Open grassland*** Better Livestock	***Emerging Habitat: Semi Humid-Bushland*** Suitable for cropping	***Emerging Habitat: Scrubland*** Un suitable for settlements And cropping	***Emerging Habitat: Semi Humid-Bushland*** Suitable for settlements Conflicts between herders and cultivators
VI	Arid	Bush land and scrubland	300 - 550	1900 – 2400	Ranching	***Emerging Habitat: Desert Scrub*** Suitable for pastoralists only	***Emerging Habitat: Bushland*** Suitable sorghum and millet cultivation	***Emerging Habitat: Desert Scrub*** Less grass for livestock	***Emerging Habitat: Bushland*** More livestock and human diseases
VII	Very Arid	Desert Scrub	150-350	2100- 2500	Nomadic and shifting grazing				

Risks and Opportunities in the Health Sector

AEZ	Climate Classification	Main Vegetation Type	Average Annual Rainfall (mm)	Average Annual Potential Evaporation (mm)	Main Human and Livestock Diseases and Vectors	Opportunities		Risks	
						Warmer & Drier	Warmer & Wetter	Warmer & Drier	Warmer & Wetter
I	Humid	Moist Forest	1100 - 2700	1200 - 2000					
II	Sub Humid	Moist and dry forest	1000 - 1600	1300 - 2100	Malaria	0	0	x	x
III	Semi Humid	Dry Forest and Moist woodland	800 - 1400	1450 - 2200	Malaria	0	0	x	x
					Plague – Meningitis	0	0	xx	xx
					Rift Valley Fever Yellow Fever	x	0	0	x
					Cholera	x	x	0	x
					Trypanosomiasis	x	x	0	xx
IV	Semi Humid – Semi Arid	Dry woodland and Bush land	600 - 1100	1550- 2200	Malaria Plague – Meningitis	0	0	0	xx
					Rift Valley Fever Yellow Fever	x	0	0	xx

					Cholera				
					Trypanosomiasis	x	0	0	x
V	Semi Arid	Bush land	450 - 900	1650 - 2300	Malaria	0	0	0	x
					Plague –				
					Meningitis				
					RVF	0	0	0	x
					Yellow Fever				
					Cholera	0	0	0	x
					Trypanosomiasis	0	0	0	x
VI	Arid	Bush land	300 - 550	1900 – 2400	Malaria	0	0	x	x
		and			Plague –				
		scrubland			Meningitis				
					Rift Valley Fever		0	0	x
					Yellow Fever	0	0	0	x
					Cholera				x
					Tryps				x
VII	Very Arid	Desert Scrub	150- 350	2100- 2500	*Too arid for disease vector habitation*				

Key: 0 = Conditions that will **not** provide opportunity or risk in reducing the spread of the disease under the two scenarios (warmer and drier/ warmer and wetter)

X = Conditions that will provide opportunity or risk in reducing the spread of the disease under the two scenarios (warmer and drier/ warmer and wetter)

C. Risk and Opportunities in the Rangelands Sector

AEZ	Climate Classification	Main Vegetation Type	Average Annual Rainfall (mm)	Average Annual Potential Evaporation (mm)	Main Livestock Production Types and Land Use Systems	Opportunities		Risks	
						Warmer & Drier	Warmer & Wetter	Warmer & Drier	Warmer & Wetter
IV	Semi Humid – Semi Arid	Dry woodland and Bush land	600 - 1100	1550-2200	Dairy, Cereals	None	Higher productions More vegetation cover in the Semi arid areas More soil formation	Less water available Less availability of livestock feeds Soil degrades faster	Water borne disease Some indigenous crops unsuitable More soil erosion
V	Semi Arid	Bush land	450 - 900	1650 - 2300	Mixed C-L Cropping alone	None	Higher production	Crop failures	Conflict over land ownership Some indigenous crops unsuitable
VI	Arid	Bush land and scrubland	300 - 550	1900 – 2400	Commercial ranching Pastoralism	None	More pastures Introduction of new crops	Famine	Conflicts between cultivators and herders Invasive species

VII	Very Arid	Desert Scrub	150-350	2100-2500	Drought tolerant breeds Pastoralism	None	More pastures	Famine	Invasive species

Climate Change Impact Pathways

Climate change as known by increased temperatures and variable water availability will impact al systems. In order to understand the chain of impact pathways, we here present the chain of impacts in different sectors of economy.

Crop Agriculture

With higher temperatures humidity will reduce due to excess evapotranspiration making the place drier. This situation may offset by excess water availability in areas where there will be increased precipitation. However, most areas will receive less precipitation thereby increasing the water stress. Crops that require a certain amount of humidity in their below and above ground environments will not do well. Poor productivity of these crops will lead to farmers either spending more on farm inputs to maintain productivity. Other farmers may decide to change the crops to those that require less humidity. In very few areas where idle land may be available, farmers may decide to migrate to where their crops of choice may do better or migrate to urban centres to engage in employment or business. In the areas where the increase in temperature will be offset by the increase in precipitation the net result is increase in wetness. This may lead to increase in vegetation cover and have positive effects on cultivation of many crops as the water stress is reduced.

Livestock Agriculture

Like in the case of cropping areas where water stress will increase impacts on livestock production will escalate. The main impacts will be in availability of feed resources. Pastures will be degraded and feed resources become scarcer. This will lead to herders travelling to further distances to graze. Other may alter their breed types to more shoats and camels than cattle while others may sell off their stock.

In areas where precipitation will offset the increase in temperatures, bush encroachment may alter the pasture composition and make less useful to livestock. In this situation herders will spend more on bush clearing in order to maintain pastures.

Health

In areas anticipated to be warmer and drier disease vectors favouring warmer conditions like mosquitoes will be more. This may increase the prevalence of malaria and other diseases whose vectors prefer warmer environments. The same case applies also to livestock diseases. An example is trypanosomiasis transmitted by tsetse flies.

Areas that will become wetter the disease challenge will be those transmitted by organisms living in water. These include typhoid and cholera, while for livestock they include Rift Valley Fever.

Energy

Energy is required in almost everything we do on our daily lives. Almost everything we use may have to be manufactured using energy at some stage. Unfortunately most of energy sources in Kenya, Rwanda and Burundi is derived from hydropower. Hydropower generation is highly dependent the amount of water available. With low water levels in the rivers, the dams used for power generation are also low and do not contain enough water to drive the turbines. As such several turbines are shut down. Search for alternative source of energy usually leads to use of diesel generators. His makes the cost of energy to be very high.

Firewood is the major source of energy for domestic use particularly in the rural areas and in some of the slum areas in the urban centers. With the increasing dryness availability of firewood will be less. For those who can afford the alternative source of energy is kerosene, but this will be at a cost compared to firewood which is usually at not financial cost. For the extremely poor who no matter what they cannot afford kerosene, the option will be to spend more time in search of firewood.

Climate Change Adaptation Signatures

Climate change adaptations have been going on for a long time. Local communities have been adapting to climate variability in many ways to adjust their lifestyles and production systems to prevailing environmental conditions. Different communities have different ways of adapting to similar climatic signals.

Adaptation to climate change in Kenya

Over the last decade, Kenya has faced a number of calamities ranging from droughts to floods. This has affected sectors such as agriculture, livestock production, energy (hydro-electric power generation), roads, tourism, wildlife, education and health. The call for adaptation to the change has therefore been echoed at all levels. We highlight some of the steps that have been taken both by the public and private sectors to enhance adaptations to climate change. Most of these strategies are crucial and may only need to be popularized and the vulnerable groups facilitated to effectively implement them.

Reviewing policies to address challenges of climate change

Our review of existing policy documents revealed that the Kenya government has since 1990s been making deliberate efforts aimed at adaptation to climate change. One of the early attempts towards addressing the challenges of climate change was formulation and implementation of the National Environment Action Plan (NEAP) in 1994, just about the time Kenya ratified the UNFCCC. This Plan highlights key activities that must be carried out if sustainable development is to be achieved. It also recognizes the need to establish some key institutions and the legal framework that should be put in place to curb environmental degradation and ensure Kenya meets her climate change obligations under the UNFCCC (MOENR, 1994; MOENR, 2002).

Implementation of this Plan culminated in development of the National Environmental Policy in the form of the *Sessional Paper No. 6 of 1999 on Environment and Development* and the accompanying legal framework, the National Environmental Management and Coordination Act, 1999. It also resulted in establishment of the National Environment Management Authority (NEMA) whose mandate is to facilitate implementation of the Act.

Other institutions that have been operationalized together with NEMA are: the National Environmental Council, NEMA Board of Management, Public Complains Committee, National Environmental Tribunal, Standards Review Enforcement Task Force, Technical Advisory Committee on Environmental Impact Assessment (EIA), Provincial and District Environment Committees, and National Action Plan Committee.

The government has also established an Inter-Ministerial Committee on Environment (IMCE) to ensure that environmental issues, including those emanating from climate change are addressed. Among the thematic sub-committees established under IMCE is the National Climate Change Activities Coordinating Committee (NCCACC) which handles issues relating to climate change. The day to day activities of this Committee is handled by the Climate Change Secretariat based at the Ministry of Environment and Natural Resources.

Since the Environmental Act came into force, all policies and projects that may have any impact on the environment must show how environmental issues will be addressed. Thus it is mandatory for such projects to carry out detailed environmental impact assessment (EIA) before they are approved for implementation.

One of the key policies that have since been formulated with environmental issues and climate change in mind is the Economic Recovery Strategy for Wealth and Employment Creation (ERS). This Strategy provides policy guidelines to ensure environmental conservation and sustainable development, including fight against desertification and flood control (GoK, 2003).

The most recent Kenya government policy document, the Vision 2030, has recognised climate change as one of the key challenges facing sustainable development in Kenya and specifically undertakes to “Improve the capacity for adaptation to global climate change”. However, this undertaking is not reflected in the list of flagship projects for the environment that will be implemented up to the year 2012 (GOK, 2007).

Under the sub-sector policies, in order to address the problem of deforestation, the government enacted the Forest Act (2005) and formulated the Forest Policy that will ensure sustained protection of the forests and reduce encroachment into the forests.

In the agricultural sector, the Strategy for Revitalizing Agriculture (SRA) was formulated and launched for implementation in March 2004. Unlike the previous agricultural policies, the SRA lays emphasis on sustainable exploitation of the arid and semi arid lands through various adaptation strategies. These include: irrigation development; water harvesting; development and promotion of early maturing, drought and pest tolerant crop varieties; and improved livestock marketing in the ASALs. This Strategy is being implemented by the Ministries of Agriculture, Livestock and Fisheries Development and Cooperative Development and Marketing.

Extension service delivery

Extension has been recognized as the motivating factor in adoption of appropriate environmental conservation methods. This is particularly so in Machakos district where women groups singled out training, education and advice from extension staff as the greatest motivating factors in their success in environmental conservation (Kamar, 2001). They reckoned that they could have not succeeded in *fanya juu* terracing and water harvesting techniques that they have implemented were it not for efforts from the extension staff.

The challenges from the climate change are making the government work closely with farmers to ensure adaptation to the change as well as addressing the causes of global warming, more so, environmental degradation. As people extend cropping into semi arid lands, possibly due to population increase and increase in precipitation in these areas, the government has been extending crop extension services into ASAL areas. This has, in some cases, resulted in staff training on new technologies such as minimum tillage, supplementary irrigation, dry land farming, water harvesting, water saving, new crop varieties, among others.

This is in line with the National Agricultural Extension Policy (NAEP) under which information packages to farmers are based on individual needs of the target groups. This policy, which is being implemented through various projects such as the National Agriculture and Livestock Extension Project (NALEP) – Sida, NALEP – GoK, Agricultural Sector Programme Support (ASPS), and Promotion of Extension Services – GTZ, are based on this framework. In Moyale district, priority extension packages are livestock marketing, environmental management, soil and water conservation.

In Garissa, Marsabit and Voi districts, priority is on community based water programs and increasing the number of operational community water points. In Kitui, extension priority is on climate change adaptation strategies such as construction of water harvesting, construction of sand dams, and off-take wells. In higher rainfall areas such as Trans Nzoia and Uasin Gishu districts, emphasis is on disseminating information on agro-forestry, soil conservation, sustainable agriculture, soil fertility improvement, among others.

Due to importance of extension services on adaptation to climate change, the government has been putting emphasis on strengthening these services. One of the ways is increased funding to the agricultural sector from Kshs. 12.95 billion in 2002/03 to Kshs. 20.01 billion in 2005/06 and further to Kshs. 29.588 billion in 2007/08. These funds mainly cover the core programmes that include research, extension, livestock disease and pest control, forestry development and environmental conservation and management (GOK, 2007).

The increased funding has enabled extension service delivery to be strengthened through modernization of field offices, provision of modern equipment and improvement of transport facilities to facilitate staff mobility. In addition, a total of 300 new graduates were recruited in 2006 to enhance service delivery and address the staff succession problem. More innovative methods of extension delivery were also introduced. These include setting up of agricultural information desks, adopting demand driven extension service, and re-engineering the Agricultural Information Resource Center (AIRC) to effectively provide information services to the sector.

Among other changes include adoption of more participatory delivery systems such as Focal Area Development Approach (FAA), Farmers Field Schools (FFS), and Promoting Farmer Innovations (PFI). Under the National Agriculture and Livestock Extension Project (NALEP) and Kenya Agricultural Productivity Project (KAPP), Common Interest Groups (CIGs) are being used as media for delivering extension packages to farmers and other target groups (MOA, 2004). Research-extension-farmer linkages have also been improved. This includes introduction of wholistic research-extension approaches through projects such as the Kenya Agricultural Productivity Project (KAPP).

Following institutionalization of the National Environment Management Authority (NEMA), environmental officers have been posted at the district level to provide the necessary technical support in environmental conservation and awareness. Consequently, environmental issues are now increasingly incorporated into all extension packages. Issues relating to agro-forestry, soil erosion control, water conservation, water harvesting, minimum tillage, are being promoted.

Adaptation to drought

Kenya increasingly experiences droughts that are more severe with time. These largely affect the Arid and Semi Arid Lands (ASALs) where 12 million people live. When droughts strike, pastoralists suffer huge livestock losses due to lack of reliable alternative market for their livestock. With climate change, it is expected that the rising temperatures in pastoral areas will make droughts more severe thereby seriously affecting the lives of pastoral communities.

In order to facilitate the pastoral communities to adapt to droughts, the Government has rehabilitated and re-opened the Kenya Meat Commission (KMC) at Athi River and Mombasa (Kibarani Slaughterhouse) to provide reliable market for livestock, especially during droughts. At the same time, two international level abattoirs have been constructed one at Mombasa and another at Lokichogio. An aggressive promotional exercise was launched by the Ministry of Livestock and Fisheries Development in 2004 in order to improve access to external markets, particularly the Middle Eastern Markets with notable success. In 2004, for example, 5,128 beef cattle were exported to the Middle East.

Global warming has been blamed for increase in prevalence of livestock diseases and pests. A lot of effort has been put towards control and eradication of notifiable epizootic diseases in collaboration with stakeholders. In 2004-2006, achievement of 90% of the planned target was recorded in the reduction of Foot and Mouth Disease (FMD). Recently, the government embarked on a campaign to eradicate trypanosomiasis in collaboration with other countries in the African Union.

During drought periods, some pastoralists adapt to the change in weather through moving livestock to wildlife zones, particularly the national parks and game reserves where they may still be some grass thereby fueling human-wildlife conflict. This also results in spread of diseases from wildlife to livestock and vice versa.
Livestock marketing was improved further through creation of Disease Free Zones at the Coast, the North Rift and Laikipia district. This has significantly improved access to lucrative markets of Mauritius and the Middle East. To improve on the marketing of live animals further, livestock holding grounds that were long dead are being re-opened. The new proposals are Bachuma and Maritini in the Coast Province that are earmarked for rehabilitation to handle screening and export of live animals.

Climate change related droughts have reduced availability of feed resources for livestock especially in the systems depending on rain fed pastures. This has forced farmers to reduce their herd sizes and some alter the composition of the herds to more shoats than cattle among the pastoralists who traditionally are cattle herders. Among the mixed crop-livestock keepers open grazing practices have turned into tethered grazing subsidized with cut and carry feeds.

Following loss of their livestock to drought, some pastoral communities adapt to the losses through illegal re-stocking of their livestock. This leads to bloody clashes. In April 2006, for example, at least 15 people were killed in a period of 3 weeks following the 2005/06 drought that left thousands of livestock dead (Gullet et al, 2006). Most affected districts were Marsabit, Moyale, Samburu, Baringo, Laikipia and Trans Nzoia. In July 2005, 70 Kenyans were killed within a week by cattle rustlers in North Eastern Kenya. A similar incident was reported in April 2003 when at least 30 people were killed (Meera, 2005).

In May 2007, violence related to cattle rustling in Laikipia and Samburu districts forced thousands to flee their homes and closure of 12 schools. During the same month, 15 people were killed in Turkana district and thousands fled their homes (IRIN, 2007a; IRIN, 2007b).

Besides forcing some people to adapt through illegal re-stocking, drought also makes some communities to violently secure watering points for their livestock. During the 2005 drought, for example, at least 22 people were killed in fighting over a water point on Ewaso Kedong river in Naivasha. Similar incidence was reported in Marsabit district where in July 12 2005, 56 people were killed in Turbi village over access to water and grazing land. In December the same year, scramble for water in Sambarwawa of Northern Kenya led to death of at least 7 people and left several others injured as water conflict took an ethnic dimension. Oxfam estimated the number of people killed from water and pasture conflicts during the beginning of 2006 at 40 (Oxfam, 2006).

In order to reduce losses of cattle when drought strikes, farmers are creating strategic feed reserves for their cattle. One way of creating the feed reserve is making forage or hay that may be stored for use during the drought period. Though large scale farmers have machines for baling hay, poorer farmers are using more labour intensive technologies for silage making. Among places where this has been observed is Mukurwe-ini in central Kenya (Winston 2006).

In order to reduce the livestock losses that arise from lack of pasture during drought period, the government through the Ministry of Livestock and Fisheries Development is planning to establish National Livestock Feed Reserves that will involve storing feeds for use during the drought periods.

Recognizing the high vulnerability of African countries to the impacts of climate change, the United Nations Environment Programme (UNEP) with the support of the Global Environment Facility initiated a project, "Integrating Vulnerability and Adaptation to Climate Change into Sustainable Development Policy Planning and Implementation in Eastern and Southern Africa" (ACCESA) in which Kenya is a beneficiary. The project is providing support for community-level actions that enhance resilience to climate change in the short and long-term. It is also supporting the development of strategic approaches for integrating adaptation to climate change into policy- and decision-making at the national and sub-national level. Execution of this project is being led by the African Centre for Technology Studies and the International Institute for Sustainable Development.

The specific goal of the project is to reduce the vulnerability of communities in Eastern and Southern Africa to the impacts of climate change, thereby improving their well-being and protecting their livelihoods. The objective of the programme is to promote the mainstreaming or integration of vulnerability and adaptation to climate change into sustainable development plans and planning processes through pilot projects undertaken in the beneficiary countries (Kenya, Mozambique and Rwanda).

In Kenya, the pilot project is being implemented in Makueni District where the focus is on increasing the community's resilience to drought. The project is promoting actions that reduce vulnerability of farming communities' to the current and future drought conditions (IISD, 2007) through actions aimed at increasing food security, reduction of poverty by improving livelihoods and facilitating the integration of adaptation to climate change in policies related to disaster management and sustainable development of arid and semi-arid lands. Implementation of this project is led by the Centre for Science and Technology Innovation in Partnership with the Arid Lands Resource Management Project (ALRMP).

National Food Security Initiatives

In order to address the problem of famine arising from climate change related crop failure, the Kenya government has set up an elaborate institutional framework to address all issues relating to food security. One of the key institutions is the Kenya Food Security Meeting (KFSM) that comprises UN agencies, NGOs, donors, and government officials. All disciplines are represented here, including provincial administration, agriculture sector ministries, meteorological department, early warning experts, Office of the President, Ministry of Finance, and grain traders such as the National Cereals and Produce Board. Besides KFSM, the Kenya Food Security Steering Group (KFSSG) has also been established to coordinate various food security activities in the districts and ensure all cases of food insecurity are addressed. At the district level, the District Steering Group (DSG) has been formed to facilitate information sharing and planning at the district level. It is where all proposals and action plans are agreed upon. Other management units that have been set up to assist in effective disaster management are:- National Committee on Disaster Management; Cabinet Sub-Committee on Disaster Management; and the Inter-Ministerial Committee on Disaster Management.

Adaptation to climate change has also been carried out through emergency response services by the above named committees. During 2005/06 drought, the KFSM estimated that at least 3.5 million people including 0.5 million school children were in need of emergency assistance. Consequently, appeals were sent out that resulted in positive response from a number of agencies. Some of these were the USA that provided relief assistance amounting to US$ 36 million, Kenya government provided US$ 18 million, UK US$ 7.8 million, Multilateral organizations US$ 6 million, Japan US$ 4 million, Canada US$ 2.7 million, and Sweden US$ 1.27 million.

In order to reduce loss of life arising from drought, floods and other calamities, the Government has established a National Food Reserve to be managed by the KFSM. This comprises: 3 million bags of maize and hard currency adequate to import another 3 million bags of maize. Of late, other food stuff like powdered milk, beans, rice, have been incorporated into the food reserves. There are also plans to establish a National Livestock Feeds Reserves to be used for feeding starving livestock during drought periods.

High incidence of food insecurity, indirectly blamed on climate related changes has resulted in the government introducing school feeding programme in various parts of the country. One of these is Narok district.

Water harvesting

Kenya though classified as water scarce country experiences heavy rains and flush floods in almost all parts of the country. Thus there may be a period of heavy rains accompanied with flooding followed with dry weather and even famine. It is for this reason that emphasis is being laid on harvesting water that goes to waste during the rainy season.

The increase in water scarcity in Kenya, and more so in the ASAL areas has prompted, the Government, NGOs, CBOs, and even some religious organizations to promote and facilitate water harvesting in various parts of the country. This is being done through roof top rain water harvesting, construction of dams, water pans and other structures to tap run-offs. The government has recently reported an expenditure of Kshs. 1.5 billion on building water pans and boreholes in the arid zones of Turkana, Samburu and Baringo districts. In addition, various regional development authorities have over the past five years carried out construction of water pans and dams in their areas of jurisdiction. In the northern Rift, for example, the Kerio Valley Development Authority (KVDA) in 2004 constructed Kimao water dam in Baringo district and water pans in East Pokot and Koibatek.

There is remarkable increase in the number of manually dug shallow wells around homes that provide water for domestic purposes and watering of kitchen vegetable gardens.

In the ASAL areas, most projects initiated under various government departments have water harvesting components. These include projects such as the Agricultural Sector Programme Support (ASPS) that covers 16 districts mainly in the ASAL areas and the recently launched ASAL Based Livestock and Rural Livelihoods Project that covers 22 ASAL districts and has major activities such as water harvesting, effective water management, construction of water pans and dams as well as drilling of boreholes. The other project whose key components are water harvesting, water saving and management is the Community Agricultural Development Project in Semi-arid Lands (CADSAL) covering Kerio Valley and Marakwet. There is also the Njaa Marufuku Kenya (NMK) covering over 50 districts in Kenya (Winston 2006).

In ASAL areas, people have adapted to water scarcity by scooping into sand beds of the dry streams to get water for domestic and livestock use. Clean drinking water that accumulated in the beds during the rainy season and prevented from evaporating by the layer of sand is received from such beds. In this connection, the local residents in the ASAL areas, and more so Kitui, Turkana, Machakos and Samburu now develop sand dams that mimic the sand beds. This involves cementing some ditches (dams) in the pathways of floods or streams. These are then filled with sand to trap water for use during the dry periods.

Construction of infiltration ditches is one of the technologies being used to harvest water from roads or other sources of runoff into ditches constructed along the contours, upslope from the crop land. The ditches are normally 0.7 – 1.5 meters deep. Water trapped in these ditches seep into the crop land down the slope thus supplying it with water through the dry period.

Also related to this is the water retaining pits that is used to harvest runoff and allowing it to seep into the soil for crop use. In this case, series of pits are dug where runoff normally occurs. A furrow is dug to carry any excess water from one pit to another. In most cases, fruit trees, especially oranges and mangoes are planted in the shallow pits with remarkable results. This method is more commonly used in Kitui, Machakos and Makueni districts.

Cut off drains are also increasing in popularity due to their dual purpose of water harvesting and protecting cultivated land, homesteads and roads from floods. These drains are constructed across a slope to intercept surface run-off and carry it to an outlet such as a stream, dam or water pan.

Under the programme, "Promoting Farmer Innovation – Harnessing Local environmental Knowledge in East Africa", SIDA's Regional Land Management Unit and UNDP developed and implemented an initiative that promotes sustainable water management in the dry-lands which involved; pastoral land-use systems, small-scale irrigation, and promotion of farmer innovation in rain-fed agriculture. The basic objective of the programme was to sustainably improve rural livelihoods and improve ecosystem dynamics through the identification, verification and diffusion of local innovations related to soil and water conservation, water harvesting and natural resource management.

Irrigation Development

Another way Kenyans adapt to increased frequency of drought is irrigation development. Various agriculture related policies have laid emphasis on irrigation to reduce possible losses that may result from erratic rainfall. These include the National Policy on Water Resource Management and Development, Economic Recovery Strategy for Wealth and Employment Creation and the Strategy for Revitalizing Agriculture (MoWR 1999; GoK, 2003; SRA, 2004).

Consequently some pastoral communities have moved into irrigated agriculture. Examples may be drawn from Narosura Irrigation Scheme in Narok district where the Maasai have taken to production of high value horticultural crops under irrigation. A similar example is found in Loitokitok and Nguruman areas of Kajiado district where some of the wetlands have been turned into irrigation farms. In the marginal areas where rainfall may be inadequate, farmers have adopted supplementary irrigation to stabilize crop production, including parts of the lake region, like Bondo district.

Despite limited water resources, area under irrigation in the arid areas has expanded rapidly. In Kilimanjaro/Kenya, for example, irrigated land expanded from 245 ha to 4,768 ha between 1973 and 2000. This expansion has had a number of implications that include reduced volumes of water flowing down stream thereby affecting viability of activities there.

Water Saving Technologies

With the rising incidence of global warming, some local communities have adopted innovative water saving technologies to mitigate against water stress. These include adoption of locally made low-head drip irrigation system that save water and reduce the possibility of soil salination. In this case, farmers use small water reservoirs such as used oil drums or buckets as header tanks while perforated plastic piping convey water to the plants. These techniques are being used in both semi arid areas and high rainfall areas of Kenya. In northern Kenya, for example, these methods are used for small scale vegetable production in Marsabit (Ngutu and Recke, 2006).

Research has established that minimum tillage saves soil water from evaporation thus retaining it to crops whose yields increase significantly compared to conventional tillage (Gicheru et al, 2006). This is the reason why in Kenya, farmers in semi arid areas such as Isiolo, Narok and Laikipia districts have adopted minimum tillage as a way of farming cereals such as wheat, barley and maize.

Consequently, yields for wheat have remained fairly stable at 25 - 29 bags per ha despite increase in frequency of drought. For other crops such as vegetables and fruits, farmers use other water retaining technologies like mulching and application of manure. The small scale farmers also use this practice to restore soil fertility. As water becomes scarce, some coping mechanisms such as recycling and reuse have been adopted. More and more households have started using domestic water wastes to irrigate their vegetables in their kitchen gardens.

In order to ensure effective water use, especially during drought periods, most water supplying agencies such as the Nairobi Water and Sewerage Company resort to water rationing. In such cases, residents are restricted to 4-5 days of water supply per week thus promptly all residents to save water for essential purposes.

Promotion of conservation agriculture is also taking root in Kenya. The country participates actively in the African Conservation Tillage Network (ACT) to promote conservation farming. It is for this reason that the country in partnership with NEPAD hosted the 3rd World Congress on Conservation Agriculture in October 2005 with the theme: "Linking Production, Livelihoods and Conservation."

Environmental Conservation

Climate change is one of the factors that have contributed to environmental degradation in Kenya. In particular, the heavy flash floods arising from climate change in parts of the country have partly been blamed for the high rates of erosion in parts of the country. Similarly, the rising average temperatures have aggravated the water stress conditions.

In this respect, various government departments and other stakeholders are involved in environmental conservation and combating possible effects of environmental degradation. The Regional Development Authorities, for example, are implementing catchment conservation programmes covering vast areas such as the Upper Turkwel under the Kerio Valley Development Authority (KVDA), Upper Masinga/Kiambere under the Tana and Athi Rivers Development Authority (TARDA) and Mau Summit under the Ewaso Nyiro South Development Authority (ENSDA). The Coast Development Authority (CDA) has trained communities in afforestation and management in Kwale, Kilifi and Mombasa. Ewaso Nyiro North Development Authority (ENNDA) successfully negotiated for financial support from ADB to facilitate conservation programmes covering natural resource catchment areas in the northern parts of the country.

In some parts of Kenya, farmers have adopted environmental conservation methods that not only address soil erosion but also water loss. Of particular interest is the "*fanya juu*" and the cut off drains that were adopted in drier parts of Machakos, Makueni and Kitui districts in Eastern Province and have since spread to other parts of the country.

Table 4. Some key soil and water saving technologies used in Kenya

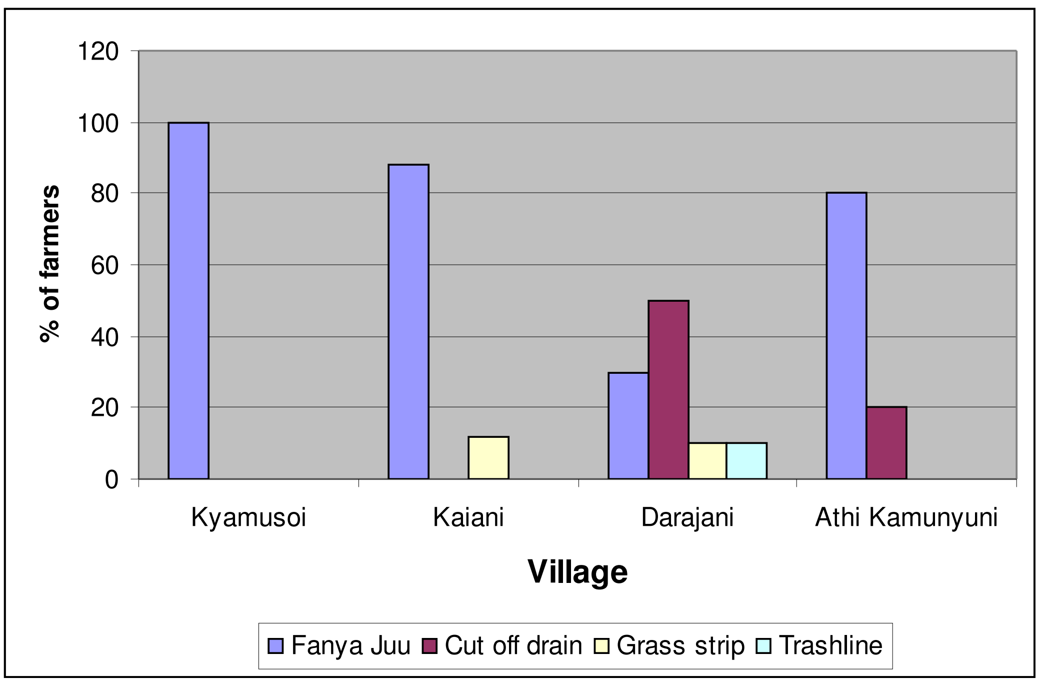
	Achievements made in 2006 for selected technologies			
Province	Fanya juu (Km)	Grass Strips (Km)	Un – ploughed strips (Km)	Retention ditches (Km)
Nyanza	73	89.95	99.35	30.37
Western	61.34	113	75.9	43.5
R/Valley	237	749	984.3	174.2
N/Eastern	12	7.2	3.5	3
Central	405	376	122	200
Nairobi	2	0	0	0

Eastern	312	401	65	340
Coast	23	10	22	42
TOTAL	**1,125.34**	**1,746.15**	**1,372.05**	**833.07**

Source: MOA

Fanya juu terraces are constructed by digging a contour trench and scooping the soil to the upper part of the trench which then forms an embankment on which fruit trees, Napier grass or bananas are planted. The trench traps and holds water that is gradually released to the farmland through natural seepage. This has worked wonders in areas that would otherwise be bare lands. In Machakos, this conservation method is particularly popular among women groups who through their united force have constructed most of the terraces in the district. The same has been reported in Makueni district where the *fanya juu* is preferred due to its ability to trap and store runoff in this low rainfall district (Gichuki, 2000).

Figure 2 Conservation Technology Ranking in Makueni District (% of farmers)



Floods control

Kenya has over the last decade been experiencing higher frequency and intensity of floods, a calamity blamed largely on climate change. This has necessitated adoption of adaptation strategies by local communities, the government and other stakeholders.

One of the key activities the government has been carrying out to control floods, especially in Budalangi and Nyando is construction of dykes along rivers Nzoia and Nyando. Some funds have also been provided for maintenance of the dykes. However, construction of dykes has not been very successful in Kenya due to their inability to sustainably control the floods.

In 2004, the government constructed dykes along river Nzoia to control Budalangi floods. However, these were damaged in the 2006 and 2007 floods with devastating effects on thousands of local residents who never expected such a calamity (Gullet et al, 2006; Bulemi, 2007).

This new development has necessitated search for a more sustainable adaptation method. It is therefore critical to explore the possibility of constructing water dams along Nzoia and Nyando rivers that will besides controlling the floods, be used for irrigation and domestic water supply. In this connection, the Kenya Government, with the support from the World Bank has unveiled a plan to implement Kshs. 10.815 billion (US$ 154.5 million) projects to counter flooding and improve natural resource management in western Kenya. The Western Kenya Community Development Project and Flood Mitigation Project with a total cost of Kshs. 6.02 billion is aimed at empowering local communities to address the recurrent floods in Western and Nyanza provinces. The Natural Resource Management Project will enhance Kenya's capacity to manage natural and forest resources and reduce the incidence and severity of drought, floods and water shortages (Kenya Times, 2007).

Due to poverty and low funding from the government, local communities continue to bear the burden of annual flooding. These include annually migrating to higher grounds, bearing the cost of rebuilding or renovating damaged buildings and replacing lost livestock and other assets. A number of these communities have adopted various practices to avoid or reduce the negative impacts of frequent floods. In Kano plains for example, the major household adaptive practices against floods include:- clearing and digging of trenches around the homesteads; piling mud around homesteads; sealing lower door entrances with mud; raising the floor of houses; planting trees and sisal around homesteads to slow down floods; evacuation to higher grounds when floods strike; and storing medicine in readiness for disease outbreak.

For a number of years the government with the help of local communities has been promoting development of gabions in areas prone to flash floods where excessive surface runoff causes soil erosion. This was particularly strengthened in the 1980s when the former President of Kenya, Daniel a rap Moi took personal initiative to participate physically in development of gabions.

In order to reduce the effect of floods on residents, the Nairobi City Council has over the past three years been improving on drainage systems in the city. This involves replacing existing drainage pipes with larger ones and cementing open drainage systems, including river banks. There is also regular maintenance of the drainage system to remove any materials that may cause flooding.

Research on drought and disease tolerant crops

As the severity of drought increases, the challenges of achieving food security in drier parts of Kenya have been increasing. Policy documents such as the National Food Policy 1994, ERS, SRA and NEAP explicitly encourage development of drought and pest tolerant crop varieties. This has further been translated into the Strategic Plan of the Kenya Agricultural Research Institute (KARI), (GoK, 2003; MOA, 2004b; MOENR, 1994).

The Kenya Agricultural Research Institute (KARI) has taken up this challenge and embarked on research on early maturing, drought and diseases tolerant crops. This has since been stepped up with KARI Katumani centre being dedicated to this important research.

In 2004, at least 10 maize varieties were released for the low rainfall parts of Kenya. Among these varieties were: KVC-0, KVC-H, and KAPT-941 all of which were bred at Katumani research Centre in Eastern Province. Other varieties released were ECA-KB-6, ECA-KB-13, ECA-KB-18, Taita Taveta, ECA-KB-21, ECA-KB-45, and ECA-KIBZIM-18 all of which are open pollinated varieties developed by KARI and CIMMYT (KARI, 2004).

In 2006, another 4 maize varieties were released for the dry areas. These are: KAT2005-1, KAT2005-2, CKIR04-002 and CKIR04-003 (Ininda, 2006).

Efforts are now being made to strengthen research into other crops such as sorghum, millet, peas and pasture crops.

Improve soil fertility

Recent studies show that fertility of Kenya's soils have been dropping over the years. This though blamed also on poor agronomic practices, has been associated with the level and frequency of rainfall (Obunde et al, 2004; Campbell et al 2003). Consequently farmers in Kabondo division in Rachuonyo district, in an interview with the researcher in February 2007 lamented that they can now barely get any maize yields if they fail to apply fertilizer or compost manure.

Due to drop in soil fertility, farmers are turning to mixed cropping from mono-cropping and where idle land is still available, shifting cultivation is practiced leaving the land with poor soils fallow. However, due to increasing demand for land that has partly been necessitated by increase in population, the length of fallow periods has declined significantly (Maitima, 2004).

To reduce the problem of soil fertility, the government through its extension services has been educating farmers on better farm management practices especially on re-cycling of crop residues into the soil rather than burning. Application of animal manure is also widely used especially in the mixed crop-livestock production areas.

In order to improve on soil fertility on a sustainable basis, agro-forestry is widely being promoted as evident in the next section.

Agro-forestry

Agro-forestry has over the years evolved to be one of the critical climate change adaptation methods in Kenya. Besides providing adequate wood for domestic use, agro-forestry protects soil from erosion and is used to enhance soil nutrient content.

This follows introduction of nitrogen fixing trees that are currently used in the agro-forestry projects. In western Kenya, agro-forestry is being promoted particularly for shrubs that significantly add nutrients to the soil. Researchers have discovered that leaves of the *tithonia* shrub, which is commonly found in many parts of Kenya, can be used to double or triple maize yields (Niang and Palm 1998). This has culminated in both government and other organizations promoting use of the shrubs in enhancing soil nutrient content.

Besides *tithonia*, some leguminous nitrogen fixing shrubs and trees have been introduced in the same region. It has been reported that six months fallow of these shrubs have tripled maize yields in some villages in western Kenya (Sanchez, 1999; Bationo et al, 2007).

A number of organizations are supporting government effort towards promoting agro-forestry in Kenya. These include the World Agroforestry Centre (ICRAF), various NGOs, CBOs, and Christian Organizations such as Christian Community Services (CCS) which operates in Busia, Teso, Mt. Elgon and Vihiga districts.

Fight against malaria

Being the leading killer, with a death toll of over 1 million in the world annually, massive campaigns aimed at eradicating malaria have been going on in Kenya supported by the government, International community and NGOs. Millions of insecticide treated mosquito nets are distributed annually to vulnerable local communities. In 2006, a massive campaign was launched in Kisumu that culminated in distribution of 5.2 million insecticide treated mosquito nets within a two month period, July – August 2006 (MoH, 2006). This has reduced the malarial deaths by more than 50% among children of five years and below. The deaths reduced from 34,000 children in 2005 to 16,000 children in 2006 (WHO, 2007).

Besides encouraging people to sleep under treated mosquito nets, awareness creation has been intensified to urge people to seek medical attention whenever they suspect malaria attack. However, the wide use of the drugs has resulted in emerging resistance of malaria parasite to chloroquine based drugs. This prompted the government in 2004 to introduce other malaria drugs such as the chlorproguanil – Dapsone (Amukoye, 2004). The continued resistance forced the Kenya government in 2006 to replace the use of sulphur based drugs in the treatment of malaria with the more effective artemisinin based combination therapies (ACTs). These are now widely used, with the government meeting the bulk of treatment expenses, particularly for children and expectant mothers.

As climate change continues to increase, prevalence of malaria, some agencies have initiated projects aimed at cutting the mosquito population. This includes the BioVision Project in Nyabondo, Western Kenya that in 2005 succeeded in cutting mosquito population by 90% within one year and consequently reduced malaria cases by 50%. The participatory approach of the project involved draining of water pools in the project area and treating with environment friendly insecticides any pools that could not be drained. This was aimed at curbing mosquito breeding. The project also involved distributing insecticide treated mosquito nets. In some rice growing villages of Mwea, some biological control agents have been introduced into stagnant water to destroy mosquito larvae (IDRS, 2005).

Energy saving technologies

One of the major contributors to global warming has been deforestation that results from felling of trees for various uses, wood-fuel included. In the semi arid areas, clearing of the bush for charcoal burning and wood-fuel has been rampant, rendering some areas bare. This is more so because in Kenya, almost 70% of the population rely on biomass for their energy needs.

This prompted Kenyans to explore ways of adapting to depletion of the biomass and saving the environment through development and promotion of energy saving technologies. One of these is the energy saving stove introduced in 1996 through the "*Upesi Project*" implemented in Trans Nzoia, Mumias, Kisumu, Rachuonyo, and Bondo districts. The new *jikos* (stoves) use 60-70% less firewood compared to the traditional stoves. This initiative has since been taken up by a large number of NGOs, CBOs, donor funded projects and government departments that are popularizing it in various parts of Kenya. Installation of such jikos has resulted in over 60% drop in energy bill in schools that adopted them.

In homes, one of the energy saving *jiko* being widely adopted is the *kuni mbili* stove. The Kenya government, in collaboration with other relevant agencies, has stepped up promotion of the *kumi mbili* and other improved firewood stoves. In this connection, the government intends to increase the percentage of people using these stoves from the current 4% to 15%, a strategy that will save about 7.7 million tonnes of wood per year (MOE, 2006).

The Ministry of Agriculture, through the Njaa Marufuku Kenya programme has stepped up production and installation of energy saving stoves in various parts of Kenya. Among the districts where installation has been intensified are Butere-Mumias, Narok, Maragwa, Homabay, Marakwet, Garissa, Mwingi, Kwale and Malindi.

In urban areas, the energy saving Kenya Ceramic *Jiko* has been widely adopted and almost entirely replaced the traditional metal stoves. It burns 25-40% less charcoal compared to the traditional stove.

In order to save trees further, some of the stoves that utilize plant leaves (e.g., dry Eucalyptus leaves), crop waste, including maize stokes as well as wastes from commercial processing of timber like saw dust, have been developed and are widely being promoted. This will ensure that fewer trees are cut down for energy purposes.

Clean Energy

Having regard to the recent environmental concerns that have focused on the link between global warming and carbon dioxide and other green house gas emissions, a direct link between energy consumption with efficiency and carbon dioxide emissions could be established. Energy efficiency must therefore be regarded as a primary means of stabilizing these emissions. Some practical measures to reduce energy use in industry are being undertaken in Kenya.

Co-generation

Implementation and planned development of co-generation of electricity by the sugar industry would result in clean fuel with minimal impact on the environment. Mumias Sugar Company is already co-generating power and selling to the national grid. Other sugar companies such as SonySugar, Nzoia and Chemelil are already seeking funds for investment in power co-generation through use of bargase.

Bio-ethanol Production

Ethyl alcohol, which is a by-product of sugarcane processing, is produced for a variety of uses. It is also increasingly being recognised as a potential source of alternative to fossil fuel for internal combustion. The Agro-chemical and Food Company and the Spectra International have been in the business of producing this product except for the policy space which has been lacking for its use as an alternative or blending with fossil fuel. There is, however, planned additional production of the product by other sugar processing factories and development of the necessary policy and legal framework to facilitate its wide usage.

Forestation and Protection of Forests

Kenya's forest cover has declined rapidly over the last five decades from 16% to less than 2% as a result of unplanned excision for settlements and excessive harvesting without adequate replanting. This has been attributed to increase in population that increased demand for land leading to the landless illegally settling in forest reserves. Consequently, forest reserves have been depleted and water catchment areas destroyed.

Some researchers estimate that Kenya has lost 2 billion trees since independence (Mburu, 2003). This has contributed to the increased rates of run-off and hence flooding and soil degradation leaving some of the previously forested areas such as Laikipia bare. The increase in rainfall and temperature anticipated under the climate change will make things worse.

A number of strategies have been adopted to reverse this trend, one of which is development and implementation of the Kenya Forestry Master Plan by the agriculture sector ministries. The intention of the Plan is to check the uncontrolled deforestation and excision of land and to protect the rare, threatened and endangered species of trees and animals.

At the global level, Kenya is a signatory to the Ramsar Convention that protects designated wetlands from destruction by man. In this connection, laws governing exploitation of wetlands have been enacted and being enforced through NEMA. In the same light, Kenya has formulated laws protecting riparian habitats.

One of the adaptation strategies of the government is to settle forest intruders in alternative suitable areas where they can continue with their economic activities with minimal negative implication on the environment. In this respect, one of the core mandates of the Ministry of Lands and Settlement is resettlement of persons internally displaced from previous forested areas such as Molo, Narok, Enosupukia, Tran Nzoia, Uasin Gishu and Burnt Forest. These resettlements however require large sums of money that has been difficult to come by.

In addition, emphasis is laid on strengthening the forest department to curb encroachment into forests, illegal harvesting, overgrazing and fire outbreaks that require a rapid response and well-equipped forest guards. The department is being strengthened through provision of training, uniform, telecommunication equipment, protection camps, transport (vehicles, motor bikes and mountain bikes) and firearms.

On realizing the importance of forests in environmental conservation and as carbon sinks, the Kenya government has been spearheading tree planting. Since 1980s, campaigns dubbed "cut one tree plant two" have been going on. This, together with powers given to local administration to regulate tree cutting, has slowed down the rate of drop in forest cover in the country (MOENR, 2001).

In support of this policy direction, various government departments have been carrying out tree planting campaigns annually. For example, the Kenya Army planted at least 160,000 trees both during Army Tree Planting Week and Recruits Tree Planting Drive in 2007. The Kenya Commercial Bank during the same year mobilized its employees to plant over 60,000 tree seedlings across the country during its Community day.

Various organizations such as the Green Belt Movement have been spearheading not only protection of existing forests but also reclaiming of forest reserves and increasing area under trees. This movement carries out tree planting campaigns that culminate in planting of thousands of trees annually. In 2006, for example, Prof. Wangari Maathai pledged to plant at least 2 million trees in Kenya annually through her Green Belt Movement. This was accomplished in 2007 when at least 2 million trees were reportedly planted through the Green Belt Movement Initiative. What remains is to ensure the trees and taken care of (EA Standard, 2006c).

Private sector companies such as Bamburi, East Africa Portland Cement and Kakuzi, are currently involved in tree planting as a mechanism not only for general conservation but also for tackling green house gas emissions and global warming by providing the necessary "carbon sinks" to sock carbon dioxide.

Other organizations such as Plant for the Planet work closely with the United Nations Environment Programme (UNEP) and Kenya government departments to plant trees throughout the country. In 2006, it supported 149 schools in Kisumu district to plant 50,000 tree seedlings.

Following realization of the impact of charcoal burning on the environment, Kenya has a legal framework regulating trade in charcoal. This is reinforced through regular bans on charcoal production and movement from areas deemed threatened by charcoal burning activities (Barnett, 2003). For example, in May 2006, ban was imposed on movement of charcoal from Turkana to neighbouring districts in an attempt to protect forests that were being depleted by charcoal burners. Among these were Kangatosa, Napusmoru, Kaptir, Kalemungorok, Kakong, Eliye Spring and Lomopus forests. These bans are reviewed regularly by the District Environment Management Committee (Daily Nation, 2006). In June 2007, another ban was imposed on charcoal burning in West Pokot following a public outcry over wanton destruction of trees in the district (Muoki, 2007).

Use of Natural Carbon Dioxide

A number of industries in Kenya, Uganda and Tanzania still use imported carbon dioxide when in reality the region is endowed with abundant supply of natural carbon dioxide that only needs filtration to the required standard. Some mining of the gas for use in industry is already being undertaken by the Carbacid Company (now part of the BOC Group) in Lari Division in Central Province.

Programmes to improve range management

In order to facilitate adaptation of the range management to the climate change, the government has introduced pilot programmes that will ensure sustainable production in the rangelands. In 2006, for example, a 6-year Range Improvement Programme that covered 5 pilot ASAL districts, each with 4 components namely: range reseeding, pasture/fodder banks, promotion of multipurpose trees and shrubs was introduced. Other components included grazing management and training of herders and extension staff.

Diversification of income source

Unlike the 1960s and 70s when policies emphasized on back to land, the current policies are aimed at de-congesting farms by providing alternative sources of income, other than farming. This was stipulated in among others the Sessional Paper No. 1 of 1996 on Industrial Development to the Year 2020. The energy policy that culminated in initiation of Rural Electrification Programme was aimed at ensuring that the rural areas are facilitated with power source so that the informal sector (jua kali) can thrive and provide alternative and supplementary income to farmers. Besides this, local communities have already started investing in micro-power plants that generate hydro-power for the communities use.

As the climate change affects the existing household livelihoods like pastoralism, some people have already changed their sources of income. An interesting case is that of Maasai community that have been known to be pastoralists taking to crop farming. Some of these pastoralists have moved into production of basic foodstuffs such as maize while others have gone into commercial production of horticultural crops in areas such as Narosura irrigation scheme in Narok district. Many other places, including Loitokitok, Kimana, Rombo and Namalok in Kajiado district experience similar developments (Campbell et al 2003).

This was further confirmed in the July 19th CLIP Workshop held in Nairobi, where participants reported that herders in southern rangelands of Kajiado, Narok and Taveta have diversified their income sources into tree planting, eco-tourism, working in mines fields such as Madadi, carrying out small scale mining, harvesting forest products such as honey and medicine, charcoal burning and trade, small scale businesses and so on. Some have also taken to education in an attempt to seek salaried employment. In the northern rangelands, participants reported that the pastoral communities have diversified their income sources to providing labour to commercial farmers. Others also carry out illegal exploitation of forest products, small scale mining, fishing, poaching and eco-tourism.

Human migration

With the increase in severity of drought, some of the formally pastoral and nomadic communities are moving to towns in search of alternative means of livelihood. Some of the migrants are people who lost their entire herd to drought and have no other ways of re-stocking. Consequently some pastoral communities such as the Maasai are migrating into towns to take up various forms of employment and businesses. These include trade in curios, Maasai cloths, herbal drugs and other traditional items. They also take up available jobs, including that of security guards.

During the July 19th CLIP Workshop held in Nairobi, stakeholders agreed that in the southern rangelands of Kajiado, Narok and Taveta districts, climate change is leading to migration of herders to wetter areas thereby causing even higher environmental degradation there. Some move to urban areas and towns either on temporary or permanent basis. In the northern rangelands of Laikipia, Samburu and Turkana, herders are migrating from the dry areas into the forests around Mt. Kenya and Aberdare ranges while others move into urban areas and towns such as Nanyuki. At the same time, stakeholders reported that in the mixed farming regions, some farmers are migrating into the ASAL areas where they introduce crop farming. It is expected that the anticipated increased rainfall in the ASAL will increase further the rate of migration into the ASAL areas.

Strengthening of Early Warning Systems

When natural disasters strike, fingers have often been pointed at the Kenya Meteorological Department for not warning about the pending calamity. This prompted the Kenya government to look for ways of strengthening the early warning system to enable the department make accurate and more specialized weather predictions. To this end, the government purchased more advanced meteorological equipment and provided the necessary capacity building to staff.

In addition, the government formed the National Disaster Management Authority, which brings together experts from all relevant sectors such as public administration, planning, agriculture, livestock, meteorology, trade, water and environment.

To strengthen the early warning system further, more effective means of disseminating early warning information to the local communities has been established. This is through the use of radio and internet. Climate change has been factored into food security and disaster preparedness and response through involvement of the Climate Change Secretariat in the disaster management efforts.

In order to strengthen the early warning system further, the seven eastern Africa countries, Djibouti, Eritrea, Kenya, Uganda, Sudan, Somalia and Ethiopia, that are members of the Inter-Governmental Authority on Development (IGAD) have established a regional climate monitoring institution to help effectively predict climate related disasters. The IGAD Climate Prediction and Application Centre (ICPAC), which was launched in April 2007 and is based in Nairobi will give information on a minute-by-minute basis (Abwao, 2007). The major objective of ICPAC is to contribute to climate monitoring and prediction services for early warning and mitigation of adverse impacts of extreme climate events on socio-economic sectors of the region. Among other things, its objective is to develop scenarios of future climate change and examine how these would impact on key sectors such as energy.

Introducing environmental courses in school curriculum

The continued environmental degradation and the global awareness of the impact of these on sustainable development have prompted the Kenya government to lay emphasis on environmental education. Consequently, the school curriculum has been revised to reflect this new development.

The Ministry of Education, for example, introduced courses on environmental studies aimed at increasing awareness among the younger generations on processes, impacts, and consequences of climate change. This is expected in the long run to increase community awareness and contribute to better adoption of environmental friendly technologies.

In schools, students are being sensitized on environmental issues and how to protect the environment from degradation. The curriculum in colleges and universities has equally changed and now reflect the important role of the environment. Besides introducing several courses on environmental science, environmental management and environmental economics, a large number of the other courses have some environmental units embedded in them.

Improved Road Construction

Kenya has experienced frequent floods over the past decade that seriously destroyed the road network. The 1997/98 El Nino, for example, destroyed several bridges and an estimated 100,000 kms of both rural and urban road network thus calling for better ways of adapting Kenya's roads to floods and El Nino like calamities. The 1998 damage was estimated at US$ 670 million (Abwao, 2007). Since 2000, Kenya has adopted new strategies of road construction that are geared towards withstanding the frequent floods. Roads within Nairobi and Kisumu cities as well as the Northern Corridor are particularly built with these in mind.

Climate Change Adaptation Options in Rwanda

Adaptation options to climate change per key sector of Rwanda economy have been identified following sectoral studies on vulnerability carried out by experts, the PRSP I, the Initial National Communication related to UNFCCC and public consultations carried out in all Provinces during the fourth term of the year 2005.

Analysis of adaptation options – NAPA-Rwanda

A first list has been prepared and comprises 40 identified options from 6 most vulnerable sectors including: Agriculture and animal husbandry, lands, water resources, forestry and health. After analysis of these potential options, a second list comprising 20 options taking into consideration the necessity to implement integrated and transversal projects within these sectors was prepared. NAPA team formulated key adaptation options which adequately respond to most immediate and urgent needs of most poor local communities and hence, most vulnerable in socio-economic and climatic point of view. These key adaptation options proposed are the ones which integrate into local dynamics or become integrated into the national development programmes:

1) Promotion of non rain-fed agriculture;
2) Increase agricultural techniques;
3) Introduction of species resistant to drought in arid and semi arid zones;
4) Introduction of precocious varieties in arid and semi arid zones;
5) Protection of basin sides in mountainous zones;
6) Promote stocking techniques of agricultural products after harvesting;
7) Reinforce early warning and rapid intervention systems;
8) Reinforce animal husbandry in permanent stalling;
9) Promote veterinary and phytosanitary services;
10) Develop alternative sources of wood energy ;
11) Rational utilisation of wood energy;
12) Preparation and implementation of forestry development plan;
13) Preparation and implementation of land development plan;
14) Integrated water resources management (IWRM including rainwater);
15) Promotion of non agricultural activities;
16) Increase the rate access of drinking water;
17) Favour access of the public to medical insurance services;
18) Prevent and fight against vectors of water-borne diseases;
19) Integration of NAPA in policies and national development plans;
20) Facilitate accessibility to health services.

Selection of potential adaptation options and integration with national objectives of sustainable development

Options and adaptation measures to climate change identified during various consultations of NAPA process constitute very important additional information of formulated national objectives and multilateral Conventions on environment ratified by Rwanda. Rwanda sustainable development objectives are stipulated in the documents of policies dealing with development, poverty and vulnerability such as vision 2020, decentralization policy, documents for strategies for poverty reduction (PRSP I and EDPRS), sectoral 41 strategies and policies, policies and plans for the implementation of MEA(Multilateral Environment Agreement) action plans such as CBD and CCD. The PRSP I review in February 2006 helped to integrate environment and other aspects of climate change such as drought, salt and pest in EDPRS – Economic Development and Poverty Reduction Strategy as an essential element of economic development so as to fight poverty and consolidate the welfare of Rwandans. Environmental data shall now be integrated in local development plans so as to determine impacts of action plans and their policies. The dimension of environment and environmental problems shall be considered and dealt with by these development plans.

After confrontation with national priorities and so as to maintain the process of analysis easy and manageable, taking into account urgent and immediate needs established in PRSP, and other development programmes, 11 priority options have finally been retained to be submitted for multicriteria analysis. They include:

1. Promotion of non rain-fed agriculture;
2. Intensive agriculture and animal husbandry;
3. Introduction of drought resistant species;
4. Integrated water resource management;
5. Stocking and conservation of agriculture produce;
6. Information systems, early warning and rapid intervention mechanisms;
7. Development of sources of energy alternative to firewood;
8. Preparation and implementation of a national land development plan;
9. Access to health facilities and fight vectors of water-borne diseases;
10. Promotion of non agricultural activities, and
11. Preparation of a forest development plan.

Selection of NAPA immediate and urgent options

Due to financial constraints and limited capacities to be developed for a better implementation of these priority options, specific criteria are utilized to select and make a hierarchy of highly priority options. The national team used criteria mostly recommended by Least Developed Countries Expert Group and also adapted to national context such as:

1. Impact on vulnerable groups and resources,
2. The contribution to sustainable development (Socio-cultural, ecological and economic),
3. the synergy with MEA (Multilateral Environment Agreement),
4. Risks reduction,
5. Cost-efficiency (financing).

These criteria have been analyzed further to show the measurement of each criterion in relation to its response to the vulnerability of option (advantages, risks reduction or its disadvantages, financial costs, non monetary constraints). In consideration of lack of exact data on the real values to attribute to each measure unit of criteria, the measure by scale was preferred by the technical team.

Table 4 Important options for climate change adaptations in Rwanda

N°	OPTIONS	CRITERIA				
Impact on vulnerable groups and resources	**Contribution to sustainable development (socio-cultural ecological and economic)**	**Synergy with MEAs**			**Risks reduction**	**Cost efficiency**
Unit	**Scale from 1 to 2**	**Scale from 1 to 3**		**Scale From 1 to 10**	**Scale from 1 to 5**	**Scale from 1 to 10**
1	**Promotion of non rain-fed agriculture**	**2**	**2**	**5**	**3**	**8**
2	**Intensive agri-animal husbandry**	**2**	**2**	**7**	**5**	**6**
3	**Varieties resisting to drought**	**2**	**2**	**3**	**5**	**7**
4	**IWRM: Integrated water resource management**	**2**	**3**	**4**	**5**	**8**
5	**Stocking and transformation of agricultural products**	**1**	**2**	**4**	**3**	**8**
6	**Information systems of early warning and rapid intervention**	**2**	**2**	**10**	**5**	**6**
7	**Development energy sources alternative to firewood**	**2**	**2**	**7**	**4**	**7**
8	**Preparation and implementation of land development plan**	**1**	**3**	**5**	**3**	**5**

9	Access to health facilities and fight against water-borne diseases	1	1	5	2	5
10	Promotion of non agricultural activities generating income	2	3	7	4	6
11	Preparation and implementation of forestry development plan	1	3	8	5	8

Source NAPA Rwanda

Past and current climate change adaptation practices in Burundi

Climate change has generated a number of needs as regards adaptation in the various vulnerable sectors. This is why strategies of response were suggested by affected population. Besides, additional strategies should be considered for the future. Practices of adaptation to the adverse effects of climate variations always existed in the history of Burundi. Vis-à-vis famine, the population moves towards areas less affected by the extreme events (dryness, invasion of locusts, etc.) where they can find some food. In these areas, the displaced people offer their services in the form of labour and receive in turn foodstuffs. Once the situation returns to normal, they return to their original places.

A traditional form of adaptation for the Burundian farmers is that they could adapt the succession of crops to the farming seasons, especially vis-à-vis the threats of diseases and plant pests. Crops most sensitive to fungal diseases are grown during the seasons with low rainfall, or even during dry seasons, whereas the crops resistant to diseases and plant pests are grown during seasons with heavy rain. In certain areas like Kirimiro, farmers have already adapted their agricultural calendar to the rhythm of seasons: crops with long vegetative cycle are planted at the beginning of the rains, to be harvested at the end of the rains. Short cycle crops are planted in March - February to be also harvested at the end of the rains. There are of course enormous losses as per the total annual production, but these losses are preferred compared to those that could result from rotten harvests. These practices are particularly

carried out by farmers with very large farms. However, some farmers grow crops that relay bean, such as cowpea, pigeon pea and groundnut, especially in the areas of Mosso and Imbo, to supplement the protein-leguminous plants whose production is in continuous reduction. In the same way, the growing of soybean, sunflower and the market gardening is becoming more and more significant. Burundians have adopted a system of conservation of genetic resources, i.e. the conservation in the form of ears or dry seeds to constitute grains in the attics. This conservation is also done by repetitive transplanting or propagation by cuttings for some dryness resistant plants. In the sector of livestock, during the crises of dryness, the stockbreeders prefer moving their herds along the rivers where they can find better fodder, or directly take refuge in other internal or external areas where they could find natural pastures. In such crises of dryness, stockbreeders also adopt the solution of selling on the hoof or by slaughtering their animals even at lower price. They thus prefer to get smaller livestock like sheep or goats, which are less affected by the periods of dryness because they are able to diversify their sources of food (herbaceous and aerial pastures, etc).

Since the most remote times, Burundians have adopted traditional methods of conservation of the natural forest ecosystems. This is a Burundian habit that consisted in respecting in a quasi religious way certain ecosystems and/or elements of biodiversity, both animal and plant biodiversity. In the Burundian tradition, cutting of trees in the Kibira forest was particularly banned. This high altitude forest was regarded as a “Symbol of Alliance between the Sky and the Earth”. Only the King was allowed to perform hunting activities in the Kibira forest. The traditional conservation also concerned certain thickets considered as sacred. These were fragments of forests prohibited t99o exploitation and bearing the name of “Intatemwa” literally “what one should not cut”, or “Ikidasha” literally “what one should not burn”.

Costing the adaptations

Climate change adaptations will be a continuous process and will be borne by all key players from the local communities, institutions, governments as internal players. There will also be external partners who may inject some financial assistance. All these can be estimated based on several assumptions ranging from the uncertain climate change scenarios, to uncertainty of the nature of responses by climate exposure units and to the uncertainty of the monetary values of the ecosystem services to be affected. The need to adapt will be based on know specific ecosystem services that will undergo changes either in the quality or quantity of the service to people.

The importance of these services will vary from one place to another. For example provisioning of timber by an ecosystem would be very important in the sub-humid to humid forests than in the semi-arid forests. To account for these variabilities we developed a group considered opinion on the relative importance of each of the recorded ecosystem services based on exposure units (Table 2). The relative importance values assigned each of the ecosystem service will vary not only by exposure but also by agro-ecological zone. To account for the variability across zones we have analyzed and grouped exposure units as per agro-ecological zones.

We have separated and averaged values of ecosystem services into four categories: 1) provisioning; 2) regulating; 3) cultural and 3) supporting. In the calculations for costs to adaptation we have summed up all the scored values per exposure unit.

We have first calculated the total environmental value of the aggregated exposure unit to gross dollar value. We have used the following estimated land values per hectare.

AEZ	Description	Approximate land value

		per hectare ($)
I	Humid	12,000
II	Sub humid	10,000
III	Semi humid	8,000
IV	Semi humid to Semi arid	6,000
V	Semi arid	4,000
VI	Arid	2,000
VII	Very arid	1,000

An estimate of the land value per hectare in each of the agro ecological zones, account for the relative importance of ecosystem services in the exposure unit. Based on the exposure unit and and agroecological zone we have estimated population pressure and assigned a values reflecting either high (3) medium (2) or low (1) since we do not have population figures per exposure unit. These are values take into account of the land and the ecosystem services as they are now before climate change (baseline conditions). Based on mean annual precipitation we have assessed the percentage change based on CLIP projected change in annul precipitation

We have used the following formula:

Adaptations Cost = LV (PEs+ REs + CEs+ SEs) X HIf x CCf

Where :

LV = Land Value in USD (an estimate of current land value assuming a mean of all land uses, and land cover

PEs = Provisioning Ecosysme services (Mean of estimated provisioning ecosystem service values)

REs = Recreation ecosystems service(Mean of estimated recreation ecosystem service values)

CEs = Cultural Ecosystems service (Mean of estimated cultural ecosystem service values)

SEs = Supporting Ecosystem service (Mean of estimated supporting ecosystem service values)

HIf = Human Impacts factor (a factor to adjust to high, medium and low population densities)

CCf = Climate Change factor (Expected change in mean annual precipitation per Agroecological zone)

Appendix 5 gives the figures for adapting people and land to climate change. We have gross costs per exposure unit which would be the cost of an area today before adapting to climate change. We have then factored in climate change per km2 to show the cost of adapting to climate change based on CLIP projections. Since the projections are for 2050 we have indicated annual costs to adapt each exposure unit per agro ecological zone. Details of these calculations are shown in the spread sheet on costings.

In total over the next 40 years Kenya will need **$99 billion** dollars to adapt to climate change. This comes to about **2.5 billion per year**. This may look like a high figure but it is less than 20% of the national budget (budget for 2009).

Conclusions

The capacity to adapt to climate change is not adequate in East Africa The knowledge base is in adequate. We need more data and information on how people have coped with droughts and floods in the past so as to enhance people's experiences with modern sciences. We need more in the following areas: Enhanced hydro-meteorological monitoring systems, and improved and expanded human resources in the hydrological and meteorological services; Analytical tools and products tailored to sector needs; Information on adaptation options based on pilots, field tests and research; Early warning systems; Information exchange networks to enable access to and exchange of data and information between all levels of user and decision makers; Regional and National Networks – Networks of agencies and policy makers, experts, knowledge bases, data and information, research and field experience (pilots, tests) is crucial to stimulating and facilitating investment in adaptation; Introduce modern technology for data collection, transmission and assessment; Introduce the use of compatible standards and systems to enhance data and knowledge sharing across sectors;

To adapt agriculture (including irrigation, watershed management & community development) we need to develop flood, drought and drainage risk maps to enhance; sector development planning; combine risk mapping with river basin and sub-basin water and resource assessments including rainfall variability. We also need more investments on forecasting coupled with training in natural resource and land management practices. We need more investment in research and extension; more investments on services to enhance production and farm incomes with a new emphasis on adaptation to climate variability and change. We need to invest in sustainable land management practices focusing on enhancing water use efficiency and soil fertility. Scale up investment in irrigation. Water management systems and water storage, especially in drought prone areas. Scale up investment in livelihood focusing on participatory rural develop including sustainable land management, watershed management and community driven development (CDD) approaches. Support livestock vaccination programs (in particular to ENSO related vector borne diseases); strengthen pastoralist support programs; develop pilot risk insurance schemes including indexed crop insurance

On water resources, we need to **i**mprove technical capacity of water resource management agencies including hydro-met and groundwater management services; Institutionalize multi-sector, integrated water resources planning and management; Strengthen the analytical and modeling capability of water resource agencies to utilize enhanced hydrologic and metrological data acquisition and monitoring networks and support river basin and sector development and management planning. Scale up investment in river basin and sub-basin water resource assessments and the associated institutional capacity to sustain such program on a continuous basis. We need to development of decision support systems (DSS) including hydrologic models and other analytical tools to enhance sector planning and risk assessment.

In the energy sector investments are needed in strengthening electricity utilities to improve their efficiency and financial viability. Strengthen sector strategic planning to include a greater with emphasis on climate vulnerability and climate change risk by introducing: Assessment of vulnerability of supply systems; renewable sources less sensitive to climate; assessment of climate change impacts on demand;

On the transport sectors we need to enhance the capacity of road and transport sector agencies in the area of strategic planning to identify and incorporate climate vulnerability into sector plans and project designs. Review and revision of planning and design standards for river and stream crossing, and cross drainage, in regions with existing and potentially increased future flood hazard including increases in high intensity rainfall. Increase the use of flood, drought (greater access to network) and drainage risk mapping in sector planning in rural and urban areas Introduce risk assessment into the selection of design standards including pavement type

In the urban areas water supply and flood management are the main areas that may need to be developed. We need to enhance strategic supply planning capability of urban water supply utilities including climate vulnerability and risk assessment of water supply sources. Strengthen urban development planning based on improved flood and drainage hazard mapping. Invest in infrastructure upgrading and improvement to mitigate and adjust to changing flood and drainage hazard patterns Invest in urban services to reduce flood and drainage risks including housing relocation, reduced encroachment into flood hazard areas, secure solid water management

On health we need to develop/strengthen climate-related surveillance systems (as part of overall monitoring system). Increase awareness of health related climate vulnerability and increase capacity to incorporate adaptation in to the healthcare system. Invest in disease vector control systems. Invest in increased surveillance of existing and emerging threat areas affected by climate variability and climate change

On forestry, biodiversity, and coastal zone management, we need to strengthen the capacity to monitor forest and biodiversity resources, evaluate their status and threats and formulate actions. There is a need to develop and test new governance arrangements for forest resources - Invest in forest resource management to enhance climate resilience, enhance livelihoods of people living near and in forest areas, and promote resource conservation - Invest in reforestation and afforestation, and in their sustainable management Invest in forest fire prevention, risk surveillance, and response Utilize carbon finance as incentive for environmental conservation and rehabilitation Pilot and up-scale agroforestry programs focused on improving land productivity and quality of ecosystem services. As can be seen, many of these investments to reduce climate risks involve faster sustainable development, careful assessment of vulnerability, strengthening institutional capacity, and re-orienting investments.

References:

Gullet Abbas, Asha Mohamed, Ahmed Abdi, and Anthony Mwangi, 2006: Kenya:Floods Update No. 6. Of 4th December 2006. Operations Update. Kenya Red Cross Society.

Maitima, J., Reid, R.S., Gachimbi, L.N., Majule, A., Lyaruu, H., Pomeroy, D., Mugatha, S., Mathai, S., Mugisha, S. 2004. The linkages between land-use change, land degradation and biodiversity across East Africa. LUCID Working Paper Series Number 42. 2004. 63 pages. www.lucideastafrica.org

MOE, 2006: Millennium Development Goals Needs Assessment Report 2006. Requirement for the Energy Sub-sector. An Enabler for Achieving MDGs. Prepared by the Ministry of Energy in Collaboration with the Ministry of Planning and National Development.

MoWR, 1999: Sessional Paper No. 1 of 1999 on National Policy on Water Resources Management and Development. Ministry of Water Resources. April 29, 1999.

Bulemi M'Mbolo, 2007: 2,460 displaced in flood-hit Budalangi. Kenya Times. 26th April, 2007.

MOENR, 1994: The Kenya National Environment Action Plan (NEAP) Report. Ministry of Environment and Natural Resources. June 1994.

Niang Amadou and Cheryl Palm, 1998: Restoring Soil Fertility in Western Kenya: International Development Research Centre Publications. 6th February 1998.

Sanchez Pedro, Anne-Marie Izac, Bruce Scott, 1999: Delivering on the Promise of Agroforestry. World Bank Newsletter of September 1999.

Bationo A; B. Waswa; J. Kihara; J. Kimetu 2007: Advances in Integrated Soil fertility Management in Sub-Saharan Africa: Challenges and Opportunities. Agriculture. Springer, June 2007.

Amukoye Evans Inyangala 2004: Chlorproguanil – Dapsone a new drug in the fight against malaria. Perspective. Africa Journal of Health Sciences, Vol. 11 No. 1-2, January-June 2004.

IDRC 2005: IDRC's Fight Against malaria. International Development Research Centre, 23rd April, 2005.

MOENR, 2001: Unpublished Environment and Natural Resources Management Report, delivered for the Agriculture and Rural Development Sector MTEF Report of 2002. Ministry of Environment and Natural Resources, 20th October, 2001.

Campbell David J., David P. Lush, Thomas Smucker, Elizabeth Edna Wangui, 2003: Root Causes of Land Use Change in the Loitokitok Area, Kajiado District, Kenya. LUCID Working Paper Series No. 19, January 2003.

MOENR, 1994: The Kenya National Environment Action Plan (NEAP) Report. Ministry of Environment and Natural Resources. June 1994.

MOENR, 2001: Unpublished Environment and Natural Resources Management Report, delivered for the Agriculture and Rural Development Sector MTEF Report of 2002. Ministry of Environment and Natural Resources, 20th October, 2001.

MOENR, 2002: First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). Ministry of Environment and Natural Resources. National Environment Secretariat. Nairobi, Kenya. June 2002.

Meera Selva 2006: Kenyan Army Steps in as Cattle Rustling Turns Lethal. The Independent. 23 July 2005.

Winston Johnston, 2006: Farmers Helping Farmers: Silage Making Kenyan Style. Blockspot. Sunday January 29, 2006.

SRA, 2004: The Strategy for Revitalizing Agriculture. Developed by the Ministry of Agriculture and the Ministry of Livestock and Fisheries Development. March 2004.

Ngutu M.N. and H. Recke 2006: Exploring Farmers' Innovativeness: Experiences with the Adaptation of Water-saving Technologies for Small scale Vegetable Production around Marsabit Mountain in Northern Kenya. Experimental Agriculture (2006). 42: 459 – 474 Cambridge University Press.

MOA 2004: Ministerial Public Expenditure Review (MPER) 2004. The Ministry of Agriculture of 19th February 2004.

KARI 2004: KARI Bred Maize Varieties, their Characteristics, how best to grow them and recommended areas to be grown. Maize variety Releases – 2004. Presented to the National Variety Release Committee on 21st December 2004 in Kilimo House, Nairobi.
Ininda Jane 2006: Public Breeding Produces New Maize Varieties for Kenyan Farmers. Seedquest – Central Information Website for the Global Seed Industry. December 2006 – Nairobi Kenya.

IPCC, 2001: Climate Change 2001: Impacts, Adaptations, and Vulnerability. Summary for Policy Makers. A Report of Working Group II of the Intergovernmental Panel on Climate Change. Approved at the Sixth Session of IPCC Working Group (Geneva, Switzerland 13-16 February 2001).

IRIN 2007a: Kenya: Schools closed as cattle raids force thousands to flee. IRIN Nanyuki 29 May 2007.

IRIN 2007b: Kenya: Hundreds displaced in cattle rustling clashes. IRIN Africa Marsabit, 14 May 2007.

Obunde Paul O., Cyrus M. Mbogo, Willis Oluoch-Kosura, and Agnes W. Kamoni 2004: Effect of Land Tenure on Agricultural Productivity, and the Environment: A Case Study of Suba and Laikipia Districts. IFPRI Eastern Africa Food Policy Network. Network Report 7. April 2004.

Obunde Paul, Joseph M. Maitima, and Jennifer Olson. Adaptation to Climate Change: 2007. A Case of Kenya. Climate Land Interactions Project working paper 63 pages

WHO, 2007: Press release by Dr. Arata Kochi of the World Health Organization (WHO) and Hon. Charity Ngilu, Kenya's Minister for Health on 16th August 2007 in Nairobi Kenya.

Mburu Chris 2003: The 60 million Plan: Planting Trees is not Easy as Chopping them down. The East African. Monday October 6, 2003.

Muoki John 2007: Government Bans Charcoal Burning in West Pokot. Kenya Broadcasting Corporation. Wednesday 27 June 2007.

Gichuki F.N. 2000: Makueni district Profile: Soil Management and Conservation, 1989 – 1998. Drylands Research Working Paper No. 4.

GoK 1994: National Environment Action Plan in 1994. Ministry of Environment and Natural Resources. 1994.

GoK, 2003: Economic Recovery Strategy for Wealth and Employment Creation (ERS 2003-2007). June 2003.

GOK, 2007: Vision 2030. A competitive and prosperous Kenya .A summary document produced by the GOK. July 2007.

Abwao Kenedy 2007: East Africa Establishes Climate Monitoring Centre. ScienceDevelopment Network (SciDevNet). 25th April 2007.

Archer, E.R.M., Beyond the "climate versus grazing" impasse: using remote sensing to investigate the effects of grazing system choice on vegetation cover in the Eastern Karoo, Journal of Arid Environments, 57, 381-408.

Bernstein L. Bosch, P., Canziani, O., Chen, Z., Christ, R., Davidson, O., Hare, W., Huq, W., Karoly, D., Kattson, V., Kundzewicz, Z., Liu, J., Lohmann, U., Manning, M., Matsuno, T., Menne, B., Metz, B., Mirza, M., Nicolls, N., Nurse, L., Pachauri, R., Plautikf, J., Parry, M., Qin, D., Ravindranath, N. Reisinger, A., Ren, J., Riahi, K., Rosenzweig, C., Rusticucci, M., Schneider S., Sokona, Y., Solomon, S., Stott, P., Stouffer, R., Sugiyama, T., Swart, S., Tirpak, D., Vogel, C., Yohe, G. 2007. Climate Change 2007: Synthesis report. Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 24-73.

Batterbury, S. and Forsyth, T., 1999: Fighting back: human adaptation in marginal environments, Environment, 41, 6, 6-11.

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, 2007: Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

Bond, W.J. and Midgley, G.F. 2000. A proposed CO2-controlled mechanism of woody plant invasion in grasslands and savannas. Global Change Biology 6:865-869

Bond, W.J., Midgley, G.F., Woodward, F.I. (2003) The importance of low atmospheric CO2 and fire in promoting the spread of grasslands and savannas. Global Change Biology 9: 973-982.

Brooks, N., 2006. Climate change, drought and pastoralism in the Sahel. Discussion noted for the World Initiative on Sustainable Pastoralism. November 2006. http://www.iucn.org/wisp/documents_english/climate_changes.pdf (Accessed 21 March 2008).

Christensen, H. and Hewitson, B., 2007: Regional Climate projections, In: Solomon, S. et al., Climate Change 2007, The Physical Science Base, Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Chapter 11, 848-940.

Conway, G. 2008. The science of climate change in Africa: Impacts and adaptations. Department of International Development, United Kingdom.

de Wit, M. and Stankiewicz, J. 2006. Changes in surface water supply across Africa with predicted climate change. Science 311 (5769) 1917-1921. 31 March 2006.

Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber and F.N. Tubiello, 2007: Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 273-313.

Elasha, B.O., Medany, M., Niang-Diop, I., Nyong, T., Tabo, R. and Vogel, C. 2006. Background paper on impacts, vulnerability and adaptation to climate change in Africa for the African workshop on adaptation - implementation of decision 1/CP.10 of the UNFCC Convention, held in Accra, Ghana, 21-23 September, 2006. 54 pp.

Fischlin, A., G.F. Midgley, J.T. Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, A.A. Velichko, 2007. Ecosystems, their properties, goods, and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge.

Hein, A.L. 2006. Climate change in Africa. Cicerone 2006 (6). (http://www.cicero.uio.no/fulltext/index.aspx?id=5249&lang=NO).

Herrmann, S.M., Anyamba, A. and Tucker, C.J., 2005: Recent trends in vegetation dynamics in the African Sahel and their relationship to climate, Global Environmental Change, 15, 394-404.

Hoffman, M.T. and Ashwell, A. 2001. Nature divided: land degradation in South Africa. UCT Press, Cape Town.

Hoffman, M.T. and Rohde, R.F. 2007. The historical impact of changing land use practices in Namaqualand. *Journal of Arid Environments* 70: 641-658.

Homewood, K., 2003: Policy, environment and development in African rangelands, Environmental Science and Policy, 7, 3, 125-143.

Hulme, M., Doherty, R., Ngara, T., News, M. and Lister, D. 2001. African climate change: 1900-2100. Climate Research 17: 145-168.

MacKellar N.C., Hewitson B.C. and Tadross M.A. 2007. Namaqualand's climate: recent historical changes and future scenarios. Journal of Arid Environments 70: 604-614.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Pres

Rohde, R.F., Moleele, N.M., Mphale, M., Allsopp, N., Chanda, R., Hoffman, M.T., Magole, L. and Young, E. 2006. Dynamics of grazing policy and practice: environmental and social impacts in three communal areas of Southern Africa. Environmental Science & Policy 9: 302-316. s, Cambridge, United Kingdom and New York, NY, USA, 746-845.

Stige, L.C., Stave, J., Chan, K-S., Cianellei, L., Pettorelli, N., Glantz, M., Herren, H. and Stenseth, N.C., 2006: The effect of climate change on agro-pastoral production in Africa, PNAS, 103, 3049-3053.

Scoones, I. (1995). 'New Directions in Pastoral Development in Africa', in I. Scoones, (ed). Living with Uncertainty: New Directions in Pastoral Development in Africa. London, Intermediate Technology Publications.

Poorter, H. and Navas, M.L. 2003. Plant growth and competition at elevated CO_2: on winners, losers and functional groups. New Phytologist 157: 175–198.

Thornton, P., Herrero, M., Freeman, A., Mwai, O., Rege, E., Jones, P. and McDermott, J. 2006a Vulnerability, climate change and livestock – research opportunities and challenges for poverty alleviation. International Livestock Research Institute (ILRI), Kenya. 23 pp.

Thornton PK, Jones PG, Owiyo T, Kruska RL, Herrero M, Kristjanson P, Notenbaert A,

Bekele N and Omolo A, with contributions from Orindi V, Otiende B, Ochieng A, Bhadwal S, Anantram K, Nair S, Kumar V and Kulkar U (2006b. Mapping climate vulnerability and poverty in Africa. Report to the Department for International Development, ILRI, PO Box 30709, Nairobi 00100, Kenya. Pp 171.

UNEP 2006. African Environment Outlook 2: Our Environment, our wealth. United Nations Environment Programme, Nairobi, Kenya. ISBN 92-807-2691-9.

Wand, SJE, Midgley GF, Jones MH, Curtis PS. 1999. Responses of wild C4 and C3 grass (Poaceae) species to elevated atmospheric CO_2 concentrations: a meta-analytic test of current theories and perceptions. Global Change Biology 5: 723-741.

Reynolds, J.F. and Stafford Smith, D.M. (eds.). 2002. Global Desertification: Do humans cause deserts? Dahlem Workshop Report 88, Dahlem University Press, Berlin. ISBN: 3 934504 108.

Rohde, R.F. 1997. Looking into the past: Interpretations of vegetation change in Western Namibia based on matched photography. Dinteria 25: 121-149.