Chapter 22. Africa

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Executive Summary

Observed trends are consistent with the projections made in AR4. There is more information about extreme temperature events in Africa. For example, there is medium confidence that extreme cold days and nights have decreased and hot days and nights have increased in number in parts of west, south and south east Africa. These trends are expected to continue in the [YEAR RANGE to be added]. The observed and projected trends in precipitation however show less consistency. Since AR4, climate science methodologies have improved to discern nuances within annual distributions and shed light on changing seasonal trends in temperature and rainfall. In AR4 there was limited knowledge about implications of climate change on extreme events, but now there is strong evidence that both means and extremes in temperature and precipitation distributions are changing. In the context of Africa, there hasn't been much progress in the climate monitoring system since AR4 and there is still a lack of recent regional data to analyze observed climate trends.

Changes in climate can shift the location and extent of biomes in Africa (High agreement, medium evidence). Vegetation models project biome changes in 5-50% of land by 2100 under different scenarios. This range of projection will not apply consistently across Africa but will differ based on vulnerability of specific ecosystems, sub-regional climate conditions and socio economic factors like ongoing land use change especially due to expansion of cultivated and grazing areas.

The impacts of climate change, mainly through sea level rise, combined with other extreme events (like high tide levels and high storm swells) are considered as having the potential to threaten coastal zones, in particular coastal towns (high confidence).

There is more evidence that the costs of these impacts will have great consequences on economic activities but also on the people living in these zones (medium confidence). It is obvious from different studies that coastal adaptation will have the potential to considerably reduce these impacts (high confidence). Ocean ecosystems, in particular coral reefs, will be affected by climate change induced ocean acidification as well as changes in upwelling, thus affecting crucial economic activities mainly fisheries (medium confidence).

Climate change is very likely to exacerbate vulnerability of Africa's water resources, which are currently subjected to high hydro-climatic variability over space and time, and are a key constraint to the continent's continued economic development (Very high confidence). Water is the primary medium through which early and subsequent climate change impacts will be felt by people, ecosystems, and economies. A large proportion of Africa's population is impoverished, rendering them particularly vulnerable. Many of the fragile terrestrial and aquatic ecosystems in Africa are implicitly or explicitly water dependent. Strategies and plans of action to adapt to climate change through an integrated approach to land and water management are urgently needed to establish effective resilience to the projected impacts of climate change, taking into account that climate change will be superimposed onto already water stressed catchments with complex land uses, water engineered systems, and a strong socio-political and economic historical footprint.

Overall, the continent as a whole has made slow progress in attaining most MDGs, which may contribute to a reduced resilience and adaptive capabilities of Africans and consequently increase vulnerability to climate change.

Progress is being achieved on managing risks to food production from current climate variability but these will likely not be sufficient to address long-term risks from climate change. (High confidence) Livelihoods-based approaches for managing risks to food production from multiple stressors, including rainfall variability, have increased substantially in Africa since the AR4. While these efforts can improve the resiliency of agricultural systems in Africa over the near-term, these adaptations are likely to be insufficient for coping with risks from long-term climate change, which will be variable across regions and farming system types. Nonetheless, processes such as collaborative, participatory research between scientists and farmers, strengthening of communication systems for anticipating and responding to climate risks, and increased flexibility in livelihood options, which serve to strengthen coping strategies in agriculture for near-term risks from climate variability, provide potential pathways for adaptation to climate change.

Recent evidence further strengthens a key finding from the AR4 that "agricultural production and food security (including access to food) in many African countries and regions are likely to be severely comprised by climate change and climate variability" (Very high confidence). Temperature rise by mid-century is very likely to cause significant crop and livestock losses, and could result in a reduction of growing season length, with strongly adverse effects on food security. Moreover, new evidence is emerging that fisheries and high-value perennial crops may also be adversely affected by temperature rise, and that biotic stresses on crops and livestock, as a result of climate change and other factors, could be an important stressor. New challenges to food security are emerging as a result of strong urbanization trends on the continent and increasingly globalized food chains, which require better understanding of the multi-stressor context for food and livelihood security in Africa.

There is more evidence that climate change is likely to increase the burden of a wider range of health outcomes (high agreement, medium confidence). Findings on malaria are similar to AR4, emphasizing the spatial and temporal spread of malaria in the East Africa Highlands and increased transmission intensity in South Africa. Leishmaniasis incidence in North Africa has been found to have a significant positive relation with rainfall pattern and changes in frequency of epidemics and spatial spread to urban areas and to Sub-Saharan Africa. Indirectly, climate change could increase the burden of malnutrition, which will have the highest toll on children and women. **Climate change is a multiplier of existing vulnerability to health outcomes (high agreement, high confidence) including inadequate water and sanitation coverage, food security, access to health care and education.** Improvement in these existing vulnerabilities will decrease the impacts of climate change on health.

Since AR4 Africa has seen more adaptation projects and studies in the health sector. Adaptation for climate sensitive health outcomes will not employ solely new techniques. The health sector response to climate change includes building on existing generic public health interventions as well as specific climate change related adaptation measures like Early Warning Systems (EWS) and vulnerability mapping. Current experiences in adaptation include but are not limited to Early Warning Systems for meningitis and Rift Valley Fever.

In all regions of the continent, the initial components of national governance systems for adaptation and responding to climate change are being developed (high confidence, medium agreement). Some progress has been made on national and sub-national adaptation policies and strategies to supplement preliminary plans such as the NAPAs; on mainstreaming adaptation into sectoral planning; and on inter-governmental and multi-stakeholder institutions for collaborative governance. There is a disconnect between institutional actors involved in policy formulation and vulnerable stakeholders carrying out autonomous adaptation responses on the ground. Institutional frameworks cannot yet effectively coordinate the range of adaptation initiatives being implemented, resulting in a largely ad-hoc and project-level approach, which is often donor-driven and may not result in local or national ownership. Additional attention is needed on the kinds of adaptive, multi-level, integrated and responsive governance systems that can deal with complex socio-ecological conditions and change.

While a wide range of adaptation options, approaches and decision tools are being tested and implemented across Africa, additional efforts at scale are needed to address the complex identified vulnerabilities and needs (very high confidence, high agreement). Adaptation options and approaches used at different levels and scales in Africa include disaster risk reduction, early warning systems and disaster preparedness; social protection and index-based weather insurance; technological approaches and climate-resilient infrastructure; sustainable land management and ecosystem restoration; and livelihood diversification. It is likely that these efforts are reducing vulnerability and enhancing resilience, at a local scale and in isolated initiatives. Greater emphasis is needed on highly vulnerable groups such as children; and an enhanced enabling environment for community-based and autonomous adaptation. Ecosystem-based approaches and pro-poor integrated adaptation-mitigation initiatives hold promise for a more coherent approach to adaptation. Key challenges for a stronger adaptation response are bridging the gap between supply and demand of user-friendly climate information, and insecure land tenure and natural resources access.

In addition to technological and infrastructural approaches, there is increased evidence of the importance of 'soft path' options and flexible learning approaches for effective adaptation (high confidence, medium agreement). There is growing evidence of the effectiveness of 'soft' measures that harness ecosystem services for climate-proofing, such as coastal afforestation and catchment restoration. In addition, an increasing number of studies highlight the importance of viewing adaptation as an iterative learning process. Options being explored include action research/learning, participatory adaptation planning, conflict resolution between different interest groups, experiential learning and adaptive management, and co-production of knowledge between different groups. Understanding has deepened of both the potentials and limits of local and traditional knowledge for informing responses to climate change; while being cognisant of cultural, ethical and rights considerations.

Growing understanding of the multiple inter-linked constraints to increasing adaptive capacity is beginning to indicate potential limits to adaptation in the African context (medium confidence, medium agreement). While African societies have historically dealt with climate variability, seasonality and uncertainty, the cumulative effect of current and future environmental, social, political, technological and institutional changes, combined with climate change, may overwhelm the ability of people to cope and adapt. Risks of maladaptation are inherent in research and development interventions that often fail to consider how different types of change interact and undermine the ability of people to cope with multiple stressors. Action is needed in general on addressing the root causes of poverty and vulnerability; and specifically on building the capacity of poorly resourced and capacitated local governments to support ongoing autonomous and community-based adaptation.

The low capacity of national governments and scientific institutions in Africa to absorb large amounts of funds allocated for adaptation has led to mismanagement and misuse of funds, which threatens to reduce the effectiveness of adaptation initiatives. Indigenous and rural poor communities in remote locations, the urban poor living in precarious settlements, and displaced persons, especially women and children are those most adversely affected by climate change and they are actually meant to be the main beneficiaries of adaptive action. However, mismanagement and misuse of funds eventually puts at risk the rights of those most vulnerable to the negative effects of climate change. The reasons for the high degree of fund mismanagement with regard to climate finance are – among other reasons - rooted in the level of complexity, uncertainty and novelty that surrounds many climate issues.

22.1. Introduction

22.1.1. Scope of the Chapter

[forthcoming]

22.1.2. Structure of the Regions

The African continent (including Madagascar) is the world's second largest and most populous (1 billion in 2009 representing 14.7% of the world population) continent behind Asia. It is composed of 55 countries (of which 5 are small island states) of which 33 are belonging to the Least Developed Countries (LDCs). The continent is organized at the regional level under the African Union (AU).[1] The AU's Assembly of Heads of State and Government has officially recognised eight Regional Economic Communities (RECs) (Ruppel, 2009; Nwauche, 2009). Except for the Sahrawi Arab Democratic Republic[2], all AU member states are affiliated to one or more of these RECs. Alphabetically listed, these RECs are: The Arab Maghreb Union (AMU), with 5 countries of Northern Africa; the Community of Sahel-Saharan States (CEN-SAD), grouping 25 countries; The Common Market for Eastern and Southern Africa (COMESA), grouping 19 countries of Eastern and Southern Africa; The East African Community (EAC), with 5 countries; the Economic Community of Central African States (ECCAS), with 10 countries; the Economic Community of West African States (ECOWAS), with 15 countries; the Intergovernmental Authority on Development (IGAD); and the Southern African Development Community (SADC), with 15 countries. This economic structure is the one used by the African Union and the NEPAD (New Partnership for Africa).

[INSERT TABLE 22-1 HERE
Table 22-1: State members of RECs officially recognized by the African Union. Source: Ruppel, 2009.]

[FOOTNOTE 1: Due to the controversies regarding the Sahrawi Arab Democratic Republic, Morocco withdrew from the OAU in protest in 1984 and, since South Africa's admittance in 1994, remains the only African nation not within what is now the African Union (AU).]

[FOOTNOTE 2: Although the Sahrawi Arab Democratic Republic was a full member of the OAU since 1984 and remains a member of the AU, the republic is not generally recognised as a sovereign state. While most African states have recognised the republic (e.g. Namibia and South Africa), several others have withdrawn their former recognition (e.g. Cape Verde, the Seychelles), and some have temporarily frozen diplomatic relations (e.g. Costa Rica, Ghana), pending the outcome of a respective UN referendum which would allow the people of Western Sahara to decide the territory's future status. The republic has no representation at the United Nations.]

22.1.3. Major Conclusions from Previous Assessments

22.1.3.1. Regional Special Report and ARs 1 - 4 / Chapter 9

The first evaluation of potential impacts of climate change in Africa was done for the IPCC special report on Regional Climate Change (Zinyowera et al., 1998). Due to the few number of studies on the impacts of climate change regarding the sectors considered (mainly water resources and coastal zones), this report presented mainly the sensitivity of the different sectors to some climatic parameters. Since this report, climate change was considered as an additional burden on a situation already alarming. The lack of data on energy sources, the uncertainties linked to the climate change scenarios (mainly for precipitation), the need for a better integration of studies as well as the necessary links between science and decision makers were underlined as major challenges for Africa. It is during the 3rd assessment report that specific chapters were dedicated to regions, Africa being one (Desanker et al., 2001). In this report, the main concern is relative to potential impacts of climate change and vulnerability for 6 sectors considered (water resources, food security, natural resources and biodiversity management, health, human settlements and infrastructure, desertification), adaptation strategies being considered for each of these sectors. The fact that desertification was considered as a sector expressed the threats of desertification and droughts on the economy of the continent. Globally, most of the adaptation options suggested was linked with a better management of the different resources. The main gaps and needs were identified like capacity building, data needs, and the development of integrated analysis as well as the consideration of other languages. The 4th assessment report just confirmed the vulnerability of the continent to the impacts of climate change mainly due to its low adaptive capacity (Boko et al., 2007). It first considered the different sources of the actual vulnerability of the continent, encompassing socio economic causes (demographic growth, governance, conflicts, etc.). Then the report examined the impacts of climate change on 8 sectors (energy, tourism and coastal zones are considered separately). The potential impacts of extreme weather events (not only droughts but also floods) were also considered. The question of the costs of adaptation was raised as well as the need for mainstreaming climate change into national development policies. Two case studies were analyzed on food security and traditional knowledge, the first emphasizing the fact that climate change could affect the three main components of food security while the second case study allowed to show that African tried to face climate variability, although it is considered that this knowledge could be insufficient to face climate change impacts. A list of needs was also identified regarding future studies: better knowledge of the climate variability, more studies needed on the impacts of climate change on water resources, energy, biodiversity, tourism, health, the links between different sectors (for example between agriculture, land availability and biofuels), the need to develop links with the disaster reduction community, an increase in the interdisciplinarity for the analysis of climate change, the strengthening of institutional capacities.

22.1.3.2. SREX

(being considered)

22.1.3.3. Renewable Energy

There has been a number of ongoing researches on identifying the most sustainable regional renewable options for Africa owing to the rapid population growth and increase in industrial activities (Sambo, 2008; Chineke et al., 2010; Chineke and Okoro, 2010; Dike et al., 2011). The optimal inclination angle for harnessing the solar energy for some selected cities within the African region has been identified with the attendant opportunity of meeting the growing energy needs of the region (Dike et al., 2012). Also, it is identified wind energy as a viable renewable energy option (Dike et al., 2011b). Solar radiation conversion technologies in Africa includes solar thermal type (solar heating, drying, pasteurization, distillation, cooking, etc) and can be supported by the technical expertise existing within the continent. However, industrial infrastructure needs to be strengthened for effective utilization of the renewable energy resources.

Given an average solar radiation level of about 5.5 kWhm–2day-1, and the prevailing efficiencies of commercial solar-electric generators, if solar collectors or modules were used to cover 1% of Nigeria’s land area of 923,773km2, it is possible to generate 1850x103 GWh of solar electricity per year. This is over one hundred times the current grid electricity consumption level in most parts of Africa. Solar thermal applications, for which technologies are already developed in Nigeria, include: solar cooking, solar water heating for industries, hospitals and households, solar evaporative cooling, solar crop drying, solar incubators and solar chick brooding. An excellent example of integrating renewable energy generation into a national utility service is available from Mauritius (UNIDO, 2007). Although reduction in carbon emissions has not been a primary reason for introducing renewables in Africa, however, such environmental reasons are seen as increasingly important (Foster-Pedley et al., 2006; Nwofor et al., 2007), In Africa also, current pattern of energy use is environmentally damaging and unsustainable, and the existing environmental problems are closely linked to energy systems. Africa has substantial renewable energy sources that could be harnessed to meet energy needs of various sectors if there is political will (Chineke and Ezike, 2010).

Mostly solar, wind (Fadare, 2008; Chineke, 2009) and biomass technologies and applications have been tested and demonstrated in Egypt that has excellent solar energy availability with the annual global solar radiation between 900-2600 kWh/m2. Over 65% of the total energy saving by renewable energies in the last decade was due to the commercialization of solar thermal technologies, mainly domestic solar water heaters. Ghana is endowed with several renewable energy resources like solar radiation, small hydro, biomass, and wind. Technologies to harness most of these resources except small hydro and wind have been demonstrated. Biomass is the dominant source of energy in Africa with about 69% of the total national energy consumption being accounted for by biomass in either direct or processed form. The biomass technologies demonstrated in Ghana for example include pyrolysis, improved cook-stoves, biomass fired dryers, sawdust briquette, improved charcoal production, biogas and cogeneration (Sambo, 2008).

Studies like Chineke (2011) and Nwofor et al., (2007) observed a high correlation between energy available to the African populate and their standard of living in extension their life expectancy because it has a ripple effect on the production of goods and services in the nation's industry, transport, agriculture, health and education sectors, as well as an instrument for politics, security and diplomacy (UN, 2006; Chineke and Nwofor, 2007; Chineke and Igwiro, 2008; Kuku, 2009; Dike et al., 2012). This deduction is a product of a critical analysis of energy sources available and their level of exploration. Africa, more especially West Africa has suffered rapid diffusion of disruptive technologies in the exploration of renewable energy resources abundantly available to her. The inadequate exploration of these resources has maintained a periodic swing between corruption in Africa and manufacturing of substandard renewable energy conversion systems for the African market in the developed Nations although the three major barriers to the adoption of renewable in Africa are policy and legal barriers, technical and financial barriers.

Renewable energy technologies can play a major role in national development in terms of job creation and income generation as well as providing an environmentally sound energy service. Aggressive lobbying for renewables at national, regional and sub-regional levels is required (Legros et al., 2009). A major task in Africa is the provision of electricity to rural communities distant from a utility network grid. With nearly 1 billion people, An example of empowering the rural poor in Africa can be through the use of photovoltaic energy. These can include central station village power-supply systems, battery charging stations, solar Home Systems. In any case a good energy strategy must satisfy these objectives: Low cost, diverse supply, and drastically reduced carbon dioxide emissions.

22.2. Observed Climate Trends and Future Projections

Generally, it should be noted that shortage of quantitative data, in addition to uncertainty about changes in the magnitude and frequency of extreme climatic events, means high levels of uncertainty. This consequently necessitates careful handling of any data on implications of climate change in Africa (Seo and Mendelsohn, 2008).

It is widely accepted that Global Circulation Models (GCMs) are the best physically based means for devising climate scenarios. They reproduce the global and continental scale climate fairly well but often fail to simulate regional climate features required by hydrological (catchment scale) and national (country scale) impact studies. The main reason for this gap, between the spatial scale of GCM output and that needed for impact studies, is the coarse spatial resolution of GCMs which restricts their usefulness at the grid-size scale and smaller. Other reasons include inadequate parameterization of several processes regarding cloud formation and land surface interactions with the atmosphere (Elshamy et al., 2009).

22.2.1. Temperature

22.2.1.1. Observed Trends

The change in temperature over Africa during the last 100 years has mirrored what is shown by global datasets (IPCC, 2001; Ben Mohamed, 2011; Clark, 2006; Conway and Schipper, 2011; Grab and Craparo, 2011; Hoffman et al., 2011; Kniveton et al., 2009) with a warming of 0.5 °C century–1. As with the global record, warming occurred rapidly in the 1910s–1930s and post 1970s. Spatially, the warming trend has dominated most of the continent with some areas of cooling around Nigeria/Cameroon in West Africa and along the coastal areas of Senegal/Mauritania and South Africa.

Collins (2011) examined satellite retrieval measurements of near-surface air temperature and found noticeable warming over all areas of the continent during the 1979-2010 period. Using a Bayesian framework, Min and Hense (2007) found strong evidence for an anthropogenic signal in continent-wide temperatures over the full 20th century and even for the last half of the century. Such a signal also appears in the frequency of unusually hot seasons over most regions of Africa (Stott et al., 2011)

Over Southern Africa, although general trends suggest smallest long-term temperature increases along coastal regions and greater temperature changes over interior regions, recent temperature changes (1961–2008) over the Southwestern Cape and adjacent interior have been highly variable (Grab and Craparo, 2011). These changes are generally higher than the increases reported for other parts of the world (IPCC, 2007; Wand et al., 2008). Increases in maximum temperatures were greater and more common than increases in minimum temperatures (Hoffman et al., 2011).

The dryness of the Sahel since 1970 (Greene et al., 2009) has received particular attention. This drying appears to be driven by warming of the global ocean, with both the ocean responses to increased greenhouse gases and aerosols possibly important, partly amplified by local land-vegetation feedbacks (Giannini et al., 2008).

22.2.1.2. Projected Trends

The warming over Africa is very likely to be largerthan globally. As simulated with the AIB climate change scenario, surface warming is largest in desert regions, and relatively more modest in equatorial regions, where the increased radiative forcing is partly used to evaporate soil moisture (Giannini et al.,2008).

Recent temperature projections concluded that by 2020–2049, an increase in mean annual maximum temperature would reach 2.3°C under scenario B2 and 2.6°C under A2 in Sahel (Republic of Niger, 2009).

Warming will be associated for the whole of Ethiopia with greater frequency of heat wave events and is likely to lead to higher rates of evaporation (Conway and Schipper, 2011).

22.2.2. Precipitation

22.2.2.1. Observed Changes

Trends in rainfall over Africa show a less coherent pattern of change than temperature. Previous assessment from Hulme et al. (2001) relates modest increases (up to 10% century−1) in rainfall over most of equatorial Africa and the Red Sea coast. Drying trends have been most pronounced (>25% century−1) over some eastern and western parts of Sahel, with more modest drying trends along the Mediterranean coast and over large parts of Botswana, Zimbabwe and Transvaal in South Africa (Hulme et al., 2001).

For Africa, the start of the wet season is getting progressively later each year (Kniveton et al., 2009).

For Eastern Africa, the most prominent trend has been a tendency towards lower rainfall during the main growing season (March–May) (Funk et al., 2008). This result is at odds with the most recent IPCC assessment (IPCC, 2007), which anticipates precipitation increases.

Some studies have also identified downward trends in many parts of Ethiopia and wider Horn, however, reviews of recent literature show that the situation is non-uniform and is highly sensitive to which region/period of time is used for analysis. There is little evidence for consistent changes in the frequency or intensity of extreme events in Ethiopia (Conway and Schipper, 2011).

For southern Africa, number of studies has documented long-term changes in observed rainfall. However these analyses return contradictory results. Some studies which state a decline of rainfall on both annual and monthly bases agreed with previous IPCC analyses, which anticipate rainfall declines. (Funk, et al,2008; Batisani and Yarnal, 2010). In contrast, few studies noted no overall wetting or drying (Mazvimavi, 2010), but did report an increase in inter-annual rainfall variability during the 20th century. Moreover, the number of rainy days has decreased across the sub region, especially in the drier areas.

Recent updates of rainfall trends across the West African Sahel confirm a decrease in rainfall associated with a decrease in number of rainy days (Ben Mohamed, 2011).

The observations made in West Africa reveal a clear depreciation or outright disappearance of the length of the August break which defines the bimodal nature of the rainy season in the southern part of Nigeria. The 2 to 3 weeks of traditional break (in rainfall) is gradually fading away and replaced by a 2 to 3 days break which is not significant enough (Chineke et al., 2010).

22.2.2.2. Projected Changes

There is no consensus among the 17 GCMs used in AR4 on the direction of precipitation change. Changes in total annual precipitation range between –15% to +14% but more models report reductions (10) than those reporting increases (7). Several models (6) report small changes within 5%. The ensemble mean of all models shows almost no change in the annual total rainfall (Elshamy et al., 2009).

The precipitation signal is less clear. Over Africa, in the A1B climate change scenario multi-model mean in precipitation suggests more intense rainfall in equatorial regions and drier conditions elsewhere, but this prediction is not unanimous across models: it is more robust in eastern equatorial Africa, where a majority of models agree on a trend towards wetter conditions, but less certain in southern Africa, where there is much scatter in the model solutions. A drying towards the west of southern Africa during summer is expected while eastern southern Africa will experience an increase in rainfall during late summer. The projected rainfall decreases are associated with decreases in the number of rainy days and in the average intensity of rainfall. These results broadly agree with the scenario, displaying trends towards decreasing rainfall (including significant decreases during winter months of southern Africa) and decreasing numbers of rainy days (Giannini et al.,2008; Hewitson, 2006; Batisani and Yarnal, 2010).

Climate change rainfall scenarios suggest the annual rainfall will decrease by up to 5% in southern Africa and this will be experienced in Namibia, Mozambique, and parts of Zimbabwe and South Africa while parts of the region lying towards the east may experience an increase in rainfall (Hewitson and Crane, 2006). Such changes have been observed around the region with temperatures rises and decreased rainfall recorded in most parts of the region (Dube and Chimbari, 2009; Matondo, 2010). It has also been predicted that the wet season in both EARV and southern Africa will shorten and become less reliable; a prediction that has been noted in the past decade and mostly the past 5 years. The change in the climate has contributed to decreased water supply for different uses such as irrigation, potable water for drinking, hydroelectricity, aquaculture, fishing, navigation and tourism in EARV and southern Africa (Odada et al., 2006; Christensen et al., 2007). In most parts of EARV and southern African region, potential evaporation is almost twice as high as rainfall totals, with the consequence that generally less than 15% of the rainfall contributes to rivers and groundwater (Mwendera, 2010).

Empirically downscaled climate change SRES A2 scenarios for southeast Africa for the 2046–2065 period confirm a reduction in rainfall during early summer and an increase in late summer. The increase in late summer rainfall which is seen in total, number of rain days and median rainfall events, can be expected over widespread areas than decrease in early summer (Tadross et al., 2009).

There is no agreement on whether the Sahel, Ethiopia and the wider Horn region will be drier or wetter in the future (Giannini et al.,2008; Conway and Schipper, 2011).
It is argued that none of the models was able to simulate current climate variability over these regions. The current challenge is to understand the complex interplay between oceanic and continental, local and remote influences of variability and change over Africa (Giannini et al.,2008; Conway and Schipper, 2011).

It should be noted that these generalised projections are highly time- and space-dependent. Some of the projected changes are also more clearly apparent in the statistics of daily rainfall as opposed to changes in total rainfall e.g. changes in rainfall intensity and number of rain days may influence total rainfall in opposition to each other (Hewitson, 2006).

22.2.3. Extreme Events: Regional Temperature and Precipitation Plots for Africa

Observed and simulated variations in past and projected future annual average precipitation and temperature are shown in Figure 22-1 for five political/economic African regions (here the northern half of COMESA starts with Rwanda, Uganda, and Kenya). Generally the observed regional temperature variations reflect global changes, which warming from 1901 to 1940, followed by a relatively stable period until 1970, and then steady warming thereafter. Consistent with simulations available for the AR4 (Christensen et al. 2007), simulations of global climate models driven with observed changes in all known external drivers (pink band) envelope this warming in all five regions. The 1901-1940 warming in these simulations is partly distinguishable from what would have been expected if anthropogenic activities had not interfered with the climate, as estimated by simulations with observed changes in natural external drivers only (blue band). In all five regions there is a distinct difference by the beginning of the 21st century, which is projected to continue to widen if emissions broadly follow the SRES A1B and RCP4.5 emissions pathways (green band). In contrast, precipitation has generally remained steady, relative to its year-to-year variability, without major changes driven by anthropogenic emissions in either the past or future as estimated from the climate model simulations. Slight exceptions are an observed dry period over ECOWAS during the 1970s and 80s (Greene et al. 2009, Hoerling et al. 2006) and a simulated drying of about 15% over the 150-year period over UMA.

[INSERT FIGURE 22-1 HERE
Figure 22-1: Observed and simulated variations in past and projected future annual average precipitation and temperature.]

22.3. Vulnerability and Impacts

In this section we are trying to present how Africa is vulnerable (given the fact that the main drivers of this vulnerability didn’t change from what is described in chapter 9, AR4) and what could be the main impacts of climate change on natural resources and ecosystems (on which the continent is dependent), as well as on different economic sectors. Figure 22-2 summarizes the main findings regarding how changes in ecosystems, sectors as well as climate parameters (mainly temperatures) are observed and how much of this can be attributed to climate change.

[INSERT FIGURE 22-2 HERE
Figure 22-2: Detection and attribution of changes in different regions of Africa (from Chapter 18).]

22.3.1. Socio-Economic and Environmental Context

Africa is the poorest continent in the World. Available data indicate that rural areas are facing endemic poverty that can jeopardize the development process. Sustainable development and its implications constitute a key issue in Africa. A major topic is population growth which is an obstacle to the achievement of Millennium Development Goals (Ferry, 2007; Andrews, 2008; Mwabu and Fosu, 2010; UNFPA, 2009). Actually African population doubled since 1980 and now exceeds one billion people. By the year 2040, it is expected to reach 1.4 billion. Two times faster than the population increase in America and Asia, this growth is a social and economic challenge. With a growth rate estimated at 4.9% the African Economic Outlook finds that the continent is on the rebound and expects its growth performance in the next years to resume at pre-crisis levels (OECD, 2011). In the recent years, African countries have faced enormous difficulties that have led, in particular because of youth unemployment, to political unrest especially in North Africa.

Aggravated by the global crisis, the continuing decline in livelihoods is accompanied by widespread poverty (Adesina, 2010; Moyo, 2009, Easterly, 2009). To the needs of economic growth necessary to maintain a good living standard, rapid population growth is causing a lot of pressure on resources and, consequently, on the environment (ECA and AU, 2009).

In rural areas as well as in urban zones, the observed changes in the demographic composition and / or spatial distribution of the population affect the environment and development. African agriculture which is the main sector of activity depends on rain at 95% and only meets 70% population's needs (PNUE, 2008). Yet, even if climate change impacts the other climatic parameters such as temperature rise, wind speed, its most visible sign is seen in the pluvial variability. Repercussions are high on the cultivated plants growth's process. Thus agricultural production is influenced by factors such as rainfall variations (Yabi and Afouda, 2010) or the reduction of arable land. It should also be noted that competition in access to land has become an important issue of food security particularly since the emergence of foreign investors (Zorgho, 2011). Another concern is the urban growth that will result in a tripling of the number of urban dwellers in the next 40 years (UN Habitat, 2010). Lagos, Cairo and Kinshasa still form the vanguard of African mega-cities but cities like Dar es Salaam, Nairobi, Ouagadougou, Abidjan, Kano and Addis Ababa will experience growth rates of up to 50% in a decade. The urban explosion which is partly due to rural-urban migration poses already, in addition to old problems such as transportation or insecurity, formidable environmental challenges such as waste management (Oteng-Ababio, 2011), natural disasters (Dossou and Glehouenou-Dossou, 2007), etc. It is now widely established that the main challenge in the context of a controlled development is to combine a judicious use of resources that are dwindling every day in order to preserve the environment (UNEP, 2006). Although such topics as the fight against poverty, good governance and popular participation are now taken into account, it is disappointing that issues such as vulnerability to climate change do not occupy the place they deserve in projects and policies of States.

Despite significant efforts, made in particular to achieve universal education (goal 4), these will not be sufficient to allow African countries, especially those in Sub Saharan Africa, to meet the millennium development goals by 2015. Progress varied greatly at sub regional and national levels (UN et al., 2008; AfDB et al., 2010; WB, 2010). This illustrates how the Africa continent is vulnerable to climate change, being not able to reach development goals.

22.3.1.1. Multiple Interacting Stresses

[forthcoming]

23.3.1.2. Millennium Development Goals

Overall, the continent as a whole has managed to make significant progress in some MDGs, but progress made towards the attainment of other goals raises causes for concern. Furthermore, progress made so far towards the attainment of the MDGs varied greatly also at sub-regional and national levels in Africa (UN et al, 2008; ADB et al, 2010; WB, 2010).

Eradicate extreme poverty and hunger: About half of population of Africa, excluding North Africa, in 2008, would be living below the poverty line. Furthermore, poverty in rural areas, though marginally declining from 64.9% in 1998 to 61.6% in 2008, is about double the prevailing average in developing countries (ADB et al, 2010). This is compounded by the type of poverty prevailing in Africa, with a significant proportion of the poor in Africa is chronically poor and thus would require considerable efforts to pull them out of poverty and keep them out of it (ADB et al, 2010).

[INSERT FIGURE 22-3 HERE
Figure 22-3: Proportion of undernourished population, 2005-2007 (%). Source: UN, 2011.]

Furthermore, stagnant agricultural yields, relative to population growth, have led to a fall in per capita food availability since the 1970s (UN et al, 2008). This, in addition to, recent rise in food prices may not only aggravate food insecurity among the poor but also undermine recent development gains (UN et al, 2008). This may have meant that some 30,000–50,000 additional children may have died of malnutrition in 2009 in Sub-Saharan Africa because of the crisis (UNSCN 2009; WB, 2010; Friedman and Schady 2009). Nevertheless, projections for sub-

Saharan Africa are slightly better than previously expected, with the extreme poverty rate in the region is expected to fall below 36% (UN, 2011).

Unemployment rates in Africa, except for North Africa, has marginally declined from about 9.0% in 1990 to 8.0% in 2007, before going up gain to 8.2% in 2009. North Africa, although achieving higher rate of progress, its unemployment rates was 9.8% percent in 2009 (ILO, 2011).

Achieve universal education: This is the MDGs where Africa made most progress, but this experience has been mixed. Net enrollment rate has increased from 65% in 1999 to 83% in 2008, with Sub-Saharan Africa having the best record for improvement in primary school enrolment, achieving 18% improvements over the period 1999-2009, (UN, 2011). Nevertheless, considerable number of children, especially girls from poor backgrounds and rural communities do not have access to primary education (UN et al 2008).

However, there is considerable doubt that African countries, except for a few ones, are expected to meet primary completion rates and young adult literacy rates goals. The proportion of children out of school in African sub-regions, except for North Africa, grew marginally from 43% in 1999 to 46% in 2008. This means that as much as 31 million children who were school-aged were not enrolled in school in these African sub-regions (ADB et al, 2010). However, the number of children out of school fell from 106 million to 67 million between 1999 and 2009, about half of which live in sub-Saharan Africa (UN, 2011).

It was found that Northern Africa achieved the most progress, with an increase of 19%, while Sub-Saharan Africa showing significant improvements with an increase of 7%. However, this region remains the one with the lowest youth literacy rate at 72 % in 2009 (UN, 2011). This despite the fact that education beyond primary school is also critical to ensure sustained progress toward other goals such as full employment, poverty reduction, and health-related MDGs (ADB et al, 2010). It is argued that challenges remain in increasing access beyond primary education, improving the quality of education and addressing threats to education from natural disasters and civil conflict (UN et al 2008).

Promote gender equality and empower women: Africa has shown recently good progress concerning gender equality and empowerment of women. African sub-regions have been showing positive growth in Gender Parity Index in primary education, with West Africa attaining most progress, followed by North Africa and East Africa during the period 1991–2008. However, progress was slower in Central and Southern Africa (ADB et al, 2010). However, progress at secondary level and tertiary education is slow, which suggests that African countries, if present trends persist, are unlikely to reach the target of gender parity in secondary and tertiary education levels by 2015 (ADB et al, 2010).

In terms of equality in employment, African countries still have a lot to do to attain such equality. Sub-Saharan Africa is partially undermined by the fact that non-agricultural wage employment represents only a minor share of employment for both men and women. The situation in Northern Africa has remained practically unchanged since 1990, with less than one in five paid jobs outside the agricultural sector are held by women (UN, 2011). Global crises, including the financial crisis of 2007/08, may contribute to a surge in informal employment, due to job losses in the formal sector. In some developing countries, including African ones, large proportion of workers with the informal jobs are women, which mean that women could be adversely affected by such crises (ADB et al, 2010).

Health: Overall, child mortality in Africa has experienced downturn decline but not to the extent of attaining the goal for child mortality. However, experiences from other regions and even among countries in Africa may suggest that this goal is still achievable. Mortality of infants under one-year-old per 1,000 live births in the same year has, for instance, shown a decline from 102 to 75 deaths per 1,000 live births between 1990 and 2009 (ADB et al, 2010). Furthermore, the number of countries with an under 5 mortality rate (U5MR) below 100 deaths per 1,000 live births increased from 17 countries in 1990 to 23 countries in 2009 (ADB et al, 2010). Some of the poorest African countries, including Ethiopia, Liberia, Madagascar, Malawi and Niger, have made significant progress experiencing absolute decline of more than 100 per 1,000 live births since 1990 (UN, 2010). This meant that in terms of the actual number of infant mortality a decline from 2.64 million in 1990 to 2.59 million in 2009 for the continent as a whole (ADB et al, 2010). However, sub-Saharan countries have experienced as much as twice the average U5MR in developing regions and around 18 times the average in developed regions (UN, 2011). Moreover, it was suggested according to the United Nations Inter-agency Group for Child Mortality Estimation (IGME), that out of the 31 countries recording U5MR of at least 100 deaths per 1,000 live births in 2009, 30 were in Africa (UNICEF, 2010).

In terms of maternal health, most maternal deaths in the world are concentrated in sub-Saharan Africa, as well as Southern Asia, together accounting for 87 per cent of such deaths globally in 2008. Sub-Saharan Africa has experienced a slow progress, with only a decline of only 26% in maternal mortality between 1990 and 2008, though evidence suggests that progress has picked up speed since 2000 (UN, 2011). Women in sub-Saharan Africa, where maternal mortality is high and access to skilled care during pregnancy and at childbirth is limited, continue to have the lowest level of contraceptive prevalence (22%), with little progress reported since 2000 (UN, 2011).

Efforts to combat HIV and AIDS, tuberculosis, and malaria under MDG 6 have, meanwhile, led to significant advances in preventing and treating these diseases (ADB et al, 2010). However, experiences have been mixed with progress recorded concerning reduction in the tuberculosis (TB) death rate in Southern Africa and improved access to insecticide-treated bed-nets (ITNs) to prevent malaria. TB prevalence in West Africa is, meanwhile, has been increasing. Furthermore, malaria is still endemic in most African countries and represents a major cause of morbidity and mortality.

In terms of HIV and AIDS prevalence rate in Africa (excluding North Africa), it was estimated that it has decreased from 5.9% in 2001 to 5.0% in 2009. Such a decline, nevertheless, has not, due to population growth, led to a decrease in the actual number of people living with HIV and AIDS, with the number of those living with HIV and AIDS increasing from 20.3 in 2001 to about 22.5 million in 2009. This mean that despite that the annual number of new HIV infections has been steadily declining since the late 1990s, this decrease is offset by the reduction in AIDS-related deaths (1.3 million in 2009 compared to 1.4 million in 2001). It was suggested that despite the overall positive trend in this respect, progress is mixed among countries and some of them have recorded setbacks, both in terms of prevention and treatment. This suggests that the continent is largely falling short of this target (ADB et al, 2010).

Ensure environmental sustainability: Africa’s performance on environment indicators has been mixed. For instance, Africa has, along with South America, experienced the largest net losses of forest areas between 2000 and 2010 (UN, 2011). The rich biodiversity of the forests remains endangered by the high rate of deforestation and forest degradation as well as a decline in primary forests. Deforestation in Africa over the periods, 1990 – 2000 and 2000 – 2010, has accounted for 4.1% and 3.7% of total forest area, respectively (UN, 2011). However, 34 countries have over the period 1990 – 2009 had registered improvements in the proportion of protected terrestrial and marine areas. By 2009, a total of 23 countries had reached the target of having at least 10 percent of their territorial and marine areas protected, compared to 19 countries in 1990 (ADB et al, 2010).

[INSERT FIGURE 22-4 HERE
Figure 22-4: Net change in forested area between 1990 and 2000 and between 2000 and 2010 (Mha yr^{-1}). Source: UN, 2011.]

Population with access to safe drinking water increased from 56% to 65% between 1990 and 2008, with Sub-Saharan Africa nearly doubled the number of people using an improved drinking water source—from 252 to 492 million over the same period. Northern Africa is, meanwhile, the only region that has already exceeded the MDG sanitation target, increasing coverage from 72% to as much as 89% between 1990 and 2008 (UN, 2011). However, there exist significant disparities in access between urban and rural with rural residents experiencing relatively less access to improved water facilities, with coverage rates of less than 50% in rural areas decreased from 26 to 17 countries between 1990 and 2008. This means that the progress in access to safe drinking water has largely been driven by the urban sector.

Use of improved sanitation facilities is generally low in Africa, at just 41 percent in 2008, reaching 41% in 2010 compared to 36% in 1990. This means that for African countries to reach such an MDG need to extend the coverage of the provision of improved sanitation facilities from an estimated 242 million people in 2006 to an additional 370 million people.

Concerning the proportion of urban population living in slums, Africa has the largest slum population worldwide, with 211.3 million persons, representing as much as 75% of its urban population living in slum areas. In North Africa, 13.3% of its population lives in slums, but in the rest of the continent the proportion is much higher, at 61.7% (UN-Habitat, 2010). In terms of progress, the lives of 24 million slum dwellers have improved during the last decade through improvements in housing conditions and better access to amenities such as water supply and sanitation. However, there has been a reduction of only 5 percent in the number of slum residents in Africa (excluding North Africa). North Africa, on the other hand, has made the greatest progress by improving the lives of 8.7 million, or 34.9%, slum dwellers (UN-Habitat, 2010).

Develop a global partnership for development: Progress in implementing the aid effectiveness agenda outlined in the Paris Declaration remains too slow. In particular, development partners need to overcome donor fragmentation; promote collaboration and complementarity, including a clearer division of labor; align their financing more clearly with country systems, strategies and policies; and increase budget support where possible (UN et al, 2008).
In conclusion, the continent has the modest progress in terms of the attainment of MDGs. This is can be attributed to a number of factors including;

- The adverse effects of the global financial, food and fuel crises
- Conflicts in the continent have inhibited the capabilities of nations experiencing conflicts or in post-conflict phase in attaining MDGs.
- Favorable trends in poverty reduction were reversed by global shocks and the absolute number of the working poor is on the rise. Indeed.
- Limited financial resources, for example, rising primary enrollment rates have not been matched by a proportionate increase in primary school completion rates, which also impacts the literacy

Furthermore, aggregate trends in Africa’s progress toward the MDGs conceal high levels of spatial and group disparities, with progress on all indicators is skewed in favor of higher-income groups and urban populations, which means further marginalization of already excluded groups.

It is worth mentioning that such slow progress in attaining most MDGs may contribute to a reduced resilience and adaptive capabilities of Africans and consequently increase vulnerability to climate change. Climate change may meanwhile impact already slow progress being made to attain the MDGs in Africa. Climate Change may for instance affect economic performance in general and reduce further livelihood assets of the poor including increased food insecurity. Climate change may adversely affect health conditions in Africa through the spread of vector-borne diseases and lack of water resources. All such impacts may in turn reduce education enrollment and completion rates. Such conditions would require enhanced global partnership in order to enable African countries to make rapid progress in attaining MDGs and increase their resilience to the impacts of climate change.

22.3.2. Ecosystems

22.3.2.1. Terrestrial

A shift in the geographic location or extent of a biome (major vegetation formation; Woodward et al., 2004) can signal a substantial change in climate and fundamentally alter habitats and the provision ecosystem services to people. While field research has detected elevational and latitudinal shifts of biomes around the world (Gonzalez et al., 2010), only a few research studies have examined biome shifts in Africa. At sites across West and Central Africa, field research on tree species distributions from 1960 to 2000 detected a southward shift of three biomes - tropical savanna (Sahel), tropical woodland (Sudan), and tropical deciduous forest (Guinea) – and attributed the shift to anthropogenic climate change (Gonzalez et al., 2012). Field data from Burkina Faso also suggest possible southward biome shifts of the Sahel and Sudan consistent with, but not formally attributed to, climate change (Wezel and Lykke, 2006; Maranz, 2009).

A number of studies indicate that precipitation is the primary factor determining tree cover in African savannas, woodlands, and forests (Bucini and Hanan, 2007; Sankaran et al., 2008; Good and Caylor, 2011; Greve et al., 2011). Disturbances that substantially modify the climatic limits of biomes include fire (Bucini and Hanan, 2007; Sankaran et al., 2008; Staver et al., 2011; Favier et al., in press), grazing (Bucini and Hanan, 2007; Sankaran et al., 2008;

Groen et al. 2011), agricultural cultivation (Bucini and Hanan, 2007; Ellis et al., 2010), and timber harvesting (Ahrends et al., 2010).

Projected changes in precipitation and disturbance under climate change may substantially alter the extent and locations of biomes. Projections of potential future vegetation indicate wide vulnerability of ecosystems in Africa to future biome shifts. A set of dynamic global vegetation models (DGVMs) and one equilibrium model project biome changes on 5-10% of land in Africa from ~1990 to 2100 for a range of the CMIP3 GCM runs of the IPCC SRES emissions scenarios (Hely et al., 2006; Scholze et al., 2006; Alo and Wang, 2008; Delire et al.; 2008; Sitch et al. 2008; Scheiter and Higgins, 2009; Gonzalez et al., 2010; Bergengren et al., 2011). An analysis of the vulnerability of ecosystems to biome shifts that combined 1901-2002 historical climate changes and 1990-2100 DGVM projections estimated that 12% of African land area is highly to very highly vulnerable to biome shifts and that over 100 million people live in those areas (Gonzalez et al., 2010) (Figure 22-5). An equilibrium vegetation model analysis for West Africa estimated that, under the A2 emissions scenario, ~10-50% of land in Africa is vulnerable to biome shifts (Heubes et al., 2011). Projections generally agree on latitudinal shifts of vegetation, degradation of tropical biomes, and vulnerability of the unique biomes of South Africa. An earth system model forced by 15 CMIP4 GCM runs projects an expansion of warm deserts globally of 10-34% by 2100, with much of this occurring as a southward expansion of the Sahara (Zeng and Yoon, 2009). Niche modeling of tropical rainforests under 4ºC of warming projects expansion in Africa up to 50% of rainforest area for 14 CMIP3 GCM runs and contraction up to 15% of rainforest area for 3 CMIP3 GCM runs (Zelazowski et al., 2011). The Congo rainforest generally shows resilience, due to high temperature tolerances and mitigation of water stress by increases in equatorial precipitation (Zelazowski et al., 2011).

[INSERT FIGURE 22-5 HERE
Figure 22-5: (a) Potential changes in vegetation under projected 2071–2100 climates where any of nine GCM–emissions scenario combinations project change. (b)Vulnerability of ecosystems to biome shifts based on historical climate and projected vegetation. Source: Gonzalez et al., 2010.]

As a first order response to continental warming, species may be expected to shift their ranges poleward and up mountain slopes however it has been difficult to directly attribute this shift to climate change. Hockey and Midgley (2009) and Hockey et al. (2011) do find some South African bird species have moved farther south over recent decades, but that many of these shifts can be explained by other factors; in particular, there is evidence of a very strong response to recent and ongoing land-use change. Foden et al. (2007) find that an aloe of the Namib is experiencing a range contraction which is consistent with increased heat-related mortality at its warming tropical extreme coupled with an inability to expand poleward quickly enough to compensate. Meanwhile, Raxworthy et al. (2008) note a general upslope movement of amphibian species on a Madagascan massif for which local warming appears to be the most parsimonious explanation.

22.3.2.2. Freshwater

Africa can be divided into 12 river basins and several hydro-ecological zones and all these regions are very sensitive to changes in climate. Higher temperatures and increased rainfall variability will have different types of impact across Africa. In terms of direct impact on society, some areas are likely to become winners for certain projected changes and new water related opportunities will arise, while other areas are likely to become losers and face more water related stresses (see Box 22-1). Scientific research on freshwater ecosystems however is limited to few regions within Africa. For example, since AR4 scientific studies have focused on implications of climate change on projected impacts on specific river systems in North Africa, freshwater ecosystems in East African Rift Valley (EARV) region, groundwater resources, and desertification in Sahel area.

22.3.2.2.1. Projected impacts on river systems in North Africa

Considerable uncertainty remains over the consequences of climate change on river flows in North Africa. For example, studies have found no consensus in direction of change in stream flow between 7 GCMs at a catchment of the White Nile (Kingston, & Taylor 2010), for 17 GCMs on the direction of change in precipitation around the upper Blue Nile (Elshamy et al 2009). A mild average increase (+4%) in the upper Blue Nile flows by 2050 for an ensemble of 6 GCMs was found (Kim and Kaluarachchi 2009) while no consensus in 17 GCMs under the A1B and B1 scenarios for outflows in the Lake Tana (Blue Nile) catchment by 2050 was found, although outflows at Lake Nyando (White Nile) were expected to increase by 2050 (Taye et al 2011). An ensemble of 11 GCMs was used to simulate flows reaching the Aswan High Dam Lake and it reported mean flows between 2010-2039 would increase by +11% for the A2 scenario and by +14% for the B1 scenario, but would decline by the period 2079-2090 by -16% for A2 and -13% for B1 (Beyene et al 2010). However, although the general trend of decline over time was consistent, there was considerable variation in the magnitude of change between models. Aerts et al (2006) found a small reduction in Nile flows of -2% over the course of the 21st century. In aggregate, these studies suggest that flows may remain stable or slightly increase initially, but may decline slightly by the end of the century.

Some studies, although limited by the number of scenarios and models included, have predicted an increase in seasonality of Blue Nile flows, with increasing flows in summer months and declining dry season flows (Soliman et al 2009; Beyene et al 2010). There are also indications ($p=0.9$) that annual variability is linked to ENSO indices, with El Nino leading to dry years and high rainfall and runoff during La Nina years (Abtew et al 2009).
Much of this uncertainty is due to challenges in integrating climatological and hydrological models, the coarse resolution and crude description of land-surface climate feedbacks in current models, and complex and sensitive relationships between rainfall, runoff, potential evapotranspiration (PET), seasonality, land-use and river flow, which vary across the Nile basin (Conway et al 2009; Elshamy et al 2009; Beyene et al 2010; Kingston, & Taylor 2010; Taye et al 2011).

22.3.2.2.2. Impact on freshwater ecosystems in East African Rift Valley (EARV)

The EARV and most parts of southern Africa are already experiencing high variability in rainfall and river flows and changes to the geographical distribution of water resources, with the arid to semi-arid areas becoming drier, while other areas are becoming wetter (Kundzewicz et al., 2007). Saline lake Beseka in the arid Ethiopian rift valley for instance has quadrupled from 11.1 km2 in 1973 to 39.5 km2 in 2002 due to increased discharge of hot springs (Goerner et al., 2009).The southern African sub-region on the other hand is experiencing flooding in the northern and southern parts and episodes of severe and prolonged droughts at greater frequencies (also associated with El Nino/Southern Oscillation (ENSO) phenomenon, and this bears impacts on the surface water resources (Beekman and Pietersen, 2007).

Much of what is happening to freshwater resources across this region is attributable to increased years of drought particularly in the past two decades (Hewitson and Crane, 2006; Alley, et al., 2007; Boko et al., 2007) which in turn are reducing river inflows (from reduced run-off), and rising temperatures that are causing increased evaporative water loss. However, other factors such as deforestation, soil erosion and domestic and industrial pollution among others are also observed as important drivers in the reductions in water quality and quantity around the regions (Hecky et al., 2010; Ndebele-Murisa et al., 2010; Beck and Bernauer, 2011; Haande et al., 2011). Nevertheless, the amount of water inflow for rivers like the Congo, Nile, Zambezi and Orange and Vaal Rivers are determined mainly by the amount of rainfall within their catchments, a process that is influenced by temperature.

In addition to changes in river inflows, declining levels of water have been observed in the freshwaters of this region. Water levels are influenced by evaporation rates with low troughs corresponding to drought periods (Ndebele-Murisa et al., 2011a and b). Reductions in water levels have also reduced habitats of aquatic organisms particularly of shoaling fish and adversely affects hydroelectricity production for such reservoirs as Kafue (Zambia), Kariba (Zambia/Zimbabwe), Caborra Bassa (Mozambique), and for stations along the Nile and Shire Rivers in Uganda and Malawi respectively the latter depending on the flow from lake Malawi (Mukheibir, 2007). Small variations in climate cause wide fluctuations in the thermal dynamics of freshwaters (Odada et al., 2006; Stenuite et al., 2007; Verburg and Hecky, 2009; Moss, 2010; Olaka et al., 2010). Thermal stratification in the regions' lakes for instance isolates nutrients from the euphotic zone, and is strongly linked to hydrodynamic and climatic conditions (Sarmento et al., 2006; Ndebele-Murisa et al., 2010). Elevated water temperatures as a consequence of elevated air temperatures attributed to global warming have been reported in surface waters of lakes like Lake Kivu, Vicotria, Malawi (Figure 22-6). In these cases moderate warming is reducing lake water inflows and therefore nutrients, destabilising plankton dynamics, thereby adversely affecting food resources for higher trophic levels of mainly planktivorous fish (Magadza 2008, 2010; Verburg and Hecky, 2009; Ndebele-Murisa et al., 2011a).

[INSERT FIGURE 22-6 HERE
Figure 22-6: Changes and impacts observed in freshwater lakes of Africa.]

In addition to strengthening the thermocline and density stratification, climate warming is leading to declining depths of light transparent epilimnions in a number of the regions’ freshwaters, due to upward shifts in thermoclines in response to elevated temperatures. This bears potential cascading effects on the aquatic ecosystems by reducing available nutrients in the upper waters thereby limiting biological production (Magadza, 2006, 2011; Ogutu-Ohwayo and Balirwa, 2006; Verburg and Hecky, 2009; Bootsma, 2006; Hecky et al., 2010; Ndebele-Murisa et al., 2010; Tierney et al., 2010, Urama and Ozor, 2010).

22.3.2.2.3. Groundwater

There are significant uncertainties regarding the extent to which climate change may impact future groundwater supplies in Africa. Analyses conducted since the AR4 (Calow and MacDonald, 2009; MacDonald et al., 2009) indicate that climate change may have no effect on future groundwater resources in areas receiving up to 200 mm per year, such as in northern Africa, where low levels of current rainfall have no substantive effects on groundwater recharge and projected changes in rainfall are not expected to change recharge rates; analysis by Moustadraf et al (2008) corroborates this. Other studies from the northern Africa region reported a strong link between future climate and aquifer recharge (Ibrahimi et al 2010; Chamchati, & Bahir 2011). Groundwater recharge in areas that receive more than 500 mm per year may also not be significantly affected by climate change where, under current extraction rates, sufficient recharge would remain even if rainfall diminished (Calow and MacDonald, 2009; MacDonald et al., 2009). By contrast, areas receiving between 200 to 500 mm per year, including the northern Sahel, the horn of Africa and parts of southern Africa, may experience a decline in groundwater recharge with climate change where prolonged droughts become more frequent. Areas in this rainfall zone have a current combined population of around 90 million people. Drought conditions that lead to insufficient groundwater recharge are compounded in places where shallow aquifers with low water storage capacity predominate (Barthel et al., 2009).

The capacity of groundwater delivery systems to meet demand may take on increasing importance with climate change even in areas where overall groundwater recharge may be relatively unaffected by climate change (Calow and MacDonald, 2009). For example, demands on groundwater can be expected to increase where surface water and shallow groundwater sources become less reliable, such as during prolonged dry periods. Also, where groundwater delivery infrastructure is poor, and the number of point sources limited, prolonged pumping can lead to periodic drawdowns and increased failure of water delivery systems. Expanding pumping capacity and improving and regularly maintaining pumping facilities, along with more accurate assessments of aquifer recharge potential will likely become more critical in areas where drought prevalence increases. Strategic coastal aquifers are also vulnerable to degradation from saltwater intrusion, possibly exacerbated by sea level rise. Whilst aquifers are already impacted by saltwater intrusion due to increased abstractions (Moustadraf et al 2008; Kerrou et al 2010; Bouchaou et al 2008), some studies have shown that the additional impacts of sea level rise on aquifer salinisation will be localised although salinity could reach very high levels (Carneiro et al 2010; Research Institute for Groundwater 2011).

While climate change may reduce groundwater recharge in semi-arid zones and more generally strain groundwater delivery systems and infrastructure in Africa, its impact on groundwater resources more generally could be relatively small when set against trends of population growth, urbanization, increased food demand, and land use change in Africa. The impact on groundwater from these non-climatic drivers may dwarf those effects directly attributable to climate change (Calow and MacDonald, 2009; Carter and Parker, 2009; MacDonald et al., 2009; and Taylor et al., 2009). For instance, rapid urbanization in Africa could significantly strain groundwater supplies to towns and cities (Carter and Parker, 2009). Competition between agricultural and non-agricultural users of groundwater may increase to the extent that increased household and industrial demands coincide with an expansion of irrigated agriculture. Fischer et al. (2007) estimated that even in the absence of climate change, irrigation water requirements in Africa could triple between 2000 and 2080 to meet future food demand. With irrigation viewed as an important adaptation strategy in rainfed cropping systems, actual water withdrawals for irrigation may be greater. Rainwater harvesting for domestic and agricultural uses, and measures to increase water productivity in agriculture, such as through improved management of crop biotic and abiotic stresses and adoption of drip irrigation could help to offset some of the increased demand resulting from expansion of irrigated production.

Future development of groundwater resources to address direct and indirect impacts of climate change, population growth, industrialization, and expansion of irrigated agriculture, will require much more knowledge of groundwater resources and aquifer recharge potentials than currently exists in Africa. Observational data on groundwater resources in Africa are extremely limited and significant effort needs to be expended to fully assess groundwater recharge potential across the continent (Taylor et al., 2009).

22.3.3. Coastal and Ocean Systems

There is an increased concern that coastal areas could suffer directly from climate change, not only through sea level rise, but also from a combination of high sea levels and storm swells (extreme events) (like it was experimented along the Durban coast in March 2007; Theron and Rossouw, 2008). Other climate change impacts (like for example an increased migration towards coastal towns due to increased drought induced by climate change; Rain *et al.*, 2011) will also affect coastal zones.

Considerable efforts have been done to assess the vulnerability of coastal zones to the impacts of climate change which are mainly focused on the impacts of sea level rise. Different approaches were used, including a risk approach for Cape Town (Cartwright, 2008a). Some of them are still qualitative (Naidu *et al.*, 2006), while others tried to quantify the impacts. These assessments are based either on a detailed survey of existing sea level trends through tide gauges (Mather, 2007; Brundrit, 2008; Mather *et al.*, 2009) or on analysis of historical trends in coastal retreat (Appeaning Addo *et al.*, 2008).

22.3.3.1. Impacts and Vulnerability

In Kenya, the impacts of climate change on the whole coastal zone were determined (SEI, 2009; see Figure 22-7), as well as for the town of Mombasa (Kebede *et al.*, 2012). By 2030, the population at risk of inundation in Mombasa, depending on the scenario used, is estimated to be between 226,780 to 299,550 inhabitants while economic assets at risk are comprised between 0.9 and 1.19 billion of US$.

[INSERT FIGURE 22-7 HERE
Figure 22-7: Population and economic losses in case of climate change for the whole Kenya coastal zone (SEI, 2009).]

The same type of assessment was done for Tanzania (Kebede *et al.*, 2010) and for Dar es Salaam (Kebede and Nicholls, 2011). For Dar es Salaam and by 2030, the population and economic assets at risk of extreme water levels (3.07 to 3.23 m), are respectively of 30,800 to 140,000 inhabitants and 35.6 to 404.1 million US$. The DIVA ((Dynamic Interactive Vulnerability Assessment) model was used to assess the impacts of sea level rise on the whole coast (3,461 km) of Tanzania and regarding non-monetary goods, it was found that by 2030, 1,924 to 7,624 km^2 will be lost, mainly through inundation; around 234,000 people per year could be inundated and between 67,000 and 852,000 people living in inundated areas will be forced to migrate. Regarding monetary costs, without adaptation, residual damages have been estimated between 20 and 42 million US$ per year of which around 2.7 million US$ could be lost due to the loss of wetlands (24% being mangroves).

In South Africa and for Cape Town, the risk assessment gave the results captured in Table 22-2 (Cartwrigth, 2008a).

[INSERT TABLE 22-2 HERE
Table 22-2: Table 22-2: Land inundated and economic impacts in Cape Town based on a risk assessment (Cartwrigth, 2008a).]

In Durban as well as in the town of Umhlathuze (Zitholele Consulting, 2009), the assessments were mainly qualitative but it was found that the proposed developing plans for tourism in Durban could be affected by sea level rise (Naidu *et al.*, 2006). In South Africa, all the authors recognize the fact that a development too close to the shoreline increases its vulnerability.

In the Southern Africa region, the following countries have also been considered (Cartwright, 2008b; Theron and Rossouw, 2008):

- Namibia where the coasts more vulnerable to sea level rise are located around the Walvis bay (with risks of breaching with potential consequences on the harbor and low lying places in the town). The diamond mining could also be affected;
- Mozambique: the risks are almost everywhere with potential impacts on the two main harbours (Maputo and Beira), but also problems with touristic infrastructure. There is also the fear that this could induce an increase in environmental refugees in South Africa. The risks induced by salinization, especially on agriculture, as well as on coral reefs are also considered.

Assessments were also developed for Western (Niang *et al.*, 2010; Appeaning Addo *et al.*, 2008) and Northern Africa (Snoussi *et al.*, 2009; World Bank, 2011) with the same conclusions as those for Eastern and Southern Africa.

22.3.2.2. Adaptation

In Cape Town, it is proposed to invest in adaptation measures that should be developed under an integrated coastal zone management plan. Different options (win win and additional options) as well as some decision tools (cost benefit analysis and combined options) and costs for some structures are suggested (Cartwright *et al.*, 2008) while Mukheibir and Ziervogel (2007) made suggestions to develop an adaptation strategy to climate change at municipal level. Moreover, Cartwrigth (2008b) suggested the need not to underestimate the role of communication as well as early warning systems. In Durban (Naidu *et al.*, 2006) as well as in the city of Umhlathuze (Zitholele Consulting, 2009), it is proposed that climate change and especially those changes affecting the coastline be included in the development plan of the towns. It is also recognized that the best option regarding adaptation in the coastal zone is not to combat coastal erosion in the long term but better let the natural processes progress.

The potential for adaptation to reduce the risks associated with sea level rise are estimated at 10 to 27 fold. Of course, adaptation will have a cost but this will be lower than the economic and social damages expected if nothing is done (Kebede *et al.*, 2010). For example, in Tanzania, the total costs of adaptation are estimated to be between 25 and 62 million per year of US$ by 2030 (Figure 22-8). It is also suggested that an integrated coastal zone management plan be developed.

[INSERT FIGURE 22-8 HERE
Figure 22-8: Total costs of adaptation per year from 2000 to 2100 for Tanzania (including beach nourishment, sea and river dykes) Source: Kebede *et al.*, 2010.]

The role of planning in the potentiality to reduce the vulnerability of coastal towns to climate change and particularly the problems of coastal flooding, is also underlined in Eastern Africa, based on the studies on Mombasa (Kenya) (Awuor *et al.*, 2008; Kebede *et al.*, 2012) and on Dar es Salaam (Tanzania)(Kebede and Nicholls, 2011). There is also a need to increase the implementation of laws and regulations, while increasing the sensitization of the population. It is considered that adaptation measures will requisite funding, political will and human capital (Awuor *et al.*, 2008). Based on the experience of Mombasa, Njue and Kimeu (2010) considered the traditional way of building which is adapted to the climate of the town. ICZM is considered as a suitable framework for climate change adaptation in coastal zones, countries having the possibility to use the experience from developed countries like UK

(Boateng, 2006). ICZM has been considered in the National Communications to the UNFCCC of Indian Ocean States (Kenya, Mozambique, Seychelles, Tanzania) (Wong, 2010).

Aylett (2010) based on the Durban experience indicated that the participative process – which is crucial for adaptation to climate change - must consider not only the consensus approach but also the role that conflicts can have in helping to change the way local governments consider the participation of the civil society. Due to the uncertainties, it is considered that a better knowledge as well as monitoring projects should be developed in order to understand the functioning of coastal systems and avoid maladaptation (Theron and Rossouw, 2008).

22.3.2.3. Marine Systems

In Africa, fisheries depend either on coral reefs or coastal upwellings. These two ecosystems will be affected by climate change through ocean acidification, rise in sea surface temperatures and changes in upwelling. Ocean acidification (OA) is the term used to describe the process whereby increased CO_2 in the atmosphere, upon absorption, causes lowering of the pH of seawater (Chapter on the oceans). The overall ramifications of OA in the marine environment are reviewed by Hoegh-Guldberg *et al*. (2007) and Fabry *et al*. (2008a). Projections indicate that severe impairment of reef accretion by organisms such as corals (Hoegh-Guldberg *et al*., 2007) and coralline algae (Kuffner *et al*., 2007) will rank amongst the most important consequences of anthropogenic production of CO_2. The combined effects of global warming and OA have been further demonstrated to lower both coral reef productivity (Anthony *et al*., 2008) and resilience (Anthony *et al*., 2011). These effects will have serious consequences for reef biodiversity, ecology and ecosystem services.

Most findings show that the consequences of OA will be deleterious to skeletal formation in marine calcifiers (e.g. Hoegh-Guldberg *et al*., 2007; Feely *et al*., 2004; Kleypas *et al*., 1999b; Marubini *et al*., 2001; Orr *et al.*, 2005), even affecting their stable isotope uptake (Krief *et al*., 2010). However, heavier calcification with OA has been demonstrated in coccolithophores (Feng *et al*., 2008; Iglesias-Rodriguez *et al.*, 2008) which, in turn, could positively affect climate change through increase in the albedo of the Earth's climate (Balch and Utgoff, 2009). It has similarly been demonstrated that an ophiuroid brittlestar will increase its skeletal deposition under OA, but at an increased metabolic cost (Wood *et al*., 2008). Further uncertainty regarding the effects of OA in the marine environment is introduced by the fact that the buffering capacity of the sea may increase in some areas with the gradual dissolution of marine carbonate reserves by acidification (Guinotte *et al*., 2003).

Regarding the status of aragonite saturation few measurements have been made in the western Indian Ocean (WIO) due to the need for sophisticated analytical equipment. While the effects of elevated sea surface temperatures (SSTs) are considered by a number of authors in discussing coral bleaching in the region (Goreau *et al*., 2000; Obura, 2005; Sheppard, 2003; McClanahan and Maina, 2003; McClanahan *et al*., 2007), only Schleyer and Celliers (2003) gave consideration to the consequences of OA on the high-latitude South African reefs. Global models have suggested that light, temperature and Ω_{arag}, particularly the last, should be limiting on these reefs (e.g. Kleypas *et al*., 1999a). Based on these projections, Schleyer and Celliers (2003) presumed that coral reef accretion would eventually be stopped by OA on the South African reefs, where accretion is already marginal. Grimmer (2011) found that the mean Ω_{arag} on South African coral reefs was to be 4.33±0.21. Other parameters like high turbulence, sediment re-suspension rather than cementation, high bio-erosion and competition between scleractinian and alcyonacean corals are thus responsible for low accretion on the reefs. This highlights the complexity of the situation, showing that in-depth studies are needed and conclusions cannot be drawn from simple mesocosm experiments.

OA is nevertheless a serious issue and together with coral bleaching resulting from climate change, it will have lasting effects on tropical reefs and other calcifiers. Of the world's coral reefs, 75% occur in developing countries where they support artisanal fisheries in some of the most populous areas (Pauly *et al.*, 2002). While these fisheries only contribute 2-5% to global fishery landings, they are an important protein source for coastal communities in developing countries (Pauly *et al.*, 2002). As these fisheries are already deemed unsustainable (McManus 1997; Pauly *et al.*, 2002; Newton *et al*., 2007), a further deterioration of coral reefs will have dire consequences for the food security of humans in these areas. In the WIO, the social adaptive capacity to cope with such change varies (McClanahan *et al*., 2009). The fisheries themselves are also likely to be directly affected by OA as it has been shown to be deleterious to fish larval development, growth, recruitment and survival (Baumann *et al*. 2011; Ferrari *et al.*, 2011; Franke and Clemmesen, 2011; Frommel *et al*., 2011).

Observed changes

An analysis of sea surface temperatures along the South Africa coast shows that during the winter the western and southern coast as well as the region of Port Elizabeth are cooling (-0.55°C/decade to – 0.35°C/decade), while in the system of the Agulhas current as well as along the Transkei zone it is warming (+0.55°C/decade) (Rouault et al., 2010). Globally, the Agulhas system is warming due to its intensification. Moreover, warm events are correlated with El Niño events (and the reverse), but the correlation is not always functioning. The ENSO has an influence on sea surface temperatures during the austral summer and autumn.

Observations of changes which are in agreement with the projections:

- Shannon and O'Toole (2003) found a progressive warming of the Benguela current region (+ 0.7°C between 1920 and 2003);
- Changes in the bird repartition (to be completed).

22.3.2.4. Key Processes and Trends

22.3.2.4.1. Desertification in Sahel area

Arid, semi-arid, and dry subhumid areas (where precipitation/potential evaporation = 0.05 to 0.65) cover 13 million km2 or >40% of the land area of Africa, based on 1951-1980 climatology (UNEP, 1997). This analysis has not been updated. Furthermore, no continent-wide analysis of land degradation using a consistent variable over time exists. One spatial analysis of 1981-2006 herbaceous vegetation data by the Global Assessment of Land Degradation and Improvement (Bai et al., 2010) indicates possible areas of recent degradation in southern Africa. This relatively short data series does not capture potential degradation since the beginning of the 20th century and does not directly analyze soil data. In Africa, research has documented the most severe desertification in the Sahel, so the most published information exists for that region.

A decline in rainfall (Dai et al., 2004; Chappell and Agnew, 2008) and an increase in temperature (IPCC 2013, Volume 1, Chapter 2) comprise the two principal forms of 20th and 21st century Sahel climate variability. Increasing sea surface temperature governs the rainfall decline (Giannini et al., 2003; Held et al., 2005; Biasutti and Giannini, 2006; Hoerling et al., 2006 ; Shanahan et al., 2009). Reduction of vegetation cover amplifies the decline through positive feedbacks between precipitation and vegetation via reduced evapotranspiration (Zeng et al., 1999; Taylor et al., 2011) and increased albedo (Charney, 1975). The Atlantic Ocean constitutes the primary source of water for the West African monsoon (Gimeno et al., 2010), while evapotranspiration from soils and vegetation maintains storm formation in the Sahel (Taylor, 2010; Taylor et al., 2011). Although lake sediment data indicate that 20th century drought in the Sahel falls within the magnitude of West African droughts during the past 2500 years (Shanahan et al., 2009), increased anthropogenic greenhouse gas forcing during the 19th and 20th centuries has increased sea surface temperatures, leading to the 19-20th century reduction in Sahel rainfall (Held et al., 2005; Biasutti and Giannini, 2006; Zhang et al., 2007). Sulfate aerosol emissions from industrialized areas of the Northern Hemisphere also explain a substantial portion of 1950-1980 precipitation declines in the Sahel (Ackerley et al., 2011).

Analyses of impacts of climate change and desertification on Sahel vegetation examine two types of trends: (1) short-term changes of grasses and other herbaceous vegetation since 1981 and (2) long-term changes in trees and other woody vegetation since the 1950s.

The remotely-sensed normalized difference vegetation index (NDVI; Tucker, 1979), an indicator of herbaceous vegetation, increased at many locations in the Sahel from 1981 to 2007 (Seaquist et al., 2006; Heumann et al., 2007; Ahmedou et al., 2008; Fensholt et al., 2009; Begue et al., 2011; de Jong et al., 2011). The length of the growing season decreased in that time, suggesting that a more intense, but shorter, season caused any increase in herbaceous vegetation (de Jong et al., 2011). In Mali, increased crop area may have contributed to the increase in NDVI (Begue et al., 2011). Rain-use efficiency (RUE; Le Houérou, 1984), the quotient of NDVI and rainfall, also seems to show increases at sites in the Sahel from 1981 to 2007 (Prince et al., 2007; Fensholt and Rasmussen, 2011). Correlation of RUE to rainfall and higher Sahel rainfall in the 2000s may explain increasing RUE, so the recent increase may not reflect a reversal of land degradation (Hein and De Ridder, 2006; Fensholt and Rasmussen, 2011; Hein et al., 2011).

Two characteristics of the NDVI data series constrain interpretation of the NDVI and RUE results. First, NDVI in the Sahel mainly tracks interannual variability of herbaceous vegetation (Anyamba and Tucker, 2005), but not necessarily the long-term condition of perennial vegetation (Gonzalez et al., 2012). Second, NDVI coverage began in 1981 at the time of a severe Sahel drought. Interdecadal variability of rainfall led to increases in the 1980s and 1990s, causing the NDVI time series to reflect a short-term rebound from the drought, but not necessarily a long-term recovery (de Jong et al., 2011; Fensholt and Rasmussen, 2011).

Tree density and tree species richness indicate vegetation condition over longer time periods than NDVI because trees often withstand years of stress before dying (Allen et al., 2010). Field counts of trees, historic aerial photos, and recent satellite images show that tree density has declined since the 1950s at sites in Mali (Ruelland et al., 2011) and Senegal (Vincke et al., 2010; Gonzalez et al., 2012). Field surveys also show that arid species have expanded since the 1950s in Burkina Faso (Wezel and Lykke, 2006; Maranz, 2009; Gonzalez et al., 2012), Chad (Gonzalez et al., 2012), Mauritania (Gonzalez et al., 2012), Niger (Gonzalez et al., 2012; Wezel and Lykke, 2006), and Senegal (Gonzalez, 2001; Wezel and Lykke, 2006; Vincke et al., 2010). These changes have shifted the Sahel, Sudan, and Guinea zones southward toward moister areas (Gonzalez et al., 2012). At one site in Mali, tree density did not, however, decrease in the period 1984-2006 (Hiernaux et al., 2009). Analysis of temperature, precipitation, population density, and soil indicate that climate dominates in explaining the declines in Sahel tree density and species richness (Gonzalez et al., 2012). Because the decline in tree cover may contribute to erosion, reduced soil fertility, and other forms of land degradation, it indicates how climate change may exacerbate desertification.

22.3.2.4.2. Land degradation

[forthcoming]

22.3.2.4.2. Water availability

[forthcoming]

22.3.3. Key Sectors

22.3.3.1. Food Production Systems and Food Security

Africa’s food production systems are among the world’s most vulnerable because of extensive reliance on rainfed crop production, high intra- and inter-seasonal climate variability and recurrent droughts and floods that damage crops and livestock (Boko et al., 2007). Rainfall variability is an important determinant of food production in SubSaharan Africa, and uncertainty and risks associated with this variability creates adverse effects to national economies throughout Africa (Brown and Lall, 2006; Brown,C et al., 2010b). Better managing risks linked to current climate variability in a multi-stressor context (e.g. poverty, weak institutions, lack of access to resources, environmental degradation, loss of biodiversity and others) presents both a critical challenge and a key opportunity for enhancing resilience of farming systems in Africa (Eriksen and Silva, 2009; Quinn et al., 2011; Tschakert, 2007).

Better managing risks associated with climate variability may help to build adaptive capacities for climate change in the near-term (Cooper et al., 2008; Funk et al., 2008; Washington et al., 2006 old reference? Cross check with AR4). However, agriculture in Africa could face significant challenges in adapting to climate changes projected to occur by mid-century, as negative effects of high temperatures become increasingly prominent (Battisti and Naylor 2009), thus increasing the likelihood that major crops in Africa could experience significant yield losses (Schlenler and Lobell, 2010). I will put all of that under adaptation Reduction in growing season length is likely to be an important consequence of temperature rise. It is estimated that with a 4° C temperature rise by 2090, the length of the growing season could be reduced of between 5 and 20 percent, especially across extensive areas of semi-arid and dry sub-humid zones, and reductions in growing season length in excess of 20 percent could occur in Southern Africa and the Sahel (Thornton et al., 2011). Temperature rise could also be an important factor in shifting current climates in Africa away from contemporary historical precedents. Burke et al. (2009a) estimated that by 2050 the majority of countries in Africa could have ‘novel climates’ occurring over at least half of their current crop areas. Conservation of crop species biodiversity in African countries that currently have analogues to those future climates will be critically important for supporting future crop breeding efforts across Africa.

22.3.3.1.1. Crops

Since the AR4, knowledge of climate change impacts on the production of crops has increased substantially, indicating a consistently negative impact across cropping systems and regions.

Cereal crops: Climate change is very likely to have an overall negative effect on yields of major cereal crops in Africa, with strong regional variability in the degree of yield reduction (Berg et al., 2012; Lobell et al., 2008; 2011; Liu et al., 2008; Thornton et al., 2009a, Walker and Schulze, 2008). Maize-based systems in Southern Africa are among the most vulnerable to climate change, with as much as a 30 percent yield loss possible from warming by 2030 relative to 1990 (Lobell et al., 2008). In Eastern Africa, maize could benefit from warming at sites above roughly 1500 m in elevation (Thornton et al., 2009a; Lobell and Burke, 2010), though the majority of current maize production occurs at lower elevations. Simulations that combine all regions South of the Sahara suggest consistently negative effects of climate change across five major staples (rice, wheat, maize, millet and sorghum) by 2050 (Nelson et al., 2009). Wheat production in North Africa is very likely to significantly decrease under future warming trends and decreased annual precipitation (Drine, 2011; Eid et al., 2007; Hegazy et al., 2008; Mougou et al., 2011). Multiple studies agree that total precipitation and the frequency of wet days will decline across North Africa (Driouech et al., 2010; Born et al., 2008; García-Ruiz et al., 2011; Abouabdillah et al., 2010). Of concern is the fact that winter precipitation, crucial for rainfed agriculture, could be most significantly affected (Abouabdillah et al., 2010; Tekken et al., 2009; García-Ruiz et al., 2011).

Non-cereal crops: Most of the literature remains focused on the main grain crops (such as maize and sorghum) but fewer studies have addressed impacts on major non-cereal sources of calories and proteins, such as groundnuts, cassava, plantains, and bananas. This remains an important gap given that these crops provide the majority of calories in some countries research gap (Lobell et al., 2008).

Climate change could have differential effects on non-cereal crops. Cassava yields could moderately benefit from warmer temperatures out to 2030 (Liu et al., 2008; Lobell et al., 2008), and suitability for growing cassava could increase with the greatest improvement in suitability in Eastern and Central Africa (Jarvis et al., 2012). However, Schlenler and Lobell (2010) estimated negative impacts from climate change on cassava at mid-century, though these impacts are less than those estimated for cereal crops. Given cassava’s hardiness to warm temperatures and sporadic rainfall relative to many cereal crops, it may provide a potential option for crop substitution of cereals as an adaptation response to climate change (Jarvis et al., 2012; Rosenthal and Ort, 2011). adaptation But capturing potential positive benefits for cassava production with climate change will require significantly greater access to fertilizers and expanded pest management options for smallholder farmers. eans could experience strongly negative impacts from climate change (Jarvis et al., 2012; Thornton et al., 2011). For peanuts some studies indicate a positive effect from climate change (Tingem and Rivington, 2009) and others a negative one (Lobell et al., 2008; Schlenker and Lobell, 2010). Bambara groundnuts (Vigna subterranea) could benefit from moderate climate change (Tingem and Rivington, 2009) though the effect could be highly variable across varieties (Berchie et al., 2012). Banana and plantain production could decline in West Africa and lowland areas of East Africa, whereas in highland areas of East Africa it could increase (Ramirez et al., 2011).

Perennial crops: Suitable agro-climatic zones for growing economically important perennial crops, such as cocoa, coffee, tea, cashew, and cotton, could significantly diminish, with a dominant effect from rising temperatures (Eitzinger et al., 2011a, b; Läderach et al., 2010; 2011a, b, c). Suitable agro-climatic zones areas that are currently classified as very good to good for perennial crops could become more marginal, and what are currently marginally suitable areas could become unsuitable. In some situations, movement of perennial crops to higher altitudes could mitigate loss of suitability at lower altitudes but this option is limited.

Cocoa production currently occurring at high latitudes in Ghana and Côte d'Ivoire may remain at its current suitability ranking or become more suitable for cocoa production, while coastal lowland areas may experience a sharp decline in suitability by 2050 (Läderach et al., 2011b). The areas most strongly affected could lose 40 to 70 percent from their current suitability rankings of between 60 and 80 percent not clear. The altitude for optimal cocoa production is estimated to shift from the current altitude of 100-230 meters above sea level (masl) to 450-500 masl by 2050. By contrast, warmer temperatures by mid-century may benefit cashew production in these two countries (Läderach et al., 2011a). New areas suitable for this production could expand.

Agro-climatic suitability for rainfed cotton production in Ghana and Côte d'Ivoire could constrict sharply by mid-century due to warmer temperatures (Läderach et al., 2011c). A loss of climate suitability by up to 40 percent is possible in the two countries, with the current optimum zone for cotton production of 350 to 450 masl being the most strongly affected. While this zone will remain the most optimal in these two countries for cotton production, its overall climate suitability will change from a designation of excellent to very good to one of good to marginal, while other areas will no longer be suitable (to be clarified). Suitability for irrigated cotton production in Egypt could change very little if farmers are able to move planting dates back several weeks to adjust for higher temperatures (Hegazy et al., 2008).

In highland areas of eastern Africa, warmer temperatures by 2050 may strongly influence the distribution of climatically suitable areas for coffee and tea production (Eitzinger et al., 2011a,b; Läderach et al., 2010). The optimum altitude for tea production in Uganda is estimated to shift from the current altitude of 1450-1650 to 1550-1650 masl by 2050. Given the current location of tea production in Uganda, areas with good or excellent climatic suitability may sharply constrict by 2050, though there could be a slight increase in suitability in the southwestern Ugandan highlands. Areas that do remain suitable for tea production could experience a decrease in suitability by 20 to 40 percent. In Kenya, the optimum altitude for tea production is expected to shift from the current altitude of 1,500-2,100 to 2,000-2,300 masl by 2050, resulting in diminished suitability for tea production in southwestern Kenya and substantially increasing suitability in the central Kenyan highlands. Overall, the negative impact of warming on the amount of land area with good to excellent suitability for tea production could be much greater in Uganda than in Kenya. Warming by mid-century could also result in a shift in the optimal coffee-producing zone in Kenya from its current altitude of between 1400 and 1600 masl and to an altitude between 1600 and 1800 masl. Coffee production at altitudes of around 1200 masl could experience the greatest decrease in suitability, while areas around 2000 masl could increase in suitability. Overall, the decline in suitability at lower altitudes could be greater than the increase in suitability at higher altitudes.

22.3.3.1.2. Livestock

Livestock systems in Africa face multiple stressors that could potentially interact with climate change and variability to amplify vulnerability of livestock-keeping communities. These stressors include rangeland degradation, increased variability in access to water, fragmentation of grazing areas, sedentarization, changes in land tenure from communal towards private ownership, in-migration of non-pastoralists into grazing areas, lack of opportunities to diversify livelihoods, conflict and political crisis, and presence of weak social security networks and weak institutions for securing access to land, markets and other resources (Dougill et al., 2010; Galvin, 2009; Smucker and Wisner 2008; Solomon et al., 2007; Speranza, 2010; Thornton et al., 2009b).

An important direct effect of climate change concerns the increased incidence of loss of livestock herds through an increased prevalence and severity of drought (Solomon et al., 2007). The Southern Africa region is of particular risk for high livestock losses (Thornton et al., 2009). A modeling study on the pastoral systems in the Kalahari (Dougill et. al., 2010), demonstrated that among several factors, climate change, and increased drought conditions in particular, had the largest negative impact on the viability and value of pastoral systems. In Morocco, decreased precipitation with climate change may sharply impinge on the ability of seasonal pastoralists to access grazing lands (Freier et al., 2012).

Adequate provisioning of water for livestock production could become more acute under climate change. One of the few direct analysis of the effect of climate change and attendant changes in water scarcity on the livestock sector was conducted for Botswana (Masike and Urich, 2008; 2009), where most of the water for livestock drinking is pumped from the aquifers. They estimated that by 2050, climate change would result in a 20 per cent increase in water demand by cattle, while at the same time the surface water availability would decline and ground water levels would drop. The resulting need for extra pumping would lead to a 23 per cent increase in costs. Although small in comparison to the water needed for feed production, drinking water provision for livestock is critical, and can have a strong impact on overall resource use efficiency in warm environments (Van Breugel et al., 2010; Descheemaeker et al., 2010b, 2011; Peden et al., 2009). Drinking water availability is often ranked very high as a factor constraining livestock production (Gruber et al., 2009; Solomon et al., 2007) Could you merge these two sets?.

Livestock production could also be indirectly affected by water scarcity through its impact on food production. Assuming no major shifts in harvest index (the proportion of non-grain biomass to grain yield), projections of decreasing crop yields imply important declines in the availability of crop residues for livestock feeding. Understanding the effects of changes in water availability on feed derived from forage crops and crop residues can be gained from studies on the effects of climate change and crop production. For example, Thornton et al. (2010) found that maize stover availability per cattle head decreased modestly in several East African countries.

The composition of farming systems from mixed crop-livestock to more livestock dominated food production may occur as a result of reduced growing season length for annual crops and increased in the frequency and prevalence of failed seasons (Jones and Thornton, 2009; Thornton et al., 2010). Transition zones, where livestock keeping is likely to replace crop cultivation, were identified in a band across West Africa, and coastal and mid altitude areas in eastern and south-eastern Africa (Jones and Thornton, 2009). By 2050 these transition areas could make up to 3 percent of the land area of the continent, areas (which ones?) that currently support 35 million people and that are chronically food insecure. In East Africa the mixed crop-livestock systems could see varying responses to climate change (Thornton et al., 2010), with likely increases in productivity in the temperate highland areas, and shifts to more livestock-oriented production in the arid and semi-arid systems.

The nature of livestock keeping may also change in response to warming trends in agricultural zones, possibly resulting in greater stocking of heat-tolerant livestock. A warming trend in lowland areas of Africa could result in reduced stocking of dairy cows in favor of cattle (Kabubo-Mariara, 2008), a shift from cattle to sheep and goats (Kabubo-Mariara, 2008; Seo and Mendelsohn, 2008), and decreasing reliance on poultry (Seo and Mendelsohn, 2008).

Climate change may alter disease pressure on livestock resulting from changes in the composition of livestock and non-livestock host populations affecting parasite reservoirs, heightened heat and water stress on livestock that increase susceptibility to diseases, and shifts in the suitable range of pathogens and parasites. Olwoch et al. (2008) estimated that the distribution of the main tick vector species (Rhipicephalus appendiculatus) of East Coast fever disease in cattle could be altered by a 2° C increase and changes in mean precipitation. The climatically suitable range of the tick may shift southward, with Botswana, Malawi, South Africa, and Zimbabwe potentially experiencing an increase in the pest, while Mozambique, Tanzania, Uganda, Kenya, the Democratic Republic of Congo, and Zambia potentially experiencing a slight decrease. However, there are a number of environmental and socio-economic factors (e.g. habitat destruction, land use and cover change and host density) in addition to climatic ones that could influence tick distribution (Rogers and Randolf, 2006).

22.3.3.1.3. Crop pests

Since the AR4, understanding of how climate change could potentially affect agricultural pests, diseases and weeds in Africa is beginning to emerge. Warming in highland regions of eastern Africa could lead to range expansion of pests into cold-limited areas. For example, in highland arabica coffee-producing areas of eastern Africa warming trends may result in the coffee berry borer (Hypothenemus hampei) becoming a serious threat. Climate envelope analysis conducted by Jaramillo et al. (2011) found that H. hampei damage could worsen in Ethiopia, Kenya, Uganda, Rwanda and Burundi, with the number of H. hampei generations per year potentially doubling. One important strategy for reducing damage from this pest under warmer conditions is to introduce shade-grown coffee production in areas currently under full sun production. Shade systems help to buffer micro-climatic extremes and may contain more natural predators of coffee pests (as reviewed by Jaramillo et al., 2011).adaptation For highland banana production areas of eastern Africa, temperature increases at high altitudes may allow the highly destructive burrowing nematode, Radopholus similis, to expand its altitudinal range to above 1,400 meters, where a significant portion of staple banana production in East Africa occurs (Nicholls et al., 2008).

Climate change may also affect the distribution of economically important pests in lowland and dryland areas of Africa. The potential effect of climate change on the parasitic weed Striga is a concern given its close association with drought-prone low fertility status soils and erratic rainfall, and the large yield reductions in maize, millet, sorghum and upland rice due to invasions in SubSaharan Africa (Rodenburg et al., 2010). Under A2A and B2A SRES and for 2020, Cotter et al. (2012) estimated that climate change could create more suitable habitats for Striga hermonthica in Central Africa, whereas the Sahel region may become less suitable for this weed under the assumption of an overall decreased area of production for S. hermonthica’s primary hosts (maize, sorghum and pearl millet). Climate change could also lead to an overall decrease in the suitable range of major cassava pests—whitefly, cassava brown streak virus, cassava mosaic geminiviris, and cassava mealybug (Jarvis et al., 2012), though southeast Africa and Madagascar could experience increased suitability for cassava pests (Bellotti et al., 2012).

22.3.3.1.4. Fisheries

Climate change is expected to impact fisheries through a variety of direct and indirect pathways. Direct effects include warming in freshwater and marine environments, ocean acidification, bleaching of coral reefs, increased frequency of diseases and toxic events, water stress and other extreme events, and salinization of coastal freshwater bodies from sea level rise (Brander, 2007; DeSilva and Soto, 2009; FAO, 2008).

Potential climate change effects on inland fisheries have been observed in Africa. For example, there is evidence that increasing temperature has reduced primary productivity of Lake Tanganyika in East Africa by increasing the stability of the water column and thereby reducing upwelling of nutrients into surface waters necessary for stimulating primary production (O’Reilly et al., 2003, as cited in Brander, 2007). These changes have been estimated to have reduced fish yields by approximately 30 percent. Also warming and drying trends around the Lake Kariba (Zimbabwe) have resulted in higher rates of evaporation of lake water and increased stratification of the water column, which reduces surface nutrient levels. These factors appear to be an important contributor to declining sardine productivity (Ndebele-Murisa et al., 2010).

Degradation and loss of reefs will result in significant social, economic and environmental impacts on fisheries and tourism. Vulnerability to reef loss was assessed by Burke et al. (2011) for inhabited reef countries and territories, based on exposure to reef threats, dependence on ecosystem services (food, livelihoods, exports, tourism, and shoreline protection), and adaptive capacity (ability to cope with the effects of degradation). Tanzania was among nine countries that were determined to be most vulnerable to the effects of coral reef degradation. A vulnerability analysis of western Indian Ocean coastal communities in five countries (Cinner et al., 2012) reported high variability in environmental factors that influence coral bleaching. Highly exposed reefs in Tanzania, Kenya, Seychelles, and northwest Madagascar were found to have environmental conditions conducive to bleaching, whereas Mauritius and southwest Madagascar experience lower seawater temperatures and UV radiation, and higher wind velocity and currents, resulting in relatively low exposure to bleaching. The greatest sensitivity to fisheries decline linked to coral bleaching was in Tanzania and parts of Kenya and Madagascar where livelihood dependence on fishing is high.

There are a number of indirect, and potentially quite significant, effects of climate change ecosystems, and on communities that heavily depend on fisheries for livelihood sustenance. Climate change could amplify negative effects from overfishing, pollution and ecosystem degradation, such as where wetland conversion for agriculture, declining mangrove forest habitat, and degraded estuaries increases vulnerability to drought, changes in rainfall patterns, storm surge, saltwater ingression and other manifestations of climate change (Badjeck et al., 2010). Also, damage to fishing infrastructure (e.g. boats, gear and landing sites), transportation networks, and other physical infrastructure from storms, storm surges, and floods disrupts access of fishing communities to fisheries, which can deepen poverty (Badjeck et al., 2010).

The consequences of the many and diverse impacts on capture fisheries and aquaculture, both positive and negative, on food security are more difficult to estimate than the biological and ecological consequences. A preliminary study by Allison et al. (2009) estimated the vulnerability of the economies of 132 countries to climate change impacts on fisheries, based on a composite of three components: exposure to the physical effects of climate change, the sensitivity of the country to impacts on fisheries (measured by total fisheries production, contribution of fisheries to national employment, export income and dietary protein) and adaptive capacity within the country (a composite index derived from life expectancy, indicators of education levels, various indicators of governance effectiveness and size of economy). Their analysis determined that two-thirds of the most vulnerable countries were in tropical Africa due to the importance of fisheries to the poor and the close link between climate variability and fisheries production. The most vulnerable of the African countries were found to be Malawi, Guinea, Senegal and Uganda.

Food security will be a major consideration in these vulnerable countries. Cochrane et al. (2009) estimated that capture fisheries (marine and inland) and aquaculture combined contributed 36 percent to Africa’s animal protein intake in 2009, while in some coastal African countries fish may contribute up to two-thirds of total animal protein intake (Allison et al., 2009). Demand for fish is projected to increase substantially in Africa over the next decade and more, with much of that new demand likely met by aquaculture. To meet fish food demand by 2020, De Silva and Soto (2009) estimate that aquaculture production in Africa would have to increase nearly 500 percent.

Economically impoverished communities whose livelihoods depend on fisheries are highly vulnerable to climate change, and require the greatest focus for adaptation. Increased flexibility in fishery livelihood options that reduce reliance on one fish species or activity, and measures to allow for diversification away from fisheries, on a periodic basis to cope with extreme events or more permanently where fishery activities can no longer be sustained, will be critical (Badjeck et al., 2010). Private and public insurance schemes that help fishing communities rebuild after extreme events, and education and skills upgrading that enable broader choices for fishing communities are recommended. Additionally, policies and measures that reduce overfishing and other environmental stressors and that strengthen governance are consistent with adaptation goals for fisheries (Allison et al., 2009; Badjeck et al., 2010).

22.3.3.1.5. Food security

Food security in Africa faces multiple stressors stemming from entrenched poverty, environmental degradation, rapid urbanization, high population growth rates, and climate change and variability. The intertwined issues of markets and food security have emerged as an important issue in Africa and elsewhere in the developing world since the AR4. Price spikes for globally traded food commodities in 2007-2008 and food price volatility and higher overall food prices in subsequent years have undercut recent gains in food security across Africa (Alem and Soderböm, 2011; Brown et al., 2009, Hadley et al., 2011, Levine, 2011; Mason et al., 2011, Tawodzera, 2011). Among the most affected groups are the urban poor, who typically allocate more than half of their income to food purchases (Cohen and Garrett, 2009; Crush and Frayne 2010), in addition to the rural poor, especially female-headed households (Kumar and Quisumbing, 2011).

The recent spike in global food prices can be attributed to a convergence of several factors, among them extreme climatic events that reduced food production in globally important cereal producing regions, rising energy prices, low global food stocks, land conversion from food to biofuel production in northern countries, and speculation on commodity futures markets (Liverman and Kapadia, 2010; Wiggins and Levy 2008). The expected intensification of climate change could exert upward pressure on food prices of basic cereals (Hertel et al., 2010; Nelson et al., 2009), though the climate change signal in the recent food price crisis was likely minor relative to other factors (Gregory and Ingram, 2008). Much more research is needed to better understand potential interactions between climate change and other key drivers of food prices that act at national, regional, and global scales. As the food system becomes increasingly globalized, African food security may become less fundamentally dependent on conditions impacting food production in Africa. As the 2008 food price crisis demonstrated, factors in other regions profoundly impact food security in Africa.

Africa is undergoing both rapid urbanization and transformation of its food system, which is becoming more complex and diverse. Sub-Saharan Africa is the world's fastest urbanizing region, driven both by migration and natural growth. In 1950 there were just 33 million urban inhabitants in Africa, rising to a projected 412 million in 2010 and 566 million by 2020 (Satterthwaite et al., 2010, 2012). As discussed in Section F1, some rural to urban migration is the direct or indirect result of climate change. With this demographic shift come related shifts in diet and the food system, which expose new points of vulnerability and resilience to climate-induced food insecurity. Reduce and perhaps to be considered under section F

The urban diet in Africa is far more dependent on markets that the rural diet. The reliance on purchased food in urban areas means that the impact of climate change on food security may need to consider not just production, but also the processing, transport, storage and preparation in the system that moves food from production to consumption. For example, there are high post-harvest losses in Africa due to inadequate transport and storage infrastructure (Godfray et al., 2010, Parfitt et al., 2010). Weaknesses in the food system may be exacerbated by climate change in the region as high temperatures increase spoilage and floods damage transportation infrastructure. Actions to address food security in Africa would therefore benefit from assessment of options and strategies to reduce vulnerabilities at each stage required to get food to households (Battersby, 2012) Research gap; this will require an examination of food security beyond a productionist framing.

As a result of the changes in local and international food markets, the African food system is becoming increasingly differentiated, with some sectors developing greater adaptive capacity to climate change. After a slow start (Traill, 2006 too old? Check), much of Africa is experiencing supermarket expansion. South Africa, Kenya and Zambia were early adapters to this system, but it is clear that many other countries are now experiencing the emergence of this sector (Neven et al., 2009, Reardon et al., 2007). There is no single model for impact of this supermarketization and of trade liberalization opening up export markets (Humphrey, 2007) Some countries, such as South Africa and Kenya, found that small holder farmers are excluded from these markets (Neven et al., 2009). Others, like Madagascar, found the opposite (Minten et al., 2009). Producers included in supermarket or export contacts may better placed to adapt to climate change because of the extension and input support provided by contractors (Minten et al., 2009; Neven et al., 2009).

22.3.3.1.6. Adaptation, agriculture and food security

Evidence has increased since the AR4 that farmers are changing their production practices in response to increased food security risks linked to climate change and variability. Examples include planting cereal crop varieties that are better suited to shorter and more variable growing seasons (Akullo and Kanzikwera, 2007, IIED check if it is the correct author, 2011, Laube et al., 2012; Thomas et al., 2007; Yaro, 2010; Yesuf et al., 2008), constructing bunds to more effectively capture rainwater and reduce soil erosion (Nyssen et al., 2007; Reij et al., 2009; Thomas et al., 2007), reduced tillage practices and crop residue management to more effectively bridge dry spells (Marongwe, 2011; Ngigi et.al., 2006), and adjusting planting dates to match shifts in the timing of rainfall (Abou-Hadid, 2006; Vincent et al., 2011). Additional assessment of adaptation in the agricultural sector is provided below.

22.3.3.2. Health

22.3.3.2.1. Vulnerability

Africa is particularly vulnerable to the health risks of climate change. Inadequate health systems, inadequate water and sanitation infrastructure, and poor governance interact with changes in climate to multiply existing vulnerabilities. Mostly women and children will feel the impacts. Adverse health consequences can arise from the interaction of generic and place-specific causes of vulnerability with climate stresses in a particular region (droughts, floods and other extreme weather events) (Chapter 11 ZOD and SREX chapter 2).

Despite efforts to meet the targets set for the MDGs, inadequate human and financial resources, poor health infrastructure and health systems (public health and health care) compound vulnerability to many food-and water-borne infectious diseases, especially in sub-Saharan Africa (SREX). The annual population growth rate is 2.4% (4.9% in the part C1). The total population exceeds 1 billion, with 341 million Africans lacking access to clean drinking water and 589 million lacking access to adequate sanitation (WHO/UNICEF 2008). Sub-Saharan Africa has the lowest drinking water coverage, with most countries having less than 50% coverage (WHO/UNICEF, 2012).

Developing countries lose $100 billion a year from the consequences of poor sanitation and water coverage, including a higher burden of infectious diseases (UN-Water, 2008; Factsheet on Water and Sanitation, UN-Water, 2008; UNDP, 2007). Frequent episodes of infectious diseases coupled with food insecurity exacerbate malnutrition, particularly in children and pregnant women. The burden of climate-sensitive diseases such as malaria, diarrhea, and malnutrition are already highest in Africa. There were 216 million cases of malaria and an estimated 655 000 deaths in 2010; a child dies every minute from malaria (World Malaria Report 2011). In 2011, malaria accounted for 22% of all childhood deaths (World Malaria Report, 2011). Globally, nearly one in five deaths in children is due to diarrhea (1.5 million deaths annually) (WHO, 2012) with 80% of deaths in Africa and Asia (UNICEF/WHO, 2009). One third of childhood mortality is linked to malnutrition; 70% of all children's deaths from malnutrition occur in Africa and Asia.

Pregnant women also are vulnerable to malaria, diarrhea, malnutrition, and other climate-sensitive health outcomes (WHO, 2011). Challenges they face that could be aggravated by climate change include activities to care for their families, such as cooking and fetching water and firewood; and access to health facilities due to poor roads, poverty, and distance (WHO, 2011). Africa has the highest maternal mortality rates (590 per 100,000 live births), with the rate in sub-Sahara Africa of 640 per 100,000 for comparison, the developed regions have a rate of 17 per 100,000 live births (WHO, 2010).

[Insert table showing gender, climate change, and health linkages]

The current high burden of diseases adversely affects development of African countries with low GDP's. Climate change may deepen this burden. For example, the worldwide costs of treating climate change-related cases of malaria, diarrhea, and malnutrition in the year 2030 may be up to $10 billion globally (Ebi, 2008).

[Insert table showing current cost of key climate change diseases (by regions in Africa) and estimated cost for adaptation by various studies]

Another emerging vulnerability is that adaptation strategies, policies, and measures implemented in other sectors may adversely affect health through changing habitats for pathogens and their vectors. For example, building new dams for irrigation could lead to epidemics or spread of leishmaniasis, a debilitating disease endemic mostly in North Africa that can cause facial scarring and stigmatization. Women agricultural workers bear the brunt of the disease burden (M.K.Chahed et al, in press). Enhanced coordination across sectors and regions, including regulations where appropriate are needed to ensure adaptation efforts consider the full range of possible consequences.

22.3.3.2.2. Impacts: current and future projections

Literature on the effects of climate change on human health in Africa generally lags other sectors. Although few, results indicate climate change is affecting the current transmission of certain vector- and food-water-borne diseases in Africa, with projections suggesting increases in the magnitude and extent of impacts with additional climate change.

Food and water-borne diseases

Cholera is primarily driven by poor sanitation, poor governance, and poverty; drivers that could be exacerbated by climate variability and long term climate change (Rodo et al., 2002; Koelle et al., 2005b; Olago et al 2007; SREX, 2012). The frequency and duration of cholera outbreaks are associated with rainfall variability in Ghana and other African countries (de Magny 2007). Further examination of common spatial and temporal patterns will facilitate development of more effective early warning (de Magny et al., 2006, 2007; Emch et al 2008). El Nino-Southern Oscillation (ENSO) is a driver of cholera pathogenicity and transmission (de Magny et al., 2007). The rainy season contributed to the worst outbreak in recent African history, from August 2008 to June 2009. An epidemic started Zimbabwe, with more than 92,000 cases and 4000 deaths; the case fatality rate was a record 4-5%. Contamination of water sources after the rains from the point source spread the disease (Mason 2009). In addition to climate, poor governance, poor infrastructure, limited supplies and human resource, and underlying population susceptibility (high burden of malnutrition) contributed to the severity and extent of the outbreak.

Climate change could increase child undernutrition in sub-Saharan Africa, even when economic growth is taken into account, causing increased rates of severe stunting; the projected increase in central Sub-Saharan Africa is 23% by 2050 (Lloyd, et. al. , 2011). However, local economic activity and accessibility are likely to reduce the incidence of malnutrition (Funk et al., 2008; Rowhani et al., 2010, 2011). Prevention of future undernutrition will require increased access to food, improved socioeconomic conditions, and reductions in greenhouse gas emissions (Lloyd et. Al., 2011).

Vector-borne diseases in Africa

Research continues to support the AR4 finding that climate change could affect the geographic range and incidence of malaria along the current edges of its distribution. Additional research is needed that takes into account current and projected economic status. Many studies concluded that altered temperatures and precipitation patterns will influence the spread of malaria, including contractions or expansions. (IPCC 2007; Ermert et al., 2011; Paaijams et al., 2010; Alonso et al 2011?). There is a growing consensus that highland areas, especially in East Africa, will experience increased malaria epidemics; the change in projected epidemic potential varies with altitude. Areas above 2000m will be affected (Ermert et al., 2011; Gething et al., 2012; Pascual et al., 2006; Peterson 2009; Patz et al., 2006, Paaijamas et al., 2010; Lou and Zhao 2010).

The shape of the association between malaria and daily temperature variation is uncertain, with some studies concluding it is non-linear and others quadratic or exponential (Alonso et al., 2011; Chaves and Koenraadt, 2010; Paaijamas et al., 2010). ENSO events in South Africa also may contribute to malaria epidemics (Mabaso et al., 2007). The debate is ongoing on local vs. international shifts in the distribution of the pathogen and vector (Ermert et al., 2011; Jackson et al., 2010; Gething et al., 2012; Caminade 2011). Whilst some claim there could be shifts in vector species rather than spread to different areas, particularly in the Sahel, (Tonnang et al., 2010), others believe there will be changes in spread (Ermert et al., 2011; Jackson et al., 2010; Gething et al., 2012; Caminade 2011). One reason for different projections could be due to use of GCMs versus REMO models (Ermert et al., 2012). Further, few models incorporate other drivers, such as public health interventions, malaria vectors, land use change, and other indirect effects (Saugeon et al., 2009; Kelly Hope et al., 2009; Omumbo et al., 2011)

Directly or indirectly, climate change may increase the incidence and geographic range of leishmaniasis. Leishmaniasis, a highly neglected disease, has recently become a significant health problem in northern Africa (Ruiz

Postigo, 2010) with a rising concern in western Africa because of co-infection with the Human Immunodeficiency Virus (HIV) (Kimutai et al., 2009). The epidemiology of the disease appears to be changing (Dondji, 2001 ; Yiougo et al., 2007; WHO 2009; 2010). Previously an urban disease, leishmaniasis now has a peri-urban distribution linked to changes in the distribution of the rodent host and of the vector over the last 20 years in Algeria (Aoun et al., 2008).

Cutaneous leishmaniasis has expanded its range from its historical focus at Biskra into the semi-arid steppe, with an associated upward trend in reported cases. In Morocco, a 2009 review reported epidemic transmission of L. major (vector Phlebotomus papatasi) with occasional outbreaks of up to 2000 cases, followed by long periods with few or no cases (Rhajaoui et al., 2011). The disease has now spread to areas in West Africa and East Africa including Leishmania major MON-26 in Mokolo, Cameroon (Dondji, 2001), new outbreaks in Libo Kemkem, Ethiopia (2006-2007), Treguine, Chad (2007), Wajir, Kenya (2008) (Dondji, 2001; WHO 2009), and in peri-urban Ouagadougou, Burkina Faso where proliferation of the vector has been linked with degraded environmental conditions (Yiougo et al., 2007). Outbreaks of zoonotic cutaneous leishmaniasis (ZCL) have become more frequent in Tunisia, Algeria and Morocco, where the disease is endemic. The spatio-temporal distribution of leishmaniasis in central Tunisia between 1999 and 2004 demonstrated several areas of high incidence rates. Climate was identified as one of multiple human and environmental factors that could have caused the changes (Salah et al., 2007). Environmental modification, such as construction of dams, can change the temperature and humidity of the soil and vegetation that may result in changes in the composition and density of sandfly species as well as changes in populations of rodent vectors. In Tunisia, data collected during 2005-2010 showed a significant positive relationship between ZCL and heavy rainfall 2 years prior, and warmer-than-average temperatures 6 months prior (Climate Change Adaptation in Africa Programme Annual Report, 2010-2011). Also, new research on ZCL in Tunisia (Interim Technical Report no.5 ,200) suggests a positive association between monthly incidence of ZCL and average temperature 3 and 6 months prior, and a positive association with host rodent density 6 months prior. Rodent density is also positively associated with average rainfall 9 months prior.

Rift Valley fever epidemics in the Horn of Africa are associated with altered rainfall patterns. Additional climate variability and change could further increase its incidence and spread. Rift Valley Fever epidemics are endemic in numerous African countries, with sporadic repeated epidemics. Recent epidemics in 2006–2007 in the Horn of Africa (CDC, 2007; WHO, 2007; Adam et al., 2010; Andriamandimby et al., 2008) and Southern Africa were associated with heavy rainfall (Chavalier, 2011), strengthening earlier analyses by Anyamba et al., 2009) showing RVF epizootics and epidemics are closely linked to the occurrence of the warm phase of the El Niño/Southern Oscillation (ENSO) (Linthicum et al., 1999) and with elevated Indian Ocean temperatures. These conditions lead to heavy rainfall and flooding of habitats suitable for the production of the immature Aedes and Culex mosquitoes that serve as the primary RVF virus (RVFV) vectors in East Africa. Flooding of mosquito habitats also may introduce RVFV into domestic animal populations by vertically infected Aedes mosquitoes.

Changing weather patterns could further aggravate poverty and hunger by expanding the distribution of ticks causing animal disease, particularly in East and South Africa. About 300 million Africans depend on livestock for their livelihood. In sub-Saharan Africa, livestock diseases cost an estimated US$ 2 billion, aggravating poverty, hunger, and disease in humans. Globally, six million cattle are exposed to ticks annually, more than a third of these in Africa. Theileriosis (ECF) ticks are vectors and agents of diseases, causing anaemia and skin damage that exposes cattle to secondary infections. Ticks are cold-blooded and thus sensitive to climatic factors. However, climate is not the only factor influencing tick distribution, habitat destruction, land use and cover change, and host density (Rogers and Randolf, 2006). Climate change is projected to affect the transmission of tick-borne diseases through its effects on ticks and pathogens. Using a climate envelope and a species prediction model (Olwoch et al., 2007), found that East Africa and South Africa are the most vulnerable to climate-induced changes in tick distributions and tick-borne diseases; more than 50 % of the 30 Rhipicephalus species examined showed significant range expansion and shifts. More than 70 % of this range expansion was found in economically important tick species.

There is growing evidence that resurgence or re-emergence of some diseases (for example Chikungunya fever and schistosomiasis) may be associated with weather and climate. In 2004, Chikungunya (CHIK), a viral disease carried by mosquitoes, re-emerged in nations cresting the Indian Ocean, affecting nearly 500,000 in Africa, including some 200 tourists who returned home with this illness. (Epstein 2007). Water resources development, such as irrigation dams recommended for adaptation in agriculture, can amplify the risk of schistosomiasis, particularly in Africa (Hunter et al., 1993; Jobin 1999; Huang 1992). Schistosomiasis causes approximately 4.6 million disability adjusted life-years (DALYs), with an estimated 280,000 deaths annually (King et al. 2008). More than 207 million are already infected, with an additional 700 million people worldwide at risk (WHO, 2011). Migration and sanitation play a significant role in the spread of schistosomiasis from rural areas to urban environments (WHO, 2011; Babiker et al., 198; Yuan et al., 2002). Water temperatures affect the survival of the host snail in China. Temperature change is projected to increase the geographic range of schistosomiasis in China (Xiao-Nong Zhou et al 2008).

Novel hantaviruses with unknown pathogenic potential have been identified in a variety of insectivores (shrews and a mole) in Africa (Klempa 2009). Climate change could affect hantaviruses by altering their natural reservoirs. Changes in the geographical distribution of the rodent carriers could deliver hantaviruses to new regions, altering species composition in ways that could be epidemiologically important (Klempa, 2009).

HIV/AIDS and climate change interact to perpetuate and increase vulnerability not only of the affected communities but also of the affected natural resources and ecosystems. This link is primarily based on exacerbated food insecurity due to climate change that further compromises the poor nutrition in most people living with HIV/AIDs (Drimie et al, 2010).

Laboratory studies support the that the geographic range of the tsetse fly (Glossina species), the vector of human and animal trypanosomiasis in Africa, may l be reduced under future warming scenarios (Terblanche et al., 2008).

Heatwaves and heat-related health effects due to climate change are only beginning to attract attention in Africa. Recent studies in West and Southern Africa indicate heat-related health effects may be of concern. Headache, fatigue, and feeling very hot among school children are associated with high indoor air temperature (Dapi et al., 2010; Mathee et al., 2010).

Future projections

Increasing global temperatures may influence the temporal fluctuations of cholera, as well as potentially increase the frequency and duration of outbreaks (Emchet al., 2008). The World Food Program projected that by 2050 the number of malnourished children in sub-Saharan Africa could increase by 24 million due to climate change (World Food Program?)

Climate change is anticipated to affect the sources of air pollutants as well as the ability of pollutants to be dispersed in the atmosphere (Denman et al., 2007). Assessments of the impacts of projected climate change on air quality indicate that changes to surface temperature, land cover, and lightning are likely to alter natural sources of ozone precursor gases and consequently ozone levels over Africa (Brasseur et al., 2005; Stevenson et al., 2005; Zeng et al., 2008). However, insufficient climate and emissions data for Africa prevent a more comprehensive understanding of the nature of the changes to air pollution. Thus the potential impact of climate change on human health due to changes in air pollution is not well understood.

[Meningitis]
[HIV/AIDs]

22.3.3.2.3. Adaptation

Generic and specific adaptations measures can reduce current and projected health burdens due to climate change. Generic measures are aimed mainly at reducing existing risks and vulnerabilities through improving public health surveillance and monitoring, access to safe water and improved sanitation, hygiene education, and waste management strategies; and providing better access to health care and health insurance (see Chapter 11, Tol, 2008, Tol et al., 2007). Specific measures include implementation of early warning systems (EWS), vulnerability mapping, and public education, discussed further below.

22.3.3.3. Industry

[tourism and others forthcoming]

22.3.4. Key Processes

22.3.4.1. Human Security

The protection of the vital core of all human lives in ways that enhance human freedoms and human fulfilment is at the core of the concept of the concept of human security. Providing human security means protecting individuals and the community from violent conflicts and from denial of civil liberties and to ensure freedom of expression and belief. It also encompasses the idea of satisfying the basic needs of individuals for food, shelter and clothing (UNDP, 1994). Climate change and variability have the potential to impose additional pressures on the various aspects of human security. Interrelating issues between climate change and human security include water stress, land use and food security, health security, and environmentally induced migration amongst others. Violence, poverty and inequality are inseparable in explaining and addressing the root problem of insecurity, whether social or economic (Kumssa and Jones, 2010). Human security of people in Africa is particularly threatened by the impacts of climate variability. Adverse climate events not only deepen poverty vulnerability in developing countries (Ahmed et al., 2009), they impact on all aspects of human security, either directly, or indirectly.

22.3.4.1.1. Agriculture, food security, and economic growth

The impacts of climate change on the agricultural sector in Africa are probably of most direct and profound nature. Impacts of climate change will particularly affect agricultural and food systems (Brown and Funk, 2008). It remains critical that increasing temperatures and declining precipitation in Africa resulting from climate change are likely to reduce yields for primary crops, changes, which will have a substantial impact on food security in Africa, although the extent and nature is uncertain (Boko *et al.*, 2007). Periods of droughts and floods will have an impact on food availability, food access, and on nutrient access (Kotir, 2010). Agriculture in Africa is to a large extent rain-fed and water scarcity has a direct impact on crop and livestock farming systems; warmer and drier climates adversely affect net farm revenues translating into worsening food security situation in the region (Nhemachena *et al.*, 2010). The ultimate damages of climate change may significantly affect economic growth (Lecocq and Shalizi, 2007). Climate extremes exert substantial stress on low income populations in particular, the poor are most vulnerable to multiple dimensions of climate change such as heat waves, sea level rise, the destruction of coastal zones and water shortages due to drought (Hope, 2009). In Tanzania for example, where food production and prices are sensitive to climate due to the fact that 98 per cent of arable is rain-fed, changes in climate volatility could have severe implications for poverty as agriculture accounts for about half of gross production, and employs about 80 percent of the labour force (Ahmed *et al.*, 2011). For Namibia, computable general equilibrium model simulations indicate that over 20 years, annual losses to the Namibian economy could be up to 5% of GDP, due to the impact that climate change will have on its natural resources alone, affecting the poorest people in first place with resulting constraints on employment opportunities and declining wages, especially for unskilled labour in rural areas (Reid *et al.*, 2008). Such losses are detrimental, considering that unemployment, poverty, the HIV/AIDS pandemic, and household food insecurity are among the main problems facing the country (Ruppel, 2011). Agriculture is also the main source of livelihood of the majority of the people living in the West African Sahel, a region stressed by a fast-growing population and increasing pressure on the scarce natural resources. Increases in temperature and/or changing precipitation patterns will impact on the agricultural sector. Thus, the vulnerability of livelihoods based on agriculture is increased and most likely exacerbate and accelerate underdevelopment, poverty and environmental degradation (Sissoko *et al.*, 2011). In Ghana, change and variability in rainfall, temperature, and the way crops and weeds respond to the carbon dioxide fertilisation effect have the potential to influence the productivity of the commercial agricultural sector in central and southern Ghana, and associated employment opportunities (Black *et al.*, 2011). The high sensitivity of cocoa can be cited as one example for agricultural products in Ghana being particularly prone to the effects of a changing climate as the geo-graphical distribution of cocoa pests and pathogens, decrease crop yields, and impact farm income; whilst the magnitude of the carbon dioxide fertilisation effect varies with different crop types (and weed types) and the supply of water and nutrients (Black *et al.*, 2011). This makes Ghana's agricultural and economic sector particularly vulnerable, bearing in mind, that cocoa is the dominant cash crop and – along with gold and timber – Ghana's single most important export product (WTO, 2008) and has been central to its debates on development and poverty alleviation strategies. Furthermore, a decline of the lake levels caused by reduced rainfall over the last forty years has been observed in Ghana, which is critical with regard to economic development considering that the demand for power is increasing due to economic growth and in view of the fact that hydroelectric power stations generate 80% of Ghana's total national power production (Black *et al.*, 2011; Kuuzegh, 2007).

22.3.4.1.2. Health

Human health is an important aspect of human security, with climate change potentially inequities between rich and poor (Costello *et al.*, 2009). Threats to health security are usually greater for poor people in rural areas, particularly children, due to malnutrition and insufficient access to health services, clean water, and other basic necessities.

22.3.4.1.3. Violent conflicts

The impacts of climate change on violent conflicts, changing migration patterns and human settlements are further aspects related to the concept of human security with particular relevance on the African continent.

Environmental conflict research and the linkage between climate-related environmental variability and conflict have attracted much attention and debate. While there seems to be consensus in that the environment is only one of several inter-connected causes of conflict and is rarely considered to be the most decisive factor (Kolmannskog, 2010), it remains disputed, whether the changing climate increases the risk of civil war in Africa. With regard to sub-Saharan Africa relevant in this context due to the region's high dependence on rain-fed agriculture, high environmental vulnerability, and weak institutional coping capacity, it is on the one hand concluded that climate variability is a poor predictor of armed conflict. Instead, African civil wars can rather be explained by generic structural and contextual conditions: prevalent ethno-political exclusion, poor national economy, and the collapse of the Cold War system (Buhaug, 2010). Another research also focusing on sub-Saharan Africa comes to the diametrically opposite result concluding that warming does increase the risk of civil war in Africa (Burke *et al.*, 2009b). It has been found that there exist strong historical linkages between civil war and temperature in Africa, with warmer years leading to significant increases in the likelihood of war. A roughly 54% increase in armed conflict incidence is predicted by 2030, or an additional 393,000 battle deaths if future wars are as deadly as recent wars. It has been argued that conflicts are more likely in regions with higher ecosystem productivity (possibly resulting from vegetation recovery after population are displaced out of conflict zones), and that increased levels of malnutrition are related to armed conflicts (Rowhani *et al.*, 2011). However, with an emphasis on the role of renewable resources such as freshwater and arable land it is argued, that as a long term trend, population growth and resource scarcities result in violent competition (Raleigh, 2010); short term causes may trigger the outbreak of conflict (Hendrix and Glaser, 2007). Distributional conflicts will arise as due to the degradation of natural resources as a result from overexploitation and global warming (Kumssa and Jones, 2010). Such distributional conflicts are for example occurring in Somalia, with the converse observation that armed conflict may exacerbate the drought due to the fact that war and military activities, and the lack of State control or any other effective form of governance have led to widespread misuse and overuse of natural resources and environmental degradation. An important part of the war economy in Somalia, namely the commercial production and export of charcoal resulting in deforestation is one example for environmental degradation contributing to drought (Kolmannskog, 2010).

Research on the links between climate and conflict has often explicitly focused on how short-term weather anomalies affect conflict occurrence directly, or indirectly through economic growth, migration and food security. Despite the growing literature designed to identify a direct relationship between climate changes, degradation, resources, disasters and violence, none have confirmed a strong and consistent relationship that is not contingent upon political and economic characteristics of states (See Nordås and Gleditsch, 2007; Raleigh and Urdal, 2007; Raleigh, 2010; Theisen, 2008; Witsenburg and Adano, 2007; Adano et al., 2012; Scheffran and Battaglini, 2011). Whether qualitative and quantitative national and sub-national levels studies of civil war, national or disaggregated studies of communal violence, the results of the direct relationship are tenuous and increasingly dependent on case selections (Sutton, 2009; Buhaug, 2010; Nordås and Gleditsch, 2007). Several strands of research suffer from a lack of theoretical connections between its main driver (climate) and its possible consequence (conflict), and largely rely on neo-Malthusian scarcity frameworks. Critiques suggest that much of the available literature continues to exaggerate the impact of environmental factors in causing or exacerbating conflict, over predicts violence and elevates possibly spurious correlations into causes (Hartman, 2010; Barnett & Adger, 2007; Gleditsch, 1998; Levy, 1995). In contrast, case study research suggests that the political manoeuvring within states, and the marginalization of the most vulnerable by the governing powers, have heightened insecurity but rarely leads to conflict (Raleigh, 2010).

22.3.4.2. Urbanization

Urban population in Africa will treble by 2050, increasing by 0.8 billion (UN, 2010). African countries are experiencing some of the world's highest urbanization rates (UN-HABITAT 2008). Many of Africa's evolving cities are unplanned and have been associated with uncontrolled growth of informal settlements, inadequate housing and basic services, and increasing urban poverty (Yuen and Kumssa, 2011).

Climate change, with its associated erratic rainfall and extreme weather events is expected to have significant impacts on urbanization in Africa. In particular, the majority of migration flows observed in response to environmental change are internal (Jäger et al, 2009; Tacoli, 2009). In particular, extreme climate variations and, more specifically, water shortages, are likely to cause abrupt changes in human settlements and urbanization patterns in sub-Saharan Africa more than anywhere else in the world (Marchiori et al, 2012). Rural-urban migration has typically been motivated by livelihood opportunities, and traditionally involves moving into large towns and cities (Barrios et al, 2006; Annez et al, 2010). Such rapid rates of urbanization represent a burden on African economies of urban areas, due to massive investments needed to create job opportunities and provide infrastructure and services provision. This meant that basic infrastructure services are not keeping up with urban growth, which resulted in decline in the coverage of many services, compared to 1990s levels (Banerjee et al., 2007).

Thus, African cities and towns represent some of the most vulnerable to the impacts of climate change and climate variability (Adelekan, 2010; Boko *et al*., 2007; Diagne, 2007; Dossou and Gléhouenou-Dossou, 2007; Douglas *et al.*, 2008; Kithiia, 2011). The impacts of climate change, which could be seen as one of the key systematic shocks, have the potential to disrupt the whole urban systems as well as its sustainability (UN-Habitat, 2010).

Furthermore, most of those migrating from rural areas have limited skills and education. This means that they often end up in the informal sector of the urban economy and settle in squatter areas in the peripheries of cities where poverty, overcrowding, unemployment, crime and environmental degradation are common (Yuen and Kumssa, 2011). For instance, despite African cities generating about 55–60% of the continent's total GDP, a massive 43% of its urban populations live below the poverty line (Eriksen et al. 2008). Moreover, Sub-Saharan African countries have the highest levels of urban poverty in the world (Eriksen et al. 2008). Similarly, a study on food security in urban settlements in Southern Africa, found that 77% of the people were food insecure (DCETO 2009).

Squatter and poor areas typically lack provisions for the reduction of flood risks or for managing floods when they happen (Douglas et al. 2008). Floods are already exerting considerable impacts on cities and smaller urban centers in many African nations – for instance the heavy rains in East Africa in 2002 that brought floods and mudslides, forcing tens of thousands to leave their homes in Rwanda, Kenya, Burundi, Tanzania and Uganda; and the very serious floods in Port Harcourt and in Addis Ababa in 2006 (Douglas et al. 2008).

Another impact of climate change on coastal settlements in Africa is the induced sea-level rise along coastal zones, which is likely to disrupt economic activities such as tourism, fisheries, and mining. It is noted in this respect that more than a quarter of Africa's population live within 100 km of the coast and that about 12% of urban population live within the low elevation coastal zones. Furthermore, coastal zones will experience significant impacts arising from storms, floods and sea level rise. In Africa, coastal cities such as Cape Town, Maputo and Dar es Salaam with large and growing populations will be affected (Bunce, 2010). Despite being the most developed of Africa’s urban areas, coastal cities are particularly vulnerable to sea level rise. “Nearly 60 per cent of Africa’s total population living in low elevation coastal zones is urban, representing 11.5 per cent of the region’s total urban population” (UN-Habitat, 2008 pg 141). Because of their large adaptation deficit, African coastal cities are poorly equipped to deal with sea level rise and will be amongst the most adversely affected, leading to devastating consequences (UN-Habitat, 2008 pg 141). All of these climate change impacts affect the poor and vulnerable most severely (Douglas *et. al.* 2008; Kithiia, 2011 pg 176) making climate change one of the greatest developmental challenges facing the continent’s cities.

African small and medium-sized cities have “low levels of capacity to adapt to the current range of climate variability, let alone any future climate impacts” (UN- Habitat, 2011 pg 178). In other words they have a high adaptation deficit (Satterthwaite *et al*., 2009 pg 9). The shortfall in infrastructure in African cities is a particularly critical concern as adaptation is often framed in terms of infrastructural changes. It is not possible, however, “to climate-proof infrastructure that is not there” (Satterthwaite *et al*., 2009 pg 9). It is also important to question the appropriateness of hard infrastructural responses such as sea walls and channelized drainage lines (Dossou and Gléhouenou-Dossou, 2007 pg, 78; Douglas *et al.* 2008 pg 199; Kithiia and Lyth, 2011 pg 251) that are costly and often maladaptive.

The reason for the high level of vulnerability and low adaptive capacity has less to do with climate change (Kithiia, 2011 pg 178) and more to do with structural factors, particularly poorly capacitated and resourced local governments. Weak local government creates and exacerbates a large number of problems including the lack of appropriate regulatory structures and mandates, poor or no planning, lack of or poor data, lack of disaster risk reduction strategies, poor servicing and infrastructure (particularly waste management and drainage) uncontrolled settlement of high risk areas such as floodplains, wetlands and coastlines, ecosystem degradation, competing development priorities and timelines and the lack of co-ordination amongst governmental agencies functions (Adelekan 2010 pg 434, 440; Diagne, 2007 pg 552, 553, 554; Dossou and Gléhouenou-Dossou, 2007 pg 70; Douglas *et. al.* 2008 pg 187,189, 195; Kithiia, 2011 pg 177, 178; Kithiia and Dowling, 2010 pg 471, 473; Mukheibir and Ziervogel, 2007 pg 153, 156; Roberts, 2008 pg 537; UNEP, 2009 pg 230). This increases local exposure risk, and as a result the adaptation agenda in African cities is increasingly being linked with the disaster preparedness agenda (Diagne, 2007 pg 553; Douglas *et al*., 2008 pg 204; Roberts, 2010 pg 402). The lack of disaster risk reduction strategies, however, produces reactive rather than proactive responses from resource-strapped local governments (Adelekan, 2010 pg 449; Kithiia and Dowling, 2010 pg 471; Kithiia, 2011 pg 179) effectively resulting in the transfer of responsibility to the individual and household level (Douglas *et al.* 2008 pg 197).

22.4. Adaptation in Africa

Since 2007, Africa has gained a wealth of experience in conceptualizing, planning and beginning to implement and support adaptation activities, from local to national levels and across a growing range of sectors. Many of these initiatives are yet to be assessed in terms of effectiveness, equity and sustainability, and there is consensus that the scale of the activities is not yet commensurate with the need. While adaptation planning is gaining traction in many countries, most of the adaptation to climate variability and change is autonomous and largely unsupported (Vermuelen et al., 2008; Ziervogel et al., 2008).

Multiple uncertainties in the African context mean that successful adaptation will depend upon developing resilience in the face of uncertainty (Conway, 2009). This uncertainty is related not just to climatic factors, but to the multiple environmental, political, social, economic and institutional stressors that act across scales, levels, stakeholder groups and sectors. At the same time, many climate-sensitive sectors in developing countries throughout the world, and including in Africa, are currently not well adapted to current climatic risks (Smith et al, 2012). An example lies in a locality where there is little or no protection from contemporary climate risks like floods and drought – referred to as the adaptation deficit (Burton, 2004). The inadequacy of developmental strategies to counter current climate risks reinforces the need for strong inter-linkages between adaptation and development, and for low-regrets adaptation strategies that produce developmental co-benefits (Bauer and Scholz, 2010). This is of particular importance for Africa, given the enduring development needs.

The recognition that adaptation and mitigation should not be viewed as trade-offs, but rather as complementary elements of the global response to climate change, is gaining traction in Africa (ref). Given the poverty and vulnerability context, this realisation is occurring within a pro-poor orientation that seeks to leverage developmental benefits from integrated adaptation-mitigation activities.

Social-ecological system - planetary boundaries (Rockstrom et. al., 2009), social foundation concept – safe and just space for humans (Raworth, 2012), Scaling up to "safe operating space" – Commission on Sustainable Agriculture and Climate Change (Beddington et al, 2012) – linked to Africa's adaptation context

22.4.1. Adaptation Needs and Gaps

Current research on adaptation and adaptive capacity emphasises the multiple stressors to which people in Africa are exposed, as set out in the foregoing text on vulnerability and impacts. There is consequently a need to strengthen or develop the capacity to cope with and adapt not just to short-term weather-related variability or to longer-term climate change, but to many more changes – demographic developments, large-scale migration, financial crises and economic conditions, changing labour markets, public health issues, quality and availability of natural resources, changing political landscapes, governance failures at multiple scales, conflicts, and so on (O'Brien and Leichenko, 2000; O'Brien et a;., 2004; Leichenko and O'Brien, 2008; Twomlow et al., 2008; Bryan et al., 2009; Goulden et al., 2009; Westerhoff & Smit, 2009; Bunce et al., 2010; Casale et al., 2010; Berrang-Ford et al., 2011).

While adaptive capacity thus encompasses the abilities needed to adapt to both climate and non-climate changes, adaptation needs should be informed by an assessment of climate risks and vulnerabilities, which may follow different methods, as discussed in Chapter 14. In Africa, the LDCs have generally used the National Adaptation Plan of Action (NAPA) process to assess vulnerabilities, explore impacts, and identify priority activities that respond to their urgent and immediate needs to adapt to climate change – those for which further delay would increase vulnerability and/or costs at a later stage (UNFCCC, 2002).

[Insert table synthesized from NAPAs, with needs, gaps and main adaptation sectors and priority actions]

The need to strengthen the capabilities to deal with and adapt to climate change and its interaction with other development pressures is particularly urgent in Africa, given the continent's foremost vulnerability to climate change, because physical effects are likely to be among the most severe globally. Secondly, overall adaptive capacity is considered to be low as a result of economic, demographic, health, education, infrastructure, governance and natural factors. Thirdly, high levels of vulnerability are observed to such impacts at household and community levels (Collier et al., 2008; Busby et al., 2010).

As Africa is still the continent most dependent on natural-resource based economies (Collier et al., 2008), most research on strengthening adaptive capacity is focused on rural contexts. There is nonetheless a growing recognition of the specific support requirements of urban dwellers and municipal planners in Africa for enhancing their adaptive capacity to climate change impacts (Lwasa, 2010). The literature, however, stresses the vast variety of contexts that shape adaptation and adaptive capacity - even when people are faced with the same stimuli, responses vary greatly (Cooper et al., 2008; Vermuelen et al., 2008; Ziervogel et al., 2008; Gbetibou, 2009; Westerhoff & Smit, 2009).

Rural people in Africa are adapting largely without external support to a range of climate change impacts (Vermuelen et al., 2008). Supporting both civil society organisations' and government's capacity to access, interpret and use information and facilitating institutional linkages and coordinating responses across all boundaries of government, private sector and civil society would further enhance adaptive capacity (Brown et al., 2010).

Adaptation needs encompass institutional, social, physical and infrastructure needs, ecosystem services and environmental needs, and financial and capacity needs. One of the most pressing knowledge gaps in Africa concerning adaptation is the gap between supply and demand of climate change information. As noted in the AR4 and subsequently highlighted in the literature, monitoring networks in Africa are insufficient and characterised by sparse coverage and short and fragmented records, which makes modelling difficult (Boko et. al.,, 2007; Goulden et al., 2009; Ziervogel & Zermoglio, 2009). Across Africa, shortage of relevant information and skills, in particular for downscaling climate models and using scenario outputs for development and adaptation planning, has been observed as well as under-resourcing of relevant organisations, such as Meteorological Agencies (Ziervogel & Zermoglio, 2009; Ndegwa et al., 2010). This is exacerbated by insufficient collaboration between scientists and practitioners towards closing the data gap and insufficient attention by the scientific community to communicate climate change information through the right channels and products targeted at specific users (Ziervogel et al., 2008).

[Systemic causes of knowledge gaps identified in parliamentarian's understanding of climate threats and responses, such as limited access to parliamentary researchers and even to the internet (IIED, 2011b).]

Technology needs assessments have been conducted in many African countries, including Cote d'Ivoire, Ethiopia, Kenya, Ghana, Mali, Morocco, Mauritius, Rwanda, Senegal, Sudan, and Zambia (GEF Evaluation Office, 2011).

[Add brief synthesis of identified technology needs]

In the field of agricultural research for food security, significant technology gaps may reduce the potential impact of biotechnology advances, including under-resourced extension services, incomplete understanding of optimal crop management practices or their application, and imperfect knowledge of target breeding environments (Reynolds et al, 2012).

In addition to these specific gaps, the need for comprehensive programmes that promote adaptation through a more holistic development approach has been identified. For the Sahel, Sissoko et al (2011) call for integrated programmes on desertification, water management and irrigation, promoting sustainable agricultural practices, and developing alternative sources of energy.

This assessment now discusses experience in Africa with building the governance system for adaptation and implementing adaptation options, before progressing to an assessment of knowledge on adaptation constraints, barriers and limits, and concludes with a summary on adaptive capacity in Africa.

22.4.2. Experiences in Building the Governance System for Adaptation

22.4.2.1. Regional and National-Level Adaptation Policies, Strategies, and Planning

22.4.2.1.1. Regional policies and strategies for adaptation

[still to be developed – will show emerging regional approach, and provide assessment of this.
Includes: SADC and Lake Victoria Basin Committee developing Climate Change Strategies and Action Plans – CCAA supported;
Agreed in 2011 to develop an African Green Growth Strategy – Towards Low-Carbon Growth and Climate Resilient development", builds a shared medium and long-term vision to promote sustainable and low-carbon growth in Africa; linked adaptation-mitigation approach, with adaptation seen as an urgent priority]

22.4.2.1.2. National policy, adaptation planning processes, and mainstreaming

African countries have initiated the comprehensive planning process for adaptation by developing National Adaptation Programmes of Action (NAPAs) or Climate Change Response Strategies (NCCRS) (Madzwamuse, 2010). As of December 2011, 32 Least Developed Countries in Africa had submitted NAPAs to the UNFCCC, with only Equatorial Guinea and Somalia not yet having done so. The NAPAs identified key adaptation measures and included criteria for prioritizing activities, as well as a prioritized short list of activities, for which short profiles of projects were developed to facilitate funding for urgent adaptation needs. Sectorally, these tend to focus on agriculture, food security, water resources, forestry, and disaster management (Madzwamuse, 2010; Mamouda, 2011), and, with respect to mechanisms, on technical solutions, education and capacity development (Pramova et al, 2012).

While constituting an extremely useful first step in developing a policy and strategic framework for climate change adaptation, a recent study found that NAPAs and NCCRS are not optimal for facilitating an integrated response as they tend to be focused on biophysical vulnerabilities, adopt sectoral and project approaches to adaptation, and do not incorporate adaptation needs at the micro-level (Madzwamuse, 2010). Thus they do not sufficiently include and address the adaptation needs of vulnerable societal sectors, such as women, poor people and children. For instance, while gender was one of the criteria for pre-selection of projects in the Burkina Faso NAPA, 67 per cent of the projects have been assessed as benefiting men in particular, with the remaining 33 per cent being of benefit to both men and women (Romero Gonzalez et al, 2011). Furthermore, NAPAs have failed to integrate energy adaptation, assuming that the energy services and infrastructure required for implementation of the identified projects is already in place, with only the Democratic Republic of Congo having developed a prioritised energy access project, apart from cross-sectoral projects in Benin, Lesotho, Rwanda, and Sudan (Mamouda, 2011).

Notwithstanding the largely sectoral approach adopted in NAPAs and NCCRS, cross-sectoral adaptation planning and response and risk management are already happening to some extent in Africa, through mainstreaming initiatives and multi-sector actions. Concerning mainstreaming adaptation into overarching economic and development planning, and into sectors, twenty countries in Africa participated in the Africa Adaptation Programme (AAP), initiated in 2008, to support integrated and comprehensive approaches. The AAP was designed as a transformative model, intended to integrate adaptation into national development priorities, in order to introduce long-term and dynamic measures to manage climate change’s intrinsic uncertainties (UNDP, 2009), including expanding financing options to meet national adaptation costs at sub-national, national and regional levels (UNDP, 2009; UNDP, 2010) – for instance, the Nigerian AAP project document included as an activity developing an expanded national resource envelope to support climate change adaptation, through development of private sector possibilities for funding adaptation activities; and through the global Adaptation Fund (Government of Nigeria et al, 2009). Assessment of the outputs and outcomes of the AAP, when available, should provide valuable lessons for further developing the adaptation systems in Africa.

[Insert table to show AAP activities, including the fiscal / budgetary components]

There is limited evidence of moves towards a more programmatic approach to national adaptation planning, such as Ethiopia’s Programme of Adaptation to Climate Change (EPACC), and the more integrated approach of national low carbon development plans and climate resilient development strategies, for instance Rwanda’s National Strategy on Climate Change and Low Carbon Development, under development in 2012.

Notwithstanding this progress, significant disconnects exist at the policy and planning level and implementation of a more integrated adaptation response is still minimal. For example, only a small percentage of the NAPA activities have received funding, and macro-economic development frameworks in Africa have been found to undercut adaptive capacity of poor people through measures to draw foreign direct investment and promote industrial competitiveness (Madzwamuse, 2010), although Collier et al (2008) find that poor business environments in Africa impede both FDI and adaptation. While subsistence farmers are amongst the most vulnerable groups in Africa, agricultural policy is frequently biased towards commercial agriculture (add other refs...; Madzwamuse, 2010). Fankhauser and Schmidt-Traub (2010) propose integrating adaptation and development by climate-proofing the MDGs (add analysis).

Developing countries are establishing national funding entities to manage international and domestic climate change funding and encourage mainstreaming programmes and projects into national development strategies and country plans (Gomez-Echeverri, 2010; Smith et al, 2012), with a national fund in the process of being established in Nigeria.

Policy and legislative activity is in some cases resulting in supportive enabling environments for adaptation, such as in Mozambique, although financial, organisational, networking and individual capacity limitations constrain mainstreaming efforts (Sietz et al, 2008). Namibia has a robust national policy on climate change (IIED, 2011b) and South Africa released a Draft National Climate Change Response Green Paper in November 2010, with adaptation strategies at national and provincial levels still under development. Further relevant policy developments in Africa for mainstreaming climate change adaptation have included a more proactive approach to risk management in disaster risk management (DRM). For instance, Ethiopia's updated Disaster Risk Management policy, which includes disaster risk reduction, focuses on proactive risk management, a multi-hazard and multi-sector approach, decision making based on strong risk assessments and early warning, and emphasizes decentralized and community-based actions (Hunde, 2012).

Legislative and policy frameworks for adaptation in southern Africa remain fragmented (IIED, 2011b), as is the case for the region as a whole, where adaptation policy approaches seldom take into account realities in the political and institutional spheres (Naess et al, 2011; Lockwood, 2012). Civil society institutions and communities have to date played a limited role in formulation of national adaptation policies and strategies, with these processes having been dominated by government actors (Madzwamuse, 2010), at the risk of inadequate inclusion of and planned response to stakeholder needs of the most vulnerable groups and communities. Moreover, children and youth, who form the majority of Africa's population, are excluded from climate change negotiations and national policy development (African Development Forum, 2010).

Spatial planning

Different approaches have been taken for integrating climate change considerations into spatial planning. In South Africa, a comprehensive system of plans for integrating biodiversity and climate change considerations into spatial and development planning has been developed, formulated by incorporating climate change design principles into the existing systematic biodiversity planning (Petersen and Holness, 2011). These still need to be effectively implemented, and will require efforts to ensure that decision makers understand that ecosystem-based adaptation is an integral component of the developmental agenda, rather than a competing 'green' agenda.

_____ START BOX 22-1 HERE _____

Box 22-1. Ecosystem-based Planning[3] for Integration of Biodiversity and Climate Change in South Africa

South Africa is one of 17 mega-diverse countries on the planet, home to three biodiversity hotspots and almost 15% of known coastal and marine species. South Africa's emerging strategy of ecosystem-based adaptation to climate change is based on maintaining an optimal configuration of intact natural habitat, identified through systematic biodiversity planning. This includes incorporating biodiversity into spatial and development planning, and a national strategy for expanding protected areas to conserve biodiversity and promote ecosystem resilience. Climate change has been specifically incorporated by identifying areas needed for maintaining ecosystem functioning under a range of climate scenarios, thereby accommodating uncertainty linked to projections. Biodiversity sector plans are being used in seven of the country's nine provinces, and aim to guide land-use planning and decision-making by all sectors that impact biodiversity. Systematic biodiversity planning has also been used to map 44 important areas that capture the full range of South Africa's biodiversity patterns and ecological processes and could form the basis for expansion of the country's protected estate. Some provinces and districts have made good progress in implementing these plans, but in general integration of biodiversity and climate change adaptation priorities into sector policies and programmes is not seen as a crucial national priority. More effective use of the biodiversity plans will require active capacity building efforts focused on land-use planners and other decision makers.

[FOOTNOTE 3: "Ecosystem-based adaptation is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change" (Secretariat of the Convention on Biological Diversity, 2009).]

Source: Petersen and Holness, 2011.

_____ END BOX 22-1 HERE _____

[Add assessment of CCA integration into spatial planning in other countries]

An inter-sectoral approach to planning and implementation for climate change can be detected in the areas of integrated water resources management, integrated coastal zone management, disaster risk reduction, and in some cases, land use planning – see case studies on multi-sector synthesis.

A number of studies have highlighted the key role for institutional capacity development in mainstreaming adaptation, for example with respect to development assistance in Mozambique (Sietz et al, 2008). The lack of inter-departmental collaboration on climate change in many African countries is an institutional constraint, as is the limited coordination between government and NGOs, CSOs and private sector actors and between different levels of government and communities (Brown et al., 2010). An illustration provided is the effect of nature conservation policies which often undermine the adaptive capacity of those depending on the resources to be protected (Brown et al., 2010; Bunce et al., 2010), although other studies highlight that adaptation strategies can be potentially harmful to biodiversity and ecosystem services (add refs). A further example lies in policy in many countries that favours sedentarisation, despite mobile pastoralists usually being better able to cope with extreme weather conditions due to their opportunistic strategy of transhumance, which enables them and their stock to track forage and water in space and time (O'Farrell et al., 2008; Mwang`ombe et al., 2011).

In general, therefore, mainstreaming climate risk at the national policy and planning level has received increased emphasis in Africa, but this is at an early stage (UNDP-UNEP Poverty-Environment Initiative, 2011b). More attention is needed on implementation of mainstreaming plans, on priorities such as mainstreaming health and climate change risks (e.g. for global Tong et al, 2008; *add Africa refs*); and on locating climate adaptation mainstreaming efforts within what Wilbanks and Kates (2010:719) refer to as "the larger envelope of social relationships, communication channels, and broad-based awareness of needs for risk management that accompany community resilience." Zhu et al (2011) highlight the importance of investigating potential changes in future economic and social systems under different climate scenarios, in order to increase understanding of the implications of adaptation strategy and planning choices.

22.4.2.2. Institutional Frameworks for Adaptation

The adaptive capacity of societies depends to a large degree on the ability to act collectively, through institutions that govern social relations between individuals and social groups and for natural resource management at multiple scales (Adger et al., 2004). In recognition of this, the Cancún Adaptation Framework sets out provisions on institutions for adaptation at the global, regional and national level. While the nature of the adaptation institutions at the global level, both within and outside of the UNFCCC, are of critical importance for Africa's ability to move forward on adaptation, this is covered in other chapters (add X-ref). Regionally, Africa has a range of institutions, existing and emerging, relevant to adaptation coordination and planning.

It is clear that governance and institutional frameworks can either enhance or constrain adaptive responses in Africa. At the national level, cross-cutting institutions on climate change exist in different forms, linked to nascent policies and strategies (IIED, 2011b). Institutional forms include inter-ministerial committees on climate change (for example, as in Ethiopia, South Africa), sometimes supplemented by multi-stakeholder institutions for adaptation planning – at multiple levels in the case of Ethiopia, which has sub-national and local coordinating forums for disaster risk reduction / climate change adaptation (Hunde, 2012). Government-sector challenges that weaken adaptive capacity include inadequate coordination linked to unclear or conflicting mandates, dysfunctional arrangements for integration between state and other actors, high staff turnover, inadequate financing levels, and the burden created by external reporting requirements – for example to the UNFCCC and donors – compounded by weak donor coordination (…; Madzwamuse, 2010; …). …… Moreover, the developing literature on institutional frameworks to deliver effective multi-level interactions for adaptation finds that country-level multi-stakeholder partnerships for national coordination need to be developed and strengthened, as do national and sub-national civil society networks (Madzwamuse, 2010; Harmeling et. al., 2011); and that climate change adaptation agendas are externally driven in many countries, by donors and international NGOs, and may reflect disparate interests rather than coherent national policy (….; Madzwamuse, 2010).

Institutions that facilitate cross-sectoral adaptation planning in order to create multiple benefits (Bizikova et al, 2010) are required at all levels in Africa. Hartmann and Sugulle (2009) show that while pastoralists in Somaliland require support for soil conservation, water harvesting, reforestation and rangeland improvement for adaptation and mitigation purposes, local institutions and international NGOs working in the area lack concrete plans for climate change awareness raising and facilitating adaptation actions.

Effective implementation of governance mechanisms for sustainable natural resource management is a critical precursor for sound adaptation responses. For example, it has been noted that policies and measures that reduce overfishing and other environmental stressors and that strengthen governance are consistent with adaptation goals for fisheries (Allison et al., 2009; Badjeck et al., 2010).

In the context of high levels of donor support for adaptation and climate-resilient development, some African countries have established technical working groups that include government, donors, UN agencies and NGOs to promote coordination and reduce the duplication of efforts and a project-level approach, for instance Ghana, Ethiopia, … (ref). A consolidated assessment of the effectiveness of such institutional mechanisms is lacking, but it has been found that scenarios developed in a participatory fashion on linkages between adaptation measures, vulnerability reduction and development priorities of the countries help to increase the integration, effectiveness and relevance of donor investments (Bizikova et al, 2010).

In contexts of particularly fragile governance, institutions for reducing climate risk and promoting adaptation may be extremely weak or almost non-existent (Hartmann and Sugulle, 2009; …). Significant investments and external support may be needed in areas where high levels of climate risk are correlated with conflict, such as in Somalia.

22.4.2.3. Sub-National and Local-Level Governance Response

Since AR4, there has been additional effort on adaptation planning at sub-national and local levels in African countries. Given the location-specific and nuanced nature of vulnerability and exposure to climate risk, local adaptation responses are essential to enhance resilience and safeguard livelihoods (Tompkins and Adger, 2004; …..). Moreover, formulating sub-national and local development and adaptation pathways is useful to identifying linkages between national and other sectoral priorities at the local and regional level, as well as with donor approaches (Bizikova et al, 2010).

Provincial/state policies and strategies: Nigeria, South Africa, others
Municipal response – cities e.g. Lagos, Durban, Cape Town, others
Integrating community-based DRR and CCA into local development planning – ACCRA work in Ethiopia – participatory methodology to enhance skills of local government
Weakness of local governments to cope with decentralised adaptation response (Madzwamuse, 2010)
There is evidence of some evolution of a multi-level and multi-sector approach, for instance Ethiopia’s Programme of Adaptation to Climate Change (EPACC), which deals with adaptation at sectoral, regional, national and local community levels (Hunde, 2012).

Local-level institutions

At the local level, institutions regulating access and use of natural resource, local action and social networks are crucial to facilitate innovation, experimentation and risk sharing for adaptive response (.....; Debsu, 2012; Rodima-Taylor, 2012). At the same time, characteristics such as wealth, gender, ethnicity, religion, class, cast or profession, can act as social barriers for some to adapt successfully or acquire the required adaptive capacities (Ziervogel et al., 2008; Godfrey et al. 2010; Jones & Boyd, 2011). Based on field research conducted in the Borana area of Southern Ethiopia, Debsu (2012) highlights the complex way in which external interventions may affect local and indigenous institutions, by strengthening some coping and adaptive mechanisms, and weakening others.

Impacts of climate change at the local level cannot be separated from other development pressures, as people do not adapt separately to pressures from climate change but to whatever mix of changes they face, emphasising the need for climate change risks to be addressed as part of ongoing development across all sectors (Klein et al., 2007; World Bank, 2010; Levine et al., 2011). Furthermore, there is general consensus that support to local-level adaptation is best achieved by starting with existing local adaptive capacity, and incorporating and building upon present coping strategies (see, for example, Archer et al, 2008; Dube and Sekhwela, 2007; Huq, 2011). The important role of local organizations and informal associations in influencing adaptation responses in poor communities in Africa is increasingly being recognised. Rodima-Taylor (2012) shows how informal associations used for conflict resolution and economic cooperation by the Kuria people of north-western Tanzania support innovative adaptation strategies that reduce local vulnerability; while Dube and Sekhwela (2007) call for frameworks to guide appropriate community participation in the governance of local resources, to mitigate against the erosion of traditional coping capacities and to support adaptive responses.

In addition to participation in governance structures, the role of participation in adaptation initiatives is also generally considered to be necessary for ownership and successful outcomes, and is discussed in subsequent text on adaptation as a participatory learning process.

22.4.2.4. Community-Based Adaptation

Developing coping mechanisms and adaptive responses to manage and ward off projected climate impacts is dependent to a large degree on local-level and community actions (Huq, 2011; African Development Forum, 2010; ...). But lack of focus on community-level practices has been a weakness of the global discourse on adaptation.

The Community-based Adaptation in Africa (CBAA) project supported three-year climate change adaptation pilot projects at community level in eight African countries (Sudan, Tanzania, Uganda, Zambia, Malawi, Kenya, Zimbabwe, South Africa), which were implemented as a learning-by-doing research approach. [Add analysis / assessment]

Recent analyses highlight the importance of social learning and collective action to promote adaptation, especially where livelihoods are particularly dependent on natural resources – for example, poor families in South Africa and Mozambique have started collective horticulture, poultry raising and maize production projects as an adaptation response to altered rainfall patterns, where formerly they had mainly worked alone. (UNDP/UNEP Poverty-Environment Initiative, 2011a).

Process-related emerging lessons from community-based adaptation pilot projects in Africa include the recognition that viewing adaptation as a response to multiple threats can help to achieve community acceptance of needed adaptation actions as co-benefits of responding to multiple stresses (Wilbanks and Kates, 2010). Furthermore, plans to support community-based adaptation must be assessed thoroughly to make sure that actions are not restricting communities’ natural adaptive capacity.

Concerning the substance of community-based adaptation, there is consensus that scientific information often fails to provide what is required to support communities in their local adaptation processes (see for example Huq, 2011) – this is discussed further in sections on needs and gaps, and on knowledge development, in this chapter. Local adaptation planning using participatory scenario development workshops has revealed the following important areas for pro-poor adaptation: social protection, services and safety nets to enhance the situation of vulnerable groups; better water and land governance to enable effective infrastructure management and community-based activities; enhanced water storage and harvesting, and better post-harvest services to maintain the livelihoods of rural people and reduce outmigration; strengthened civil society, and involving decentralised structures and traditional authorities in planning; and more attention to urban and peri-urban areas heavily affected by migration of poor people, yet lacking production systems and livestock (Bizikova et al, 2010). These findings are based on work carried out in Mozambique, Ghana, and Ethiopia, as well as Bangladesh.

Given that much of the adaptation responses happening in Africa are autonomous, capacity development to advance bottom-up adaptation planning is required, as well as regional institutional capacity building, including through networks of practitioners (UNEP report (2011) and ACCA 2009). Country actions on developing the enabling environment for community-based adaptation are in their infancy, but examples include the developing frameworks in Morocco for up scaling community-based adaptation both horizontally, through replication of successful pilot projects, and vertically, through integration of community-based adaptation into national strategies and policies (Oumoussa, 2012).

[Incomplete – refs to add: Koelle and Anneke, undated; Heltberg et al, 2012; etc]

22.4.2.5. Equity, Gender, Children, and Human Rights-Based Approaches in Adaptation

While limited attention has been paid to the factors of equity and social justice in adaptation initiatives (Thomas and Twyman, 2005), including questions on the differential distribution of adaptation benefits and costs (Burton et al, 2002), some additional experience has been gained in the recent past in Africa with respect to several critical thematic areas for an equitable approach to adaptation: gender, human rights based-approaches, and involvement of vulnerable or marginalized groups such as indigenous peoples and children. This is a vital area for further study and assessment: as noted in the Special Report on Extreme Events, “Inequalities influence local coping and adaptive capacity, and pose disaster risk management and adaptation challenges from the local to national levels” (SREX SPM, 2012: 8).

22.4.2.5.1. Gender and adaptation in Africa

Gender is one of the critical dimensions for investigating how the impacts of climate change are distributed, as well as for optimising adaptation actions (Patt et al, undated). It is increasingly understood that gender inequalities amplify climate risks and vulnerabilities (Watkins, 2007). Given existing low levels of gender equality - a 2012 estimate was that 34 – 77% of the global population fall below the social foundation for gender equality (Raworth, 2012) – climate risks place gains made in this area in jeopardy. This relates both to a lack of empowerment and participation in decision-making (Patt et al, undated), as well as by placing a heavier burden on women’s household roles (UNDP, 2011). In Africa, actions to cope with climate-related depletion of natural resources increase women’s workload and worsen women’s time poverty, through for example additional time spent by women to fetch water or firewood (Romero Gonzalez et al, 2011). This threatens developmental gains – for example, educational achievements, if girls are kept out of school to assist with heavier household duties (Raworth, 2008). Despite differential impacts, there has been little research on understanding different adaptive strategies of benefit for women and men. Adaptation actions in Africa since the AR4 have made additional efforts to integrate gender as a cross-cutting issue. Gender-sensitive approaches adopted to mainstream gender into climate change adaptation planning and decision-making by the 20 African countries implementing the Africa Adaptation Programme (AAP) fall into three categories, as depicted in Table 22-3.

[INSERT TABLE 22-3 HERE
Table 22-3: Mainstreaming gender into climate change adaptation in the AAP.]

As the analysis in which these examples were presented was made in early stages of implementation of the AAP, results are not yet available from full implementation. It will also be important to understand how gender dimensions are being integrated into disaster risk reduction, preparedness and response, given the heightened vulnerability of women and girls to disasters (WFP, ??). Security of tenure over land and resource access is commonly seen as a critical enabling provision for enhancing adaptive capacity of poor and vulnerable people (African Development Forum, 2010; add refs), but this, together with opportunities for employment, is frequently not sufficiently extended to women in adaptation response frameworks (Madzwamuse, 2010).

A recent study points to opportunities inherent in adaptation for women. It notes that women have been shown to be better at the kind of decision making demanded by adaptation to climate change, including long-term thinking, trusting and integrating scientific knowledge, and learning how to take decisions in uncertain conditions (Patt et al, undated). *Look for relevant African analysis and reference*

22.4.2.5.2. Child-centered approaches to adaptation

While children and youth have largely not been involved in national or sub-national adaptation policy and strategy formulation, an increasing number of programmes and research initiatives in Africa are now focusing on the vulnerability of these groups to climate change, and on targeted adaptation responses for them, or what some term a child-centred approach to disaster risk reduction and adaptation (Tanner and Seballos, 2011). Many of these involve seeing children and youth as critical change agents (Unicef refs, IDS), and using approaches that stress agency and empowerment, rather than passive victimization (Seballos and Tanner, 2011), or using the opportunities inherent in their 'innovative energies' to constructively tackle climate change risks (African Development Forum, 2010:6), while others caution on limits to this agency related to power imbalances between children and adults, and different cultural contexts that may constrain children's agency (IDS – Cannon ref).

[Develop this section, drawing on refs in Africa, including IDS, Save the Children, Plan International, Unicef (country studies: South Africa, Kenya), Child-centred CBA in the Horn of Africa - Save the Children
Link with percentage of African population under 18]

22.4.2.5.3. Human rights-based approaches to adaptation

Using a human rights-based approach to development (HRBA) can assist with ensuring that equity issues are understood and interventions are designed to promote greater equity in development, disaster risk reduction and adaptation to climate change. Using HBRA means asking the critical questions of 'what, why, who and what capacities?' (UNDG, 2009 *check date)*. For example, in the context of disaster risk, this means a risk analysis based on human rights, which would include asking questions about what the underlying and root causes of the vulnerabilities that are leading certain groups to suffer from disaster risk are, who has the duty to reduce these disaster risks, and what capacities are needed to address disaster risk, both for rights holders and duty bearers. [Show link to context of gender and children, e.g. Plan International – Climate change undermines children's rights - add examples, and discussion on use in Africa in adaptation context]

At the community level in Africa, people continue to use indigenous and traditional knowledge that provides valuable input towards identifying measures for climate change adaptation. However, indigenous peoples remain hardly recognized in climate change policies and mechanisms, internationally and nationally, and their own potential to adapt is still barely understood and supported (Salick and Byg 2007). In addition, current agricultural policies, subsidies, research and intellectual property rights promote modern varieties at the expense of local knowledge and biodiversity (IIED 2011a).

HRBA highlight the need to focus adaptation efforts on vulnerable groups, which would include children and youth, aged and disabled people, internally displaced persons and refugees. Given their higher vulnerability to climate change, and lower adaptive capacity in many cases, adaptation responses need to specifically target these groups (...; African Development Forum, 2010; ...). Concerning the overall approach to adaptation, some argue that what they see as the necessary shift from technological-based adaptation to rights-based adaptation has yet to be made (Harjeet Singh, Action Aid, personal communication at CBA6, 19th April 2012, *add document ref)*.

[Explore potential contribution to changing power relationships through HRBA]

22.4.2.6. Interactions between Adaptation Governance Levels

Policies and institutions impact on the local level / autonomous response, and projects / local experiences may also impact on policy
Emphasis in recent adaptation initiatives on policy advocacy; and importance of leadership and decision making

At national level, generally weak institutional capacity, in particular for managing shared natural resources such as international rivers or other water bodies and forests (Goulden et al., 2009; Brown et al., 2010), for integrating climate adaptation with development activities to coordinate and lead local level efforts (Belay Simane et al., 2012) or for co-producing and integrating different knowledge systems between farmers and agricultural experts (Newsham & Thomas, 2011) is what hinders adaptive capacity of people are local level.

There is evidence of the influence of local-level projects on the adaptation policy environment too. *Include examples from AAP.* Tschakert *et al*. (2010) suggests that dominant discourses on climate change in West Africa, which emphasize drought and desertification are out of touch with local realities. Based on a case study of Ghana, she found that extreme rainfall events – and related flooding – are prominent in local perceptions of climate risks, and communities have developed a range of response strategies to cope with them. The official bias towards drought means that policies do not capitalize on such local knowledge and experience for building resilience to future climate change.

Institutional factors that have been highlighted as particularly crucial for adaptive capacity in Africa are related to land tenure and secure access to other natural resources (Brown et al., 2010; Bryan et al, 2009). Tenure security over vital assets, not necessarily private ownership, is widely accepted as being crucial for enabling people to make longer-term and forward-looking decisions in the face of uncertainty, such as changing farming practices, farming systems or even transforming livelihoods altogether.

Add: Emerging view that combination of bottom-up and top-down approaches is key to effective and equitable adaptation

Under uncertain climatic futures, hierarchical governance systems that operate within siloes will no longer be viable, but will need to be replaced with more adaptive, integrated, multi-level and flexible governance approaches, and inclusive decision making that can operate successfully across multiple scales – or adaptive governance and co-management (Folke et al., 2005; Olsson et al., 2006; Koch et al, 2007; Berkes, 2009; Pahl-Wostl, 2009; Armitage & Plummer, 2010; Bunce et al., 2010; Plummer, 2012). Such governance systems, dealing with complex social-ecological conditions are increasingly emerging and are recognising feedback processes, nonlinearity, collaborative processes and systematic learning as a way of dealing with resource uncertainty and environmental change by fostering multi-level (global to local) interactions among social actors, often with conflicting interests, innovative ways of producing and sharing knowledge, and linking science and policy through communities of practice (Plummer & Armitage, 2010).

There has been additional emphasis in the literature and in practice on developing African leadership for climate change. Initiatives have included building research leadership through the Africa Climate Change Fellowship Programme (Climate Change Adaptation in Africa Programme, 2011); strengthening climate negotiators from LDCs including through bursaries for extra delegates, evidence-based technical support and regional workshops to develop negotiating strategies and develop relationships with finance, planning and foreign affairs officials and parliamentarians (IIED July 2011 Reflect & Act); and other initiatives.

Decision-making for adaptation

Making decisions about adaptation largely concerns managing uncertainty and incorporating the perspectives of diverse stakeholders and system components, especially the most vulnerable. Some have conceptualized the decision-making process in terms of a set of steps, for instance, vulnerability and risk assessment, identifying options for adaptation, and prioritizing options (Zhu et al, 2011).

To be developed
"decisionmaking processes should be participative, facilitated, and consensus-building oriented" "To assist with decision-making, the Community–based Adaptation (CBA) framework is proposed for creating inclusive governance. The CBA framework engages a range of stakeholders directly with local or district government and national coordinating bodies, and facilitates participatory planning, monitoring and implementation of adaptation activities." (Zhu et al, 2011)
Stakeholder processes & criteria for prioritizing adaptation options (Zhu et al, 2011)
A critical issue is how planning and decision making for adaptation uses scientific evidence and projections, while also managing the uncertainties within the projections (…; Dodman and Carmin, 2011).
Range of tools used in adaptation planning; most tools focus on early stages of planning, with fewer tools available to assist with implementation and evaluation (CDKN guide and article)

22.4.2.7. Economics of Adaptation

Additional case study: Multiple stakeholders' economic analysis in climate change adaptation: case study of Lake Chilwa Catchment in Malawi - Lunduka (IIED)

22.4.2.8. Monitoring and Assessing Adaptation

As defined in Chapter 14, success in adaptation is regarded as any type of adjustment that reduces climate risks or vulnerability to climate impacts to previously determined levels and that promotes efforts to achieve economic, social, and environmental sustainability (Doria, *et al.*, 2009).

Regional / global assessments e.g. evaluation of the GEF Special Climate Change Fund (SCCF)
Assessing policy: Halsnæs and Verhagen (2007) show that it is possible to use indicators of wellbeing to assess development-based climate change adaptation and mitigation.
Local-level monitoring of adaptation actions: e.g. in a participatory action research framework, combined with integrating climate projections, local monitoring of climate variables and collaborative assessment of coping/adaptation actions (for example, Archer et al (2008) in marginal environment of the Koue Bokkeveld, South Africa)
A further identified problem is that vulnerability analysis mostly does not provide a baseline for measuring progress (Moench, 2011).
Brooks et al (2011); Anderson (2011); UNDP evaluation framework

Osbahr et al (2010) focus on features of climate adaptive processes that lead to successful adaptation, while emphasising that assessment of adaptation success is constrained by "the scale of analysis in terms of the temporal and spatial boundaries of the system being investigated" *re-word once additional references are added for this point.* Notwithstanding these constraints, possible key success factors lie in the role of social networks and institutions, social resilience and innovation (Osbahr et al, 2010).

Adaptation actions funded through international funding mechanisms have been found to be highly relevant to national sustainable development agendas of participating countries (GEF Evaluation Office, 2011). Some assessments indicate that donor portfolios are supportive of adaptation – for instance, donor investment at the sub-national level in Mozambique was assessed as having a high share invested in sectors with climate sensitivity, and to some degree in areas with high risks of cyclones, floods and droughts (Sietz et al, 2008). *Add counterview*

22.4.3. Experiences with Adaptation Options

22.4.3.1. Overview

There has been considerable progress in exploring adaptation options, approaches and decision tools in Africa since the IPCC Fourth Assessment Report. However, planning and selection of options for adaptation responses is still an evolving knowledge area (Dodman and Carmin, 2011), and many of the diverse initiatives implemented in Africa have been at the pilot or experimental scale. Adaptation options and approaches used at different levels and scales in Africa include disaster risk reduction, early warning systems and disaster preparedness; social protection and index-based weather insurance; technological approaches and climate-resilient infrastructure; sustainable land management and ecosystem restoration; livelihood diversification and other social processes and socio-economic mechanisms. Projects, initiatives and programmes combine different approaches and mechanisms temporally and spatially, as do people and households.

In recognition of the socio-economic dimension of vulnerability (Bauer and Scholz, 2010), the previous focus on technological solutions to directly address specific impacts is now evolving towards a broader view that highlights the importance of social, institutional, policy, knowledge and informational approaches (African Development Forum, 2010; Chambwera and Anderson, 2011), and on linking the diverse range of adaptation options to the “multi-faceted livelihood-vulnerability risks” faced by many people in Africa (Tschakert and Dietrich, 2010). “Soft path” measures are seen as holding promise for adaptation strategies, as well as the possible objectivity of criteria-based selection of adaptation options, compared to expert judgement (Martens *et al.*, 2009).

Adaptation measures are presented in various categorisations, often in terms of apparent opposites: autonomous and planned, anticipatory and reactive, private and public (AR4; Bauer and Scholz, 2010; Collier et al, 2008), and there is consideration of what constitutes successful adaptation. Examining small-scale farming livelihoods in southern Africa, Osbahr et al (2010) define as successful actions that promote the resilience of systems and ‘legitimate’ institutional change, thereby initiating and maintaining collective action.

Given the variety of intersecting social, environmental and economic factors that may prevent (in the case of limits) or hamper (in the case of barriers) society, governments, communities and individuals adapting to perceived and future unknown climate variability and change (Jones et al. 2010, Jones 2011, Figure to be added), adaptation is increasingly recognised as a complex process involving multiple linked steps at several scales rather than a series of simple planned technical interventions (Moser and Ekstrom 2010). Thus an evolving focus in the literature is on flexible and innovative approaches to planning and implementing adaptation. Flexible approaches are required to deal with the uncertainty inherent in climate projections, compounded by other sources of flux that impact on populations in Africa, and the desirability of adjusting approaches based on lessons learned (*many more refs to add*; Dodman and Carmin, 2011; ...), through a learning-by-doing or experiential learning modality (....; ...; Huq, 2011). Innovation is seen as a key component of potentially successful adaptation processes (Tschakert and Dietrich, 2010; Scheffran et al, 2011; Dodman and Carmin, 2011). These issues are discussed further below.

Importance of gender analysis beforehand and consistent application of it: adaptation projects aimed at women may actually negatively impact women – for example, by increasing their workload without giving them any more control over assets, if they have not factored in strategic interests such as access to and control over resources (Romero Gonzalez et al, 2011)

Within the context of the emerging Green Economy discussions, and given Africa’s ongoing development needs, questions to ask include how adaptation programmes can be designed towards meeting the health, education and employment needs of communities (African Development Forum, 2010). Similarly, for integrated adaptation and mitigation strategies to be effective and sustainable, it is necessary to understand the synergies and trade-offs between approaches – for instance, in the agriculture sector, between various practices for food security and for mitigation of greenhouse gases (Chambwera and Anderson, 2011).

Recent analyses emphasise the magnitude of actions for adaptation that are needed to protect societies and economies from climate change impacts at the local scale, in both rural (refs) and urban (Dodman and Carmin, 2011), and *add quote on significant amount of adaptive capacity to be built.*

The following discussion of adaptation options and approaches under discrete headings does not imply that these are mutually exclusive or being approached in isolation – people, institutions and projects are employing a range of approaches in varying degrees of coordination and synthesis, as some of the discussion and examples that follow indicate.

22.4.3.2. DRR and Disaster Risk Management

The link between disaster risk reduction and adaptation to climate change is well accepted, and African countries have gained experience in a range of approaches to offset the impacts of natural hazards on individual households, communities, and the wider macro-economy. Risk reduction strategies employed in Africa include early warning systems, emerging risk transfer schemes, social safety nets, contingency funds and investment to address disaster risk in national and local public planning and budgeting (....;UNISDR, 2011). These are important in responding to sudden disasters, slow-onset disasters, and complex emergencies, all of which may be climate-related.

The paradigm shift from crisis management to proactive risk management apparent at the global level has been taking place in Africa too. Investment in disaster risk reduction reduces both the short- and long-term impacts of disasters, and the co-benefits of integrating DRR and climate adaptation are becoming increasingly accepted (X-ref to chapter 14). Risk reduction mechanisms are intended to reduce vulnerability and strengthen resilience, thereby building capacities to advance adaptation to climate change impacts (UNFCCC, 2008; UNISDR, 2011). There are successes and challenges associated with each particular risk management strategy.

22.4.3.2.1. Early warning systems

Early warning systems (EWS) are gaining prominence as stakeholders from within and outside government in Africa are strengthening early warning capabilities in order to assess and monitor risks and warn communities of a potential crisis. Effective EWS are essential in order to assess, to monitor risk and warn communities of a potential crisis, and to save lives and livelihoods (UNFCCC 2008). Regional systems such as the Permanent Inter-States Committee for Drought Control in the Sahel (CILSS) have been providing farmers with critical agro-meteorological information and their operation as EWS is seen as crucial in the context of adaptation (Sissoko et al, 2011).

There are several national and local EWS on food and agriculture in West Africa and the Sahel that take various food and nutritional threats into account. For example, Niger's EWS collects food availability and accessibility data twice a year, helping both the government and international community effectively react to the food, nutritional and pastoral crisis that raged in 2010. Additionally, community-based EWS and emergency response initiatives have also been promoted in this region (FAO 2012). In Mauritania, following a locust outbreak in 2003 and 2004, surveillance devices were strengthened to allow for regular information gathering, propagation risk assessment and implementation of adequate response plans, preventing further upsurge to other countries in the sub-region (FAO 2012). A similar system is found in Ethiopia and Burkina Faso in which monthly monitoring is conducted by local government officials against a set of indicators, including food production, prices, human and animal health and the onset and distribution of rains. There are also ad hoc assessments following the onset of a crisis (Pantuliano and Wekesa 2008). *Add on FEWSNET and other national / regional responses*

Kenya, Mauritius, Tanzania and Tunisia are introducing EWS through their participation in the Africa Adaptation Programme, focusing on different issues and sectors, and with a gendered approach. In Kenya, local knowledge systems used for making short, medium and long-term decisions on farming and livestock-keeping are being supported by the EWS, whereas in Tunisia, the early warning system includes agreed indicators for coastal flooding, sea-level rise and salt content in groundwater (UNDP, 2011).

In the health sector, EWS that have employed weather forecasting to predict disease have also been used for adaptation planning and implementation for some diseases. In Botswana, the incidence of malaria four months prior to a possible outbreak has been documented (see Chapter 11). Eco-climate data associated with disease outbreaks in man and animals can be effectively monitored using global satellite data (Ayamba, 2006). Using a combination of satellite and other measurements, including sea surface temperatures, outgoing longwave radiation, rainfall, and landscape ecology using the normalized difference vegetation index (NDVI), conditions likely to lead to an outbreak of Rift Valley fever (RVF) were predicted and a 2-6 weeks warning provided, prior to the occurrence in the Horn of Africa from December 2006 to May 2007. Entomological confirmation was later done in the areas predicted. This facilitated prompt disease outbreak response and is likely to form a basis for future outbreak predictions using global satellites (Ayamba et al., 2009). Models used to predict the incidence of meningitis are now also more advanced and will be useful in adaptation planning and implementation (Thomson et al., 2006; Cuevas et al., 2007).

While there is evidence that African households can effectively manage climate variability if they receive early warnings (refs), the challenge of conveying useful information in local languages remains a problem (FAO, 2011). Moreover, households rarely have direct access to EWS as communication to remote areas remains a problem due to limited electricity and phone access (Hellmuth et al., 2007). Another challenge with EWS is national-level mistrust of locally collected data, which is perceived to be inflated to leverage more relief resources, resulting in additional seasonal assessment exercises that prevent timely responses to crises (Pantuliano and Wekesa, 2008). Assessment will be needed to understand whether and how the latest generation of EWS currently being developed in Africa are able to overcome these challenges.

22.4.3.2.2. Vulnerability assessment and emergency preparedness

Experience, capacities, tools and systems in food security and vulnerability analysis and mapping, emergency preparedness and response
Integrating climate change considerations into existing vulnerability and food security assessments; good example WFP in Kenya, linking with preparedness
Van Vliet (2010) – participatory vulnerability assessment in Cameroon

Adaptation projects, including a SCCF project in Tanzania (ID2832), often use participatory vulnerability assessment methods that incorporate local community experiences into the design of the adaptation activity. While effectiveness of these approaches will only be demonstrated over time, there is promising evidence of intermediate achievements towards project objectives (SCCF evaluation, 2011). However, vulnerability assessment at the national level, carried out as a basis for the development of national adaptation plans and strategies, has not always been conducted in a participatory fashion – for example, one study found that out of eight countries analysed, only three (Uganda, Ghana and Tanzania) had conducted participatory vulnerability assessment (Madzwamuse, 2010).

While highest exposure and risk do often correlate with vulnerable ecosystems, socially marginalized groups and areas with at-risk infrastructure, Moench (2011) cautions that when impacts are felt, those who are actually most vulnerable may be in unexpected segments of the population, and calls for vulnerability analysis to be considerably strengthened.

Vulnerability mapping can be used to pinpoint hotspots with nutritional problems to aid in adaptation planning in the health sector. A study in Sub-Saharan Africa attempted to pinpoint hotspots of undernutrition using a spatial resolution of 30 arc-minutes and investigating anthropometric data on weight and length of individuals. The impact of climate change on production of six major crops (cassava, maize, wheat, sorghum, rice and millet) was analyzed with a GIS-based Environmental Policy Integrated Climate (GEPIC) model with the same spatial resolution. Future hotspots of hunger were projected in the context of the anticipated climate, social, economic, and bio-physical changes. The study concluded that in the near future, regions located in Ethiopia, Uganda, Rwanda and Burundi, southwestern Niger, and Madagascar are likely to remain hotspots of food insecurity, while regions located in Tanzania, Mozambique and the Democratic Republic of Congo might face more serious undernutrition. Some regions in northern and southwestern Nigeria, Sudan and Angola with a currently high number of people with undernutrition might be able to improve their food security situation mainly through increasing purchasing power

(Lui et al., 2008). Mapping has also been useful in meningitis (Cuevas, 2007).Mapping of local factors associated with vulnerability to climate can guide allocation of interventions to reduce exposures and/or impacts (see Chapter 11).

[Insert figure on hotspots of undernutrition and food insecurity]

22.4.3.2.3. Disaster risk reduction through resilience-building activities

Resilience building activities and conceptual link with 3 kinds of adaptation activity, and with natural disasters; X-ref SREX
Links between strengthening food security and household resilience through community level initiatives and delivery of environmental conservation, asset creation and infrastructure development objectives and co-benefits

22.4.3.2.4. Role of DRR and indigenous knowledge in building resilience

For centuries, traditional and indigenous peoples around the world have adapted their livelihoods to a wide variety of disturbances caused by environmental variability and change, in order to survive, and there is a wide range of case studies documenting these efforts (Macchi et al., 2008). Initiatives in Kenya, South Africa, Swaziland and Tanzania have also sought to deploy local and traditional knowledge for the purposes of disaster preparedness and risk management (Galloway Mclean, 2010; Mwaura, 2008).

In a case study covering three South African provinces (Limpopo, North West and KwaZulu Natal) Thomas et al. (2007) found a range of specific coping and adaptation strategies employed by farmers to respond to climate shifts. For example, in response to perceived seasonal changes in moisture, farmers increased the planting distance of some crops, planted short-maturing varieties of maize and build stone bunds to reduce soil erosion, which was perceived to have increased in the last five years linked directly to changes in weather patterns (i.e. more intense and earlier rainfall events). In another study conducted by Akullo and Kanzikwera (2007), the authors show how farmers in Uganda adapt to the negative impacts of natural disasters by applying appropriate agricultural technology and methods, such as selecting crop varieties resistant to droughts and flooding, as well as managing natural resources and using ecosystems sustainably. In coastal Kenya, many farmers are going back to using traditional maize varieties as they are hardy and better able to cope with unpredictable weather conditions and local pests. In addition, they grow different varieties together to reduce the risk of crop loss and ensure some varieties survive even if crops fail completely in some parts of the community area (IIED 2011a).

The challenges associated with the current risk reduction strategies call for improved user-friendliness of, and accessibility to, early warning information to promote timely and informed actions by disaster risk management decision-makers and practitioners at different levels; the need for enhanced understanding of locally available resources, including community embedded knowledge and technologies, and their roles in systematic disaster risk management processes; integrating social protection measures with disaster risk reduction and climate change adaptation; and creating a platform where countries can share their lessons learned. Future analysis can examine the importance and uptake of such mechanisms in other parts of Africa.

Still to include:
Livelihood recovery actions - "more difficult for women, who have no savings, since they spend all their income on their children's food, health and education, and who usually find it hard to access formal credit, since they have no assets to serve as security in order to obtain a loan (whereas men may have land or livestock)." (Romero Gonzalez et al, 2011) study on woman farmers in Burkina Faso)
Child-centred DRR and DRM; AusAid-financed Somaliland pastoralist project (Save the Children) - component on risk reduction and resilience building added in response to chronic and complex emergency situation

22.4.3.3. Adaptation as a Participatory Learning Process

Participation and multi-stakeholder dialogue/processes; experiential learning; towards social and behavioural change; innovation
Learning throughout the adaptation process … ways of sharing experiences between communities; horizontal and vertical
Transdisciplinary approach (e.g. Evans 2010 for urban)

A number of approaches to adaptation currently being explored in Africa emphasise the importance of iterative and experiential learning for a flexible adaptation planning and management process, usually through an enabling participatory approach (Suarez et al, 2008; …; Koelle et al, date; ….). The Climate Change Adaptation in Africa programme’s 46 projects highlight the utility of participatory action research for managing uncertainty in adaptation responses (Ziervogel and Opere, 2010; CCAA, 2011). Plummer (2012) points out the potential for adaptive co-management, understood as “a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, on-going, self-organized process of learning-by-doing” (Folke et al., 2002: 20), to develop capacity for climate change adaptation. Some experience is being gained on the strategic adaptive management (SAM) approach in protected areas of river systems, with implications for adaptation, for example, with respect to aquatic protected areas in South Africa (Kingsford et al, 2011).

Based on work in Ghana, Tschakert and Dietrich (2010) propose creating learning spaces for iterative learning-by-doing to promote anticipatory adaptation, drawing together learning and principles from both resilience thinking and action research/learning from a dynamic systems perspective. They put forward a methodological framework for iterative learning processes and practical adaptive decision making, to support adaptation in contexts of high poverty and complex vulnerability, as found in Africa.

Both of these studies emphasise the desirability of seeing adaptation as a learning process, which enables people to adopt a proactive or anticipatory stance, and to build their capacity to prepare for surprises, as opposed to “learning by shock” (Tschakert and Dietrich, 2010:*page*). They do, however, note several caveats and constraints. Plummer (2012) cautions that employing adaptive co-management as a strategy for climate change adaptation has inherent difficulties as “it is neither a set prescription nor a governance panacea”, but does provide a means to develop capacity to deal with change, and support governance for adaptation. Tschakert and Dietrich (2010) highlight the time and resources required from both local actors and external facilitators, as well as the need to develop more creative learning tools for encouraging adaptation processes, particularly for countries where climate impacts with high levels of uncertainty are likely to have serious negative effects on existing complex vulnerabilities.

Concerning the integration of participatory scenario development with other research tools, Bizikova et al (2010) find that in the interests of balance between participation levels, qualitative methods, data collection and applying models for relevant outcomes, project goals and objectives should be clear.
Creating safe/enabling spaces - for civic engagement, multi-stakeholder processes, experiential learning, child-centred adaptation; Tompkin and Adger (2003) - expand spaces of engagement for enhancing both social and ecological resilience.
Creating such space for ‘civic engagement’ is limited by human resources, financial, and political constraints (Madzwamuse, 2010).
Characteristics of local organizations that enable experimentation and learning for adaptation (Rodima-Taylor, 2012).

There is increasing emphasis on the importance of innovation for successful adaptation in both rural and urban contexts, relating to interventions that employ innovative methods, as well as the innovation role of institutions (Tschakert and Dietrich, 2010; Scheffran et al, 2011; Dodman and Carmin, 2011). Adaptation projects are using innovative methods to overcome the lack of relevant data, particularly local climatic data and analysis capability (Tschakert and Dietrich, 2010; GEF Evaluation Office, 2011). Using a conceptual framework that links social capital and networks, human capability and sustainable livelihoods, social resilience and co-development, Scheffran et al (2011) show the role of institutional innovation triggered by migration in response to climate threats in the Western Sahel. They view communities and migrants as active social agents, with migrant social organizations initiating innovations across regions by transferring technology and knowledge, as well as remittances and resources. They postulate that these processes could enhance the creativity and flexibility of communities in the process of addressing climate risk. Child-centred approaches to adaptation have been shown to deliver creative adaptation solutions advocating for change in households and communities (Tanner refs; Save the Children Horn of Africa project; Unicef refs).

Box on participatory investigation into community responses to urban flooding in Mathare Valley Slums, Nairobi, Kenya (Thorn, University of Oxford)

22.4.3.4. Knowledge Development and Sharing

22.4.3.4.1. Climate data, observation, monitoring and prediction

Key problems regarding how science can inform decision making and policy are how best to match scientific information, for example about uncertainty of change, with decision needs, how to tailor information to different constituencies, what criteria to use to assess whether or not information is legitimate to influence policy and decision making or how to support scientists to provide information in such a way that it is accessible by practitioners (Vogel et al., 2007; Hirsch Hadorn et al., 2008).

Because adaptation in most African contexts is autonomous and rather an individual than a government decision, supporting adaptive capacity and decision-making in view of choosing specific adaptation actions needs to be informed by farmer’s perceptions and be supported by the right information (Ziervogel et al., 2008; Bryan et al., 2009; Godfrey et al., 2010). Use of climate information can, if accurate and relevant to the scale where decisions are made, increase adaptive capacity while poor forecast information can be harmful (Ziervogel et al., 2005; Vogel & O’Brien, 2006).

In addition to the inadequacy of climate information in Africa, Ziervogel & Zermoglio (2009) identify three main problems related to the lacking contextualisation of climate change information with special reference to Africa’s agricultural sector: Firstly, climate change impacts are considered in isolation from the broader development context (declining yields are considered a result of changing rainfall patterns but not of overall degradation of the natural resource base (Ifejika Speranza, 2010)); secondly, the vulnerability context is not understood; and thirdly, climate change adaptation efforts often fail to contextualize climate change risks within the set of other climate information, including historical data, real-time data and traditional knowledge, all of which are currently used in decision-making at multiple levels.

There is increasing interest in and growing information on the potential of local and traditional knowledge for informing climate risk management in Africa, particularly at the community scale, where there may be limited access to, quality of, or ability to use scientific information. Across the continent, people use environmental observations to forecast weather and climate events and their agricultural and livelihood impacts, and growing literature demonstrates the relevance of local observations (or perceptions) of weather and climate, including rainfall, temperature, wind, and seasonal shifts, to climate change adaptation in Africa (Jennings and Magrath, 2009).

A significant amount of literature has been devoted to mapping local indicators of seasonable variability and change through zoological, botanical, climatic and other indicators across Africa (Orlove et al. 2009; Newsham and Thomas, 2011; West et al, 2008; Ziervogel and Opere, 2010). Indicators are typically used to predict the onset of rainfall or the outcome of the rainy season. In some cases, local indicators are perceived to have become less reliable as a result of socio-cultural, environmental, and climate changes (Hitchcock 2009; Jennings and Magrath 2009), but it is clear that they continue to play an important part in many areas (Orlove *et al*., 2010). A key question is the extent to which local observations correspond to scientific records, with some literature pointing to strong agreement (West *et al*. 2008 in Burkina Faso) while other studies find weaker correlation (Rao et al. 2011; Osbahr *et al*., 2011).

Building on the tendency of local and traditional knowledge systems to incorporate other ways of knowing, including scientific information and introduced technologies, recent efforts have been made to combine lessons from local and traditional knowledge systems with Western science. In Kenya and Tanzania, this integration has resulted in greater perceived reliability and uptake of scientific forecasts (Guthiga and Newsham, 2011; IDRC, 2010; Ziervogel and Opere, 2010). Such efforts have also allowed contextualizing scientific data in particular settings (West et al. 2008, Roncoli et al. 2009) as well as complementing scientific records with information on more locally relevant parameters.

The extent to which the strategy of providing climate information to farmers in the form of daily and seasonal forecasts, to increase the ability of farmers to take informed decisions on how to manage their crops was tested in Uganda and Ghana using a gender lens (CCAFS and FAO ref). *Add findings*

A key contribution of local knowledge in responding to a changing climate is in insights into how decisions are made. Ifejika Speranza *et al*. (2010) emphasise the importance of understanding how local knowledge forms the "knowledge frame" through which scientific forecasts are interpreted (Roncoli *et al.* 2009; Ifejika Speranza *et al.*, 2010). In a case from North-Central Namibia, Newsham and Thomas (2011) suggest that there are opportunities to strengthen adaptive capacity through processes where knowledge is exchanged and "co-produced" between farmers and agricultural extension workers. However, careful attention is needed to facilitate processes that enable such co-production.

22.4.3.4.2. Research

Research – or the social contract between science and society (Vogel et al., 2008) - has a key role to play in providing information, that allows people at local to national levels to make informed decisions based on an understanding of likely future changes, their complexity and interactions with other changes, while minimising the risk of mal-adaptation (Frankhause & Tol, 1997; Ziervogel et al., 2008; Arendse & Crane, 2010). The importance of an ongoing and regularly updated discussion between scientific and policy arenas has been highlighted (Dodman and Carmin, 2011). Research information that supports adaptive capacity includes seasonal climate forecasting, impacts of climate change, and adaptation options and how to assess them. While there is significant activity in research institutions in Africa on adaptation, a number of constraints have been identified. A study conducted in eight countries found that much African research capacity is spent on foreign-led research which responds to external research interests and may not relate to national knowledge gaps on climate change (Madzwamuse, 2010). African research does not always enjoy the policy uptake or global recognition that it merits, partly because it is often not published in peer-reviewed literature (Denton et al, 2011).

Strengthening agricultural research: Irrespective of climate change, tertiary agricultural education and training in Africa is substantially under-resourced with respect to the challenge of sustainably increasing food production to meet increasing demand. The declining trend in public investment in agricultural science and technology, observed throughout Africa in recent decades, has begun to turn around in a few countries, where governments are actively investing in agricultural science and technology, and through the formation of agricultural education and research networks such as Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) and the African Network for Agriculture, Agroforestry, and Natural Resources Education (ANAFE) (Beintema and Stads,2010 ; Okyere and von Braun, 2009). Innovations in agricultural education and training that promote trans-disciplinary investigations, forge linkages between students, educators and farmers, allow for multidirectional flows of knowledge, and increase awareness of links between research and policy (Spielman et al., 2008) can provide a foundation for learning that is adaptation focused. Such efforts help to build skills for conducting participatory action research for adaptation that depend on integrating diverse knowledge streams (Bongkoungou et al., 2010; Hounkponou et al., 2010), and for understanding complex issues, such as how interlocking climatic and non-climatic stressors shape vulnerability and affect adaptive capacity (Laube et al., 2012; Tschakert, 2007; Ziervogel et al., 2006). Areas for research specifically identified in the context of climate change include strengthening capacity for surveillance, diagnosis, and early detection of agricultural pests and diseases in order to respond to new and emerging threats (Barba et al., 2010; Smith et al., 2008) research gaps. Such efforts both build response capabilities for new threats and provide a basis for better managing existing problems, thus providing a strong development-adaptation synergy.

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22.4.3.4.3. Local and traditional knowledge and climate change adaptation in Africa

Studies published since the IPCC 4th Assessment Report show how local knowledge continues to play an important role in adaptation to climate variability and change in Africa (Nyong *et al*., 2007; Osbahr *et al*., 2007; Ifejika Speranza *et al*., 2010; Goulden *et al*., 2009). The Institute of Advanced Studies at the UN University recently identified more than 400 examples of indigenous peoples' roles in climate change monitoring, adaptation and mitigation (McLean 2010).

Responses are determined by the broader risk environment people live in, and mediated by the social, economic and policy context. Local knowledge informing practice reflects a mix of planning and improvisation, referred to as processes of "performance" (Richards 1993) and "planning" (Batterbury, 1996; Crane, 2010).

There are concerns about the future adequacy of local knowledge to respond to climate impacts amidst other social, economic, and environmental changes. One concern is the decline in intergenerational transmission as elders who held and used local knowledge are dying out and their authority is being undermined by social transformations associated with a globalised world (e.g. Ifejika Speranza *et al*., 2010).

Another concern is that knowledge-based practices which worked well under one climate regime may not do so under new and unfamiliar climate patterns (Berkes, 2009). Based on analysis of the responses to the Sahel droughts during the 1970s and 80s, Mortimore (2010) argues that local knowledge systems are more dynamic and robust than what is often acknowledged. As pointed out by Nyong *et al*. (2007), the climate shifts that Sahel underwent during the 1970s and 1980s exceed those predicted for the future.

22.4.3.4.4. Rights and cultural concerns

The ethical and political dimensions of engaging with local and traditional knowledge on climate change adaptation are an important but under-examined issue, especially in Africa. While the rights of indigenous peoples to participate actively and meaningfully in global processes that affect their livelihoods and culture are enshrined in the UN Declaration on the Rights of Indigenous Peoples (UN General Assembly, 2007), indigenous voices continue to be largely absent or marginalized from UNFCCC and IPCC deliberations (Green and Raygorodetsky, 2010; Ford *et al*., 2011; Salick and Ross, 2009; Macchi *et al.*, 2008). While the concept of indigeneity is debated in Africa, the claims for active participation of marginalised groups in global climate deliberations described above are significant for a wide range of communities in Africa.

Beyond participation and recognition within these processes, however, the undervaluing of local and traditional knowledge in relation to Western scientific knowledge further marginalises the potentially valuable contributions that indigenous peoples can make to the broader discourse on climate change mitigation and adaptation (Green and Raygorodetsky, 2010). It also threatens the sustainability of this knowledge as younger generations are in turn educated into accepting the primacy of Western scientific knowledge over local ways of knowing (Ifejika Speranza *et al*., 2010).

In sum, recent literature has confirmed the role of local and traditional knowledge in shaping perceptions of and responses to climatic variability and change in Africa. There is an expanding mapping of how local indicators intersect with Western scientific models and increasing attempts to forge dialogue between them. There is also increased recognition of importance of this knowledge to resilience and adaptive capacity in Africa. Notwithstanding this utility, many argue that local knowledge should not be reduced to a technical input for adaptation planning processes and science frameworks (Berkes, 2002; Harvey, 2009; Kronik and Verner, 2009).

Consideration must be given to the close link between this knowledge on the one hand and cultural systems and power relations on the other. This awareness must guide strategies to engage with local and traditional knowledge in ways that a) recognize and affirm the cultural meanings that infuse it and b) support and protect the rights and claims of vulnerable and marginalized groups.

22.4.3.4.5. Knowledge sharing

To be developed
Knowledge sharing networks e.g. AfricaAdapt
Of critical importance for learning by doing, has received insufficient attention
Little exchange of experiences and lessons takes place where networks of local NGOs are active on adaptation initiatives (Madzwamuse, 2010).

While there is emphasis on knowledge management in adaptation interventions, many opportunities for learning and sharing experiences are not being optimized, and more comprehensive and proactive systems for knowledge sharing are needed (GEF Evaluation Office, 2011).

22.4.3.5. Communication, Education, and Training

To be developed
Important for raising awareness, empowerment, behavioural change
Innovative ways being used to understand and communicate – photo stories, oral history videos, drama, radio, television, festivals, involvement of youth, use of participatory video in communicating CBA within and between communities, and influencing policy decisions
Not enough awareness. Strategies being used include children as change agents. Importance of awareness leading to behavioural change
Training usually a component in most adaptation interventions, sometimes gender sensitive, youth too
Education – e.g. UNICEF in Nigeria; peer-to-peer education
Need to optimize lessons learning and knowledge sharing – knowledge management systems (link with M&E), networks of CBA groups and practitioners, research networks, government to government at different levels etc
"effective flows of information through appropriate dissemination channels" (Zhu et al, 2011) Huq, 2011

Understanding of climate change, its manifestation, its impacts, physical and social aspects of adaptation and the perception of climate change and adaptation options by various stakeholders in most African contexts is currently limited to a few experts and decision-makers (Belay Simane et al., 2012). Better evidence-based communication processes are required that will enhance awareness of climate change and available responses, for both policy makers and those involved in community level development. That requires that multiple users and producers of both scientific and local knowledge, including civil society and the private sector, are brought together in a transdisciplinary process (Hirsch Hadorn et al, 2008) to achieve a better understanding of the dimensions of the problem, including the multiple causes that lead to it, as well as the political context in which interventions towards reducing vulnerability and enhancing adaptive capacity is embedded (Vogel et al., 2007; 2008).

Communicating the role of social protection and resilient livelihoods in CBA – Save the Children; children as communicators and advocates for behavioural and policy change on DRR and CCA (IDS ref)
Enhancing political support for adaptation through methods that convey scientific evidence in targeted ways (….; Dodman and Carmin, 2011; …).
What is the status quo with respect to awareness of climate change impacts and adaptation in Africa? And to what extent is civil society lobbying and advocating for enhanced response?

Concerning the impact of radio, cinema and vernacular publications in enhancing community based adaptation to climate change in Malawi, Chikapa (2012) finds such tools to be critically important in influencing the efforts of communities to mitigate climate change impacts and for long-term enhancement of rural development.

Public education using video and participation approaches have been shown to be useful tools to provide information and knowledge on community-level adaptation initiatives in Malawi and Mozambique, for example on health risk management, in a form that is accessible and useful to local decision-makers (Suarez et al., 2008).

22.4.3.6. Ecosystem Services, Biodiversity, and Natural Resource Management

There has been an increasing focus over the past few years on how Africa's longstanding experiences with natural resource management and utilization of biodiversity may be harnessed for adaptation responses, with some evidence that the conservation and sustainable use of natural resources can be an effective adaptation measure (refs). The relevant experiences include coastal and inland afforestation, rangeland regeneration, catchment rehabilitation, community forestry and other forms of community-based natural resource management. The evolving field of ecosystem-based adaptation is discussed in the Emerging Issues section of this chapter.

There is growing recognition that intact ecosystem services and biodiversity are critical components for successful human adaptation to climate change that may be more effective and incur lower costs than 'hard' or engineered solutions (Abramovitz et al, 2002; ...; Petersen and Holness, 2011; UNDP/UNEP Poverty-Environment Initiative, 2011a; IFRI, ...; ...). This understanding provides a compelling reason for linking biodiversity, developmental and social goals. Responding to climate change provides an opportunity to enhance awareness that maintaining ecosystem functioning underpins human survival and development in the most fundamental way. This is of particularly immediate significance in Africa, with its "dynamic and complex linkages and feedbacks between human vulnerability and ecosystem vulnerability" (Shackleton and Shackleton, 2011).

Africa's long tradition of community-based natural resource management (CBNRM) was not specifically implemented as a climate change adaptation response in the past, but embodies an approach that can form – and arguably already is forming - part of local adaptation strategies, through placing greater responsibility on local stakeholder institutions, which are then enabled to respond more flexibly to changing climatic conditions. Past experience highlights the possibility inherent in CBNRM for improving links between ecosystem services and poverty reduction (Shackleton et al, 2010), which will be an important component of sustainable adaptation approaches.

Add IFRI data for African countries showing community forestry approaches can significantly enhance adaptive capacity and resilience of forest communities

Natural resource management practices that address desertification can also serve as adaptation measures for climate change by improving the resilience of ecosystems and people to long-term changes in climate. Two dual-benefit practices that have become widespread in Africa are natural regeneration of local trees and water harvesting.

Natural regeneration, or the traditional selection and protection by farmers and herders of small trees to maturity has in the Sahel, perhaps for centuries, produced extensive parks of *Acacia albida* (winter thorn) in Senegal (Lericollais, 1989), *Adansonia digitata* (baobab) in West and Southern Africa (Sanchez *et al.*, 2011), and *Butyrospermum parkii* (Shea butter) in Burkina Faso (Gijsbers *et al.*, 1994). Recent natural regeneration efforts have increased tree density and species richness at locations in Burkina Faso (Ræbild *et al.*, in press) and Niger (Larwanou and Saadou, 2011), though adoption and success is somewhat dependent on soil type (Haglund *et al.*, 2011; Larwanou and Saadou, 2011). Certain fire-dependent Sudanian tree species require the heat and smoke of fire for natural regeneration (Dayamba *et al.*, 2008).

Water harvesting practices[4] have increased soil organic matter, improved soil structure, and increased agricultural yields at sites in Burkina Faso, Mali, Niger, and elsewhere (Fatondji *et al.*, 2009; Vohland and Barry, 2009; Larwanou and Saadou, 2011). In one area of Burkina Faso, 60% of farmers use these water harvesting techniques (Barbier *et al.*, 2009). Although these and other practices serve as adaptations to climate change, revenue generation and other concerns outweigh climate change as a motivating factor in their adoption in individual villages in Burkina Faso (Nielsen and Reenberg, 2010) and Senegal (Mertz *et al.*, 2009).

[FOOTNOTE 4: Water harvesting refers to a collection of traditional practices in which farmers use small planting pits, half-moon berms, rock bunds along contours, and other structures to capture runoff from episodic rain events (Kandji et al., 2006).]

One potential measure to address desertification and adapt to climate change is the destocking of livestock during drought periods. The lack of individual incentives to destock (Hein *et al.*, 2009), however, and other cultural barriers to this and other climate change adaptation measures for livestock herders inhibit their widespread adoption in the Sahel (Nielsen and Reenberg, 2010).

There is growing differentiation in the literature, particularly in the field of integrated water resources management, between ‘hard path’ and ‘soft path’ approaches to adaptation (Sovacool, 2011; Kundzewicz, 2011), with ‘soft path’ approaches sometimes equated with ‘low regrets’ approaches to adaptation (Kundzewicz, 2011; ...). For example, conventional ‘hard path’ flood control may be based on embankments (levees) and dams, while the ‘soft path’ of flood risk management aims to understand, adapt to and work with the forces of nature (International Rivers Network, 2007).

Concerning flood risk management, there has been additional experience in Africa on climate change adaptation based on the protection of natural infrastructure such as forests in watersheds and on floodplains, more efficient resource use, better power and water sector planning, and decentralized technologies such as rainwater harvesting, and power generation from geothermal, wind, solar, and sustainable biomass sources, as well as small and unconventional hydropower technologies (e.g. kinetic “free-flow” turbines, wave and tidal power). *Check latter, and add examples – Nigeria AAP for SHP.*

Some argue, on the one hand, that the performance and safety of dams and other “hard” river infrastructure such as flood-control embankments will be seriously compromised by the intensification of the hydrological cycle (International Rivers Network, 2007; ...). Furthermore, the inflexibility of hard flood control is felt to be a major weakness not only due to climate change, but also because urbanisation, other land-use changes and natural geomorphological processes result in changed timing and size of floods (IRN, 2007; ...).
Section incomplete
4 SCCF projects on coping with drought and CC: Ethiopia, Kenya, Zimbabwe and Mozambique
SCCF: Reducing Disaster Risks from Wildfire Hazards in South Africa (ID 3934
Discuss these showing how they combine multiple components of NRM

22.4.3.7. Technological and Infrastructural Adaptation Options

This section to be largely composed from relevant text on adaptation in the freshwater, agriculture, urban, health and coastal sections of this chapter

22.4.3.7.1. Technologies for adaptation

To be developed from sectoral adaptation text

Technological and infrastructural adaptation options are being used in agricultural and water management responses, and for climate-proofing infrastructure, for instance construction of submersible roads, raising homesteads, retrofitting or designing buildings, and building sea and flood defences.

Based on an extensive literature review, Zhu et al (2011) identify 22 technologies for adaptation in the agricultural sector, grouped under sustainable water use and management, soil management, sustainable crop management, sustainable livestock management, and sustainable farming systems. (Two further groupings are planning for climate change and variability, and capacity building and stakeholder organisation.)

Much can be learned from the body of literature on adoption of new technologies in agriculture with regards to which assets and factors are crucial for supporting adaptive capacity: household characteristics (age, household size, education, health), farm characteristics (size and land fragmentation), physical characteristics (agro-climatic conditions, topography, soils, water), and economic and institutional factors (markets, infrastructure, land tenure regime, labour and financial markets, extension) (Doss, 2003; Spielman, 2005; Maddison, 2006; Knowler & Bradshaw, 2007). With regards to how assets relate to the propensity to adapt to climate change no major differences to the findings from research on technology adoption are to be expected, and assets that enhance adaptive capacity to climate change are related to human assets (household size, education, health, knowledge, skills, farming practices, perception of natural resources, and access to extension), wealth (physical and financial assets and access to credit), institutions (availability of off-farm activities, property rights, markets) and climatic conditions, both averages and extremes (Gbetibou, 2009).

Conservation agriculture: Conservation agriculture has good potential to both bolster food production and enable better management of climate risks (Kassam et al., 2012; Syampungani et al., 2010; Thierfelder and Wall, 2010; Thomas, 2008; Verschot et al., 2007). Such practices, which include conservation/zero tillage, soil incorporation of crops residues and green manures, building of stone bunds, agroforestry, and afforestation/reforestation of croplands, reduce runoff and protect soils from erosion, increase rainwater capture and soil water holding capacity, replenish soil fertility, and increase carbon storage in agricultural landscapes.

Expansion of irrigation in SubSaharan Africa holds significant potential for spurring growth in the agricultural sector while also better managing water deficiency risks associated with climate change (Dillon, 2011; You et al., 2011). Suitable approaches to expand irrigation in Africa, such as use of low-pressure drip irrigation technologies, are becoming more widely available in SubSaharan Africa and can help foster diversification towards irrigated high-value horticultural crops (Karlberg et al., 2007; Woltering et al., 2011). Construction of small reservoirs also provide opportunities for diversification to high value crops, in addition to providing for livestock watering, and as a source for supplemental irrigation of field crops to bridge dry spells (Biazin et al., 2011; Oweis and Hachum, 2006). Efforts to manage agricultural water for adapting to increased drought risk and changes in rainfall patterns requires a broader strategic approach that encompasses overall water use efficiency for both rainfed and irrigated production (Weiβet al., 2009), embeds irrigation expansion efforts within a larger rural development context that includes increased access to agricultural inputs and markets (Burney and Naylor, 2012; You et al., 2011), and that involves an integrated suite of options, (e.g. plant breeding and improved pest and disease and soil fertility management, and in-situ rainwater harvesting) to increase water productivity (Biazin et al., 2011; Passioura, 2006 this is an old reference check). Embedding irrigation expansion within systems-level planning that considers the multi-stressor context into which irrigation expansion is occurring can help to ensure that efforts to promote irrigation can be sustained and do not instead generate a new set of hurdles for producers or engender conflict (Burney and Naylor, 2012; Laube et al., 2012; van de Giesen et al., 2010; Ziervogel et al., 2006).

_____ START BOX 22-2 HERE _____

Box 22-2: Conservation Agriculture Successes in Africa

Recent success stories from smallholder systems in Africa illustrate the potential for transforming degraded agricultural landscapes into more productive and sustainable systems that are also resilient to climate risks. The integration of trees into annual cropping systems has been a critical element of this transformation. The presence of trees in crop lands reduces exposure of crops to wind and heavy rainfall, enhances moisture retention and rainwater capture, increases yields of grain crops, and provides for production of fruits, animal fodder and fuelwood from trees that expand livelihood options. For example in Zambia and Malawi, an integrated strategy for replenishing soil fertility on degraded lands, which combines planting of nitrogen-fixing Faidherbia trees with small doses of mineral fertilizers, has consistently more than doubled yields of maize leading to increased food security and greater income generation (Garrity et al., 2010). In southern Niger, farmer managed natural regeneration of Faidherbia albida and other field trees, which began in earnest in the late 1980s, has led to large-scale increase in tree cover across 4.8 million ha (Reij et al., 2009; Sendzimir et al., 2011). Devolvement of tree ownership from the state to the farmer was an important catalyst for stimulating farmer managed natural regeneration, which has subsequently spread through community-based efforts that include partnerships through farmers and NGOs. Adoption of these appropriate land management

_____ END BOX 22-2 HERE _____

Most of the continent's irrigated agriculture takes place in Northern Africa, where water resources for agriculture will experience increasing pressures from degradation of the resource base, climate change and competition from non-agricultural uses. The profound pressures facing the region's water supplies may prompt a need to shift policy from increasing water supply to better managing water demand (Sowers et al., 2011) and from maximizing land productivity for agriculture to that of maximizing water productivity (Thomas, 2008). Agriculture remains the predominant use of water, accounting for more than 75% of water withdrawals in Algeria, Morocco, Egypt, and Libya (AQUASTAT, 2012), and agriculture remains a key economic sector and source of employment in these countries. With rainfed agriculture sensitive to changes in the seasonality, distribution and intensity of rainfall, and increases in aridity, there is an increasing tendency for farmers to use groundwater to better control irrigation, often without effective government control, placing more stress on aquifers (Chenini et al., 2008; Tekken et al., 2009; Mougou et al., 2011; Sowers et al., 2011). Moreover, risks of salinization of agricultural lands are increasing with greater reliance on degraded irrigation water sources, such as where saltwater intrusion of aquifers has occurred due to over-extraction of groundwater (Sowers et al., 2011).

As population and non-agricultural demand for water increases in Northern Africa, agriculture will need to reduce its dominant consumptive use of water through adaptation in irrigation systems (Rochdane et al., 2012; Iglesias et al., 2010; Hanafi et al., 2011). Investments to upgrade and modernize irrigation and drainage networks would help to stem the significant loss of irrigation water that occurs in poorly maintained systems (Sowers et al., 2011; World Bank, 2006 The reference is quite old and check if it is the good name for the author). Governments in the region have begun to incentivize adoption of water demand management technologies, in particular drip irrigation. Water pricing can encourage water efficiency, but if not managed carefully could have negative implications for those without the capacity to shift to more efficient irrigation regimes (Frija et al., 2011; Chebil et al., 2010). The diversity of agricultural and irrigation regimes employed by farmers are thought to reduce the potential effectiveness of centralized approaches to groundwater management, and there have been initial experiments in and analyses of more flexible strategies, including those based on participatory dialogue (Kuper et al., 2009; Bekkar et al., 2009; Errahj et al., 2009; Batt and Merkley, 2009; Faysse et al., 2010).

In addition to improving irrigation systems, importing food crops and the 'virtual water' embedded in their production may become an increasingly attractive option for addressing Northern Africa's water supply problem (Chapagain and Hoekstra, 2008; El-Sadek, 2010; Zeitoun et al., 2010). Some estimates of current virtual water imports for Egypt are as high as 300 BCM per year, chiefly in terms of soy and wheat (Zeitoun et al., 2010), while other estimates for Egypt give more conservative values of 10.9 BCM (what is the meaning this is an acronym) per year, but calculate a net deficit in virtual water trade across North Africa of 45 BCM due to agricultural exports (Chapagain and Hoekstra, 2008). There are high political and economic costs associated with increased water dependency resulting from virtual water trades (El-Sadek 2010), particularly in light of recent price volatility for globally traded agricultural commodities.

Using a case study of drought-tolerant maize technology in Nigeria, Tambo and Abdoulaye (2012) show that more support is needed for adoption and investment by smallholder farmers, notwithstanding the appropriateness and value of the technology under conditions of climate change. Overcoming adoption constraints will necessitate improving timely access to information about climate change and to the available adaptation technology and complementary inputs, as well as better access to credit for resource-poor farmers.

Plots of land worked by women smallholder farmers may produce lower yields and be more vulnerable to climate change for a variety of reasons. Gender-related non-ownership of land has been shown to lead to non-investment in plots in Burkina Faso, compounded by as non-employment of adaptation techniques such as *zai* pits and stone walls as women may lack the physical strength, lack of access to appropriate tools which are reserved for men's plots, and non-use of fertiliser which may be reserved for family plots (Romero Gonzalez et al, 2011).

Food storage: Food security can be enhanced by reducing post-harvest losses through improved storage technologies, more efficient food preservation, greater access to processing facilities, and improved transportation systems that deliver products to markets more quickly (Brown et al., 2009; Codjoe and Owusu 2011; Godfray et al., 2010). Rough estimates place global losses of food to waste between 30 and 40 percent (Godfray et al., 2010). Inadequate food storage was identified as a key concern in vulnerability and adaptation analyses carried out in Nigeria and Sudan (Ziervogel et al., 2006), and Ghana (Armah et al., 2011; Codjoe and Owusu, 2011; Yaro et al., 2010). Low cost farm-level storage options, such as metal silos (Tefera et al., 2011), and triple-sealed plastic bags (Bauoa et al., 2012) are effective for reducing post-harvest losses from pests and pathogens. Better storage would also allow farmers greater flexibility in when they sell their grain, thus potentially reducing the selling of their yield at low prices after harvest and buying it back at higher prices during times of shortage (Brown et al., 2009). Moreover, improved storage increases food safety through reducing post-harvest infection of grain by aflatoxins, which is linked to human immune suppression and liver cancer (Shephard, 2008), and is a widespread threat to food safety in Africa. The severity of aflatoxin infection of grain increases with drought stress and high humidity during storage (Cotty and Jaime-Garcia, 2007).

22.4.3.7.2. Infrastructure

To be developed from sectoral adaptation text
Madagascar – submersible roads (IFAD)
Enhanced construction and infrastructural standards such as raising foundations of buildings, strengthening roads and increasing storm water drainage capacity are steps to safeguard buildings in vulnerable locations or with inadequate construction (UN-Habitat and UNEP, 2010; Mosha, 2011).

22.4.3.8. Social Protection and Other Socio-Economic Responses

There has been a significant increase in attention, effort, and practice to implement effective national and local instruments to offset the impact of natural hazards in Africa. Particularly in countries like Ethiopia, Rwanda, and Malawi, there is a growing focus on the socio-economic aspects of risk as demonstrated via existing social protection mechanisms and insurance schemes used to buffer against the impacts of disasters.
Social protection mechanisms are being used to buffer against the impacts of shocks and disasters by building assets and increasing household resilience of both chronically and transiently poor people (Heltberg et al. 2009; other refs). Examples of social protection systems being progressively scaled up to allow for a more predictable and established system to respond to larger shocks are Ethiopia’s Productive Safety Net Program (PSNP), and Rwanda’s “Vision 2020 Umurenge Program” (VUP). The PSNP, established as a response to the frequent droughts, combines public works employment opportunities with non-labour provisions for those who cannot work (del Ninno et al. 2009; Morton and Mousseau 2010; Pelham et al. 2011). Initiated in 2008 in Rwanda, the VUP system of cash transfers for public works to extremely poor households was active in the four poorest sectors in all 30 districts, with plans to expand coverage year-by-year (World Bank 2011).

22.4.3.8.1. Insurance

By providing financial security against droughts, floods, tropical cyclones and other forms of weather extremes, insurance instruments present an opportunity for developing countries in their concurrent efforts to reduce poverty and adapt to climate change (Linnerooth-Bayer et al. 2010). In recent years, there have been number of new approaches and instruments in the insurance sector in Africa, including the emergence of index-based insurance contracts as opposed to traditional loss-based insurance, which pay out not with the actual loss but with a measurable event that causes loss.

_____ START BOX 22-3 HERE _____

Box 22-3. Experience with Index-Based Weather Insurance in Africa

Malawi's initial experience of dealing with drought risk through index-based weather insurance directly to smallholders appears positive: 892 farmers purchased the insurance in the first trial period, which was bundled with a loan for groundnut production inputs (IRI 2009). In the next year, the pilot expanded, with the addition of maize, taking numbers up to 1710 farmers and creating stimulated interest among banks, financiers and supply chain participants such as processing and trading companies and input suppliers (IRI 2009). A pilot insurance project in Ethiopia was designed to pay claims to the government based on a drought index that uses a time window between observed lack of rain and actual materialization of losses (Krishnamurty 2011). This allows stakeholders to address threats to food security in ways that prevent the depletion of farmers' productive assets, which reduces the future demand for humanitarian aid by enabling households to produce more food during subsequent seasons (Krishnamurty 2011). Another key innovation in Ethiopia is the insurance for work program which allows cash-poor farmers to work for their insurance premiums by engaging in community identified disaster risk reduction products, such as soil management and improved irrigation (WFP 2011). This makes insurance affordable to the most marginalized and resources poor sectors of society (WFP 2011).

_____ END BOX 22-3 HERE _____

While insurance programs can offer affordable economic security to vulnerable communities, UNFCCC (2008) found that fewer than five percent of households and business in the developing countries actually have insurance coverage for catastrophic risks. Instead, such risks are dealt with by a mix of social networks and informal post-event credit. Lack of insurance may also stunt development because smallholders cannot risk investing in fixed capital or concentrating on profitable activities and crops for fear of losing them, and falling into debt (UNFCCC 2008).

In the fisheries sector, where fishery activities can no longer be sustained, private and public insurance schemes that help fishing communities rebuild after extreme events, and education and skills upgrading that enable broader choices for fishing communities, have been recommended (Badjeck et al., 2010).

While social protection and disaster risk reduction measures designed to limit damages from shocks and stresses may be helping Africa adapt to climate change, these mechanisms may not be sufficient in the longer term (Davies et al., 2009). For social protection to be resilient to climate change impacts, it will need to consider how reducing dependence on climate sensitive livelihood activities can be part of adaptive strategies.

22.4.3.8.2. Migration as an adaptive response

Whilst migration is often portrayed as a negative consequence of climate change, leading to increases in livelihood insecurity and increased exposure to hazards, others have noted that it is wrongly identified as conflict-inducing (see Goldstone, 2002; Urdal, 2005; Reuveny, 2007; Fox and Hoeshler, 2010), seeing it instead as a fundamentally critical process for most African families to incorporate agency into their risk profile. Especially in chronically violent environments, migration is used as a key strategy to limit predation (Adano et al., 2012; Mkutu, 2008), although this migration differs in structure form typical labour migration processes (Young et al., 2005).

Other authors have highlighted that the decision to migrate is made within a complex decision-making process and often supports adaptation to climate change (McLeman and Smit, 2006; Scheffran et al, 2012), and may specifically unlock diverse and innovative responses through the regional role of migrant social institutions (Scheffran et al, 2011). As key responses to environmental (and non-environmental) transformations and pressures (Tacoli, 2009), mobility and migration should be considered in policy responses. Measures to prevent harmful environmental changes and build resilience will diminish the influence of environmental change on migration, but are unlikely to fully prevent it (Foresight Migration and Global Environmental Change, 2011). In some areas, there is evidence of the increased importance of migration and trade, as opposed to subsistence agriculture, and a decreasing importance of climate factors for livelihood strategies, as shown by Mertz et al (2011) for the Sudano-Sahelian region of West Africa.

22.4.3.8.3. Cultural aspects

There is agreement that culture - shaping social norms, values and rules including those related to ethnicity, class, gender, health, age, social status, cast and hierarchy - is of crucial importance for adaptive capacity. Culture is important both as a positive attribute but also as a barrier to successful adaptation at the local level, as well as being important in defining who will lose and who will win from adaptation. However, further research is required in this field, not least because culture is highly heterogeneous within a society or locality (Adger et al, 2007; 2009; Nielsen & Reenberg, 2010; Jones, 2011).

Extraction of local and traditional knowledge from the social context that gives it meaning and legitimacy may expose it to the risk of being misunderstood, misused, or misappropriated (McGregor, 2004). To avoid these pitfalls and realize beneficial synergies of local and scientific knowledge, it is therefore essential to ground their encounter in appropriate and equitable processes of participation and communication between scientists and local people (Nyong *et al*, 2007; Orlove *et al*, 2010). Ford *et al.* (2011) also suggest that integrating cultural components such as stories, myths and oral history into initiatives to document this knowledge is a key to better understanding how vulnerability and adaptation are experienced and broaden our perspectives on how climate change is framed.
Crane (2010)

Given the integral link between culture and local knowledge on adaptation (Ensor and Berger, 2009), culture can present both opportunities and barriers to effective adaptation. Nielsen and Reenberg (2010) found that in Northern Burkina Faso, issues of social prestige and cultural identity prevent upper caste households from engaging in adaptive strategies, such as labour migration, employment with development projects, dry season gardening, and women’s income-generation activities. Further, while traditional knowledge may hold significant adaptive and broader social value, it may also be closely-guarded or selectively transmitted (Davis, 2010). Social and cultural norms may prevent public discussion or sharing or such knowledge with outsiders or even with certain social groups within the community (Roncoli *et al.*, 2009).
Customs and legal barriers in many parts of Africa restrict women’s ownership of land, thereby limiting their financial and economic opportunities (McFerson, 2008) and their adaptive capacity. Furthermore, land provides financial and food security, and can be a significant asset in the event of an emergency (Denton, 2002).

22.4.3.8.4. Financial mechanisms

Rural finance and micro-credit (IFAD) as enabling activities for adaptive response
Credit and storage systems to support families during the lean period to prevent sale of assets to buy food when market prices are higher (Romero Gonzalez, 2011)

In addition to improving irrigation systems, importing food crops and the ‘virtual water’ embedded in their production may become an increasingly attractive option for addressing Northern Africa’s water supply problem (Chapagain, & Hoekstra 2008; El-Sadek 2010; Zeitoun et al 2010). Some estimates of current virtual water imports for Egypt are as high as 300 BCM per year, chiefly in terms of soy and wheat (Zeitoun et al 2010), while other estimates for Egypt give more conservative values of 10.9 BCM per year, but calculate a net deficit in virtual water trade across North Africa of 45 BCM due to agricultural exports (Chapagain, & Hoekstra 2008). There are high political and economic costs associated with increased water dependency resulting from virtual water trades (El-Sadek 2010), particularly in light of recent price volatility for globally traded agricultural commodities.

22.4.3.9. Livelihood Diversification

Increasing evidence of the importance of livelihood diversification as a defence against climate shocks

Livelihood diversification enables households to build resilience by spreading risk.

There is evidence that over the past 20 years, households in the Sahel have reduced their vulnerability and increased their wealth through livelihood diversification, particularly when diversifying out of agriculture (Mertz et al, 2011). Households may employ a range of strategies, including on-farm diversification or specialization (Sissoko et al, 2011).

Market failure as a hindrance to livelihood diversification (Laube et al, 2012)

Diversification may replace formerly sustainable practices with livelihood activities that are socially and environmentally detrimental. For example, a study conducted in pastoral societies of Somaliland shows that charcoal-burning has become a major source of income for 70 percent of poor and middle-income pastoralists in some areas, with resultant deforestation, while income from charcoal is often spent on the stimulant ‘qat’, rather than on food for families (Hartmann and Sugulle, 2009).

Risks that the traditional adaptive pastoralism system may be replaced by maladaptive activities

22.4.3.10. Maladaptation Risks

Exposure to multiple stressors and their interactions, manifested in context, outcome and feedback (Bunce et al., 2010), relates both to countries and to people – and in both cases there are winners and losers (O’Brien and Leichenko, 2000). There are risks of maladaptation that may serve short-term goals but come with future costs to society because research and development intervention often fail to consider how different types of change interact and undermine the ability of people to cope with multiple stressors. This leads to policy interventions being designed which in themselves act as stressors or allow people only to react to short-term climate variability (Bryan et al., 2009; Bunce et al., 2010). The short-term nature of many development interventions and of national policy and development priorities favouring economic growth and modernisation over resilience and human security (Brooks et al., 2009) in much of Africa contribute to the vulnerability of poor communities and those dependent on natural resource-based livelihoods to acquire the necessary adaptive capacity to deal with multiple stressors (Bunce et al., 2010).

Add brief discussion of some practical examples, link with transformation

22.4.4. Constraints, Barriers, and Limits to Adaptation in Africa

Local and traditional knowledge studies in Africa can assist with understanding the barriers that exist to adaptation. Smucker and Wisner (2008) found that political and economic changes in Kenya mean that farmers can no longer use traditional strategies for coping with climatic shocks and stressors, and particularly the poorest increasingly have to resort to coping strategies that undermine their long term livelihood security, such as more intensive grazing of livestock and shorter crop rotations.

The UN Permanent Forum on Indigenous Issues (UNPFII) has reported that “the main barrier to indigenous peoples’ coping and adaptation capacities is first and foremost the lack of recognition and promotion of their human rights” (UNPFII, 2008).

Barriers and limits: point about Africa’s population – Africa is hot-spot for increased water stress (New et al, 2011), and the driver for this is primarily population, with climate an additional stressor (Mark New Inaugural Lecture, UCT, 11th April 2012)

SREX states that there is high agreement and robust evidence that “actions that range from incremental steps to transformational changes are essential for reducing risk from climate extremes” (SPM page 18).

Shift to solutions – in the form of common principles for building adaptive capacity - from problem identification – analysing vulnerability (in context of vulnerability analysis) (Moench, 2011)

Transformations are "facilitated through increased emphasis on adaptive management and learning. Where vulnerability is high and adaptive capacity low, changes in climate extremes can make it difficult for systems to adapt sustainably without transformational changes". (SREX SPM page 18)

The last few years have seen the emergence of a growing body of theoretical and conceptual literature on the constraints, barriers and limits to climate change adaptation that places much greater emphasis on the influence of social factors, in relation to more widely acknowledged and discussed biophysical, financial and technical factors, on the process of adaptation, on adaptive capacity and on the uptake of adaptive strategies (Agrawal 2008, Agrawal et al. 2008, Adger et al. 2009, Moser and Ekstrom 2010, Jones 2011). This has come partly in response to the realisation that neither autonomous nor planned adaptation to climate change is necessarily materialising in the ways expected nor at the pace desired, and that simply providing the right technology and sufficient funding to carry out local level programmes (the dominant approach to adaptation to date) is seldom a guarantee for change on the ground (Ludi et al. 2012). There is increasing evidence that there are many significant hurdles to adaptation and that these interact in multiple and complex ways across scales influencing how local people both decide or are enabled to respond or not to changes in their environment.

Adaptation requires identifying and learning about risks, evaluating response mechanisms, creating enabling conditions, mobilising resources, implementing adaptation options, and revising choices with new learning. Moser and Ekstrom (2010) argue that barriers can emerge at multiple stages in this process. There is a need for improved knowledge regarding what influences decision making at these different steps. For instance, the best technical solutions may be ignored or rejected if cognitive, behavioural and cultural barriers exist regarding the need to adapt and the willingness to accept change. In other situations, the ability of certain individuals to employ particular forms of adaptation may be impeded by regulative controls, societal norms and various forms of institutional inequities.

Relatively few studies from Africa have specifically employed a barriers and limits lens or framework to understanding the factors that may prevent or constrain adaptation at the local level amongst different social groups. However, it is possible to distil out some of the barriers, both perceived and experienced, from the general literature on adaptation in Africa and from case studies. Several case studies (e.g. Roncoli et al. 2010, Bryan et al. 2011, Nyanda et al. 2011, Ludi et al. 2012) have attempted to identify constraints (as one of several research questions) from the perspective of the resources needed for adaptation, the factors influencing adaptive capacity, the reasons for not employing particular adaptive strategies or not responding to climate change signals, and the reasons why some groups or individuals adapt and not others. It is these that are discussed here. The available literature, especially the peer reviewed literature, tends to be dominated by studies from East and southern Africa, and this is reflected in the observed barriers described below (Berrang-Ford 2011).

[INSERT TABLE 22-4 HERE
Table 22-4: Summary of recorded barriers and limits to climate change adaptation in Africa. [STILL COLLECTING LITERATURE TO ADD TO THIS TABLE AND THINKING RE THE BEST WAY TO DO THIS]]

In a comprehensive study of climate change adaptation amongst small-scale farmers in Ethiopia, Kenya and South Africa it was found that 37%, 19% and 62% respectively of farmers interviewed had not attempted to take any adaptive action to perceived changes in climate conditions (Bryan et al. 2009). The reasons for this lack of response were explored. In Kenya, the responses farmers reported employing to climate variability tended to be fairly low cost (e.g. planting new varieties, soil and water conservation), while those that they mentioned they would like to adopt, such as irrigation, water harvesting or changes of crop variety, were often constrained by a lack of money or resources (Bryan et al. 2009). Specific barriers or constraints mentioned included financial (lack of cash or credit), biophysical (lack of access to water), institutional and physical (lack of access to land, lack of access to inputs), and informational (lack of information on agroforestry/reafforestation, different crop varieties). Other constraints mentioned included shortage of labour, poor quality of seed and inputs attributed to a lack of quality controls by government and corrupt business practices by traders, poor soil quality, land fragmentation, poor roads and pest and diseases (Roncoli et al. 2010). Participatory exercises emphasised the importance of improving human and organisational capacity, training and the formation of groups suggesting that these are currently social barriers. Other social and political barriers highlighted included the growing rate of theft, crime, insecurity, violence and conflict and governance issues such as corruption and poor quality services (Roncoli et al. 2010). It was also found that farmers in more arid environments were less likely to adapt relative to those in temperate regions, and that amongst the latter a greater range of adaptive responses were recorded (27 versus 10). This suggests biophysical barriers to adaptation in the arid areas of Kenya that could present as limits for more vulnerable groups if current climate change trends continue. For example, Sallu et al. (2010) in Botswana found that the most vulnerable members of their study communities had not succeeded in fully recovering from a severe drought experienced 10 years previously – this group lacked adaptive options surviving by working for others and relying on social welfare. Such groups may face real limits in the future and need targeted support.

Among the high proportion of farmers in South Africa (Bryan XXXX) that had not taken any action to perceived climate change, the following reasons were put forward for this. Similar results were found in a study of livestock farmers in the East Cape in South Africa, where Mandeleni and Anim (2011) found that 71% of 500 farmers interviewed had not employed any climate change adaptation strategies, with the following barriers highlighted as preventing adaptation: lack of climate information (2.9%), lack of money (22.9%), lack of inputs (45.7 %), lack of property (8.6 %) and lack of other information (17.1 %).

Few of these local level studies have tried to dig deeper into understanding the role of cognitive and normative behavioural or cultural barriers, and most were focussed on agriculture, failing to consider the multiple livelihood strategies that underlie the livelihoods of many rural households in Africa. Nyanga et al. (2011) argue that the extension services in Zambia focus too much on technical skills and fail to address the social factors that influence the adoption of new technologies. They saw this as a major barrier to farmers making the links between climate change and conservation agriculture as an adaptive strategy. Ludi et al. (2012) also argue that the top-down mode of planned adaptation support commonly provided by NGOs and governments can act as a barrier to long-term adaptation as little attention is given to building local agency and innovation through the provision of information and opportunities for learning.

Cognitive barriers – Case study from Zimbabwe – Grothman and Patt (2005)
Cultural barriers - Case study from Northern Burkina Faso – Nelisen and Reenberg

The use of predictive models and early warning systems in the health sector provides an example of how technical, social and cultural barriers to adaptation may be inter-linked. Despite the potential of predictive models for disease control, there are lengthy timeframes for validation and operationalisation of them (Cuevas, 2007) Limits to model accuracy may limit use of climate data for early warning systems, rendering some geographic locations more suitable than others. The cost of developing the system, including the cost of errors, has been identified as one of the barriers. A more practical barrier is appropriate societal response which will lead to societal benefits. This requires an understanding of the particular societal context and processes including cultural norms, as availability of the data itself will not usually generate a societal response (Aron et al., 2006).

Institutional barriers have similarly not received as much attention as they should. In a recent briefing paper, Ludi et al. (2012) list three ways in which institutional barriers were found to prevent sustainable adaptation based on evidence from an ACCRA project (Africa Climate Change Resilience Alliance: 2010 -2011) in Uganda, Ethiopia and Mozambique. These included: 1) elite capture of some institutions and corruption; 2) poor survival of institutions without social roots – e.g. a savings group that did not conform to existing norms; and 3) the lack of attention to the institutional requirements of new technological interventions. For example, they show that where water infrastructure is improved this does not necessarily guarantee access for everyone. Institutional and social barriers play a role: women remonstrated that they lacked money to pay bribes and the social standing to make claims and so continued to experience water insecurities (Ludi et al. 2012). There is also evidence that innovation may be suppressed if the dominant culture disapproves of departure from the ‘normal way of doing things’ (Ludi et al. 2012). In particular, women’s ideas may not be supported because their opinion may not be valued or given much weight (REFS). Other barriers mentioned by these authors included a lack of ability to take financial risk, lack of confidence and limited access to information and new ideas.

Other social barriers – add some examples related to gender – Peach Brown 2011, Djoudi and Brockhaus 2011, Ardey et al. 2012

At a higher level many of same types of barriers emerge. Some policy orientated studies have shown that adaptation options in Southern Africa have been blocked by political and institutional inefficiencies (Magadza 2000). Other authors suggest that adaptation is often not perceived as a priority. Madzwamuse (2010) suggests that the slow response to climate change adaptation in South Africa is the result of the dominance of the mitigation discourse because of the country's heavy reliance on fossil fuels. The neglect of the poor, in particular, is attributed to the lack of political champions to speak for and represent the interests of this group. She argues that to move forward with climate change adaptation implementation "a deeper understanding of the barriers to adaptation both by African governments and the donor community" is required and this is currently lacking. Berrang-Ford et al. (2011) suggest that poor measurement of progress on adaptation may act as a barrier to governments investing in adaptation interventions. Policy and government laws and regulations themselves can also act as barriers to adaptation at a local level. Bunce et al. (2010) found that government policies related to the control of water flows in upstream dams, the designation of conservation areas and the expansion of urban development and tourism all worked as barriers to adaptation amongst poor coastal communities in Tanzania and Mozambique. Discourses and policies that take a disaster-focused short-term view of climate variability and that focus on transient food insecurity and relief can act as a barrier to a longer term perspective that emphasises adaptation, livelihood security and resilience (Conway and Schipper 2011). They also argue that the perception of climate change as an environmental issue in government in Ethiopia rather than as a broad development issue constitutes a barrier to action. In Mali Brockhaus and Djoudi (2008) argue that "adaptation in soci-political subsystem is lagging behind autonomous reactive adaptation and hindering the switch from the latter to planned adaption through reflective and strategic decision making processes".

Mather et al. 2010. Durban case study
FIND AND ADD MORE THIS PART ON HIGHER LEVEL BARRIERS; MORE EXAMPLES OF KNOWLEDGE BARRIERS NEEDED

Climate uncertainty, high levels of variability, a lack of information on the frequency and intensity of extreme events and poor predictive capacity at a local scale are often cited as barriers to adaptation from the individual to national level (Repetto 2008). At the local level, it is very difficult for untrained observers to detect trends amidst short term fluctuations – variability has always been a feature of the weather. Consequently, these issues can result in cognitive barriers to adaptation. Perceptions studies from Africa, however, show that most rural farmers are perceiving changes in weather patterns and acknowledge the associated risks, although the cause of the changes are not always known (Mandleni and Anim 2011, Roncoli et al. 2010, Byran et al. ###, Clarke et al. 2012 REFS). This differs from the USA and Australia where there is much more overt scepticism and divided views (e.g. Repetto 2008, Buys and Van Megen 2011). However, access to appropriate real-time and future climate information that can help in decision-making for different users is a universal barrier.

Interaction with cognitive barriers – Case study from Zimbabwe – Grothman and Patt (2005)
Conway and Schipper – Ethiopia 2011

Regarding autonomous adaptation, in many parts of Africa especially the drylands, traditional adaptation strategies have been constrained by social-ecological change and drivers such as population growth, land privatisation, land degradation, widespread poverty, poorly conceived policies and modernisation and erosion of traditional knowledge to the extent that it is difficult or no longer possible to respond to climate variability and risk in ways that people did in the past (The African Drought Risk and Development Network (ADDN) 2008). As a result the number of response options has decreased and traditional coping strategies are no longer sufficient. Increasingly people are reporting obstacles to mobility, past collective practices, use of indigenous knowledge and diversification activities that hinder their ability to adapt. Studies have shown that most autonomous adaptation usually involves minor adjustments to current practices (e.g. changes in planting decisions); there are simply too many barriers to implementing substantial changes that require investment (e.g. agroforestry and irrigation) (Bryan et al. 2011). Such adaptation strategies require government and private sector/NGO support.

Urban examples East African cities - Kithiia 2011. South Africa – book

22.4.4.1. Expected Barriers, Residual Damage, and Limits to Climate Change Adaptation in Africa

Small island states, coastal area, arid areas…. Moving into the area of uncertainty.. But evidence of limits in the future.
HAVE SOME REFS BUT STILL NEED TO WORK ON
Addo et al. 2011
Hinkel et al. 2012

22.4.4.2. Overcoming Barriers and Limits

Main Points that will be discussed
Paper on regreening of the Sahel. Sendzimir, J., Reij, C.P. and Magnuszewski, P. 2011. Rebuilding resilience in the Sahel: regreening in the Maradi and Zinder regions of Niger. Ecology and Society 16(3):1 http://dx.doi.org/10.5751/ES-04198-160301.
Expanding access to credit or cash earning opportunities would enable farmers to meet the initial costs of more considerable investments such as irrigation (Bryan et al. 2011).
In cases where barriers limit adaptation (such as the arid zones of Kenya) more needs to be done to build resilience to climate crises such as the integration of drought management and drought preparedness plans into rural development efforts, the development of early warning systems and expanding access to weather insurance (Bryan et al. 2011). Emergency relief does not build long term resilience.
Effective policy levers to overcome adaptation barriers include access to social safety nets, extension services, credit and climate information (Bryan et al. 2011). Furthermore, the focus should not be only on investments in agriculture, but also on providing options for livelihoods diversification.
There is a need for multisectoral interventions and adaptations that include technical and institutional supports (Roncoli et al. 2010). Local people themselves recognise the need for enhancing human and social capital at the local level, not only to build capacity to understand climate information and adaptation options and technologies but also to ensure empowered citizenship.
Based on evidence from the ACCRA project CCA interventions, if they are to help people overcome multiple barriers to adaptation, should provide information and the means to access and select different adaption options rather than directly providing technologies and assets – e.g. instead of handing out seeds put farmers in touch with seed providers (Ludi et al. 2011). “Seeing information and knowledge as key components of adaptive capacity would encourage use to put more emphasis on giving people a much wider range of information, appropriate to a much wider range of circumstances” (Ludi et al. 2012).
Adaptation is not only about technology and physical structures – it is about enhanced adaptive capacity and developing innovation. To ensure this, particular attention needs to be paid to informational, social and institutional barriers.
Lindsey Jones – 2010 Overcoming social barriers to adaptation – ODI background note. Some good points to include in this section.
List of issues in ADDN 2008 – page 14, 17. ADD
Add a section on forms of social protection as a way to overcome barriers - example Conway and Schipper 2011

22.4.5. Funding Constraints for Adaptation in Africa

Currently, developing countries receive an estimated US$1–4 billion per year in international financial support for adaptation, which is significantly below estimated future needs. There are indications that Africa receives proportionately lower amounts. For example, while 12 out of 35 Special Climate Change Fund projects were in Africa, the nine projects located in Asia accounted for 31% of the SCCF funding (GEF Evaluation Office, 2011).

Based on an analysis of governance arrangements in eight countries, Madzwamuse (2010) points to insufficient investment in strategic areas of adaptation such as coordination, financial cooperation, advocacy and legislative components, with most actors being involved in awareness raising, capacity development and research.

Appeals for increased funding for adaptation for highly vulnerable regions like the Sudano-Sahelian region of West Africa (Patt et al, 2010).
Insurance companies have pointed out that the adaptation deficit seems to be growing, as shown by the increasing losses from climate-related extreme weather events (Munich Re, 2008).
Evidence of need for more coordinated approach ... Coordination between development funds and adaptation funds could help ensure that all funds support development and adaptation to climate change"
Increase capacity building through concrete adaptation projects funded internationally

22.4.6. Adaptive Capacity in Africa

Re-work and develop further

While African societies have developed an inherent capacity to cope, adapt and respond to unforeseen climate variations or weather extremes linked to the seasonality, variability and uncertainty inherent in African climates (Cooper et al., 2008), it is uncertain that these strategies will be capable of dealing with future changes, among them climate change (van Aalst et al., 2008), and its interaction with other development processes. There is thus a need to build on, strengthen and if required support the development of a new set of capacities that allow people, communities and nations to deal with new challenges, and to make sound decisions in an overall environment of growing uncertainty.

In the emerging field of adaptive capacity, national level assessments have been carried out using a range of indicators and indices, including economic wellbeing and stability, demographic structure, global interconnectivity, institutional stability and wellbeing and natural resources dependence (Vincent, 2007; WRI, 2009). An analysis of 1,741 documents by Berrang-Ford et al. (2011) concluded that there are distinct differences in adaptation between high and low-income countries as a result of their adaptive capacity. Adaptation in most low-income countries, including most African countries, is reactive in response to short-term motivations, is usually occurring at the individual / household level with weak involvement or support from government stakeholders, and adaptation activities are more likely to occur in relation to natural resource-based livelihoods, such as agriculture, forestry or fisheries.

22.5. Case Studies

22.5.1. Climate Change Impact on Kilimanjaro

Kilimanjaro in Tanzania, Africa´s highest summit and a global symbol for the continent, is a typical example of conditions prevalent in many other parts of Africa but unique in combining them on one mountain, with its huge diversity of habitats, the wide-ranging systems of land tenure and management that are practiced there, and the variety of livelihoods that Kilimanjaro supports. In addition to its melting glaciers, several ecological consequences are observed in the mountain regions. Climate change impacts are in many cases exacerbated by other global change components such as land use intensification and anthropogenic land cover changes, whose direct impacts on biodiversity, ecosystem functioning and livelihood are assumed to be even stronger than future effects of climate change, especially in tropical regions (Sala et al. 2000, Jetz et al. 2007, Lovett & Hemp, 2010).

Observed Changes
Kilimanjaro has lost over 80% of their extent since 1912 (Thompson et al., 2002) and annual precipitation decreased by over 30% (Figure 22-9; Hemp, 2005a). This declining trend in precipitation and air humidity is increasingly held responsible for the retreat of glaciers since 1880 (Kaser et al., 2004; Mölg et al., 2008, 2009a) rather than increasing temperature. For East Africa, a re-analysis of meteorological data indicates a surface temperature increase of about 0.95 K over the past 60 years (sector: 2.5° to 5.0° South, 37.5° to 40.0°East), and the latest IPCC A1B scenarios reveal that an increase of another 3 K must be expected by 2100 (IPCC, 2007; Boko et al., 2007; Hudson &Jones, 2002; Nakicenovic et al., 2000). Regarding precipitation patterns, the IPCC A1B scenarios indicate an overall annual increase in rainfall and a shift in its inter-annual distribution for East Africa (IPCC, 2007). However, changes

in local climatic conditions are likely to be triggered not only by large-scale effects (such as ocean circulation and dust-aerosol interactions), but also by regional orographic effects (Mölg et al., 2009b) and land-use feedback effects (e.g. Christensen et al., 2007; Pepin et al. 2010; Mölg et al. 2012).

[INSERT FIGURE 22-9 HERE
Figure 22-9: Annual precipitation in Kilimanjaro (1900-2005). Source: Hemp, 2005a.]

Impact

Fires: Due to a drier and warmer climate and higher anthropogenic impact, fires played increasingly a destructive role in the forests of Kilimanjaro during the last 100 years but in particular over the last three decades. During this period Kilimanjaro has lost about 150 km² of high altitude forests due to fire, which is nearly 15 % of Kilimanjaro's forest and the upper closed forest line was lowered by 900 m (Figure 22-10; Hemp, 2005a, b, 2009). During this period several 10,000 years fires occurred with various intensities on Kilimanjaro, as suggested by old charcoal horizons in the soil (Hemp & Beck, 2001; Verschuren et al., 2009; Zech et al., 2011; Schüler et al., 2012).

However, speed and extent of recent fire-driven changes in forest cover are alarming. High frequency of fires in the upper regions have caused typical alpine Helichrysum heath to extend downslope, replacing sub-alpine forests. This is in contrast with trends seen in temperate-zone mountains, where alpine vegetation has been found to migrate upslope under climate change (Grabherr & Pauli, 1994; Körner, 2003). The pyrophytic ericaceous belt and the drier climate hold the explanation. In addition, losses due to clear cutting of lower elevation forests amount to 450 km2 since 1929 (i.e. Kilimanjaro had lost about 40% of its forests; Hemp 2006b; Hemp et al., in press). This sum does not account for the massive logging inside the still existing forest belt as documented during an aerial survey in 2001 (Lambrechts et al., 2002).

[INSERT FIGURE 22-10 HERE
Figure 22-10: Changing land cover in Kilimanjaro. Source: Hemp, 2005a,b, 2009.]

Impact on water balance and consequences for livelihood

The average annual water yield of the whole forest belt can be estimated at about 500 million m3. The loss of 150 km2 of cloud forests since 1976, which have an important function of fog water collecting in addition to the normal rain water input, corresponds to an estimated loss of 20 million m3 of fog water per year (Hemp, 2005a). This is equivalent to the annual water demand of the 1 Million inhabitants on Kilimanjaro. In contrast, the annual water output of the glaciers of only 1 million m3 is hydrologically almost negligible. For the Chagga people, who – with their extensive irrigation system – are highly dependent on steady river flows, the loss of fog-intercepted water presents a serious threat to the long-term sustainability of their livelihoods. The problem is being compounded by population growth and increasing water demand (United Republic of Tanzania & CES, 2002). The situation on Kilimanjaro affects a much larger region. Water resources within the Pangani Basin, with a catchment area of roughly 42,000 km2, originate largely from Kilimanjaro. The Pangani River, one of Tanzania's largest rivers, provides water for the hydro plants of Nyumba ya Mungu (8 MW), Hale (17 MW) and Pangani Falls (66 MW), which together generate some 20 % of Tanzania's total electricity output. A water shortage during dry periods would increase the incidence of power cuts, which even now are severely inhibiting economic growth. Fishing in the Nyumba ya Mungu dam yields a catch of about 4,000 tonnes annually. Water from the Pangani River underpins the large-scale South-East Moshi rice scheme. The southern slopes of Kilimanjaro also provide the water that feeds the Arusha Chini sugarcane plantations of the Tanganyika Planting Company (TPC). In Kenya, the Amboseli ecosystem – including the wetlands of Ol Tukai and Kimana, which support Masai pastoralists and abundant wildlife – depends for its survival on Kilimanjaro's water catchments (Hemp et al., in press).

Changing weather patterns and migration of animals

Changing weather patterns influence also the distribution of animals. The Amboseli National Park in Kenya, on Kilimanjaro's northern foothills, has experienced sweeping habitat changes since the early 1960s, including a dramatic loss of tree and shrub cover, driven to a large extent by a growing elephant population, rapidly increasing populations of Masai and their livestock and by rising temperatures (Altmann et al., 2002). This has caused an increasing migration of elephants from the Amboseli ecosystem via the so-called Kitendeni Corridor into the forests of Kilimanjaro with negative consequences for forest cover (impeded forest regeneration and increasing the risk of fire; Hemp et al., in press).

Striking examples for an upward movement of organisms on Kilimanjaro can be found amongst the grasshopper fauna. In contrast to alpine flora, savanna grasshoppers are spreading from lower elevations to the submontane, montane and even afroalpine zone due to anthropogenic opening of the closed forest and a warmer microclimate (Figure 22-11; Hemp & Hemp, 2008).

[INSERT FIGURE 22-11 HERE
Figure 22-11: Upward movement of organisms in Kilimanjaro. Source: Hemp and Hemp, 2008.]

Climate change impact on agriculture

The traditional Chagga homegardens, covering an area of about 1000 km2 represent a special type of coffee-banana agro-forestry. The large species diversity provides both subsistence and cash crops and minimizes risk (less production failure, increased resistance against droughts and pests; Hemp 2006a; Liniger et al., 2011). However, part of the homegarden area is irrigated by a network of canals depending on runoff from the montane forest and, thus, with this suffering from forest loss as described above. Therefore, many systems are now in disrepair. Today, the Chagga highland homegarden works only in combination with a lowland field where maize, beans and sunflower are grown to ensure food security. These foreland crops depend on sufficient precipitation and are prone to drought.

Degradation of natural savanna vegetation

Loss of natural habitats due to land cover changes and fires is most severe in the foothills of Kilimanjaro. Between 1976 and 2000, over 40 % of the natural vegetation was converted into cultivated fields, resulting in land degradation and erosion, as well as the loss of wildlife habitat and biodiversity (Hemp et al., in press). As a result Kilimanjaro is becoming an increasingly isolated ecosystem, an island surrounded nearly entirely by cultivation. In 1976, there was a corridor of sub-montane forest linking Kilimanjaro with Mt. Meru, but this has now completely vanished. In the past, it facilitated the dispersal of forest animals, as illustrated by the large number of endemic forest grasshopper species that are shared by both mountains (Hemp & Hemp, 2008). Today such movement has been curtailed.

Impact on scenery of the shrinking glaciers

The most pronounced impact of the shrinking glaciers is likely to be purely sentimental. Since 1848, when Rebmann first drew the world’s attention to the presence, so close to the Equator, of glaciers on Kilimanjaro, this ice-capped dome in the hot African sun has not only intrigued scientists, geographers, geologists and biologists (among them Meyer, Volkens, Lent, Jaeger, Klute, Uhlig, von Höhnel, Johnston, and Schlieben), but also writers such as Hemingway. Today, the Kilimanjaro National Park (KINAPA) is a major tourist attraction, generating more foreign currency earnings for Tanzania than any other national park (Newmark & Nguye, 1991). Since the Park was established in 1972, the number of visitors to KINAPA has increased five-fold. Most visitors are intent on reaching the summit of Kibo, known as Uhuru Peak, the highest point in Africa. Kilimanjaro will undoubtedly lose part of its beauty once all its glaciers have disappeared and an important palaeoclimatic archive (Thompson et al., 2002). But even without glaciers, Kilimanjaro will still be covered with snow periodically, and will remain the highest mountain in Africa, a key consideration for most tourists and climbers (Hemp et al., in press).

Conclusions

Changing weather conditions, large-scale habitat conversion, agricultural intensification and rapid human population growth have reached a critical stage at Kilimanjaro. Decreasing precipitation is the main driver for increasing forest fires in combination with illegal logging activities affecting e.g. fog water collecting capacity and with this, the water balance of the whole mountain. Kilimanjaro has lost about 40% of its natural forests, in the upper areas, largely by climate change driven fires, on the lower forest border mainly caused by clearing. This endangers its function as water tower for northern Tanzania, on which nearly 10 million people depend on. The problem is exacerbated by an increase in local population density (10 times in 90 years to over 1 Million in 2002). Based on current global climate scenarios, Kilimanjaro’s ecosystems will be subject to significant further climate warming and shifts in precipitation patterns, enhancing the above threats (Christensen et al., 2007; Huntingford et al., 2005; McDonald et al., 2005).

22.5.2. Multi-Sector Synthesis Case Studies

[possible Durban and Madagascar case studies forthcoming]

22.5.3. Okavango Delta Case Study

(short blurb now, more will be added in next draft)

Living conditions along the Okavango are changing. Communities are growing and so is the demand for resources such as food and energy. Globalization, the connection to global markets, changes consumption patterns and further affects demand in resources. Intensification of land use has emerged for instance in the form of large scale irrigation projects which consume large amounts of water and are not well adapted to small scale farmers' needs. Climate change is predicted to increase water related stress and the decline of the Miombo belt continues. In addition, the use of the river in Angola influences the use opportunities in Namibia. At the same time Botswana is cautiously looking at how the upstream use affects the natural jewel of the Okavango Delta. These changes will need integrated and coordinated decision making and management in order to use the river for the benefit of the people in the basin and the environment alike.

22.5.4. Coastal Zones and Urbanization

The city of Lagos, located in the low-lying coastal zone of south west Nigeria is one of Africa's particularly vulnerable coastal lowland cities to climate change, sea-level rise and flooding. Changes in the intensity and pattern of rain storms coupled with land use changes and subsequent changes in the hydrological fluxes of the urban watershed associated with urban growth have increased flood risks in many parts of the metropolis

A comparison of rainfall characteristics for the periods 1971–1995 and 1996–2005 show marked differences even though the mean annual rainfall is not significantly different (1,697.8 millimetres for 1971–1995 and 1,647.3 millimetres for 1996–2005). Analyses of rainstorms for the period 1971–2005 show that in the latter years (1996–2005), heavier rainstorms were recorded while the number of rain days per annum had decreased (Adelekan, 2010). Fewer rain days were recorded during the more 1996-2005 period, indicating that rainstorms in the latter period were much heavier than those of the earlier period and resulted in more flooding. An earlier study of nine poor urban communities in different parts of metropolitan Lagos showed that flooding appears to have worsened between 2002 and 2006, with 71 per cent of respondents reporting flooding of their streets in 2006 compared with 54 per cent in 2002 (LMDGP, 2006).

The impact of floods in the city of Lagos though widespread is especially felt by the urban poor. A study of four poor urban communities in Lagos by Adelekan (2010) showed that recent flood events usually leave communities flooded for up to four days, with the level of water in communities reaching no less than knee high. The range of impacts in poor communities includes damage to roads, flooding of houses, and disruption of movement. Although the severity of impacts varies within communities, they nevertheless affect the functioning of the community and its members. In Makoko, for example, residents noted that sections of the community that have benefited from an improved drainage system experienced less flooding than areas where the drainage system was poor.

At the household level impacts of flood events are observed in flooding of houses and rooms, loss or damage to household property, and displacement from homes. The impacts of floods on the health status of household members are also evident as floodwater, sometimes reaching waist height, flow into homes carrying a mix of drainage, surface run-off, sewage and all sorts of organic wastes(Adelekan, 2010; Douglas et al, 2008). The worsened environmental conditions arising from flood events contribute to the prevalence of waterborne diseases, hepatitis, intestinal diseases and malaria in poor urban communities. Douglas et al (2008) also noted the impact of floods on child health in the poor urban communities of Iwaya/Makoko in Lagos. Furthermore, potable water shortages, due to water pollution and damage to water pipes following flood events, were highlighted by 94.5 per cent of respondents as burden consequent on flood events. A high percentage (91%) of households in affected poor urban communities make regular visits to health centres because of ill-health, incur increased medical expenses and income loss due to inability to work as a result of illness. Households also incur cleaning and repair costs associated with floods.

A noteworthy impact of flooding in these poor urban communities relates to the mental health of residents. As a result of the annual flooding of communities, the urban poor live in perpetual fear of future flood events and the possible outbreak of an epidemic. The consequence of this include loss of peace of mind, the inability to sleep well, loss of appetite, discouragement and a feeling of neglect. This can lead to depression as the flood-affected population feels helpless due to the overwhelming impacts. The mental health aspects and consequences of repeated flooding can therefore be far-reaching, difficult to cope with, and call for some consideration in the planning of formal responses.

At the individual level, flooding of homes and communities deter social interactions as friends and family cannot visit. The nutritional status of members of flood-affected households is also affected as the floods result in loss of food items and scarcity of food. In terms of economic and livelihood activities, over 90 per cent of respondents in the four communities indicated that flood events denied them of job opportunities or hindered their economic activities. Restrictions on economic activities as a result of floods make poor urban dwellers highly vulnerable as majority depend on wages earned from daily work.

22.6. New Emerging Issues

22.6.1. Climate as a Push Factor – Migration

A common theme in discourses on climate is that future changes will lead to the displacement of millions of people as “environmental refugees” or “environmental migrants”. While the terminology in this respect is varying and inconsistent and creates conflicts of legal nature, when it comes to the question as to whether or not a person can be classified as a refugee with the legal consequences of international refugee law, it can generally be stated that there are people who migrate either temporarily or permanently, within their country or across borders, and who have an environmental signal in their reason for migration (Warner *et al.*, 2010). The available evidence suggests that, globally, the large majority of people displaced by disasters caused by sudden-onset hazards (hurricanes, floods, earthquakes, etc.) remain temporarily and internally displaced with people returning home to rebuild their homes and lives (Tschakert *et al.*, 2010; IDMC, 2011). However, this may apply in the case of slow onset disasters such as droughts and sea level rise with increasing cross-border movement of permanent nature (US National Intelligence Council, 2010).

The issue of internal displacement has been taken up by the African Union by adopting the African Union Convention for the Protection and Assistance of Internally Displaced Persons in Africa in 2009 in Kampala. It is the first regional legal instrument in the world containing legal obligations for states with regard to the protection and assistance of Internally Displaced Persons (IDPs) (Ruppel, in print). So far, the Kampala Convention has 34 signatories.[5] Only 9 countries[6] have ratified the Kampala Convention and it has thus not entered into force.[7] The Kampala Convention defines IDPs as “persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognized State border.” The Convention explicitly recognises its relevance for climate change induced displacement as it is states in Article 5 that “States Parties shall take measures to protect and assist persons who have been internally displaced due to natural or human made disasters, including climate change.” However, the Kampala Convention applies to all situations of internal displacement regardless of its causes (Article 15).

[FOOTNOTE 5: SADC Member States signatories to the Kampala Convention are the Democratic Republic of Congo, Lesotho, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe.]

[FOOTNOTE 6: As of 4 January 2012, the following Member States have ratified the Convention: Central African Republic, Chad, Gabon, Gambia, Guinea-Bissau, Sierra Leone, Togo, Uganda and Zambia.]

[FOOTNOTE 7: Ratification of 15 Member States is required for the Convention to come into force.]

The evidence base in the field of migration is both varied and patchy. An absence of a coherent framework for addressing the role of future environmental change on migration may explain why different assessments of future trends have recently produced contradictory conclusions (e.g. ADB, 2011; Tacoli, 2011).

A global study conducted in 2009 reveals that in 2008, at least 36 million people were newly displaced by sudden-onset natural disasters such as floods and storms, of those 697,066 in Africa. The number of displaced people in Africa has increased from 697,066 in 2008 to 1,1 million in 2009 and 1,7 million in 2010 (IDMC, 2011). Of the 36 million people displaced, over 20 million were displaced by sudden-onset climate-related disasters, i.e. disasters which climate change can influence both in terms of frequency and severity. It is likely that many more are displaced due to other climate change-related drivers, including slow-onset disasters, such as drought and sea level rise (OCAH, 2009).

It should be noted, however, that estimates on migration flows resulting from climate change remain speculative, as migration drivers are usually not mono-causal but influenced by multiple factors (Smith, C *et al.*, 2011) (Table 22-5).

[INSERT TABLE 22-5 HERE
Table 22-5: Percentage of people displaced; global summary 2008–2010. Source: IDMC, 2011.]

22.6.1.1. Migration Drivers

The causes for disasters, displacement, and migration, are manifold, however, climate change is one of the interlinking issues. Potential drivers of migration are push and pull factors related to the region or country of origin or destination respectively, and intervening factors that facilitate or restrict migration, all of which may interact in different ways (Black *et al.*, 2011b). Besides economic, social and political reasons, environmental conditions have been identified as drivers for migration (Foresight, 2011; Thomas, 2011; Middleton *et al.*,, 2011; Beauchemin, 2011; Parnell and Walawege, 2011). If environmental factors do play a part, they typically reinforce existing migration patterns. The typical migrant engages in temporary, circular and internal movements (Raleigh and Jordan, 2010) and is responsive to income variability (Lilleør and Van Der Broeck, 2011).

Three types of impacts of climate change on migration have been identified that seem most likely to have an effect on migration patterns: Extreme weather events, sea-level rise and water stress (Gemenne, 2011a). With regard to forced migration in sub-Saharan Africa a study observed that conflict and the quest for job opportunities are the most significant determinants of international migration, but that environmental factors are also important. It was found that one additional natural disaster per year could lead to an increase in net migration of 0.6 per 1,000 (Naude, 2010).
One approach in assessing future migration potentials, with considerable relevance to the African context focused on capturing the net effect of environmental change on aggregate migration, through analysis of both its interactions with other migration drivers and the role of migration within adaptation strategies rather than identifying specific groups as potential ‘environmental migrants’ (Foresight, 2011).

_____ START BOX 22-4 HERE _____

Box 22-4. Framework for Assessing the Impact of Climate and Environmental Change on Migration

The framework distinguishes between types of migration, rather than the types of migrant, because migration is typically a function of multiple drivers. A distinction is drawn between **mobility** and **displacement**, and it is recognised that these can be seen as two ends of a continuum. Displacement is broadly interpreted as a reaction to an event which challenges safety, security or livelihoods, and is usually seen as involuntary and/or forced, and frequently sudden. Mobility is broadly interpreted as a proactive move to improve livelihoods and opportunities, and is typically seen as voluntary and planned.

Human migration has social, political, demographic, economic and environmental drivers, which may operate independently or in combination, and all of which may be affected, one way or another, by the additional impacts of future environmental and climatic changes (Foresight 2011, Figure 22-12). The conceptual framework accounts for factors that drive migration, but these same factors can cause some people to stay. Most of the world's population are not and do not want to be migrants. This is because they lack the resources – personal and financial - to move. The potential impacts thereon of future environmental and climatic change were considered in the context of scenarios of low to high global economic growth and fragmented-inclusive global governance. Using these analyses, movement outcomes for the future were considered in terms of those likely to present potential operational or geopolitical challenges in terms of both displacement and planned migration.

[INSERT FIGURE 22-12 HERE
Figure 22-12: Drivers of migration, which can all be influenced by future environmental change, and the link to the decision to migrate or not. Source: Black *et al*., 2011b.]

Source: Foresight, 2011.

_____ END BOX 22-4 HERE _____

Future climate change will undoubtedly impact on the suite of drivers of human migration in Africa. Even if Africa's population doubles by 2050 to 2 billion (Lutz and Samir, 2010) and the potential for displacement rises as a consequence of the impact of rapid-onset climate events, recent analysis (Foresight, 201;, Black *et al*., 2011a) shows the picture for future migration is much more complex than previous assessments of a rise in climate refugees suggest, and relates to the intersection of multiple drivers with rates of global growth, levels of governance, and climate change.

Further empiric research is required on displacement related to climate related shocks and slow-onset disasters in Africa, to provide more evidence on the links between climate change, conflict, and displacement, and climate change impacts on those who already are displaced. Further topics will need to be considered, such as displacement linked to measures to mitigate or adapt to climate change. Biofuel projects and forest conservation could for instance lead to displacement if not carried out with full respect for the rights of indigenous and local people (Kolmannskog, 2010).

22.6.1.2. Impacts

Empirical base for major migration consequences is very weak (Gemenne, 2011b; Lilleør and Van Der Broeck, 2011; Black *et al*., 2011b) and non-existent for international migration (Marchiori *et al*., 2011). Temporary, circular, and internal migration is an important aspect of spatial mobility in drought-affected areas; and is often a component of household survival strategies for coping with drought and high levels of production uncertainty (Perch-Nielsen *et al*., 2008). However, even across the same climate disaster, the response can vary. Soil quality is correlated with a decrease in migration in Kenya, yet is with an increase in Uganda (Gray, 2011). Rainfall deficits tend to increase the risk of long-term migration to rural areas and decrease the risk of short-term moves to distant locations, but in parts of Kenya and Niger, this has resulted in mobility decreases due to lack of labor demands (Findlay, 2011) whereas in cases of flooding, movement in Ethiopia and Niger was very short term while in Chad and Somalia, drought may push movement, but only if ongoing conflict allows for mobility (Raleigh, 2011).

Climate change impacts on size and characteristics of rural and urban human settlements in Africa. Ecological hazards occur with sufficient frequency to influence how people incorporate such risks into their livelihoods (Perch-Nielsen *et al*., 2008; Piguet, 2010; Piguet et. al., 2011). Where, or if, people move in response to a calamity is often strongly shaped by social networks (de Haas, 2011). People are most attracted to close areas, and closer small to large cities in the global south (Potts, 2010; Beauchemin, 2011). Yet, potential or destination characteristics beyond economic gain are increasingly shaping movement (Brooks & Waters, 2010; Brettell, 2008).

Mobility is indeed a strategy (not a reaction) to high levels of climatic variation that is characteristics of Africa (Tacoli, 2011; Perch-Nielsen *et al*., 2008) and the specifics of the response is determined by the economic context of the specific communities. Urbanization through migration is also leading to new vulnerabilities as new migrants face significant ecological issues including floods etc. (Seto, 2011). African urban dwellers have the least access to water and sanitation (McGranahan *et al*., 2009). There are millions of urban dwellers that have unsafe, unreliable, difficult and possibly privatized access to water; less than 10% of the population is connected to sewers (Satterthwaite, 2010).

The problems associated with voluntary or involuntary environmentally induced migration to Africa's large and intermediate cities will exacerbate as a result from climate change. Migration flows can be observed away from flood-prone localities, as well as potentially large-scale internal and cross-border mobility away from agricultural zones undermined by changing climatic conditions or declining water availability (UN-Habitat and UNEP, 2010). Environmental and climatic stress not only raises existing inequalities between rich and poor, it also contributes to rural-urban migration on the African continent (Scheffran and Battaglini, 2011; Hope, 2011). In sub-Saharan Africa, climatic change is considered to be an important determinant of urbanization growth and climatic conditions push people out of rural/agricultural areas to urban areas (Barrios *et al.*, 2006). Declining rainfall, droughts and floods have the potential of rendering agricultural lands unproductive or making rural settlements inhabitable, which in turn affects the livelihoods of rural residents, forcing them to migrate to the urban areas (Hope, 2011). As a result, African large and medium-sized cities experience extreme population growth. In 2009, almost 40 per cent of Africa's total population of one billion lived in urban areas and it is estimated that by 2030, Africa's collective population will become 50 per cent urban and 60 per cent by 2050 respectively (UN-Habitat and UNEP, 2010). Africa counts 37 cities with populations above one million, half of which are within low elevation coastal zones (Mosha, 2011). Low-lying cities located on lagoons, estuaries, deltas or large river mouths, such as Alexandria, Cotonou, Dar es Salaam, Lagos, Maputo and Mombasa as well as the Cape Flats area of Cape Town are particularly vulnerable to extreme weather events caused by climate change. They are likely to experience storm surges, sea-level rise, increased flooding, (semi-) permanent inundation, coastal erosion, landslides, and the increase of water-borne diseases, which may all have devastating effects on human settlements, especially, if no measures have been taken to ensure risk reduction in terms of urban planning, land-use management and the quality of housing and infrastructure (Mosha, 2011). In this regard, the high risk for low-lying urban slums has to be pointed out. Although the proportion of urban slum dwellers is decreasing, informal settlements remain one of the major threats to African urban stability and, by extension, to overall political stability (UN-Habitat and UNEP, 2010). African inland cities are rather exposed to experience higher ambient temperatures and more frequent heat waves, with potential risk of water shortages, damage to infrastructure, and desiccating vegetation, due to the impacts of climate change.

Climate change not only affects populations; increased flooding, more frequent severe storms and rising sea levels increasingly influence the integrity of the built environment including the supporting infrastructure consisting, amongst others of roads, transport, water supply, sewers, energy, electrical grids, and telecommunications. Depending on their location and nature of construction, buildings and supporting infrastructure are vulnerable to flooding and other extreme weather events, which increase the likelihood of landslides and building subsidence, especially on clay soils, requiring enhanced construction and infrastructural standards for resistance for initial protection, such as, raising foundations of buildings, strengthening roads and increasing storm water drainage capacity (UN-Habitat and UNEP, 2010; Mosha, 2011).

The evidence base suggests that climate change will have a significant but complex impact on African migration, affecting those who migrate, those who cannot and the nature of migration itself (Foresight, 2011). However, this has to be set in the context of migration already being a vital dynamic of African livelihoods and societies, with the environment playing an important role in migration characteristics. Recent population displacements due to productivity failures and rapid onset events have occurred respectively due to drought in the Horn of Africa and southern Sudan and floods in western Zambia and northern Namibia. Planned movement within households is however a major characteristic of populations in many sub-Saharan African drylands (Tacoli, 2011). It is a strategy of livelihood diversification for coping with uncertainty, spatial differentiation in resource availability, and the slow onset effects of land degradation on ecosystem services including crop yields (Gray 2011, from Kenya), as well as of drought (Burkina Faso: Henry *et al*., 2004, Ethiopia: Gray and Mueller in press).

A meta-analysis of 34 case studies, many from Africa, identifies the capacity to respond to environmental and climate stress by migrating is greater for households with accumulated capital (Stafford Smith, 2011), with poorer groups lacking the ability and resources to move in a planned way (e.g. Van der Geest, 2011b). In this respect those previously affected by environmental disturbances such as drought may have less capital to respond through movement to subsequent environmental stresses. Consideration of future migration dynamics in Africa needs to recognise not only groups that choose to migrate or are forced to move, but also those who are 'trapped' and unable to move despite wishing to (Black *et al*., 2011b).

Despite doubts over the contribution of migration to recent African urban growth, a recent assessment predicts an increasing role in coming decades (ARI, 2012). A decline in rural prospects or a sudden economic collapse, either of which might be driven e.g. by the impact of negative climate changes on the rural resource base and economy, could trigger longer-term mobility or short-term reactive displacements towards urban areas, trends that have been noticeable in recent decades to date in Asia but also in some African contexts (e.g. Karley, 2009). Some of these are in low lying coastal areas, where net in-migration of c5 million occurred in Africa between 2000-2010 (CEISIN, 2011), with the low elevation coastal population of North Africa additionally modelled to rise from 1.5 million in 2000 to 7-12 million by 2060 and in sub-Saharan Africa from 2.7 million to 16-24.5 million (Foresight, 2011).

Regardless of whether it is natural growth or in-migration that drives urban population growth in Africa, the number of African urban poor is expected to rise in the future. Within urban areas the poor have least choice of where to live, such that the dominance of slum growth is expected to continue as African urban centres grow further (Pieterse, 2011). Linked with this, 40% of new migrants to Dakar, Senegal have moved to areas subject to high flood risks (World Bank, 2010a), with the number of people living in urban areas prone to flooding predicted to rise in Africa from 2 million in 2000 to 26-36 million by 2060 (depending on scenario, Foresight 2011).

Besides low-lying islands and coastal and deltaic regions, sub-Saharan Africa is one of the regions that would particularly be affected by environmentally induced migration (Gemenne, 2011a). Case studies from Somalia and Burundi (Kolmannskog, 2010), two African countries considered to be among the most vulnerable countries in the world, emphasise the interaction of climate change, disaster (in particular drought), conflict, displacement, and migration. Not only armed conflicts, but also the changing climate and droughts in particular are the main drivers for displacement in Somalia and some of the displaced crossed the border to Kenya, a country which itself has experienced one of the worst droughts in 2009, with millions in urgent need of food aid. Many different protection challenges arise from climate-related disasters and conflict, such as food, water, shelter, healthcare, and sexual and gender-based violence (Kolmannskog, 2010). Although there was no survey or systematic monitoring of people moving away (or subsequent returns) in Burundi, a country that has recently come out of a civil war, the drought in 2008 in the northern province of Kirundo resulted in many people displaced, some of them moving across the border to neighbouring Rwanda (Kolmannskog, 2010). In Ghana for example, an African country with few conflicts caused by political, ethnic, or religious tensions, and thus with migration drivers more likely related to economic and environmental motivators (Tschakert and Tutu, 2010), some different types of migration flows are considered to have different sensitivity to climate change. Seasonal migration of pastoralists and agricultural labour to the North of Ghana for example have a high sensitivity to climate change, long-term rural-rural and rural-urban migration have a medium sensitivity to climate change while long-term urban-rural (return), intraregional and international migration are considered to have a low sensitivity to climate change (Black *et al.*, 2011b). One analysis shows that at Ghana's national level, districts with more out-migration than in-migration tend to be more sparsely vegetated than districts with a migration surplus. It has been found that migration flows in Ghana can be explained partly by vegetation dynamics but are also strongly related to rural population densities, because access to natural resources is often more important than the scarcity or abundance of natural resources per se (Van der Gesest *et al*., 2010). In Mozambique, floods, cyclones and droughts are natural hazards particularly affecting the people, just as coastal soil erosion with a particularly high risk of inundation and erosion for the river delta regions. The floods in 2000, the tropical cyclones in 2000 and 2007 and following flooding made thousands of people temporarily homeless. In 2008 the Zambezi River flooded once again, displacing more than 90,000 people and it has been observed that along the Zambezi

River Valley, with approximately 1 million people living in the flood affected areas, temporary mass displacement is taking on permanent characteristics (Warner *et al.*, 2010; EACH-FOR, 2009).

22.6.2. Futures with Alternative Pathways

[forthcoming]

22.6.3. REDD+ Experience in Africa

Forest cover in Africa currently stands at 675 million hectares, which represents 21% of global carbon forest biomass in 2010 (FAO 2011). This endows the continent with great potentials for global climate change response in mitigation depending on the carbon dynamics in accretion or depletion (Williams et al. 2007). Forest integrity in Africa is highly threatened by both climate and non-climatic factors. The most dominant systematic change in land use occurring in the continent is deforestation and forest degradation severely affecting forest cover (Nakakaawa et al. 2011). The principal non-climate drivers of forest land use change are market access, poverty and population (Nakakaawa et al. 2011). Other non-climate drivers included slope, soil quality and presence or absence of a stream network. In Africa, there is an uneven distribution of forest cover; Central Africa (37.79%); Southern Africa (28.81%); North Africa (11.69%); West Africa (10.86%); and East Africa (10.85%) (FAO, 2011). This creates differential potentialities for REDD+ including carbon stock per hectare in the region, as well as shapes the architecture of livelihood dependencies on forest resources. Over the period of 2000 – 2010, deforestation rate was -0.49% with the highest rates in West Africa (-1.12 %) and East Africa (-1.01%). The loss of forestlands has the twin consequence on climate change by contributing to emission levels and loss of vital carbon sinks, and by reducing the adaptive capacity of communities who depend on forest resources. Abating CO2 emissions characterizing land use change has emerged as an important mechanism for addressing climate change through REDD+. Framed in market instruments, this introduces a global service for tropical forests besides their local services for national development and local communities through the goods and services they provide (Metzger et al. 2006). There is an increasing trend in Africa reported in the area planted to forest (2.5% of total forest area), and forest area designated for conservation of biodiversity (14%) (FAO 2011).None of these motivated trends is attributed to or triggered by the incentives of REDD+. Globally, there have been increases in biomass across many forest types and attributed to climate change (McMahon et al. 2010). However, the consistent vegetation greening trend occurring in the Sahel which includes shrublands, cannot be explained by simply climate change (Olsson et al. 2005).

Forest remains intricately linked and spatially connected to people in Africa serving as dwelling places for communities such as the case of over 30 million forest indigenous people (e.g. Pygmies etc.) in the Congo Basin Forest of the Central African Region (CBFP 2006), and as sources of resources for rural and urban communities in both nearby and distant places following the multiple goods and services they provide for household livelihoods as well as contribution to the national economic development, and safeguarding other ecosystems (CBFP,2006). In support of food security, forests provide vital nutritional supplements especially for children, and constitute major dietary complements such as bush meat as principal protein sources for households (Nasi et al. 2008, Dudley et al. 2008). The medicinal products they provide, serve as frontline interventions for household healthcare for majority of people in rural areas (Colfer et al. 2006). This makes adaptation and mitigation inseparable as climate change responses in forest systems (Guariquata et al. 2007; Nkem et al. 2007). By linking global processes and national and local needs, REDD+ is entrapped under different climate change priorities which requires reconciliation between mitigation and adaptation especially in using spatial planning in finding solutions (Apuuli et al. 2000; Biesbroek et al. 2009). Harnessing the full potentials and cost-effectiveness of REDD+ depends on the opportunity cost (Kremen et al. 2000), which in the case of Africa, links to the trade-offs in social benefits for local communities as well as support for national development efforts in addressing demands for food, fuel and fiber underlying the decision making process for land use change (Thomson et al. 2010).

The lack of affordable alternatives in household energy supply, continue to challenge forest integrity that is required for the implementation of REDD+. Fuelwood remains the dominant and pro-poor household energy supply (Howells et al. 2006) especially among the rural and peri-urban population and with significant contribution to household income in addressing poverty (Manyatsi and Hlophe 2010). Forest wood removal in Africa as fuelwood represents 33% of the global total of fuelwood removal (FAO 2011). Industrial woods represent about 10% of wood removals in Africa which, together with fuelwood amount to US$2.9 billion in 2005. This holds significant economic potentials for countries in the continent yet, industrial woods removal only represents 11% of the global total (FAO 2011). This draws concerns on the cost-benefits analysis for land use change.

Besides the expected range of benefits, directly in cash-flow from developed to developing countries, reducing emissions, and indirectly for biodiversity conservation, improvement in other ecosystem services e.g. hydrological services etc. implementation poses major methodological challenges (Karsenty and Pirard 2008). Under vastly different context in the implementation of REDD+, the implications on rural communities is also largely different and shaped by local context (Westholm and Kokko 2010). For example, the conversion of grassland for the establishment of tree plantation for carbon offset could be detrimental to local communities in accessing land for grazing, biodiversity resources, water and cropland (Karumbidza and Menne 2011).

Although forests play important roles in rural household livelihoods in Africa, their use for anticipatory adaptation is limited and predominantly serves for reactive coping (Fisher et al. 2010). Opportunity exists in using forests for planning adaptation especially through forest governance reforms that improve access by communities to forest resources (Kalame et al. 2008). At the national level of planning, there is very little attention in integrating forests in national programmes and strategies on adaptation as compared to mitigation (Bele et al. 2010; Kalame et al. 2011; Sonwa et al. 2011). Forest goods and services are primarily used as safety nets other than the financial returns from markets through sales of forest goods and services including REDD+ that can contribute to planned adaptation to climate change (Nkem et al. 2010). Discourse among forest actors shows separate policy pathways and inclinations for adaptation and mitigation with a strong government preference for mitigation while the priority of local communities and community-based actors is on adaptation (Somorin et al. 2011). Reconciling financial and non-financial motivational use of forest goods and services by communities has major implications for REDD+ implementation (Paumgarten and Shackleton 2011).

Forest ownership in Africa is highly centralized and predominantly state ownership with limited community and private ownership (CBFP 2006, Sunderlin et al. 2008). This raises serious issues of tenure and the need for land ownership reforms for the effectiveness of forest governance for climate change response in mitigation and adaptation (Agrawal et al. 2008; Unruh 2008). Surrounded by indigenous communities, the rights to forests and the rules for resource use that pose major risks and vulnerability of forest indigenous communities remain contentious issues in the implementation of REDD+ (Larson 2011). Gains made developing countries in the trend in decentralization of forest management that empowers forest communities with the rights of access and use could be jeopardized with the centralization of REDD mechanism in national systems (Phelps et al. 2010). There is a fear of exclusion of local communities from REDD+ which raises major concerns on the equity outcomes under current forest governance structure (Suivi 2010). Enhanced governance and resilience are vital conditions for managing climate risks and reducing the vulnerability of forest dependent communities (O’Brien et al. 2006). Local communities have important roles to play in carbon offset systems through community forest but this entails land-use flexibility (Purdon 2010). Incorporating trees on-farm could expand the opportunity for participation in carbon offset schemes by smallholder farmers (Kung’u et al. 2011). Similarly, the local knowledge of communities can support adaptation and mitigation efforts drawing from locally appropriate options (Nyong et al. 2007; Ogden and Innes 2009).

Flexibility in the presently centralized system of REDD+ could reduce the complexity, transactions and improve on the efficiency in risk reduction and the welfare of the forest-dependent poor (Peskett and Harkin 2007). This is important in overcoming some of the perceived challenges of REDD+ in terms of the complexity in the design, technical capacity for implementation, opportunities for participation, and benefit sharing and addressing shifting cultivation for food production (Brown et al. 2011). Therefore, flexible REDD+ model that include agriculture and adaptation may widen the scope for pro-poor participation (Wertz-Kanounnikoff et al. 2011) especially in Africa where food security and adaptation are major priorities (Nkem et al. 2008). This is crucial in avoiding the undesirable trade-offs in the local adaptive capacities of communities, ecosystems and nations as well as increased vulnerability of some key sectors like agriculture, with the implementation of REDD+ (Kimbowa et al. 2011).

Rural livelihood in Africa will continue depend on forest resources which contributes to their vulnerability to climate impacts under environmental degradation especially forest loss (Sale and Agbidye 2011). REDD+ therefore offers opportunity for synergy between mitigation and adaptation that could be universally applicable and can be communalized and translated into local contexts. Adaptation measures are required in addressing other climate-induced decline in forest stands, production, and soil carbon stocks other than human-induced deforestation and degradation that could affect REDD+, such as drought- and heat-related tree decline and mortality (Allen et al. 2010; Martinez-Vilalta et al. 2011). Maintaining the integrity of mangroves and mitigating anticipated losses under climate threats of sea level rise, requires adaptation measures that improves resistance and resilience through coastal planning to facilitate mangrove migration with sea level rise (Gilman et al. 2008).

22.6.4. Biofuels and Land Use

The potential for first-generation type biofuel production in Africa, derived from bioethanol from starch sources and biodiesel production from oilseeds, are significant given the continent's extensive arable lands, labor availability, and favorable climate for biofuel crop production (Amigun et al., 2011; Arndt et al., 2010; and Hanff et al., 2011). Africa's large extent of marginal and 'abandoned' lands are viewed as particularly suitable for biofuel feedstock production in light of the need to avoid competition for land between food and energy crop production. Several governments in Africa are moving forward with efforts to introduce policies for and entice investments in biofuel production. Land acquisition for domestic biofuel production in Africa is lagging substantially behind that of foreign investment for export production of biofuels, where, according to Amigun et al. (2011), individual land acquisitions from foreign interests range from tens of thousands to millions of hectares. Foreign demand for biofuels from Africa are occurring in response to mandates for blended fuels in the European Union, which are prompting private sector investment from northern countries in Africa, as well as government and private sector investment from fast growing regions outside Africa to help address energy security needs of these regions.

While biofuel production could have positive energy security and economic growth implications, the prospect of wide-scale biofuel production in Africa carries with it significant concerns about environmental and social sustainability. Among the concerns are competition for land and water between fuel and food crops, adverse impacts of biofuels on biodiversity and the environment, contractual and regulatory obligations that expose farmers to legal risks, changes in land tenure security, and reduced livelihoods opportunities women, pastoralists, and migrant farmers who depend on access to the land resource base (Amigun et al., 2001; German et al., 2011; Schoneveld et al; 2011, Unruh; 2008). Much more research is needed to fully understand the distributional consequences of biofuel production across different African countries and to develop effective policy frameworks that avoid or mitigate negative consequences from biofuel production on food and livelihood security and the environment in Africa.

The effect of biofuel production, particularly large-scale schemes, on land-use change and subsequent food and livelihood security, is a critical knowledge gap. For instance, an important justification for pursuing biofuel production in Africa is that the continent contains extensive areas of marginal and/or abandoned lands that would be suitable for biofuel crops capable of growing under harsh conditions (Cai et al., 2011). However, the concept of 'abandoned lands' is contested. Unruh (2008) argues that land in Africa is rarely ever abandoned but rather that these marginal areas serve as a common property resource under traditional jurisdictions for transient and seasonal use by pastoralists and that women are often allocated low quality lands for food and medicinals production. Conversion of marginal or abandoned lands for biofuel plantations could therefore impact the ability of these groups to participate in land-use and food production decisions (Amigun et al., 2011; Schoneveld et al; 2011). Biofuel production could potentially lead to extensification of agriculture into forested areas. As noted by German et al. (2011) in Zambia "Significant land use changes, both direct and indirect, were observed as a result of the integration of Jatropha into smallholder farms. Direct land use changes occurred due to the integration of Jatropha into permanent cropland, the opening of fallow vegetation or the opening of mature woodland. Indirect land use changes were also observed in many households as new plots were opened in fallow or mature forest to offset food crop displacement."

Better agronomic characterization of biofuel crops is another important knowledge gap. For example, there is a dearth of information with respect to the agronomic characteristics of the oilseed crop Jatropha (Jatropha curcas) under conditions of intensive cultivation across differing growing environments, despite the fact that Jatropha has been widely touted as an appropriate feedstock for biofuel production in Africa because of its ability to grow in a wide range of climates and soils. Oilseed yields of Jatropha can be highly variable, and even basic information about yield potential and water and fertilizer requirements for producing economically significant oilseed yields is scanty (Achten et al., 2008; Hanff et al., 2011; Peters and Thielmann, 2008). Such knowledge would not only provide a basis for better crop management but would also help to gain better estimates of the extent of water consumption for biofuel production in the context of non-biofuel water-use needs across landscapes. Assessments of Jatropha's potential as an invasive species and its potential allelopathic effects on native vegetation are also needed, in light of the fact that some countries have designated Jatropha as an invasive species (Achten et al., 2008).

22.6.5. Ecosystem-Based Adaptation

Ecosystem based Adaptation (EbA) aims to support human adaptation to climate variability and change through the sustainable management, conservation and restoration of ecosystem services. EbA promotes proactive, 'no regret', adaptation strategies which embrace both reducing people's vulnerability and safeguarding ecosystem resilience (Roberts et al., 2011).

Because of their low cost and accessibility, ecosystem based strategies are the first line of defence for the poorest and are integral for their income generation and food security. For instance, forest ecosystem services constitute important safety nets in times of extreme droughts for many vulnerable pastoral herders in the Sahel, ensuring the survival of herds for several months (Djoudi et al., 2012). Forest goods and services reduce the negative impacts of drought and floods on agricultural and livestock-based livelihoods in Mali, Tanzania and Zambia (Robledo et al., 2011). When drought affects agriculture, vulnerable women in several African countries assure their livelihoods by using different forest products such as charcoal and non-timber forest products (Brown, 2011; Paavola, 2008).

In the global climate change debate, EbA is an emerging concept; however, ecosystem-based strategies are not new in many African local contexts. Based on their long experience with climate variability, people in the Sahel have developed different ecosystem-based responses. Pastoralists practice mobile grazing to deal with both spatial and temporal rainfall variability (Djoudi et al., 2012). Communities in the Maradi and Zinder regions of Niger have restored large degraded areas by planting trees, which decreased the sensitivity of their production systems to drought. The livelihoods of those farmers were less affected by the last droughts compared to other regions in Niger (Tougiani et al., 2009; Sendzimir et al., 2011). Despite the evidence from studies such as those cited above, scaling-up to prioritise ecosystem-based adaptation plans at the national level and in policy has been slow.

The National Adaptation Programmes of Action (NAPAs) were the first national adaptation planning exercise for many African countries to set a policy framework and to prioritize most urgent adaptation needs and projects. Even though many NAPA projects focus on technical solutions, education, and capacity-building without direct management of ecosystem services, some include ecosystem measures (Pramova et al., 2012). In these projects, ecosystem conservation or restoration can have different objectives: (1) reducing human vulnerability to climate variability or change, (2) increasing human well-being, or (3) benefiting the environment. Projects with objective 3 focus solely on ecosystems, for example, Sierra Leone proposes new forest reserves and Burundi the reduction of ecosystem vulnerability through conservation but none specify how these actions help people adapt. Although important, they cannot be considered EbA. Projects with objective 2 aim at enhancing the provision of ecosystem services to support local livelihoods; for example, the Central African Republic promotes suburban forestry to support Shea oil, timber and firewood livelihoods, while forest restoration in Malawi is proposed to regulate water flows and diversify livelihoods with forest goods. Projects with objective 1 have a more explicit contribution to adaptation; for instance, Djibouti targets mangrove restoration to reduce salt water intrusion and coastal production losses due to climate hazards, while Sudan prioritizes agroforestry to protect land and production against drought and desertification (Pramova et al., 2012)(Figure 22-13).

[INSERT FIGURE 22-13 HERE
Figure 22-13: Some examples of ecosystem-based adaptation. Source: Pramova *et al*., forthcoming.]

Tree-planting is a popular measure in African NAPAs (e.g. Burkina Faso, Niger, Senegal, Sudan, and Gambia) but getting the seedling in the ground should not be the sole focus. In order to avoid mal-adaptation, more attention should be paid to livelihood obstacles and enhancing farmer capacities to manage both short- and long-term risks, as research in the gum-arabic agroforestry systems of the Sudanian NAPA has shown (Kalame et al., 2011). South Africa's early EbA experience has demonstrated that structured programmes leading to direct and immediate development co-benefits for local communities are essential (Roberts et al., 2011).

Adaptive environmental governance represents one of the future challenges for the implementation of EbA strategies in Africa. Sustainable use of resources, secure access to meet needs under climate change, and strong local institutions to enable this are further challenges. Issues strengthening underlying conflicts over resources in Africa, such as unclear land tenure and legislation forbidding ecosystem use, will have to be resolved if ecosystems are to contribute to adaptation beyond short-term coping (Robledo et al., 2011).

22.6.6. Integrated Adaptation / Mitigation Approaches

[forthcoming]

22.6.7. Climate Finance and Management

Mismanagement and misuse of funds transferred to developing countries to address the risk of climate change is a serious challenge (Transparency International 2011:xxvi). Indigenous and rural poor communities in remote locations, the urban poor living in precarious settlements, and displaced persons, especially women and children are those most adversely affected by climate change and they are actually meant to be the main beneficiaries of adaptive action. However, mismanagement and misuse of funds eventually puts at risk the rights of those most vulnerable to the negative effects of climate change. The reasons for the high degree of fund mismanagement with regard to climate finance and adaptation funds are rooted in the level of complexity, uncertainty and novelty that surrounds many climate issues. Another challenge is that adaptation funds are often provided to national governments that may or may not direct the funds to the most vulnerable.

22.7. Cross Cutting Themes: Livelihood and Poverty, Gender, Children

22.7.1. Human Rights in Africa and Climate Change

In 2009, the Human Rights Council adopted Resolution 10/4[8] which noted the effects of climate change on the enjoyment of human rights, and reaffirmed the potential of human rights obligations and commitments to inform and strengthen international and national policy making. In that resolution, the Council welcomed the exchange of information between the Office of the High Commissioner for Human Rights (OHCHR) and the UNFCCC Secretariat (McInerey-Lankford, 2009).

[FOOTNOTE 8: U.N. Doc. A/HRC/10/L.11.]

The impacts of climate change on human rights have also been explicitly recognised by the African Commission on Human and Peoples’ Rights (hereafter African Commission). In its AU Resolution (ACHPR/Res 153 XLV09) the African Commission called on the Assembly of Heads of State and Government to take all necessary measures to ensure that the African Commission is included in the African Union’s negotiating team on climate change. The 1981 African (Banjul) Charter on Human and Peoples’ Rights (hereafter African Charter) is a human rights treaty that protects the right of peoples to a ‘general satisfactory environment favorable to their development’ (Article 24). The recognition of this a right by the African Charter and the progressive jurisprudence by the African Commission underline the relevance and linkage between climate change and human rights (Ruppel, 2010).

Many if not most African countries have acceded to both the International Covenant on Civil and Political Rights (ICCPR) and the International Covenant on Economic, Social and Cultural Rights (ICESCR), together with the Universal Declaration of Human Rights (UDHR), are often referred to as the International Bill of Rights. Both the ICCPR and the ICESCR call on State Parties to take steps (legislative or other measures) to give effect to the rights contained therein. Most of the rights and freedoms recognised in the ICCPR are also entrenched in national constitution's Bill of Rights. This may include, amongst others, the right to dignity, the right to life, the right to health, the right to water, the right to legal representation, the guarantee against torture and other cruel or inhuman treatment or punishments, the protection against discrimination on any ground, and others. The ICESCR and the ICCPR provide internal protection for specific rights and freedoms. Both Covenants recognise the right of peoples to self-determination; both have provisions which prohibit all forms of discrimination in the exercise of human rights; and both have the force of law for the countries which have ratified them. States have obligations under international human rights law to address disadvantage, threats to human rights and ensure that policies aimed at limiting the effects of climate change are not implemented effectively and in ways that don't overburden or discriminate against specific vulnerable groups, e.g. women, children and indigenous people (Ruppel, 2011).

Article 3 of the ICESCR encourages States Parties to ensure the equal right of men and women to the enjoyment of all economic, social and cultural rights as set forth by the Covenant. The Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) obliges States Parties to take all appropriate measures, including legislation and temporary special measures, to ensure that women enjoy all their human rights and fundamental freedoms. The Beijing Declaration embodies the commitment of the international community to the advancement of women and to the implementation of the Platform for Action, ensuring that a gender perspective is reflected in all policies and programmes at national, regional and international levels. The Beijing Platform for Action, on the other hand, sets out a number of actions for national and international implementation for the advancement of women (Ruppel, 2008).

Adherence to the Convention on the Rights of the Child (CRC) could require that national government policymakers, especially those in developed countries, ensure the fair representation of children and young people and that children's specific needs are given due consideration in adaptation and mitigation policy (UNICEF, 2009). Particularly relevant to climate change are the principles contained in the CRC Articles 2, 3, 6 and 12, covering the issues of non-discrimination; the best interests of the child; the right to life, survival and development; and respect for the views of the child. No less important in the same context are the rights contained in the CRC referring to civil rights and freedoms, containing inter alia the right to access to appropriate information; and the right not to be subjected to torture or other cruel, inhuman or degrading treatment or punishment. The group of basic health and welfare summarises the Convention's Articles 6, 18(3), 23, 24, 26, and 27(1)–(3), namely the right to survival and development; the right to special protection of children with disabilities; the right to health and health services; the right to social security and child care services and facilities; and the right to an adequate standard of living. In this context, national climate change related efforts to combat HIV and AIDS and diseases such as malaria and tuberculosis, particularly among special groups of children at high risk, need to be mentioned. Special protection measures are laid down providing for, *inter alia*, children in situations of emergency; refugee children; children in conflicts; children in situations of exploitation; and children belonging to minority or indigenous groups (Ruppel, 2009).

The Declaration on the Rights of Indigenous Peoples reaffirms that indigenous peoples, in the exercise of their rights, should be free from discrimination of any kind, recognising the urgent need to respect and promote the inherent rights of indigenous peoples which derive from their political, economic and social structures and from their cultures, spiritual traditions, histories and philosophies, especially their rights to their lands, territories and resources (Meijknecht, 2001).

22.8. Research Gaps

The following data and research gaps have been identified:

- Multi-tiered approach to building institutional and community capacity to respond to climate risk
- Developing methods in vulnerability analysis for capturing the complex interactions in systems across scales

- Frameworks for designing adaptation measures to cope with high levels of uncertainty
- Improved analysis of adaptation technologies to build adaptive capacity and resilience
- Methodologies / "cyclical learning and decision-support tools to explore anticipatory adaptation in high poverty/high vulnerability contexts" (Tschakert and Dietrich, 2010)
- Integrating a differentiated view of poverty into climate change adaptation and disaster risk reduction in order to more effectively address the root causes of poverty and vulnerability, which can be promoted through further integration of CCA and DRR with social protection.
- Frameworks for identifying and eliminating factors that constrain women's ability to adapt, at multiple levels
- Understanding and demonstrating how greater integration of women in decision making could address the inequitable distribution of climate impacts, and could improve adaptive decision making more broadly.
- Understanding the factors that determine the effectiveness of adaptation activities in building resilience and increasing adaptive capacity and the effectiveness of community-based adaptation (CBA) to climate change and variability.
- Monitoring adaptation

Examples of possible research questions on barriers and limits

- Who uses what adaptation strategies and why – are there barriers to certain people taking up certain strategies?
- What changes are needed? What might be the barriers to implementing these – either identified externally or by locals themselves?
- Are there some adaptation options that have more barriers than others? Why?
- What options are more likely to be accepted in certain context than others – what is appropriate in what context given barriers?
- What are the barriers at higher levels to supporting adaptation at the local level?
- How do barriers influence trade-offs/choices between different adaptation options.
- How do we overcome knowledge and information barriers by providing people with useful information that can help them make decisions?
- What is needed to overcome social and cognitive barriers – e.g. education, awareness, information sharing, social learning, etc.?
- How do different types of barriers interact?
- How can previous endogenous/autonomous strategies be built on/ reconfigured by overcoming barriers?
- Where are the limits to adaptation for particular groups? Where is other support and social protection needed – where is transformation the only option?

22.9 Conclusions

[forthcoming]

Frequently Asked Questions

FAQ 22.1: What is the significance of migration in context of climate change adaptation in Africa?

Migration was considered as a negative impact in the last decade however. There is now a perception of potential positive role of migration in climate change adaptation. Even if classical literature tend to ignore environment as a key driver of migration, new theories on African mobility state that migration is a central issue in the adaptation process and one of the most relevant responses to climate change in Africa regardless some negative effects on environmental degradation. As in most regions of the world, environmental change will continue to affect African migration during the coming years. In addition to economic, social and political drivers, environmental change will play a key role in the migration process by empowering its main drivers. The impact of environmental change on migration will affect livelihoods making migration a main answer or the only response. A better management of African migration and displacement is a core issue to avoid humanitarian emergencies and the risk to jeopardize the necessary population mobility due to environment change.

FAQ 22.2: How could climate change impact food security in Africa?

Food security is comprised of food availability, access, quality, utilization, and acceptability. There is strong consensus that climate change will have a significantly negative impact on food availability in Africa. This could occur through direct climate impacts on crops and livestock, such as through increased incidence of floods, drought, shifts in the timing and amount of rainfall, and high temperatures, or indirectly through increased soil erosion brought on increased incidence of heavy storms and through increased pest and disease pressure on crops and livestock. The link between climate change and food access is less clear though there is evidence that climate change impacts in important cereal producing regions of the world, could, along with other factors, contribute to increasing food prices, which impedes the ability of the poor and middle class in Africa to purchase food, hence their reduced access. The impact of climate change on food quality could occur through increased risk of spoilage of fresh food and pest and pathogen damage on stored (cereals, pulses, tubers) foods under warmer and more humid conditions. Climate change could impact food utilization through increased gastro-intestinal diseases, malaria and other diseases that reduce the ability of the human body to absorb nutrients from food. There is no known link between climate change and food acceptability.

FAQ 22.3: What has been the experience in Africa on planning and implementing adaptation since the AR4, and what are some key gaps and barriers?

There has been considerable progress in exploring adaptation options, approaches and decision tools in Africa since the IPCC Fourth Assessment Report. However, planning and selection of options for adaptation responses is still an evolving knowledge area, and many of the diverse initiatives implemented in Africa have been at the pilot or experimental scale. Options and approaches used at different levels and scales in Africa include disaster risk reduction, early warning systems and disaster preparedness; social protection and index-based weather insurance; technological approaches and climate-resilient infrastructure; sustainable land management and ecosystem restoration; livelihood diversification and other social processes and socio-economic mechanisms. Most adaptation is still happening autonomously at the household level, with little or no institutional support. Reflecting the multiple socio-economic dimensions of vulnerability, the previous focus on technological adaptation solutions to directly address specific impacts is now evolving towards a broader view that highlights the importance of social, institutional, policy, knowledge and informational approaches. An evolving focus is on flexible, innovative and gender-sensitive approaches to planning and implementing adaptation, with value placed on learning-by-doing in order to deal with the uncertainty inherent in climate projections, compounded by other sources of flux that impact on people in Africa. Key gaps and barriers relate to structural poverty, information deficits and broader governance constraints.

Additional questions being considered

- How has the understanding of vulnerability in Africa changed since the AR4?
- How has the scientific evidence about climate trends and projections in Africa changed since AR4?
- How the experience with multi sector water management strategies has been in Africa?

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Table 22-1: State members of RECs officially recognized by the African Union. Source: Ruppel, 2009.

AMU	Algeria, Libya, Mauritania, Morocco, Tunisia
CEN-SAD	Benin, Burkina Faso, Central African Republic, Chad, Comoros, Cote d'Ivoire, Djibouti, Egypt, Eritrea, Gambia, Ghana, Guinea-Bissau, Kenya, Liberia, Libya, Mali, Mauritania, Morocco, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, Somalia, Sudan, Togo, Tunisia
COMESA	Burundi, Comoros, DRC, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Seychelles, Sudan, Swaziland, Uganda, Zambia, Zimbabwe
EAC	Burundi, Kenya, Rwanda, Tanzania, Uganda
ECCAS	Angola, Burundi, Cameroon, Central African Republic, Chad, Congo, DRC, Gabon, Guinea, São Tomé and Príncipe
ECOWAS	Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo
IGAD	Djibouti, Ethiopia, Kenya, Somalia, Sudan, Uganda
SADC	Angola, Botswana, DRC, Lesotho, Madagascar, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe

Table 22-2: Land inundated and economic impacts in Cape Town based on a risk assessment (Cartwrigth, 2008a).

Sea level rise scenarios	Land inundated	Economic impacts (for 25 years)
Scenario 1 (+ 2.5 to 6.5 m depending on the exposure) 95%	25.1 km^2 (1% of the total CT area)	5.2 billion R (794 million US$)
Scenario 2 (+ 4.5 m) 85%	60.9 km^2 (2% of the total CT area)	23.7 billion R (30.3 billion US$)
Scenario 3 (+6.5 m) 20%	95 km^2 (4% of the total CT area)	54.8 billion R

Note: The economic impacts are determined based on the value of properties, losses of touristic revenues and the cost of infrastructure replacement. The total geographical gross product for Cape Town in 2008 was 165 billion of Rands.

Table 22-3: Mainstreaming gender into climate change adaptation in the AAP.

Category	**Activities under implementation**	**Examples**
Decision-making power	Developing women's leadership for analysis of climate impacts and policy, regulatory and financing issues for adaptation, including gendered analysis, focusing on key institutions, including Ministries, parliamentarians, state and local governments and civil society	Nigeria Malawi Ethiopia
Information & education	Climate change adaptation training programme for vulnerable groups, for women at the community level, and/or for professionals from sectoral ministries	Burkina Faso Gabon
	Conferences, activities and/or policy mainstreaming on climate change and gender	Lesotho Kenya
	Local-level awareness campaigns and workshops are being conducted to promote gender-sensitive adaptation approaches	Malawi Cameroon
	Gender vulnerability assessments, and/or assessing gender-related opportunities associated with adaptation to climate change	Mozambique Namibia Tanzania Ethiopia
Financial & economic opportunities	Re-aligning budgeting processes so that they incorporate funding for climate change adaptation, including the special needs of women, as well as funding specific programs with a focus on reducing the gender sensitivity of climate change Innovative financial measures that take into account gender issues	Ghana Lesotho Nigeria Rwanda

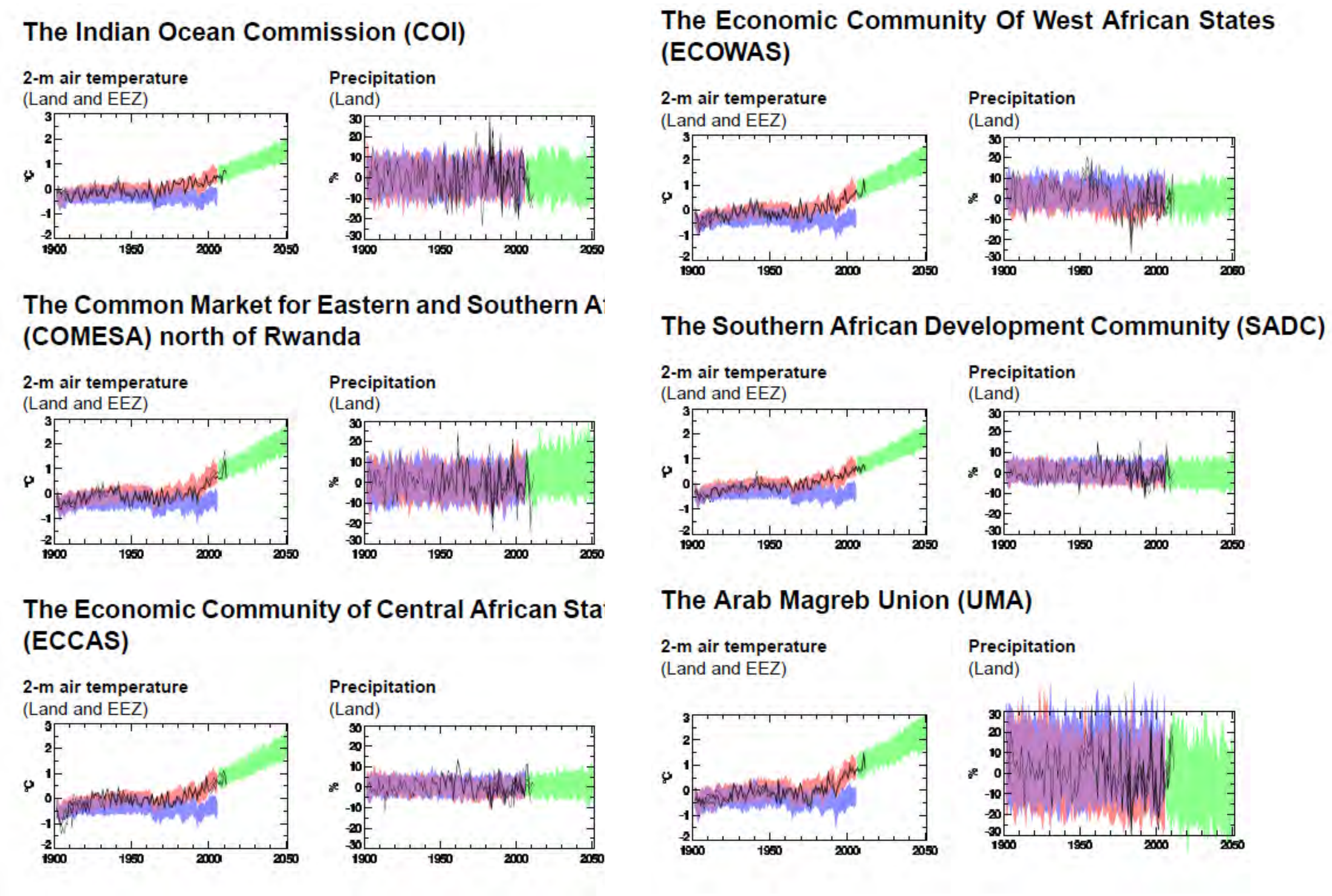
Adapted from UNDP (2011)

Table 22-4: Summary of recorded barriers and limits to climate change adaptation in Africa. [STILL COLLECTING LITERATURE TO ADD TO THIS TABLE AND THINKING RE THE BEST WAY TO DO THIS]

Source	**Where**	**Barriers mentioned**
Bryan et al. 2011	Kenya	Financial (cash and credit), organisational, informational
Ludi et al. 2012	Ethiopia, Mozambique and Uganda	Institutional, cultural, informational, cognitive
Mandeleni and Anim 2011	South Africa	Financial, assets

Table 22-5: Percentage of people displaced; global summary 2008–2010. Source: IDMC, 2011.

Number of people displaced (millions)			
Cause of displacement	**2008**	**2009**	**2010**
Climate-related disasters	20.3	15.2	38.3
Geophysical disasters	15.8	1.5	4.0
Total	**36.1**	**16.7**	**42.3**



The Indian Ocean Commission (COI)

The Economic Community Of West African States (ECOWAS)

The Common Market for Eastern and Southern A (COMESA) north of Rwanda

The Southern African Development Community (SADC)

The Economic Community of Central African Sta (ECCAS)

The Arab Magreb Union (UMA)

Figure 22-1: Observed and simulated variations in past and projected precipitation and temperature.

Precipitation over COI, land only: pr_COI_20120420.eps
Temperature over COI, both land and EEZ: tas_COI-eez_20120420.eps
Precipitation over the northern half of COMESA, land only: pr_COMESA-north_20120420.eps
Temperature over the northern half of COMESA, both land and EEZ: tas_COMESA-north-eez_20120420.eps
Precipitation over ECCAS, land only: pr_ECCAS_20120420.eps
Temperature over ECCAS, both land and EEZ: tas_ECCAS-eez_20120420.eps
Precipitation over ECOWAS, land only: pr_ECOWAS_20120420.eps
Temperature over ECOWAS, both land and EEZ: tas_ECOWAS-eez_20120420.eps
Precipitation over SADC, land only: pr_SADC_20120420.eps
Temperature over SADC, both land and EEZ: tas_SADC-eez_20120420.eps
Precipitation over UMA, land only: pr_UMA_20120420.eps
Temperature over UMA, both land and EEZ: tas_UMA-eez_20120420.eps

Note: Variations in past and future regional climate over Africa. Precipitation plots cover land territory only, while temperature plots cover both land and exclusive economic zone territory. Black lines show annual average values from observational datasets, namely GISTEMP (Hansen et al. 2010), HadCRUT3 (Brohan et al. 2006), and MLOST (Smith et al. 2008) for temperature, and CMAP (Xie and Arkin 1997), CRU TS 3.10 (Mitchell and Jones 2005), GPCP v2.2 (Adler et al. 2003), and PRECL (Chen et al. 2002) for precipitation. The colored bands show the 10-90th percentile range of annual average values from 32 simulations from 12 climate models from the WCRP CMIP3 and CMIP5 projects (Meehl et al. 2007, Taylor et al. 2012) run under different scenarios of changes in external drivers. The pink band is from simulations driven with observed changes in all known external drivers over the 1901-2005 period; while the blue band is from simulations driven with observed changes in natural external drivers only. The green band is from simulations running over 2006-2050 driven under either the SRES A1B or the RCP4.5 emissions scenario. All regional values are plotted as anomalies from their 1901-2005 average in the case of observed data, or from the average of the respective simulations driven with past changes in all known observed external drivers; precipitation is plotted as the percentage anomaly from the annual regional average. Observed estimates suffer in some areas from sparse monitoring coverage.

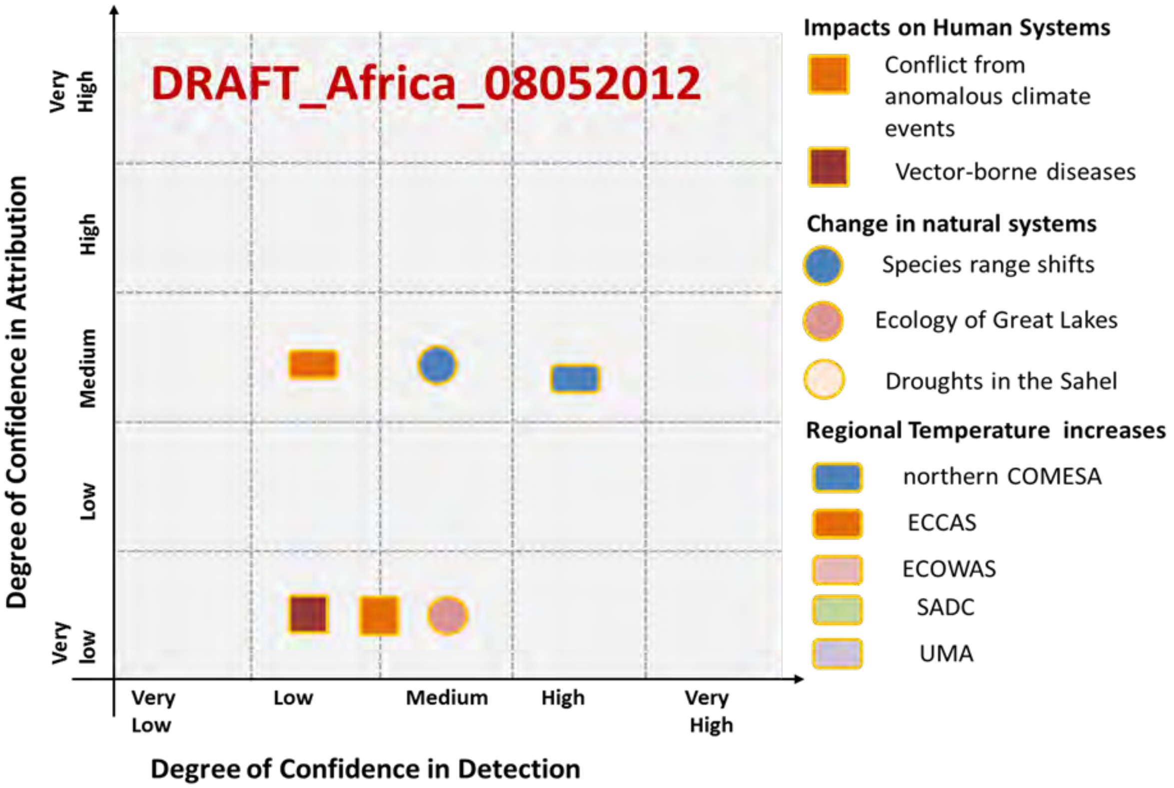


Figure 22-2: Detection and attribution of changes in different regions of Africa (from Chapter 18).

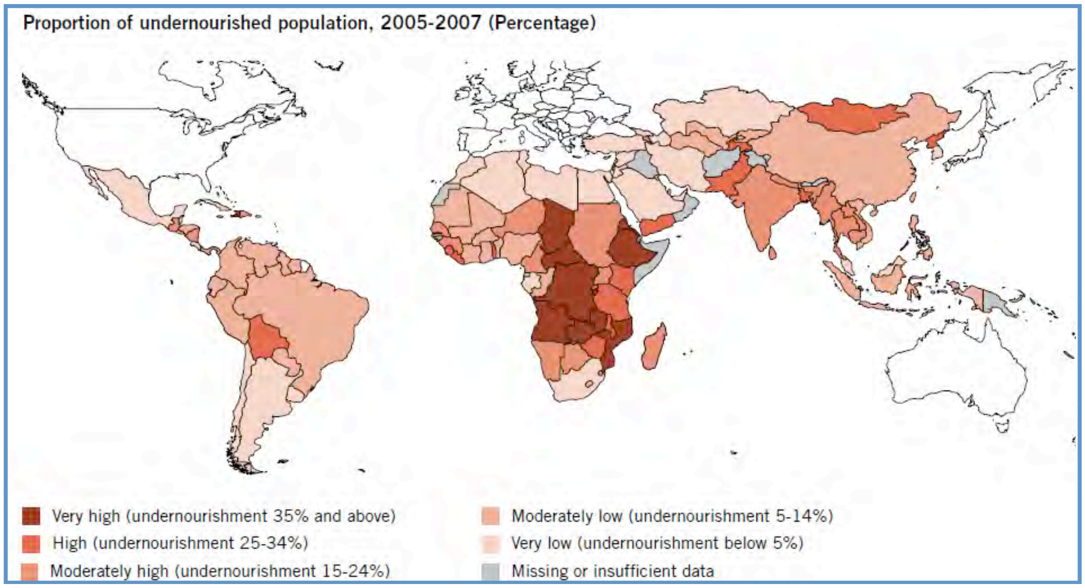


Figure 22-3: Proportion of undernourished population, 2005-2007 (%). Source: UN, 2011.

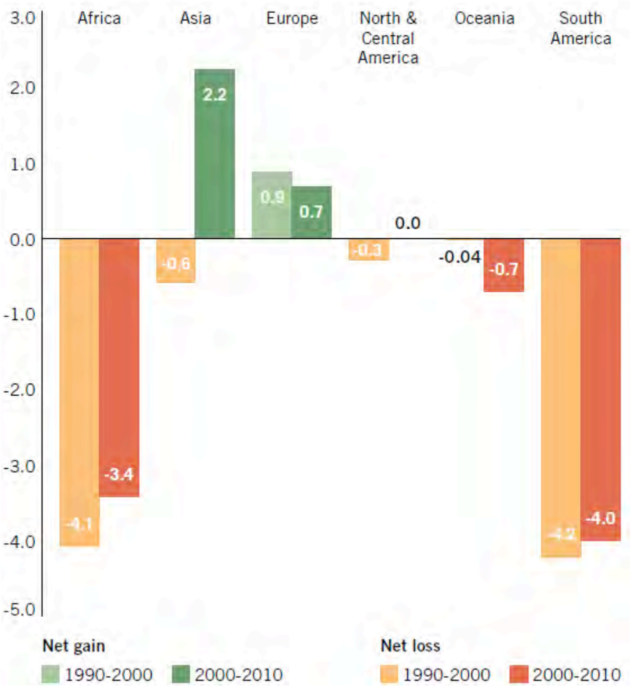


Figure 22-4: Net change in forested area between 1990 and 2000 and between 2000 and 2010 (Mha yr^{-1}). Source: UN, 2011.

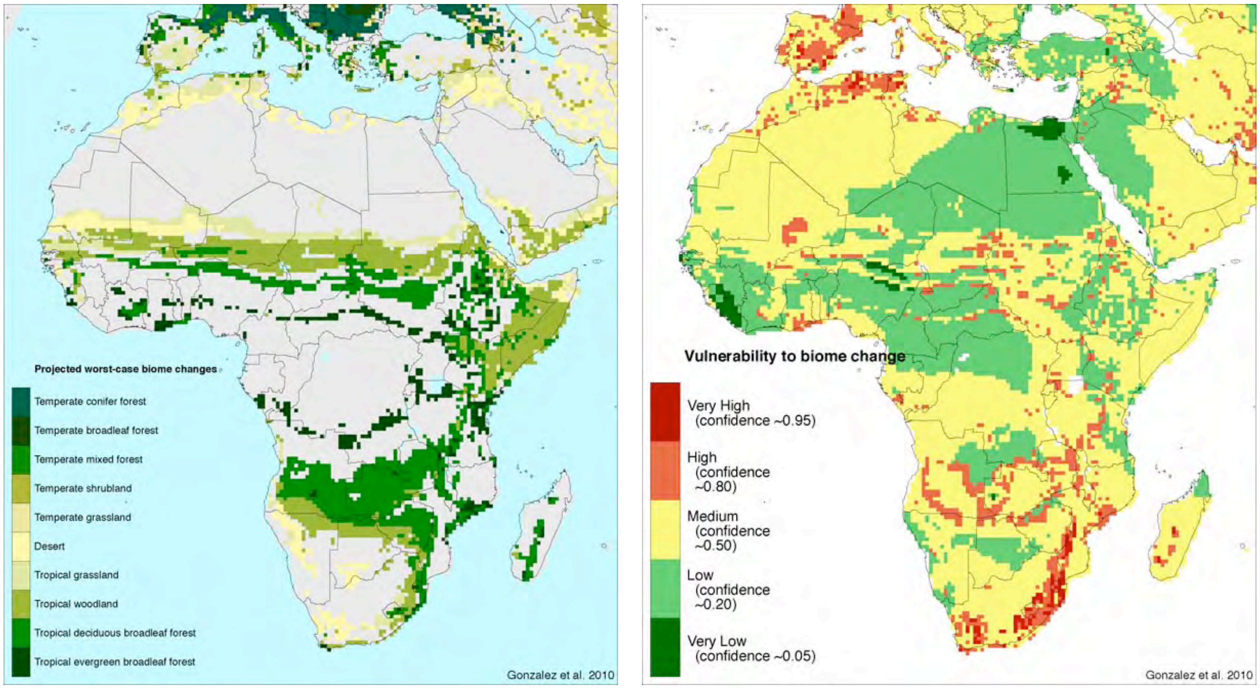


Figure 22-5: (a) Potential changes in vegetation under projected 2071–2100 climates where any of nine GCM–emissions scenario combinations project change. (b)Vulnerability of ecosystems to biome shifts based on historical climate and projected vegetation. Source: Gonzalez et al., 2010.

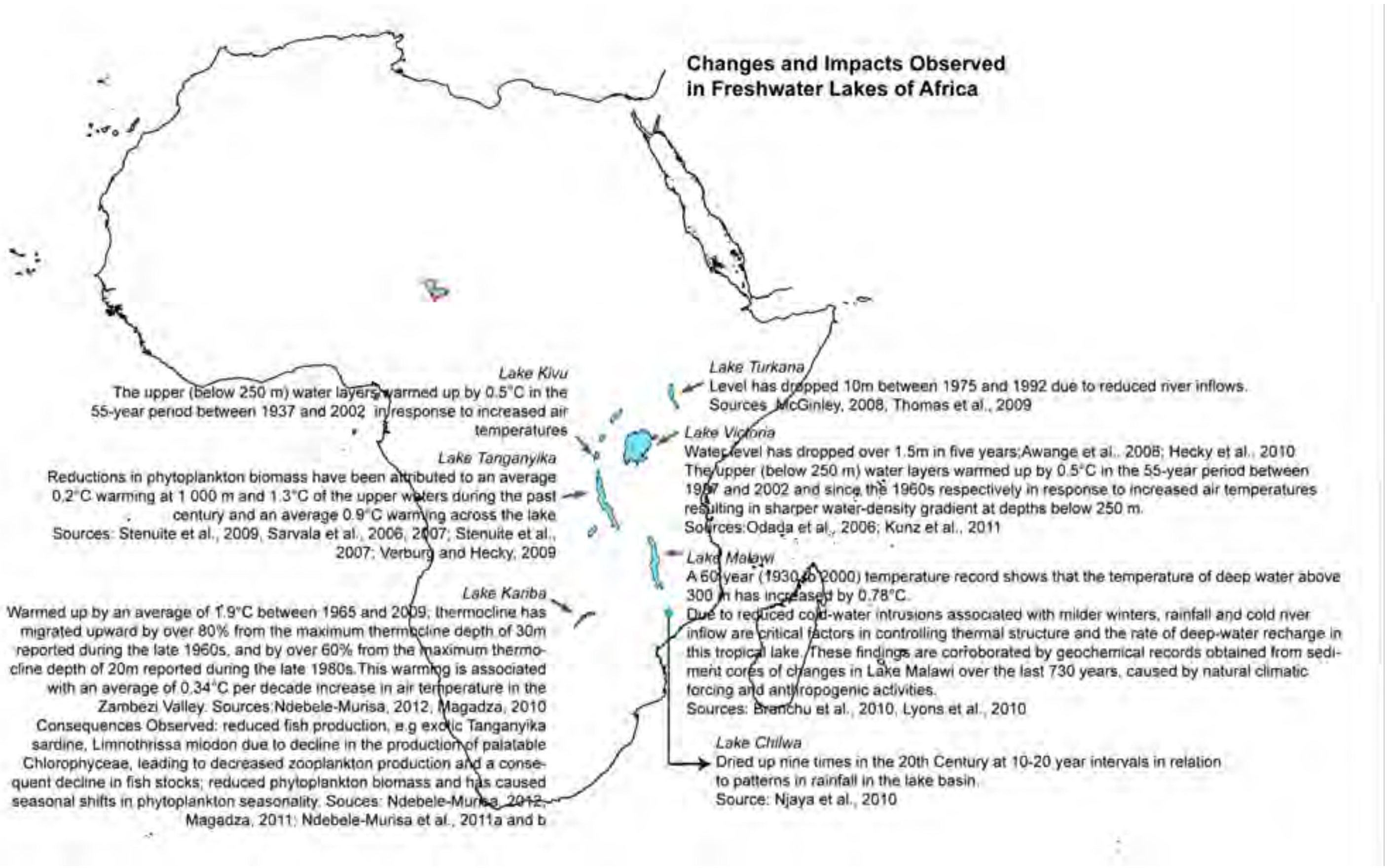
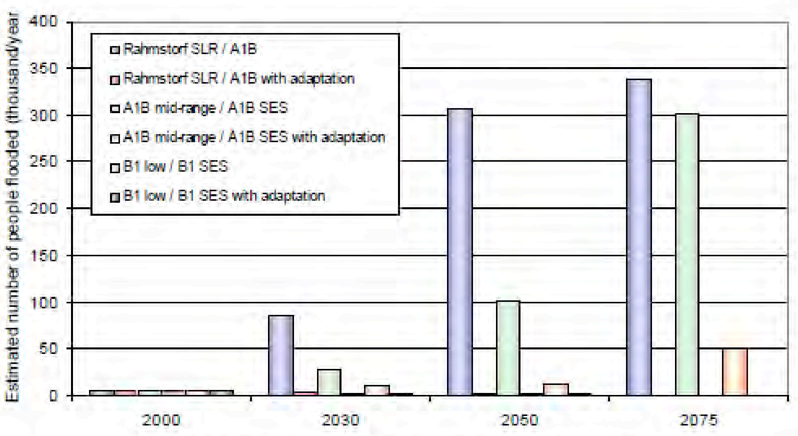
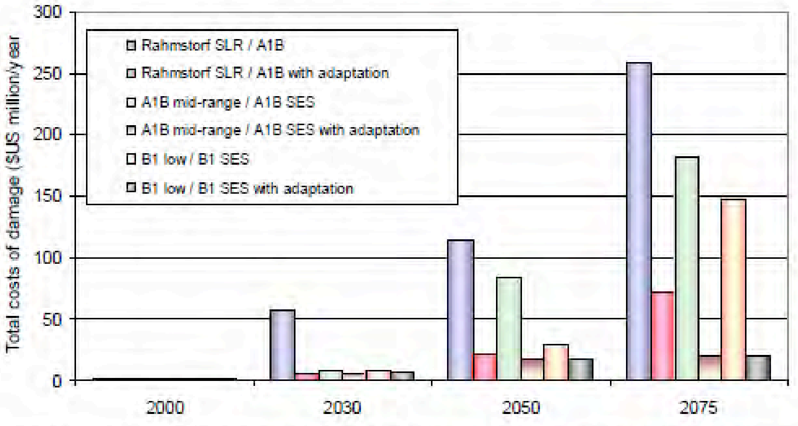


Figure 22-6: Changes and impacts observed in freshwater lakes of Africa.



Estimated number of people flooded, with and without adaptation



Total economic costs ($US million/year) from all categories (flooding, erosion, ecosystem loss)
With and without adaptation

Figure 22-7: Population and economic losses in case of climate change for the whole Kenya coastal zone. Source: SEI, 2009.

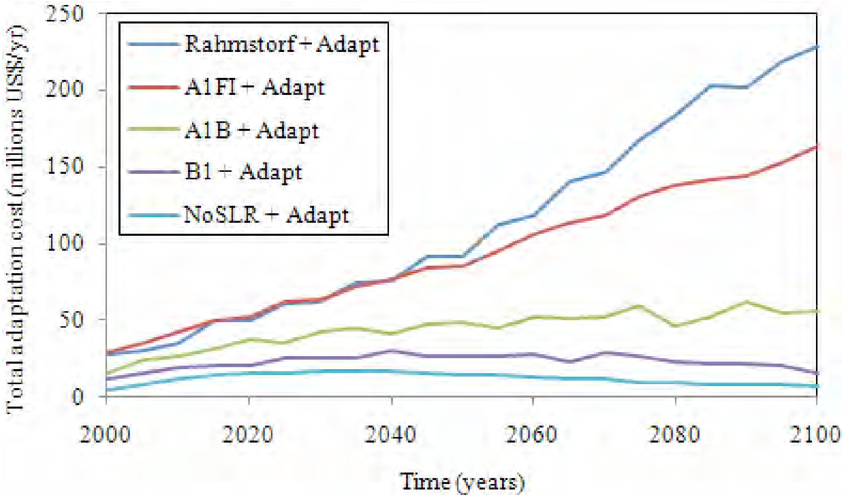


Figure 22-8: Total costs of adaptation per year from 2000 to 2100 for Tanzania (including beach nourishment, sea and river dykes) Source: Kebede *et al.*, 2010.

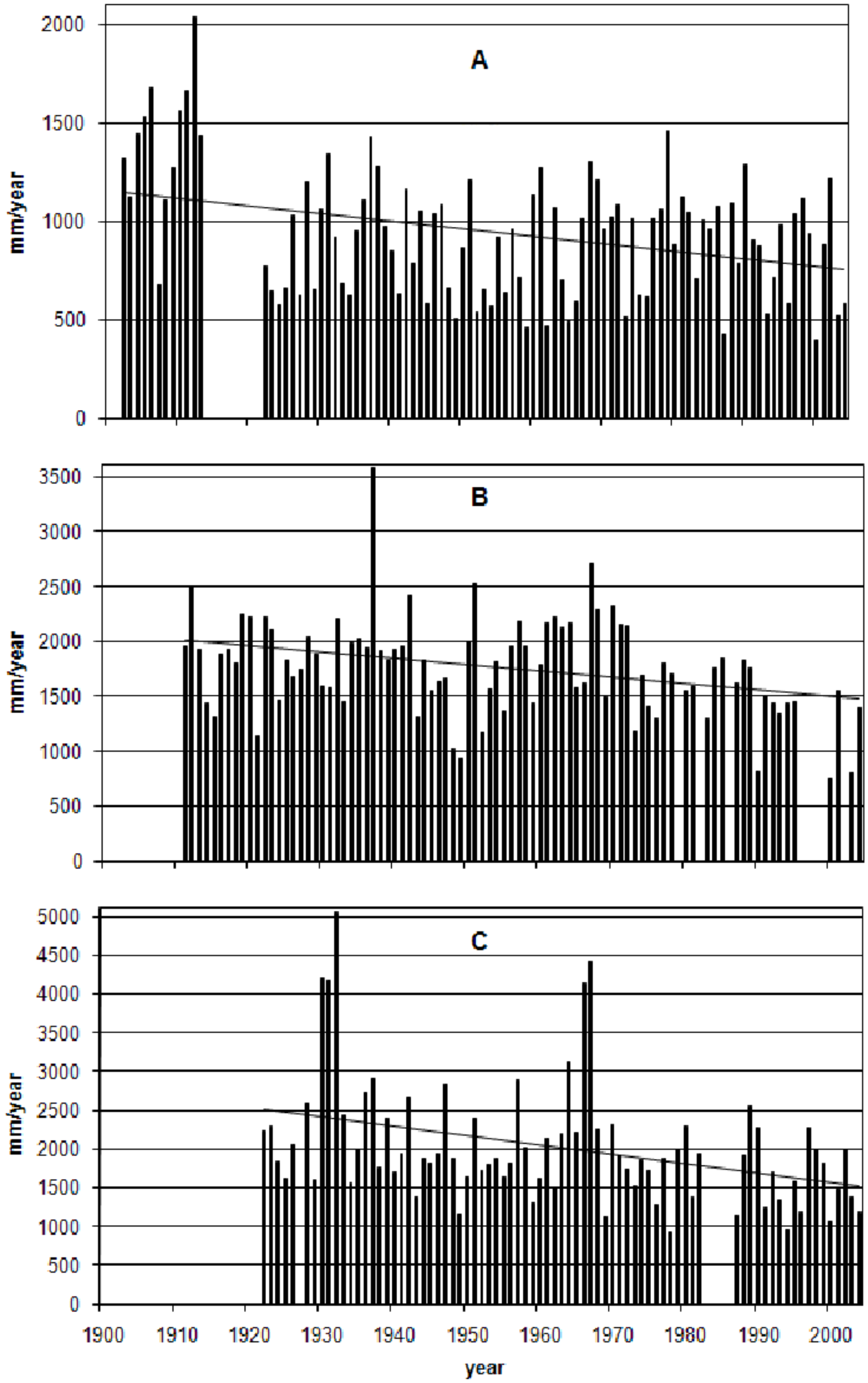


Figure 22-9: Annual precipitation in Kilimanjaro (1900-2005). Source: Hemp, 2005a.

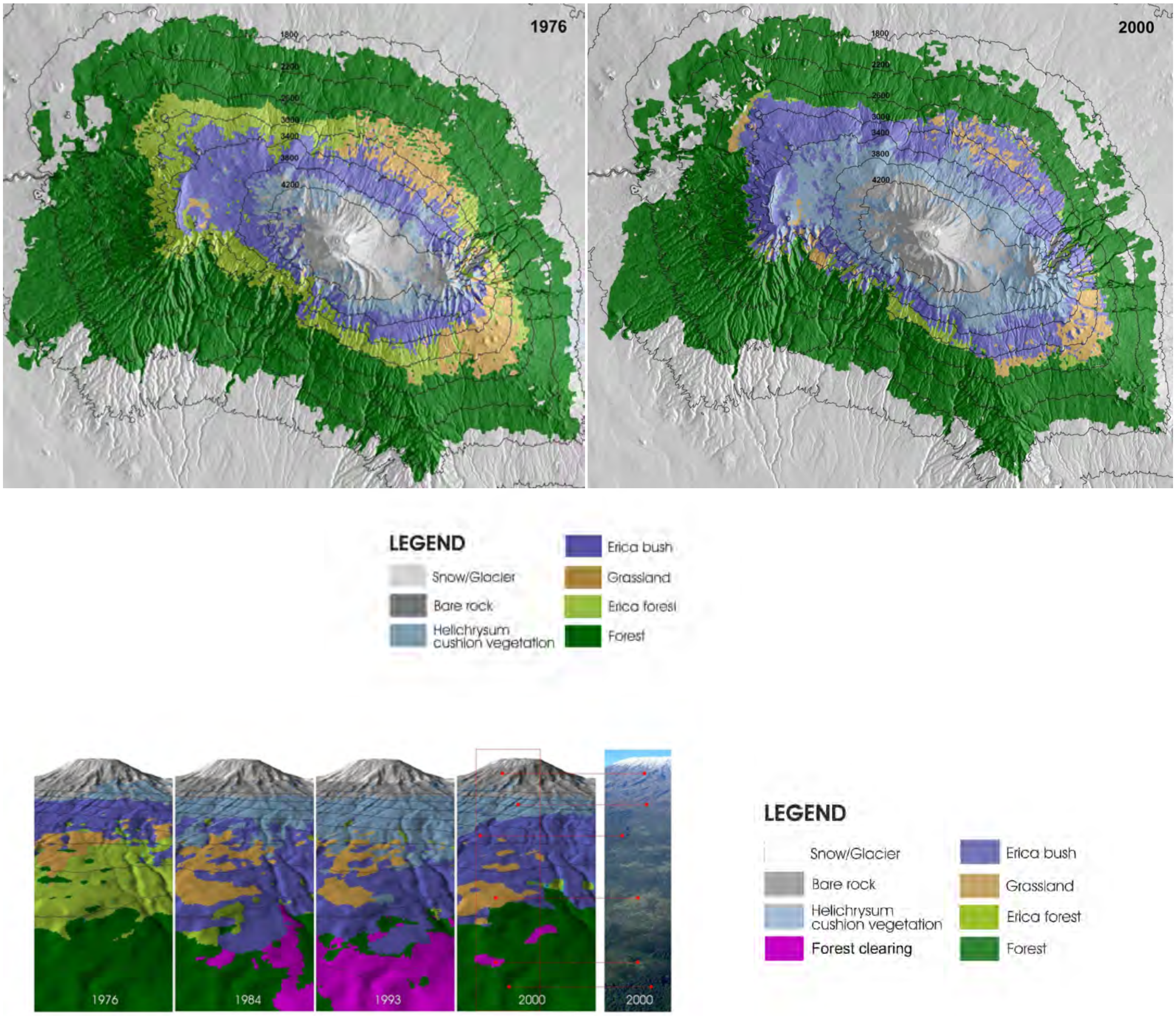


Figure 22-10: Changing land cover in Kilimanjaro. Source: Hemp, 2005a,b, 2009.

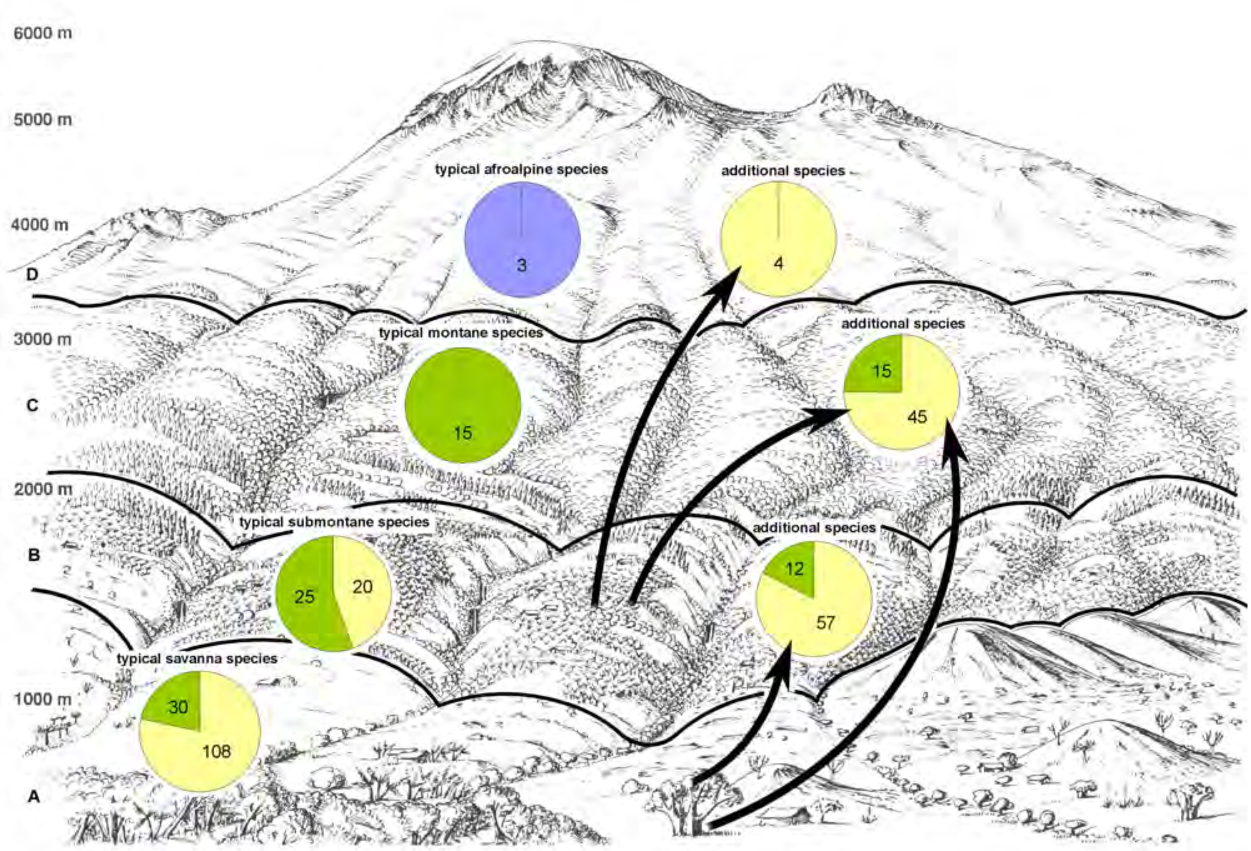
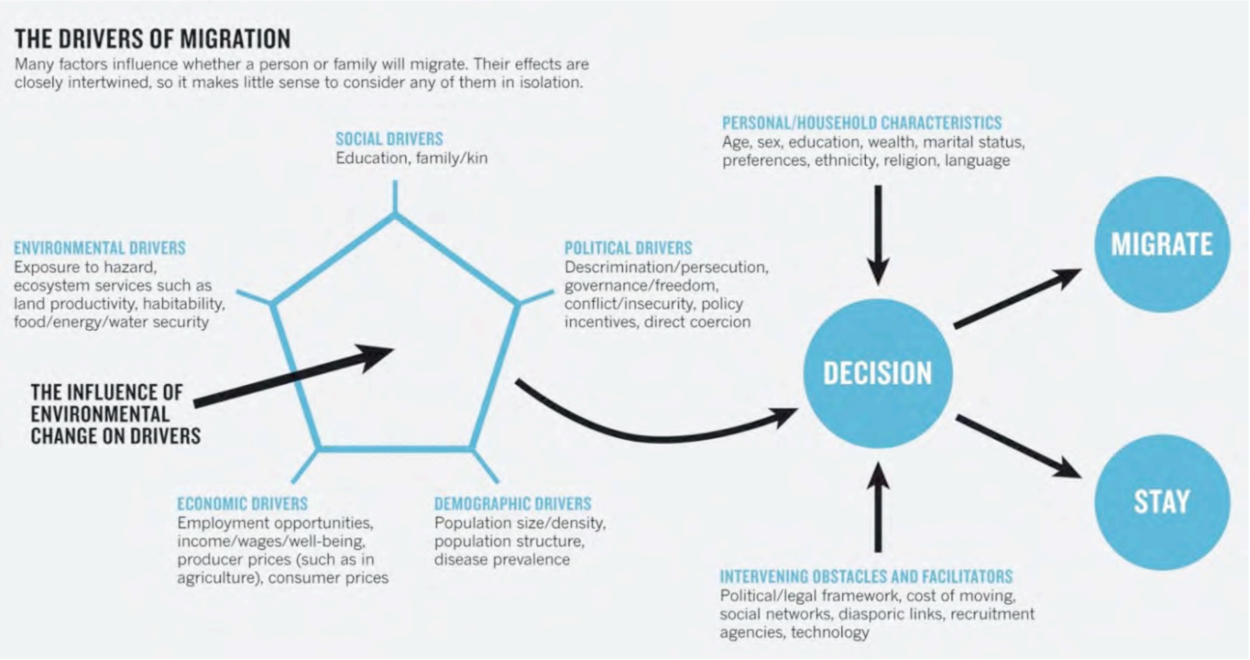


Figure 22-11: Upward movement of organisms in Kilimanjaro. Source: Hemp and Hemp, 2008.



THE DRIVERS OF MIGRATION

Many factors influence whether a person or family will migrate. Their effects are closely intertwined, so it makes little sense to consider any of them in isolation.

Figure 22-12: Drivers of migration, which can all be influenced by future environmental change, and the link to the decision to migrate or not. Source: Black *et al*., 2011b.

Figure 22-13: Some examples of ecosystem-based adaptation. Source: Pramova *et al*., forthcoming.