Chapter 22. Africa

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Executive Summary

Evidence of warming over land areas, consistent with anthropogenic climate change, has increased (*high confidence*). Decadal analyses of temperatures strongly point to an increased warming trend across the continent. In addition, changes in the seasonality and amount of precipitation have also been observed in sub-regions of Africa that include reduced long rains over parts of Eastern Africa and reduced summer precipitation over parts of Southern Africa. [22.2.1.1, 22.2.2.1]

Temperature rise by the end of this century are likely to exceed a 2° C threshold (*medium confidence*). Warming projections under medium and high Representative Concentrations Pathways (RCP) for GHG emissions indicate that extensive areas of Africa (medium RCP) and all of Africa (high RCP) will exceed 2° C by the last two decades of this century. Under a high RCP, that exceedence could occur by mid-century across much of Africa. [22.2.1.2, 22.2.2.2]

Attainment of the Millennium Development Goals (MDGs) in Africa would strengthen the region's resilience to various external shocks, including climate change. Vital links exist between climate change and the MDGs in Africa. On one hand climate change may adversely affect progress toward reaching the MDGs, while slow development can exacerbate the effects of climate change in the region (*confidence level to be added*). [22.3.1]

Africa as a whole has made significant progress on a number of MDGs, including education and gender equality and empowerment of women. However, slower progress has been made on MDGs such as the eradication of extreme poverty and hunger, and improvements in health and environment such as an increase in sanitation and basic housing facilities for poor populations including people living in slums. Moreover, progress toward the MDGs conceals high levels of spatial and group disparities, as improvement in development indicators is skewed in favor of higher-income groups and urban populations (*high confidence*). [22.3.1]

The impacts of climate change, mainly through sea level rise, combined with other extreme events (such as high tide levels and high storm swells) have the potential to threaten coastal zones, particularly coastal towns (*high confidence*). The example of the Kwa Zulu Natal coast (South Africa), where Durban is located, which was damaged by a combination of high water level and high storm swell in March 2007, is indicative of what could happen. **Evidence is growing that the costs of these impacts will increase for economic sectors and people living in these zones (medium confidence). [22.3.2.3.1, 22.3.7]**

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*). [22.3.2.3.2, 22.3.4.4]

The impact of climate change on water availability in Africa is uncertain (*high confidence*). Water resources are subjected to high hydro-climatic variability over space and time, and are a key constraint on the continent's continued economic development. Water is the primary medium through which early and subsequent climate change impacts will be felt by people, ecosystems, and economies. Many of the fragile terrestrial and aquatic ecosystems in Africa are implicitly or explicitly water-dependent. The impacts of climate change will be superimposed onto already water-stressed catchments with complex land uses, engineered water systems, and a strong historical socio-political and economic footprint. 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. [22.3.2.2, 22.3.3]

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*). Livelihood-based approaches for managing risks to food production from multiple stressors, including rainfall variability, have increased substantially in Africa since the IPCC's Fourth Assessment Report (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 that includes 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 adaptive capacities for climate change. [22.4.5.4, 22.4.5.7, 22.4.6, 22.6.1]

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 compromised by climate change and climate variability" (*high confidence*). Temperature rise and a reduction in growing season length by mid-century are very likely to significantly reduce crop productivity with strong adverse effects on food security. New evidence is also emerging that fisheries and high-value perennial crops could also be adversely affected by temperature rise, and that the pressure of pests and diseases on crops and livestock is expected to increase as a result of climate change and other factors. Moreover, 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 of food and livelihood security in Africa. [22.3.4]

Evidence is growing 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 the 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 the 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 confidence*) including inadequate water and sanitation coverage, food security, and access to health care and education.** Improvements in these existing vulnerabilities will decrease the impacts of climate change on health. [22.3.5]

In all regions of the continent, national governments are initiating governance systems for adaptation and responding to climate change (*medium evidence*, *high agreement*). Some progress has been made on national and sub-national policies and strategies beyond the initial National Adaptation Programmes of Action, and on mainstreaming adaptation into sectoral planning, for example in the health sector. **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 (*medium agreement, medium evidence*).** While institutions for collaborative governance are developing, a separation remains between policy formulation and vulnerable people adapting autonomously on the ground, exacerbated by low levels of capacity in local governments to deal with complex socio-ecological change. National policies are often at odds with autonomous local adaptation strategies, which can act as a barrier to adaptation, especially where cultural, traditional and context-specific factors are ignored (*high confidence*). [22.4.4]

While a wide range of adaptation options, approaches, and decision tools are being tested and implemented at different scales across Africa, these have not yet been taken to a scale that would address the complex vulnerabilities and needs identified (*medium evidence, high agreement*). Efforts such as disaster risk reduction, social protection, adaptation technologies, climate-resilient infrastructure, ecosystem restoration, and livelihood diversification are reducing vulnerability and enhancing resilience, but this is still largely confined to local scales and isolated initiatives. Ecosystem-based approaches and pro-poor integrated adaptation-mitigation initiatives hold promise for a more coherent approach to adaptation; and emphasis on highly vulnerable groups such as children and an enhanced policy environment for community-based adaptation can promote equity goals. **Coastal adaptation has the potential to considerably reduce projected impacts in the coastal zones (*high confidence*).** Adaptation in the health sector will build on existing public health interventions as well as specific adaptation measures such as early warning systems. [22.4.5]

In addition to technological and infrastructural approaches, evidence has increased of the importance of 'soft path' options and flexible and iterative learning approaches for effective adaptation (*medium evidence, medium agreement*). 'Soft' measures include harnessing ecosystem services for climate proofing, such as coastal afforestation and catchment restoration. Learning approaches being explored include action research, participatory adaptation planning, and adaptive management, and may involve co-production of knowledge – such as combining local and traditional knowledge with science, and conflict resolution. Attention to the cultural, ethical, and rights considerations of adaptation has also increased. [22.4.5]

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 (*high confidence*). [22.4.3]

Growing understanding of the multiple interlinked constraints on increasing adaptive capacity is beginning to indicate potential limits to adaptation in Africa (*limited evidence, high agreement*). Climate change combined with other external changes (environmental, social, political, technological) may overwhelm the ability of people to cope and adapt, especially if the root causes of poverty and vulnerability are not addressed. The risks of maladaptation are increased by development interventions that often fail to consider how different types of change interact and undermine the ability of people to cope with multiple stressors. Evidence is growing for the effectiveness of flexible and diverse development systems that are designed for reducing vulnerability, spreading risk, and building adaptive capacity. These points indicate the need for new development trajectories that place climate resilience, ecosystem stability, equity and justice at the centre of development efforts. [22.4.6]

Human security of people in Africa will increasingly be threatened by the impacts of climate variability (*high agreement*, *medium* to *robust evidence*). Food and health insecurity, migration and displacement, and violent conflict are particular areas of concern for the African continent. The impacts of climate change have the potential to increase food insecurity and distributional conflicts. Evidence is growing that displacement and migration patterns due to climate change-related drivers will be subject to substantial shifts. **The degree of adaptation will be decisive with regard to the risks related to human security in Africa**. Based on the multi-model CMIP5 analysis, which indicates that temperature rise will exceed a 2ºC threshold across Africa by the middle to end of this century, the risks for human security will be high to very high by 2080-2100 and medium to high by 2030-2040. [22.3.6]

Institutional capacities and governance mechanisms need to be strengthened with respect to the ability of national governments and scientific institutions in Africa to absorb and effectively manage large amounts of funds allocated for adaptation, in order that the effectiveness of adaptation initiatives is assured (*medium confidence*). 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 while they are actually meant to be the main beneficiaries of adaptive action. It is therefore imperative that strong institutional capacity to manage climate finance funds be made a priority. The potential for ineffective and mismanaged climate finance funds are – among other reasons – rooted in the level of complexity, uncertainty, and novelty that surrounds many climate issues. [22.4.4.3, 22.6.2]

22.1. Introduction

22.1.1. Structure of the Regions

The African continent (including Madagascar) is the world's second largest and most populous continent (1 billion in 2009, representing 14.7% of the world's population) behind Asia. It is composed of 55 countries (of which 5 are small island states) of which 33 belong 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 recognized eight Regional Economic Communities (RECs) (Ruppel, 2009; Nwauche, 2009). Except for the Sahrawi

Arab Democratic Republic,[2] all AU member states are affiliated with one or more of these RECs. These RECs include the Arab Maghreb Union (AMU), with 5 countries in 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 in 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. The regional subdivision of African countries into REC's is a structure used by the AU and the NEPAD (New Partnership for Africa).

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

[FOOTNOTE 2: Although the Sahrawi Arab Democratic Republic has been a full member of the OAU since 1984 and remains a member of the AU, the republic is not generally recognized as a sovereign state. While most African states have recognized 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 United Nations (UN) referendum that would allow the people of Western Sahara to decide the territory's future status. The republic has no representation in the UN.]

22.1.2. Major Conclusions from Previous Assessments

22.1.2.1. Regional Special Report and Assessment Reports 1 – 4 / Chapter 9

The first evaluation of the potential impacts of climate change in Africa was done for the IPCC special report on regional climate change (Zinyowera *et al.*, 1997). This report presented mainly the sensitivity of water resources and coastal zones to some climatic parameters. Since the report was published, climate change was considered as an additional burden on an already stressful situation. 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, and the necessary links between science and decisionmakers were underlined as major challenges for Africa. In the Third Assessment Report, specific chapters were dedicated to regions, Africa being one (Desanker *et al.*, 2001). In the third report, the main focus is on the potential impacts of climate change and vulnerability for the six sectors considered (water resources, food security, natural resources and biodiversity management, health, human settlements and infrastructure, and desertification). Literature on adaptation strategies was included in the assessment for each of these sectors. That desertification was considered as a sector expressed the threats of desertification and droughts to the economy of the continent. Globally, most of the adaptation options suggested were linked with better management of the different resources. The main gaps and needs, such as capacity building, data needs, and the development of integrated analysis, as well as the consideration of other languages, were identified. The Fourth Assessment Report (AR4) confirmed that the vulnerability of the continent was mainly due to its low adaptive capacity (Boko *et al.*, 2007). It considered the different sources of vulnerability, encompassing socioeconomic causes (demographic growth, governance, conflicts, etc.) and examined the impacts of climate change on various sectors (energy, tourism and coastal zones are considered separately). The potential impacts of extreme weather events (droughts and floods) were also considered in AR4. The question of adaptation costs was raised, as well as the need for mainstreaming climate change adaptation into national development policies. Two case studies were analyzed, on food security and traditional knowledge. The first emphasized that climate change could affect the three main components of food security while the second case study illustrated that African communities have prior experience with climate variability, although this knowledge will be sufficient to face climate change impacts. A list of needs was also identified regarding future studies: better knowledge of climate variability; more studies on the impacts of climate change on water resources, energy, biodiversity, tourism, and health; the links between different sectors (e.g., between agriculture, land availability, and biofuels); developing links with the disaster reduction community; increasing interdisciplinary analysis of climate change; and strengthening institutional capacities.

22.1.2.2. Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)

Due to the high vulnerability of the African continent to the negative effects of climate change, the Special Report of the IPCC on managing the risks of extreme events and disasters to advance climate change adaptation (IPCC, 2012) is of particular relevance. According to the report, confidence in observed trends in daily temperature extremes in Africa generally varies from *low* to *medium* depending on the region (Seneviratne *et al*., 2012). In southern Africa, there is *medium confidence* that droughts will intensify in the 21st century in some seasons, due to reduced precipitation and/or increased evapotranspiration (Seneviratne *et al*., 2012).

22.2. Observed Climate Trends and Future Projections

22.2.1. Temperature

22.2.1.1. Observed Trends

Over the last 100 years Africa's temperature has increased by 0.5°C (Desanker *et al*., 2001; Clark, 2006; Kniveton *et al*., 2009; Mohamed, 2011; Grab and Craparo, 2011; Hoffman *et al*., 2011). Near-surface air temperature anomalies in Africa were significantly higher for the period 1995–2010 compared to the period 1979–1994 (Collins, 2011). Over West Africa, warming is likely due to natural variability or human activity, rather than a result of variations in the El Niño-Southern Oscillation. Min and Hense (2007) found strong evidence of an anthropogenic signal in continent-wide temperature increases in the 20th century. Over most regions of Africa, such a signal appears in the frequency of unusually hot seasons (Stott *et al*., 2011) and the increase in the number of droughts occurring in the Sahel since 1970 is well documented (Greene *et al*., 2009).

Anyah and Qiu (2012) indicate that both equatorial and southern parts of the eastern Africa region have been experiencing a significant increase in temperature since the beginning of the early 1980s. Similarly, recent reports from the Famine Early Warning Systems Network (FEWS NET) indicate that there has been an increase in seasonal mean temperature over time in many areas of Ethiopia, Kenya, South Sudan, and Uganda (Funk *et al*., 2011; Funk *et al*., 2012). In addition, warming of the surface temperature and an increase in the frequency of extreme warm events has been observed for countries bordering the western Indian Ocean between 1961 and 2008 (Vincent *et al*., 2011).

In recent decades, most of southern Africa has also experienced upward trends in annual mean, maximum, and minimum temperature over large extents of the subregion during the last half of the 20th century, with the most significant warming occurring during the last two decades (Zhou *et al*., 2010; Collins, 2011; Kruger and Sekele, 2012). Minimum temperatures have increased more rapidly relative to maximum temperatures, which has decreased the diurnal temperature range over inland southern Africa (New *et al*., 2006) is influenced by decreases in surface solar heating (Zhou *et al*., 2010). A reduction in cold night occurrences is consistent with an increase in minimum temperatures (Kruger and Sekele, 2012).

22.2.1.2. Projected Trends

James and Washington (2012) find that in the context of a 1°C to 4°C global temperature increase by the end of the century, temperatures in Africa are projected to rise more than the global average, particularly in the more arid regions. Coupled Model Intercomparison Project phase 3 (CMIP 3) models, in the A1B middle-of-the-road scenario indicate that by the end of the 21st century, summer temperatures in the Sahel will be higher than any in recorded history (Battisti and Naylor, 2009; Biasutti and Sobel, 2009). Oguntunde and Abiodun (2013) project a drier climate during the rainy season and a wetter climate during the dry season between 2030 and 2050, and a warmer climate over the Niger River basin (NRB) in all months.

Climate model projections from the IPCC Special Report: Emissions Scenarios (SRES) A2 and B1 emissions scenarios over Ethiopia show warming in all four seasons across the country, which may cause a higher frequency of heat waves as well as higher rates of evaporation (Conway and Schipper, 2011). Projected minimum temperatures over equatorial eastern Africa are more than 2°C higher than the 1981–2000 average by the middle and end of the 21st century (Anyah and Qiu, 2012). Elshamy et al. (2009) projected a temperature increase over the upper Blue Nile of between 2°C and 5°C at the end of the century.

Mean warming in Southern Africa is projected to exceed global warming in all seasons (Sillmann and Roeckner, 2008; Watterson, 2009; Mariotti *et al*., 2011; James and Washington, 2012; Orlowsky and Seneviratne, 2012). Furthermore, towards the end of the 21st century, the projected warming, which is greater than 4ºC under the highest radiative forcing, far exceeds natural climate variability (Moise and Hudson, 2008). Higher warming rates are evident over the semi-arid southwestern parts of the subregion covering northwestern South Africa, Botswana, and Namibia. These areas are thus projected to become even drier in the future climate (Moise and Hudson, 2008; Engelbrecht *et al*., 2009; Watterson, 2009; Shongwe *et al*., 2009). Accelerated warming is consistent with reduced surface evaporative cooling. Observed and simulated variations in past and projected future annual average temperature over five African regions (UMA, SADC, ECCAS, ECOWAS, SADC and COMESA) are captured in Figure 22-2. Multi-model CMIP5 analysis indicates that temperature rise will exceed a 2°C threshold across Africa by the middle to end of this century (Figure 22-1).

[INSERT FIGURE 22-1 HERE
Figure 22-1: Observed and simulated variations in past and projected future annual average precipitation and temperature. For the CRU observations, differences are shown between the 1986-2005 and 1906-1925 periods, with white indicating areas where the difference between the 1986-2005 and 1906-1925 periods is less than twice the standard deviation of the 20 20-year periods beginning in the years 1906 through 1925. For CMIP5, white indicates areas where <66% of models exhibit a change greater than twice the baseline standard deviation of the respective model's 20 20-year periods ending in years 1986 through 2005. Gray indicates areas where >66% of models exhibit a change greater than twice the respective model baseline standard deviation, but <66% of models agree on the sign of change. Colors with circles indicate the ensemble-mean change in areas where >66% of models exhibit a change greater than twice the respective model baseline standard deviation and >66% of models agree on the sign of change. Colors without circles indicate areas where >90% of models exhibit a change greater than twice the respective model baseline standard deviation and >90% of models agree on the sign of change. The realizations from each model are first averaged to create baseline-period and future-period mean and standard deviation for each model, from which the multi-model mean and the individual model signal-to-noise ratios are calculated. The baseline period is 1986-2005. The late-21st century period is 2081-2100. The mid-21st century period is 2046-2065.]

[INSERT FIGURE 22-2 HERE
Figure 22-2: Observed and simulated variations in past and projected future annual average precipitation and temperature over five African regions (Arab Maghreb Union- AMU, Common Market for Eastern and Southern Africa – COMSEA, Southern African Development Community – SADC, Economic Community of West African States – ECOWAS, Economic Community of Central African States – ECCAS). Black lines show several estimates from observational measurements. Shading denotes the 5-95 percentile range of climate model simulations driven with "historical" changes in anthropogenic and natural drivers (68 simulations), historical changes in "natural" drivers only (30), the "RCP4.5" emissions scenario (68), and the "RCP8.5" (68). Data are anomalies from the 1986-2006 average of the individual observational data (for the observational time series) or of the corresponding historical all-forcing simulations. Further details are given in Box 21-3. The regions are described in 22.1.2, but COMESA-north covers COMESA north and inclusive of Rwanda, Uganda, and Kenya. Precipitation is included for land territories only, while temperature is included for both land and exclusive economic zone territories.]

22.2.2. Precipitation

22.2.2.1. Observed Changes

At the beginning of the 21st century, Sahel rainfall was recorded as being moderately stable around the 1961–1990 average of 371 mm, although this period was about 25% drier than earlier decades of the 20th century. Recent studies of rainfall trends across the Sahel confirm a decrease in rainfall associated with a decrease in the number of rainy days (Mohamed, 2011). Observations of the Guinea coast reveal a clear depreciation of the length of the rainfall break in August that defines the bimodal nature of the wet season in the southern part of Nigeria. The two- to three-week period of temporary rainfall cessation is gradually declining into a relatively insignificant two- to three-day break (Chineke *et al.*, 2010).

Precipitation in eastern Africa shows a high degree of spatial variability dominated by a variety of physical processes (Hession and Moore, 2011). Williams and Funk (2010) and Funk et al. (2008) indicate that over the last three decades rainfall has decreased over eastern Africa during the 'long-rains' season, which usually lasts from March to May/June. The suggested physical link to the decrease in rainfall is the rapid warming of Indian Ocean sea surface temperature (SST), which causes an increase in convection and precipitation over the tropical Indian Ocean and thus contributes to increased subsidence over eastern Africa and a decrease in rainfall during March to May/June (Funk *et al.*, 2008; Williams and Funk, 2010). Similarly, Lyon and DeWitt (2012) show a decline in the March–May seasonal rainfall over eastern Africa, with particular attention to the abrupt decline of precipitation during the long-rains of 2011. Summer (June–September) monsoonal precipitation has declined substantially throughout much of the Great Horn of Africa over the last 60 years (during the 1948–2009 period; Williams *et al.*, (2012)) as a result of the changing sea level pressure (SLP) gradient between Sudan and the southern coast of the Mediterranean Sea and the southern tropical Indian Ocean region (Williams *et al.*, 2012). These results are contrary to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (AR4) findings, which indicate a precipitation increase over eastern Africa (Christensen *et al.*, 2007). Lyon and DeWitt (2012) conclude that recent east African precipitation trends differ from projected climate model trends because recent cooling in the eastern equatorial Pacific offsets the equatorial Pacific SST warming that is projected by CMIP3 Global Circulation Models (GCMs) in future scenarios.

During the second half of the 20th century, a 20% reduction in late summer precipitation as well as increased aridity has been reported over the western parts of southern Africa, extending from Namibia, through Angola, and toward the Congo (Hoerling *et al.*, 2006). The drying is associated with an upward trend in tropical Indian Ocean SSTs. Modest downward trends are found along Botswana, Zimbabwe, and western South Africa. Apart from changes in total or mean summer rainfall, certain intra-seasonal characteristics of seasonal rainfall such as onset, duration, dry spell frequencies, and rainfall intensity as well as delay of rainfall onset have changed (Tadross *et al.*, 2005; Thomas *et al.*, 2007; Tadross *et al.*, 2009; Kniveton *et al.*, 2009). An increasing trend in daily rainfall intensity is compensating for the increase in the frequency of dry spells (New *et al.*, 2006).

22.2.2.2. Projected Changes

Precipitation projections show high inter-model variation in both the amplitude and direction of change, but in all models precipitation changes are enhanced as global temperatures increase, and the degree of response is regionally specific. Paeth and Thamm (2007) report that until 2025 a considerable reduction in precipitation over most of tropical Africa can be expected. The reduction will amount to more than 20 to 40% of the annual total and be most concentrated in the Congo Basin and the Sahel. Diallo et al. (2012) and Caminade and Terray (2010) report that the western Sahel will undergo substantial drying in the future mostly due to a decrease in peak monsoon rainfall. Projected midsummer drought over the Guinean Coast region is partly related to a weakened monsoon flow, which is a function of SST gradients (Patricola and Cook, 2010a).

Shongwe et al. (2011) suggest that there will be a wetter climate with more intense wet seasons and less severe droughts over eastern Africa during October November December (OND) and March April May (MAM) seasons, with some uncertainty about the rate of change. Patricola and Cook (2010b) predict severe drying over most parts of Uganda, Kenya, and South Sudan in August and September by the end of the 21st century as a result of a weakening Somali jet and Indian monsoon. Climate model projections over Ethiopia indicate a wide range of rainfall spatial pattern changes (Conway and Schipper, 2011). As indicated by Elshamy et al. (2009) GCMs do not agree on the direction of precipitation change in the upper Blue Nile basin between 2080 and 2098.

Precipitation projections exhibit higher spatial and seasonal dependence than temperature scenarios (Orlowsky and Seneviratne, 2012). In the annual mean, models show a dry signal over the climatologically dry southwest, extending northeastward from the desert areas in Namibia and Botswana (Moise and Hudson, 2008; Engelbrecht *et al.*, 2009; James and Washington, 2012; Orlowsky and Seneviratne, 2012). During the austral summer months, dry conditions are projected in the southwest while wetter conditions, within natural climate variability (Moise and Hudson, 2008), are projected in the southeast of South Africa (Hewitson and Crane, 2006; Engelbrecht *et al.*, 2009). Consistent with the AR4, drier winters are projected over a large area in southern Africa as a result of the poleward displacement of mid-latitude storm tracks (Moise and Hudson, 2008; Engelbrecht *et al.*, 2009; Shongwe *et al.*, 2009; Seth *et al.*, 2011; James and Washington, 2012). Rainfall decreases are also projected during austral spring months, implying a delay in the onset of seasonal rains over a large part of the summer rainfall region of Southern Africa (Shongwe *et al.*, 2009; Seth *et al.*, 2011). The sign, magnitude, and spatial extent of projected precipitation changes are dependent on the coupled general circulation model (CGCM) employed, due primarily to parameterization schemes used and their interaction with model dynamics (Hewitson and Crane, 2006; Rocha *et al.*, 2008). However, CGCMs do converge on their synoptic-scale circulation response to radiative forcing which, when downscaled, project that the eastern parts of South Africa will become wetter toward the end of the 21st century (Hewitson and Crane, 2006). Multi-model CMIP5 analysis indicates the potential for wide-scale changes in precipitation across Africa by the middle to end of this century (Figure 22-1). Observed and simulated variations in past and projected future annual average precipitation over five African regions (UMA, ECCAS, ECOWAS, SADC and COMESA) are captured in Figure 22-2.

22.2.3. Extreme Events

Climate extremes such as droughts and floods, which are aggravated by climate change and variability, are being experienced more frequently over eastern Africa (Funk *et al.*, 2008; Williams and Funk, 2010; Shongwe *et al.*, 2011; Lyon and Dewitt, 2012). Recent research has suggested that continued warming in the Indian–Pacific warm pool is likely to contribute to more frequent East African droughts, such as the 2011 drought, during the spring and summer seasons.

An increase in warm extremes and a decrease in cold extremes in recent decades is consistent with the general warming trend over southern Africa (New *et al.*, 2006; Tebaldi *et al.*, 2006; Kruger and Sekele, 2012). The probability of austral summer heat waves over South Africa increased over the last two decades of the 20th century compared to 1961 to 1980 (Lyon, 2009). Enhanced heat wave probabilities are associated with deficient rainfall conditions that tend to occur during El Niño events.

Future projections indicate that all heat wave indices and warm spell durations will increase, suggesting an increased persistence of hot days toward the end of the century (Tebaldi *et al.*, 2006; Orlowsky and Seneviratne, 2012). An increase in sensible heat flux relative to latent heat flux is related to this, a condition favorable for a higher frequency and/or intensity of heat waves (Lyon, 2009). Future precipitation projections demonstrate changes in the scale of the rainfall probability distribution, indicating that extremes of both signs will become more likely in the future (Kay and Washington, 2008). The southwestern regions are projected to be at a high risk of severe droughts during the 21st century and beyond (Hoerling *et al.*, 2006; Shongwe *et al.*, 2011). Intense floods are projected over northern Mozambique, Malawi, and southern Tanzania. Large uncertainties surround likely changes in tropical cyclone landfall from the southwest Indian Ocean that have resulted in intense floods during the 20th century.

22.3. Vulnerability and Impacts

This section highlights how Africa is vulnerable (since the main drivers of vulnerability have not changed since AR4) and the main observed and potential impacts of climate change on natural resources and ecosystems, as well as on different economic sectors. Figure 22-3 summarizes the main conclusions regarding observed changes in regional climate and their relation to anthropogenic climate change (described in 22.2) as well as regarding observed changes in natural and human systems and their relation to observed regional climate change (described in this section). Detection and attribution of anthropogenically-driven climate change is highest for temperature measures.

In many regions, evidence is constrained by limited monitoring. However, impacts of observed precipitation changes are amongst the observed impacts with the highest assessment of confidence, implying that some of the potentially more significant impacts of anthropogenic climate change for Africa are of a nature that challenges detection and attribution analysis (18.5.1).

[INSERT FIGURE 22-3 HERE
Figure 22-3: Summary of detection and attribution assessments of the relation of observed climate change over Africa with anthropogenic emissions (left) and of the relation of observed changes in natural and human systems with observed regional climate changes (right). All detection assessments are against a no-change reference and all attribution assessments for a major role of anthropogenic emissions (left) or observed regional climate change (right), except for "change in disease incidence" for which the detection assessment is relative to what would have been expected based on changes in livelihoods and health care and for which the attribution assessment is for a minor role of climate change in disease incidence. COMESA-n covers the half of COMESA north of and including Rwanda, Uganda, and Kenya. Discussion of these assessments are in 22.2, 22.3, 22.5.1, WGI AR5 Chapter 10, SREX 3.3, SREX 3.5, and 18.5.1. The detection and attribution assessments follow the specifications described in 18.2.]

22.3.1. Socioeconomic and Environmental Context

Socioeconomic development in Africa may strengthen its resilience to various external shocks, including climate change. In 2009, the Human Rights Council adopted Resolution 10/4[3] 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.

[FOOTNOTE 3: U.N. Doc. A/HRC/10/L.11.]

The impacts of climate change on human rights have been explicitly recognised by the African Commission on Human and Peoples' Rights (hereafter African Commission) in its Resolution on Climate Change and Human Rights and the Need to Study its Impact in Africa (ACHPR/Res 153 XLV09). The 1981 African (Banjul) Charter on Human and Peoples' Rights (hereafter African Charter) protects the right of peoples to a 'general satisfactory environment favorable to their development' (Article 24). The recognition of this right and the progressive jurisprudence by the African Commission in environmental matters underline the relevance and linkage between climate change and human rights (Ruppel, 2012). Strong links exist between climate change and the MDGs: climate change may adversely affect progress toward attaining the MDGs, while slow progress in attaining most MDGs has a negative impact on the resilience and adaptive capabilities of African individuals, communities, states, and nations and consequently decreases their adaptive capacity to climate change.

The African continent has managed to make significant progress on some MDGs but not all. Aggregate trends in Africa's progress toward the MDGs conceal high levels of spatial and group disparities, and progress on all indicators is skewed in favor of higher-income groups and urban populations, which means further marginalization of already excluded groups (United Nations *et al.*, 2008; African Development Bank *et al.*, 2010; World Bank and International Monetary Fund, 2010). As a whole, the continent is experiencing a number of demographic and economic constraints (Muchena *et al.*, 2005; Fermont *et al.*, 2008). The population of the continent has more than doubled since 1980; exceeding one billion in 2011 and expected to reach 2.9 billion by the year 2050 if fertility were to remain constant (United Nations Department of Economic and Social Affairs, 2011). The global economic crisis is adding other constraints on economic development efforts resulting in increased loss of livelihood and widespread poverty (Moyo, 2009; Easterly, 2009; Adesina, 2010). The percent of the population below the poverty line has decreased from 56.5% in 1990 to 47.5% in 2008 (excluding North Africa), however a significant proportion of the population living below the poverty line remains chronically poor (Economic Commission for Africa *et al.*, 2012). And although poverty in rural areas has declined from 64.9% in 1998 to 61.6% in 2008, it is still double the prevailing average in developing countries in other regions (IFAD, 2010).

African agriculture, which is the main economic activity in terms of employment share, is 95% rain fed (UNEP, 2008). Stagnant agricultural yields, relative to the region's population growth, have led to a fall in per capita food availability since the 1970s (United Nations *et al*., (2008); Figure 22-4).[4] In addition, the recent rise in global food prices aggravates food insecurity among the poor, increasing the risk of malnutrition and its consequences (United Nations *et al*., 2008). For example, it was estimated that the global rise in food prices has contributed to the deaths of an additional 30,000 to 50,000 children suffering from malnutrition in 2009 in sub-Saharan Africa (Friedman and Schady, 2009; UNSCN, 2009; World Bank and International Monetary Fund, 2010; UNDP *et al*., 2011). This situation may be complicated further by changes in rain variability and extreme weather events affecting the agriculture sector (Yabi and Afouda, 2012).

[INSERT FIGURE 22-4 HERE
Figure 22-4: Number of undernourished people in Africa between 1994/1996 and 2010/2012
Source: www.fao.org/fileadmin/templates/ess/foodsecurity/Food_Security_Indicators.Xlsx.]

[FOOTNOTE 4: Lack of extension services for farmers in Africa can also prevent the utilization and spread of innovations and technologies that can help mitigate climate change.]

Africa has made much progress in the achievement of universal primary education, however, the results are unevenly distributed. The net enrollment rate in primary education has increased from 65% in 1999 to 83% in 2008, with an 18% improvement in sub-Saharan Africa. Nevertheless, a considerable number of children, especially girls from poor backgrounds and rural communities, still do not have access to primary education (United Nations *et al*., 2008). From the livelihood perspective, African women are vulnerable to the impacts of climate change because they shoulder an enormous but imprecisely recorded portion of the responsibility for subsistence agriculture (Viatte *et al*., 2009).[5] Global financial crises, such as the one experienced in 2007/2008, may cause job losses in the formal sector and men may compete for jobs in the informal sector that were previously undertaken by women, making them more vulnerable (African Development Bank *et al*., 2010).

[FOOTNOTE 5: For instance, more than 84% of women in sub-Saharan Africa, compared with 71% of men, are engaged in such jobs. In Northern Africa, even though informal or self-employment is less predominant, the gender gap is stark, with almost twice as high a proportion of women as men in the more vulnerable informal and self-employed status (53% of women compared with 28% of men) (UN DESA, 2010).]

Efforts to combat AIDS, tuberculosis, and malaria under the MDGs have led to progress in preventing and treating these diseases (African Development Bank *et al*., 2010), however, malaria is still endemic in most African countries and represents a major cause of morbidity and mortality.

Deforestation in Africa over the periods 1990–2000 and 2000–2010 has affected 4.1 and 3.7% of total forest area, respectively (UNDP *et al*., 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. Monitoring of biodiversity is weak in Africa, such that almost 50% of medicinal plants surveyed in 2009 – used by 80% of the population – faced extinction (UNEP, 2012).

Significant efforts have been made to improve access to safe drinking water and sanitation in Africa, with access to safe drinking water increasing from 56 to 65% between 1990 and 2008, with sub-Saharan Africa nearly doubling the number of people using an improved drinking water source – from 252 to 492 million over the same period. Despite such progress, significant disparities in access to safe water and sanitation, between not only urban and rural but also between large- and medium- and small-sized cities, still exist (UNDP *et al*., 2011). Use of improved sanitation facilities, meanwhile, is generally low in Africa, reaching to 41% in 2010 compared to 36% in 1990 (UNDP *et al*., 2011).

22.3.2. Ecosystems

Regarding the vulnerability and impacts of climate change on ecosystems, it is recognized that interactions between the different drivers of ecosystems behavior are complex, which makes the prediction of the impacts of climate change more difficult (see Chapter 4). In AR4, the chapter on Africa indicated that extensive pressure is exerted on different ecosystems by human activities (deforestation, forest degradation, biomass for energy) as well as processes inducing changes like fires or desertification. Even if the trend is toward better preservation of ecosystems and a decrease in degradation (like deforestation), pressures linked, for example, to agriculture and food security, energy demand, and urbanization are increasing, putting these ecosystems at risk. This chapter emphasizes a few findings regarding the vulnerability and impacts of these ecosystems, including terrestrial, freshwater, and coastal/ocean systems.

22.3.2.1.Terrestrial Ecosystems

A shift in the geographic location or extent of a biome can signal a substantial change in climate and fundamentally alter habitats and the provision of ecosystem services to people. While field research has detected numerous elevation and latitudinal shifts in biomes around the world attributable to climate change more than to human land use change (Gonzalez *et al*., 2010), only a few efforts 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). Land use change may be a factor in the Burkina Faso sites.

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, grazing, agricultural cultivation, and timber harvesting (Bucini and Hanan, 2007; Sankaran *et al*., 2008; Ahrends *et al*., 2010; Ellis *et al*., 2010; Groen *et al*., 2011; Staver *et al*., 2011; Favier *et al*., 2012).

Projected changes in precipitation and disturbance under climate change may substantially alter the nduextent and locations of biomes. Projections of potential future vegetation indicate the 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 over 5 to 10% of the land in Africa from around 1990 to 2100 for a range of the Coupled Model Intercomparison Project phase three (CMIP3) general circulation model (GCM) runs of the IPCC Special Report on Emissions Scenarios (SRES) emissions scenarios (Hély *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 change 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, some 10 to 50% of the land in Africa is vulnerable to biome shifts (Heubes *et al*., 2011). Projections generally agree on latitudinal shifts in 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 a global expansion of warm deserts by 10 to 34% by 2100, with much of this due to a southward expansion of the Sahara (Zeng and Yoon, 2009). Niche modeling of tropical rainforests under a 4ºC warming projects expansion in Africa up to 50% of rainforest area for 14 CMIP3 GCM runs and contraction of up to 15% of rainforest area for 3 CMIP3 GCM runs. 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 between the periods 1961-1990 and 2071-2100, where any of nine combinations of three GCMs (CSIRO Mk3, HadCM3, MIROC 3.2 medres) and three emissions scenarios (B1, A1B,

A2) project change. This is the worst case in comparison to the case of complete agreement of the nine combinations. (b) Vulnerability of ecosystems to biome shifts based on historical climate (1901-2002) and projected vegetation (2071-2100), where all nine GCM-emissions scenario combinations agree on the projected biome change. 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 that 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 that 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. Validation of niche model results against field observations shows limitations to model accuracy (Hanspach *et al.*, 2011).

22.3.2.1.1. Forests

The impacts of climate change on forests are not clear since some studies predict an increase in productivity while others indicate the reverse (Chidumayo *et al.*, 2011). Forest cover in Africa currently stands at 675 million hectares, which represented 21% of global carbon forest biomass in 2010 and 17% of the world forest area, with the Congo basin in Central Africa being the world's second largest continuous block of tropical rain forest (AMCEN and UNEP, 2006; FAO, 2011; Chidumayo *et al.*, 2011). Forests play a key role in the livelihoods of local communities depending on them (over 30 million indigenous people such as Pygmies in the Congo Basin Forest, and 70% of the total population in Africa; Chidumayo *et al.,* (2011)), providing food (bush meat, roots, tubers, fish, insects, fruits); wood (mainly for cooking and building; wood removal in Africa as fuelwood represented 33% of the global total of fuelwood removal); medicinal products (Colfer *et al.,* 2006; Dudley *et al.,* 2008; Nasi *et al.,* 2008; Manyatsi and Hlophe, 2010; FAO, 2011); other non-timber products; soil conservation; and water quality. They also are important for national economies (forests represent about 6% of gross domestic product (GDP)). For example, in Africa, industrial woods represented about 10% of wood removal that, together with fuelwood, amounted to US$ 2.9 billion in 2005 (FAO, 2011). The loss of forestlands has a dual consequence for climate change by contributing to emission levels and loss of vital carbon sinks and by reducing the adaptive capacity of communities that depend on forest resources.

Forest integrity in Africa is highly threatened by both climate and non-climatic factors. Between 2000 and 2010, the annual deforestation rate was 0.49% despite the fact that there is an increasing trend in Africa of the area planted to forest (2.5% of total forest area), and also for conservation of biodiversity (14%) (FAO, 2011). However, the pressure on these resources is supposed to increase given the needs – among others – for food but also for biofuels. It is also currently recognized that the question of policies (e.g., land tenure) and strategic plans for development will be crucial for the future of forests in Africa (Agrawal *et al.,* 2008; Kalame *et al.,* 2008; Sunderlin *et al.,* 2008; Unruh, 2008; Suivi, 2010; Larson, 2011; Paumgarten and Shackleton, 2011; Somorin *et al*., 2012). Forests are at the crossroads between development and conservation.

In Africa, the major contribution of greenhouse gases is from deforestation, which contributes 20% to global emissions (Chidumayo *et al*., 2011). This importance of forests was recognized through the Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism under the United Nations Framework Convention on Climate Change (UNFCCC). The first experiences indicate the need to synthesize actions toward mitigation and adaptation in the forest sector (Bwango *et al*., 2000; Guariquata *et al*., 2007; Nkem *et al*., 2007; Nyong *et al*., 2007; Nkem *et al*., 2008; Biesbroek *et al*., 2009; Oyden and Innes, 2009; Chia, 2011; Richard *et al*., 2011). There is also a need to address other causes of forest degradation such as drought (Allen *et al*., 2010; Martínez-Vilalta *et al*., 2012).

22.3.2.1.2. *Desertification in the Sahel*

Analyses of the impacts of climate change and desertification on Sahel vegetation examine two types of trends: (1) short-term changes in 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), 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; Bégué *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 (Bégué *et al*., 2011). Rain-use efficiency (RUE) also seems to show increases at sites in the Sahel from 1981 to 2007 (Prince *et al*., 2007; Fensholt and Rasmussen, 2011). The correlation of RUE with rainfall and higher Sahel rainfall in the 2000s may explain an 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 (Wezel and Lykke, 2006; Gonzalez *et al*., 2012), 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, however, tree density did not decrease between 1984 and 2006 (Hiernaux *et al*., 2009). Analyses 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.

22.3.2.2. *Freshwater Ecosystems*

Since the 2008 IUCN red list analysis, it is recognized that freshwater ecosystems, particularly in Africa, will be seriously at risk from climate change (Vié *et al*., 2009; Darwall *et al*., 2011), mainly be through changes in water quantity and quality.

The East African River Valley (EARV) is already experiencing high variability in rainfall and river flows and changes in the geographical distribution of water resources, with the arid to semi-arid areas becoming drier and other areas becoming wetter (Kundzewicz *et al*., 2007). Saline Lake Beseka in the arid Ethiopian rift valley, for instance, has quadrupled from 11.1 km^2 in 1973 to 39.5 km^2 in 2002 due to increased discharge from hot springs (Goerner *et al*., 2009). Much of what is happening to freshwater resources across this region is attributable to increased years of drought, particularly in the past two decades (Boko *et al*., 2007; Solomon *et al*., 2007a), which in turn are reducing river inflows (from reduced runoff), 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 reduction of water quality and quantity around the region (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, and Zambezi 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 water levels have been observed in the freshwaters of this region. Water levels are influenced by evaporation rates with low levels corresponding to drought periods (Ndebele-Murisa *et al*., 2011a; Ndebele-Murisa *et al*., 2011b). Reductions in water levels have also reduced habitats of aquatic organisms, particularly shoaling fish, and adversely affect 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 (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 Kivu, Victoria, and Malawi (Odada *et al*., 2006; Verburg and Hecky, 2009; Marshall *et al*., 2009; Hecky *et al*., 2010; Magadza, 2010; Tierney *et al*., 2010; Olaka *et al*., 2010; Magadza, 2011; Woltering *et al*., 2011; Osborne, 2012; Ndebele-Murisa *et al*., 2012) (Table 22-1). Moderate warming is reducing lake water inflows and therefore nutrients, destabilizing plankton dynamics and thereby adversely affecting food resources for higher trophic levels of mainly planktivorous fish (Magadza, 2008; Verburg and Hecky, 2009; Magadza, 2010; Ndebele-Murisa *et al*., 2011a).

[INSERT TABLE 22-1 HERE
Table 22-1: 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. These changes have been observed in lakes Kivu, Kariba, Malawi, Tanganyika, and Victoria, particularly in the past 50 years (Awange *et al*., 2008; McGinley, 2008; Tumbare, 2008; Njaya *et al*., 2011; Ndebele-Murisa, 2011). This has potential cascading effects on aquatic ecosystems by reducing available nutrients in the upper waters, thereby limiting biological production (Bootsma, 2006; Magadza, 2006; Ogutu-Ohwayo and Balirwa, 2006; Magadza, 2008; Verburg and Hecky, 2009; Hecky *et al*., 2010; Ndebele-Murisa *et al*., 2010; Tierney *et al*., 2010; Urama and Ozor, 2010).

22.3.2.3. Coastal and Ocean Systems

Coastal and ocean systems are crucial for the economies and livelihoods of African countries and climate change will increase their existing challenges (overexploitation of resources, habitat degradation, loss of biodiversity, salinization, pollution, and coastal erosion) (Arthurton *et al*., 2006; UNEP and IOC-UNESCO, 2009; Diop *et al*., 2011). Concern is increasing 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). For example, a conjunction between storm swell up to 14 m, due to winds generated by a cyclone, and high astronomic tide at 2.2 m was experienced along the Durban coast in March 2007, which led to damages estimated at US$ 100 million (Theron and Rossouw, 2008; Mather and Stretch, 2012). Other climate change impacts (such as flooding of river deltas or an increased migration toward coastal towns due to increased drought induced by climate change (Rain *et al*., 2011) will also affect coastal zones.

22.3.2.3.1. Impacts and vulnerability of coastal ecosystems

Different studies assess the vulnerability of the African coast to sea level rise. They all consider that the impacts could be important, especially in coastal towns.

In Kenya, the impacts of climate change on the entire coastal zone were determined (SEI (2009); see Figure 22-6 (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 between US$ 0.9 and 1.19 billion.

[INSERT FIGURE 22-6 HERE
Figure 22-6: Population and economic losses in case of climate change for the whole Kenya coastal zone. Source: (SEI, 2009).]

A similar assessment for Dar es Salaam (Kebede and Nicholls, 2011a) estimated that by 2030, the population and economic assets at risk of extreme water levels of 3.07 to 3.23 m are 30,800 to 140,000 inhabitants and US$ 35.6 to 404.1 million US$. The Dynamic Interactive Vulnerability Assessment (DIVA) model was used to assess the monetary and non-monetary impacts of sea level rise on the entire coast (3,461 km) of Tanzania. It estimated that by 2030, 1,924 to 7,624 km^2 would be lost, mainly through inundation; around 234,000 people per year could be potentially affected by inundation, and between 67,000 and 852,000 people living in inundated areas would be forced to migrate. Without adaptation, residual damages have been estimated at between US$ 20 and 42 million per year, of which around US$ 2.7 million could be due to the loss of wetlands (24% of which will be mangroves). Table 22-2 shows the economic impacts of land inundated in Cape Town based on different sea level rise scenarios.

[INSERT TABLE 22-2 HERE
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 development 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, Namibia has coasts vulnerable to sea level rise located around Walvis Bay (with risks of breaching with potential consequences for the harbor and low-lying places in the town). Diamond mining could also be affected. And in Mozambique the risks are almost everywhere, with potential impacts on the two main harbors (Maputo and Beira), but also problems with tourism infrastructure. This could also induce an increase in environmental refugees in South Africa. The risks of salinization, especially for agriculture and on coral reefs are also considered. (Theron and Rossouw, 2008; Cartwright, 2008b):

Assessments for western (Appeaning Addo *et al.*, 2008; Niang *et al.*, 2010) and northern Africa (Snoussi *et al.*, 2009; World Bank, 2011) arrived at the same conclusions as those for eastern and southern Africa.

22.3.2.3.2. Impacts and vulnerability of marine systems

In Africa, fisheries depend on either coral reefs or coastal upwelling. These two ecosystems will be affected by climate change through ocean acidification, a 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 (CC-OA). Projections indicate that severe impairment of reef accretion by organisms such as corals (Hoegh-Guldberg *et al.*, 2007) and coralline algae (Kuffner *et al.*, 2008) 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.

OA is nevertheless a serious issue and together with coral bleaching resulting from climate change, 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 to 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 (Ferrari *et al.*, 2011; Franke and Clemmesen, 2011; Baumann *et al.*, 2012; Frommel *et al.*, 2012).

22.3.3. Water Resources

Knowledge has advanced since the AR4 regarding current drivers of water resource abundance in Africa, and in understanding of potential future impacts on water resources from climate change and other drivers. Recent long-term studies assessing changes in surface water resources in Africa provide evidence that climate change is currently having a minimal effect on water abundance (*low confidence*). Findings on the availability of freshwater in the region should be taken with caution considering the systemic limitations associated with inadequate observational data in Africa (Neumann *et al*., 2007; Batisani, 2011). As explained in Chapter 3, surface and groundwater hydrology are governed by multiple, interacting drivers and factors, such as land use change, water withdrawals, and natural climate variability, which make detection and attribution exceedingly difficult.

A growing body of literature amassed since the AR4 suggests that climate change in Africa will have an overall modest effect on future water scarcity relative to other drivers, such as population growth, urbanization, agricultural growth, and land use change (Alcamo *et al*., 2007; Carter and Parker, 2009; MacDonald *et al*., 2009; Taylor *et al*., 2009; Calow and MacDonald, 2009; Abouabdillah *et al*., 2010; Beck and Bernauer, 2011; Droogers *et al*., 2012; Notter *et al*., 2012; Tshimanga and Hughes, 2012) (*medium confidence*). However, broad-scale assumptions about drivers of future water shortages can mask significant sub-regional variability of impacts, particularly in water-stressed regions that are projected to become drier, such as southern and northern Africa. For example, rainfed agriculture in northern Africa is highly dependent on winter precipitation and would be negatively impacted if total precipitation and the frequency of wet days declines across North Africa as has been indicated in recent studies (Born *et al*., 2008; Driouech *et al*., 2010; Abouabdillah *et al*., 2010; García-Ruiz *et al*., 2011). Similarly, climate model predictions based on average rainfall years do not adequately capture interannual and interdecadal variability that can positively or negatively influence surface water runoff (Beck and Bernauer, 2011; Notter *et al*., 2012; Wolski *et al*., 2012). Key challenges for estimating future water abundance in Africa lie in a better understanding of the relationships between evapotranspiration, soil moisture, and land use change dynamics in the context of climate change (Goulden *et al*., 2009a) and to understand how compound risks such as heat waves and seasonal rainfall variability might interact under climate change to impact water resources.

Several studies from Africa point to a future decrease in water abundance, particularly in southern and northern Africa (*high confidence*). For example, all countries within the Zambezi River Basin could contend with increasing water shortages (A2 scenario) although non-climate drivers (e.g., population and economic growth, expansion of irrigated agriculture, and water transfers) are expected to have a greater influence on future water availability than climate change (Beck and Bernauer, 2011). In Zimbabwe, climate change could increase water shortages for downstream users dependent on the Rozva dam (Ncube *et al*., 2011). The Okavango Delta could experience increased drying from both climate change and water withdrawals for irrigation (Murray-Hudson *et al*., 2006; Milzow *et al*., 2010; Wolski *et al*., 2012), and the Breede River in South Africa could face decreased runoff (Steynor *et al*., 2009). For North Africa, Droogers et al. (2012) estimated that climate change will account for 22% of future water shortages in the region while 78% of increased future water shortages can be attributed to socioeconomic factors. Abouabdillah et al. (2010) estimated that higher temperatures and declining rainfall (A2 and B1 scenarios) would reduce water resources in Tunisia, though future land use and socioeconomic changes were not considered in the analysis. Reduced snowpack in the Atlas Mountains could reduce supplies of seasonal meltwater for Morocco (García-Ruiz *et al*., 2011).

Potential climate change impacts on the Nile Basin are of particular concern given the basin's geopolitical and socioeconomic importance. Several studies since the AR4 examine potential changes in water resources for the Nile Basin. Reduced flows in the Blue Nile of around 22% at the Ethiopia-Sudan border are possible due to a combination of climate change (higher temperatures and declining precipitation) and upstream water development for irrigation and hydropower by 2100 (A1B) (McCartney and Menker Girma, 2012). Elshamy et al. (2008) also estimated increased moisture constraints in the Blue Nile Basin by late century driven by higher evapotranspiration under temperature rises between 2°C and 5°C. Beyene et al. (2010) estimated that streamflow in the Nile River will increase in the medium term (2010–2039) but will decline in the latter half of this century (A2 and B1 scenarios) as a result of both declining rainfall and increased evaporative demand, with subsequent diminution of water allocation for irrigated agriculture downstream from the High Aswan Dam. Kingston et al. (2010) reached a similar conclusion about an initial increase followed by a decline in surface water discharge in the Upper Nile Basin in Uganda but caution that limitations inherent in GCMs hamper the robustness of these findings. Also in eastern Africa, Dessu et al. (2012) reported a potential increase in Mara River flow in the second half of this century (A1B, A2, and B1), though under assumptions of current land use patterns. Seasonal runoff volumes in the Lake Tana Basin, Ethiopia, could decrease by the 2080s under the A2 and B2 scenarios (Abdo *et al.*, 2009). In West Africa, the Bani River Basin could experience substantial reductions (60–65%) in runoff (A2 scenario) due to reduced rainfall, with catchment discharge potentially decreasing to levels similar to those observed during the severe drought of the 1980s (Ruelland *et al.*, 2012). However, high uncertainty about the direction and magnitude of future precipitation in the Sahel (Chapter 14, WG1) warrants caution. The impact of climate change on total runoff in the Congo Basin could be minimal (A2 scenario) (Tshimanga and Hughes, 2012).

Groundwater resources in Africa could be variably affected by climate change. An analysis by MacDonald et al. (2009) indicated that changes in rainfall would not be expected to directly impact the recharge of deep aquifers in areas receiving below 200 mm rainfall per year, where recharge is negligible due to low rainfall. Groundwater recharge may also not be significantly affected by climate change in areas that receive more than 500 mm per year, where sufficient recharge would remain even if rainfall diminished, assuming current groundwater extraction rates. By contrast, areas receiving between 200 to 500 mm per year, including the Sahel, the Horn of Africa, and southern Africa, may experience a decline in groundwater recharge with climate change if prolonged drought becomes more frequent with climate change.

Coastal aquifers are particularly vulnerable to climate change due to high rates of groundwater extraction, which leads to saltwater intrusion in aquifers, coupled with increased saltwater ingression resulting from sea level rise (Moustadraf *et al.*, 2008; Bouchaou *et al.*, 2008; Al-Gamal and Dodo, 2009; Kerrou *et al.*, 2010). Some studies have shown additional impacts of sea level rise on aquifer salinization with salinity potentially reaching very high levels (Carneiro *et al.*, 2010; Niang *et al.*, 2010; Research Institute for Groundwater, 2011). Although these effects are expected to be localized, in some cases they will occur in densely populated areas (Niang *et al.*, 2010). The profitability of irrigated agriculture in Morocco is expected to decline (under both B1 and A1B scenarios) due to increased pumping of groundwater and increased salinization risk for aquifers (Heidecke and Heckelei, 2010).

The capacity of groundwater delivery systems to meet demand may take on increasing importance with climate change (Calow and MacDonald, 2009). For example, where groundwater pumping and 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 or increased saline intrusion (Moustadraf *et al.*, 2008). Thus if drought conditions become more prevalent in Africa with climate change, stress on groundwater delivery infrastructures could increase.

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 assess groundwater recharge potential across the continent (Taylor *et al.*, 2009). A preliminary analysis by MacDonald et al. (2012) indicates that total groundwater storage in Africa is 0.66 million km^3, which is “more than 100 times the annual renewable freshwater resources, and 20 times the freshwater stored in African lakes.” However, borehole yields are variable and in many places water yields are relatively low. Detailed analysis of groundwater conditions for water resource planning would need to consider these constraints. In this respect, developing organizational frameworks and strengthening institutional capacities for more effectively assessing and managing groundwater resources in Africa are critically important (Nyenje and Batelaan, 2009; Braune and Xu, 2010).

22.3.4. Agriculture 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, recurrent droughts and floods, and persistent poverty that limits the capacity to adapt (Boko *et al.*, 2007). In the near term, better managing risks associated with climate variability may help to build adaptive capacities for climate change (Washington *et al*., 2006; Cooper *et al*., 2008; Funk *et al*., 2008). 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; Burke *et al*., 2009a), thus increasing the likelihood that major crops in Africa could experience significant yield losses (Schlenker and Lobell, 2010). Climate change is likely to reduce the growing season length in Africa (Thornton *et al*., 2011) although not in all sub-regions (Cook and Vizy, 2012). The composition of farming systems from mixed crop-livestock to more livestock dominated food production could occur as a result of reduced growing season length for annual crops and increases in the frequency and prevalence of failed seasons (Jones and Thornton, 2009; Thornton *et al*., 2010). Transition zones, where livestock keeping is projected to replace crop cultivation by 2050, occur in the West African Sahel and in coastal and mid-altitude areas in eastern and southeastern Africa (Jones and Thornton, 2009), which currently support 35 million people and are chronically food insecure.

22.3.4.1. 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 (Lobell *et al*., 2008; Liu *et al*., 2008; Walker and Schulze, 2008; Thornton *et al*., 2009a; Lobell *et al*., 2011; Roudier *et al*., 2011; Berg *et al*., 2013) (*high confidence*). One exception is in eastern Africa where maize production could benefit from warming at sites above roughly 1,500 m in elevation (A1FI scenario) (Thornton *et al*., 2009a), although the majority of current maize production occurs at lower elevations thereby implying a change in the distribution of maize cropping. Maize-based systems in southern Africa are among the most vulnerable to climate change, with recent yield losses estimated at 18% (Zinyengere *et al*., submitted) and 30% (Lobell *et al*., 2008) relative to current yields. In eastern Africa, simulations that combine all regions south of the Sahara suggest consistently negative effects of climate change on five major staples (rice, wheat, maize, millet, and sorghum) by 2050 (A2 scenario) (Nelson *et al*., 2009). Wheat production in North Africa is vulnerable to projected warming trends in that region (Eid *et al*., 2007; Hegazy *et al*., 2008; Drine, 2011; Mougou *et al*., 2011).

Climate change will likely have differential impacts on non-cereal crops, with both production losses and gains possible (*low confidence*). Cassava yields in eastern Africa could moderately increase up to 2030s assuming CO2 fertilization and under a range of low to high emissions scenarios (Liu *et al*., 2008), findings that were similar to Lobell et al. (2008). Suitability for growing cassava could increase with the greatest improvement in suitability in eastern and central Africa (A1B scenario) (Jarvis *et al*., 2012). However, Schlenker and Lobell (2010) estimated negative impacts from climate change on cassava at mid-century, although these impacts are less than those estimated for cereal crops. Given cassava's hardiness to higher 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 (Rosenthal and Ort, 2011; Jarvis *et al*., 2012). Bean yields in Eastern Africa could experience yield reductions by the 2030s under an intermediate emissions scenario (A1B) (Jarvis *et al*., 2012) and by the 2050s under low (B1) and high (A1FI) emissions scenarios (Thornton *et al*., 2011). For peanuts, some studies indicate a positive effect from climate change (A2 and B2 scenarios) (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) (A2 and B2 scenarios) although 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).

Suitable agro-climatic zones for growing economically important perennial crops could significantly diminish, largely due to the effects of rising temperatures (Läderach *et al*., 2010; Eitzinger *et al*., 2011a; Läderach *et al*., 2011a; Eitzinger *et al*., 2011b; Läderach *et al*., 2011b; Läderach *et al*., 2011c). With a 2°C or greater temperature rise by mid-century, suitable agro-climatic zones that are currently classified as very good to good for perennial crops could become more marginal, and what are currently marginally suitable zones could become unsuitable; the constriction of crop suitability could be severe in some cases (Table 22-3). Movement of perennial crops to higher altitudes could mitigate the loss of suitability at lower altitudes but this option is limited. Loss of productivity of high-value crops such as tea, coffee and cocoa would have detrimental impacts on export earnings.

[INSERT TABLE 22-3 HERE
Table 22-3. Projected changes in agro-climatic suitability for perennial crops in Africa under an A2 scenario.]

22.3.4.2.Livestock

Livestock systems in Africa face multiple stressors that could potentially interact with climate change and variability to amplify the 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, weak social safety nets, and insecure access to land, markets, and other resources (Solomon *et al.*, 2007b; Smucker and Wisner, 2008; Galvin, 2009; Thornton *et al.*, 2009b; Dougill *et al.*, 2010; Ifejika Speranza, 2010).

Loss of livestock under prolonged drought conditions is a critical risk given the extensive rangeland in Africa that is prone to drought. Regions that are projected to become drier with climate change, such as northern and southern Africa, are of particular concern (Solomon *et al.*, 2007b; Masike and Urich, 2008; Thornton *et al.*, 2009b; Dougill *et al.*, 2010; Freier *et al.*, 2012; Schilling *et al.*, 2012). Adequate provision of water for livestock production could become more difficult under climate change. For example, Masike and Urich (2009) estimated that the cost of supplying livestock water from boreholes in Botswana could increase 23% by 2050 due to increased hours of groundwater pumping needed to meet livestock water demands under warmer and drier conditions. 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 (Peden *et al.*, 2009; van Breugel *et al.*, 2010; Descheemaeker *et al.*, 2010; Descheemaeker *et al.*, 2011). Livestock production could be indirectly affected by water scarcity through its impact on crop production and subsequently the availability of crop residues for livestock feeding. Thornton et al. (2010) estimated that maize stover availability per head of cattle could decrease in several East African countries by 2050.

The extent to which increased heat stress associated with climate change could affect livestock productivity has not been well established, particularly in the tropics and sub-tropics (Thornton *et al.*, 2009b), although a few studies point to the possibility that keeping heat-tolerant livestock could become more prevalent in response to warming trends. For example, higher temperatures 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). Livestock keeping in highland areas of East Africa, which is currently cold-limited, would presumably benefit from increased temperatures (Thornton *et al.*, 2010).

22.3.4.3.Agricultural Pests and Diseases

Since the AR4, understanding of how climate change could potentially affect crop and livestock pests and diseases and agricultural weeds in Africa is beginning to emerge. In the case of livestock, 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 temperature increase and changes in mean precipitation resulting in the climatically suitable range of the tick shifting southward. However, 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 influence tick distribution and need to be considered in assigning causality (Rogers and Randolph, 2006).

Warming in highland regions of eastern Africa could lead to range expansion of crop pests into cold-limited areas (*medium confidence*). 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 in coffee-growing regions of Ethiopia, Kenya, Uganda, Rwanda, and Burundi (Jaramillo *et al.*, 2011). Temperature increases in highland banana-producing areas of eastern Africa enhance the risk of altitudinal range expansion of the highly destructive burrowing nematode, *Radopholus similis* (Nicholls *et al*., 2008); however, no detailed studies have assessed this risk. Ramirez et al. (2011) estimated that increasing minimum temperatures by 2020 could expand the suitable range of Black Leaf Streak disease (Mycosphaerella fijiensis M.) of banana in Angola and Guinea.

Climate change may also affect the distribution of economically important pests in lowland and dryland areas of Africa (*low confidence*). Under A2A and B2A for 2020, Cotter et al. (2012) estimated that changes in temperature, rainfall, and seasonality could result in more suitable habitats for *Striga hermonthica* in central Africa, whereas the Sahel region may become less suitable for this weed. Striga weed infestations are a major cause of cereal yield reduction in Sub-Saharan Africa. Climate change could also lead to an overall decrease in the suitable range of major cassava pests – whitefly, cassava brown streak virus, cassava mosaic geminivirus, and cassava mealybug (Jarvis *et al*., 2012), although southeast Africa and Madagascar could experience increased suitability for cassava pests (Bellotti *et al*., 2012).

22.3.4.4.Fisheries

Fisheries are an important source of food security in Africa. Capture fisheries (marine and inland) and aquaculture combined contribute over one-third of Africa's animal protein intake (Cochrane *et al*., 2009), while in some coastal countries fish 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 few decades. To meet fish food demand by 2020, De Silva and Soto (2009) estimated that aquaculture production in Africa would have to increase nearly 500%.

Climate change is beginning to affect African lakes, as evident by increasing surface water temperatures in eastern and southern Africa lakes (O'Reilly *et al*., 2003 as cited in; Brander, 2007; Sitoki *et al*., 2010; Ndebele-Murisa *et al*., 2011b; Marshall, 2012). The effect of warming on fisheries in these lakes is uncertain, with some studies indicating that reduced fisheries output is linked to drought conditions and warming that have reduced upwelling of nutrients necessary for stimulating fish production (O'Reilly *et al*., 2003 as cited in; Brander, 2007; Ndebele-Murisa *et al*., 2011b), and other studies urging caution in over-attributing fisheries decline to climate change given the intense pressures on fisheries from overfishing, pollution, and invasive species (Marshall, 2012). Loss of fisheries and tourism livelihoods resulting from coral bleaching is another critical concern in Africa. An analysis by Cinner et al. (2012) indicated that Tanzania, Kenya, Seychelles, and northwest Madagascar are among the most vulnerable to losses from bleaching because of warm seawater temperatures and high ultraviolet exposure. Livelihood dependency on fishing, and thus high sensitivity to fisheries decline linked to coral bleaching, is particularly great in Tanzania (Burke *et al*., 2011; Cinner *et al*., 2012) and parts of Kenya and Madagascar (Cinner *et al*., 2012).

The vulnerability of national economies to climate change impacts on fisheries can be linked to exposure to the physical effects of climate change, the sensitivity of the country to impacts on fisheries, and adaptive capacity within the country (Allison *et al*., 2009). An analysis of 132 countries by Allison et al. (2009) estimated that two-thirds of the most vulnerable countries were in Africa. Among these countries, the most vulnerable were Malawi, Guinea, Senegal, and Uganda, due to the importance of fisheries to the poor and the close link between climate variability and fisheries production. Coastal countries of West Africa could experience a significant negative impact from climate change. Lam et al. (2012) projected that by 2050 (under an A1B scenario) the annual landed value of fish for the region could decline by 21%, resulting in a nearly 50% decline in fisheries-related employment and a total annual loss of US$ 311 million to the region's economy.

22.3.4.5.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 (Brown *et al*., 2009; Hadley *et al*., 2011; Mason *et al*., 2011; Tawodzera, 2011; Alem and Söderbom, 2012; Levine, 2012). Among the most affected groups are the urban poor, who typically allocate more than half of their income to food purchases (Cohen and Garrett, 2010; Crush and Frayne, 2010), in addition to the rural poor, especially female-headed households (Kumar and Quisumbing, 2011). Although the recent spike in global food prices can be attributed to a convergence of several factors, the expected intensification of climate change could become more important in the future for exerting upward pressure on food prices of basic cereals (Nelson *et al.*, 2009; Hertel *et al.*, 2010), which could have serious implications for Africa's food security. As the recent wave of food price crises demonstrates, factors in other regions profoundly impact food security in Africa. 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.

Africa is undergoing both rapid urbanization and subsequent transformation of its food systems to accommodate changes in food processing and marketing as well as in food consumption patterns. Considering the increasing reliance on purchased food in urban areas, approaches for addressing the impacts of climate change on food security will need to encompass a food systems approach (production as well as processing, transport, storage, and preparation) that moves food from production to consumption (Battersby, 2012). Weaknesses in the food system may be exacerbated by climate change in the region as high temperatures increase spoilage and floods damage transportation infrastructure. In this respect, high post-harvest losses in Africa resulting in a large part from inadequate transport and storage infrastructure (Godfray *et al.*, 2010; Parfitt *et al.*, 2010) are an important concern.

22.3.4.6. Biofuels and Land Use

The potential for first-generation biofuel production in Africa, derived from bioethanol from starch sources and biodiesel production from oilseeds, is significant given the continent's extensive arable lands, labor availability, and favorable climate for biofuel crop production (Amigun *et al.*, 2011; Arndt *et al.*, 2011; Hanff *et al.*, 2011). 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 livelihood opportunities for women, pastoralists, and migrant farmers who depend on access to the land resource base (Unruh, 2008; Amigun *et al.*, 2011; German *et al.*, 2011; Schoneveld *et al.*, 2011).

More research is needed to understand fully the socioeconomic and environmental tradeoffs associated with biofuel production in Africa. One critical knowledge gap concerns the effect of biofuel production, particularly large-scale schemes, on land use change and subsequent food and livelihood security. For example, the conversion of marginal lands to biofuel crop production would impact the ability of users of these lands (pastoralists and in some cases women who are allocated marginal land for food and medicinal production) to participate in land use and food production decisions (Amigun *et al.*, 2011; Schoneveld *et al.*, 2011). In addition, biofuel production could potentially lead to the extension of agriculture into forested areas, either directly through conversion of fallow vegetation or the opening of mature woodland, or indirectly through use of these lands to offset food crop displacement (German *et al.*, 2011). Such land use conversion could result in biofuel production reducing terrestrial carbon storage potential (Vang Rasmussen *et al.*, 2012a; Vang Rasmussen *et al.*, 2012b).

Better agronomic characterization of biofuel crops is another key knowledge gap. For example, little information exists 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; Peters and Thielmann, 2008; Hanff *et al.*, 2011). 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).

22.3.5. Health

22.3.5.1. Vulnerability

Africa currently experiences high burdens of health outcomes whose incidence and geographic range could be affected by changing temperature and precipitation patterns, including malnutrition, diarrheal diseases, and malaria and other vector-borne diseases, with most of the impact on women and children. Worldwide in 2010, there were 216 million cases of malaria (malaria (81% of episodes were in Africa) and an estimated 655,000 deaths with most (91% deaths) of the cases in Africa; a child dies every minute from malaria (WHO, 2011). In 2011, malaria accounted for 22% of all childhood deaths (WHO, 2011). Globally, nearly one in five deaths in children is due to diarrhea (1.5 million deaths annually) with 80% of deaths in Africa and Asia (UNICEF and WHO, 2009). Other drivers of these health outcomes include inadequate human and financial resources, inadequate public health and health care systems, insufficient access to water and sanitation, and poor governance. For example, of the more than 1 billion Africans, 341 million lack access to safe drinking water and 589 million lack access to improved sanitation, with sub-Saharan Africa having the lowest coverage (UNICEF and WHO, 2008; UNICEF and WHO, 2012). The health impacts of climate change will arise from the interactions of changing weather patterns with generic and place-specific sources of vulnerability (Cardona *et al*., 2012).

Further emerging vulnerabilities can arise from adaptations implemented in other sectors through, for example, changing habitats for pathogens and their vectors. Building dams for irrigation could lead to epidemics or the spread of leishmaniasis, a debilitating disease endemic in North Africa that can cause facial scarring and stigmatization, affecting primarily women agricultural workers (M.K.Chahed and al, in preparation, Plos journal).

22.3.5.2. Impacts: Current and Future Projections

Literature on the health effects of climate change in Africa generally lags other sectors. Recent climate change appears to be affecting the incidence and geographic range of certain vector-, food-, and water-borne diseases, with projections suggesting increases in their magnitude and extent with additional climate change.

22.3.5.2.1. Food and water-borne diseases

Cholera is primarily associated with poor sanitation, poor governance, and poverty, and could be exacerbated by climate variability and long-term climate change (Rodó *et al*., 2002; Koelle *et al*., 2005; Olago *et al*., 2007; Murray *et al*., 2012). The frequency and duration of cholera outbreaks are associated with rainfall variability in Ghana and other African countries (de Magny *et al*., 2007). The El Niño-Southern Oscillation (ENSO) is a driver of cholera pathogenicity and transmission (de Magny *et al*., 2007). The worst outbreak of cholera in recent African history occurred in Zimbabwe from August 2008 to June 2009. The epidemic was associated with the rainy season and caused more than 92,000 cases and 4,000 deaths. Contamination of water sources spread the disease (Mason, 2009). Poor governance, poor infrastructure, limited human resources, and underlying population susceptibility (high burden of malnutrition) contributed to the severity and extent of the outbreak (Murray *et al*., 2012).

Climate change is projected to increase child malnutrition (as measured by severe stunting) in sub-Saharan Africa, even taking economic growth into account; the projected increase in central sub-Saharan Africa is 23% by 2050 (Lloyd *et al*., 2011). Local economic activity and food accessibility can reduce the incidence of malnutrition (Funk *et al*., 2008; Rowhani *et al*., 2011). Prevention of future malnutrition would require, in addition, improved socioeconomic conditions and reductions in greenhouse gas emissions (Lloyd *et al*., 2011). By 2050, the number of malnourished children in sub-Saharan Africa could increase by 24 million due to climate change (Parry *et al*., 2009b; ADB and IFPRI, 2009).

22.3.5.2.2. Vector-borne diseases

A wide range of vector-borne diseases contribute to premature morbidity and mortality in Africa. New research has been published since the AR4 on malaria, leishmaniasis, Rift Valley fever, and tick- and rodent-borne diseases.

Malaria: Weather and climate are among the determinants of the geographic range and incidence of malaria. The association between temperature and malaria varies regionally, with some studies concluding it is nonlinear and others quadratic or exponential (Chaves and Koenraadt, 2010; Paaijmans *et al*., 2010a; Alonso *et al*., 2011; Gilioli and Mariani, 2011). Total precipitation, rainfall patterns, and the water temperature of breeding sites will likely alter disease susceptibility (Bomblies and Eltahir, 2010; Paaijmans *et al*., 2010b; Afrane *et al*., 2012). ENSO events also may contribute to malaria epidemics (Mabaso *et al*., 2007; Ototo *et al*., 2011). The complexity of the malaria transmission cycle makes it difficult to determine whether the distribution of the pathogen and vector are already changing due to climate change.

Research continues to support the AR4 finding that climate change could affect the geographic range and incidence of malaria, particularly along the current edges of its distribution, with contractions and expansions, and increasing and decreasing incidence (Yé *et al*., 2007; Peterson, 2009a; Parham and Michael, 2010; Paaijmans *et al*., 2010b; Alonso *et al*., 2011; Chaves *et al*., 2011; Egbendewe-Mondzozo *et al*., 2011; Paaijmans *et al*., 2012; Parham *et al*., 2012; Ermert *et al*., 2012), depending on other drivers, such as public health interventions, factors influencing the geographic range and reproductive potential of malaria vectors, land use change (e.g., deforestation), and drug resistance, as well as the interactions of these drivers with weather and climate patterns (Chaves *et al*., 2008; Kelly-Hope *et al*., 2009; Paaijmans *et al*., 2009; Saugeon *et al*., 2009; Artzy-Randrup *et al*., 2010; Dondorp *et al*., 2010; Gething *et al*., 2010; Jackson *et al*., 2010; Kulkarni *et al*., 2010; Loha and Lindtjørn, 2010; Tonnang *et al*., 2010; Stern *et al*., 2011; Caminade *et al*., 2011; Omumbo *et al*., 2011; Afrane *et al*., 2012; Edlund *et al*., 2012; Gething *et al*., 2012; Githeko *et al*., 2012; Himeidan and Kweka, 2012; Jima *et al*., 2012; Lyons *et al*., 2012; Ermert *et al*., 2012; Mordecai *et al*., 2013). Because various *Anopheles* species are adapted to different climatic conditions, changing weather and climate patterns could affect species composition differentially (Afrane *et al*., 2012).

Consensus is growing that highland areas, especially in East Africa, will experience increased malaria epidemics, with areas above 2,000 m particularly affected (Pascual *et al*., 2006; Peterson, 2009b; Lou and Zhao, 2010; Paaijmans *et al*., 2010a; Ermert *et al*., 2012; Gething *et al*., 2012). Reasons for different projections across models include using GCMs versus regional climate models (Ermert *et al*., 2012); the need for finer-scale and higher-resolution models of the sharp climate variations with altitude (Bouma *et al*., 2011); and the extent to which other drivers of the geographic range and incidence of malaria are included, including how these drivers interact with climate change.

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 (Postigo, 2010) with a rising concern in western Africa because of co-infection with HIV (Kimutai *et al*., 2006). The epidemiology of the disease appears to be changing (Dondji, 2001; Yiougo *et al*., 2007; WHO, 2009; Postigo, 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, epidemic transmission of leishmania major (vector *Phlebotomus papatasi*) occurred in 2009 with occasional outbreaks of up to 2,000 cases, followed by long periods with few or no cases (Rhajaoui, 2011). The disease has spread to areas in West Africa and East Africa (Dondji, 2001; Yiougo *et al*., 2007; WHO, 2009). Outbreaks of zoonotic cutaneous leishmaniasis (ZCL) have become more frequent in Tunisia, Algeria, and Morocco, where the disease is endemic. In Tunisia, weather patterns, including heavy rainfall up to two years prior and warmer than average temperature three to six months prior to an outbreak, are associated with changes in the geographic range and incidence of the disease and/or changes in rodent density and density of sandfly species (Salah *et al*., 2007; Interim Technical Report, 2011). Environmental modifications, such as dam construction, can change the temperature and humidity of the soil and thus affect vegetation that may result in changes in the composition and density of sandfly species and rodent vectors.

Rift Valley fever (RVF) 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 is endemic in numerous African countries, with sporadic repeated epidemics. Epidemics in 2006–2007 in the Horn of Africa (Nguku *et al*., 2007; WHO, 2007; Adam *et al*., 2010; Andriamandimby *et al*., 2010) and southern Africa were associated with heavy rainfall (Chevalier *et al*., 2011), strengthening earlier analyses by Anyamba et al. (2009) showing that RVF epizootics and epidemics are closely linked to the occurrence of the warm phase of ENSO and La Nina events (Linthicum *et al*., 1999; Anyamba *et al*., 2012) and 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 vectors in East Africa. Flooding of mosquito habitats also may introduce the virus into domestic animal populations.

Changing weather patterns could expand 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, with more than one-third of these in Africa. Theileriosis (East Coast Fever) ticks are vectors and agents of diseases, causing anemia and skin damage that expose cattle to secondary infections. Habitat destruction, land use and cover change, and host density also affect tick distribution (Rogers and Randolph, 2006). 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.

Approximately 243 million people are infected with schistosomiasis, of which 90% live in underdeveloped areas of Africa (WHO, 2013). Water resource development, such as irrigation dams recommended for adaptation in agriculture, can amplify the risk of schistosomiasis (Huang and Manderson, 1992; Hunter *et al*., 1993; Jobin, 1999). Migration and sanitation play a significant role in the spread of schistosomiasis from rural areas to urban environments (Babiker *et al*., 1985; WHO, 2013). Temperature and precipitation patterns may play a role in transmission (Odongo-Aginya *et al*., 2008; Mutuku *et al*., 2011; Huang *et al*., 2011). A relation between climate variability and schistosomiasis has been noted elsewhere (Huang *et al*., 2011) and there is the need for further research in Africa to assess the possible climate change impacts on the disease.

Researchers have found a strong relationship between the seasonal pattern of meningococcal meningitis and climate (environmental factors) this includes a relationship between the seasonal pattern of the harmattan dusty winds and the onset of the epidemic and the seasonal cycle of meningitis. Links with other environmental factors affected by climate change like wind and humidity have been noted. Epidemics occur throughout Africa in the dry season and coincide with periods of very low humidity and dusty conditions. The epidemics disappear with the onset of the rains (Molesworth *et al*., 2003). Recently, other researchers have corroborated with earlier hypothized relationships between weather and meningitis, (Yaka *et al*., 2008; Palmgren, 2009; Roberts, 2010; Dukić *et al*., 2012). Further, in the northern region of Ghana, a follow-on study to Hodgson et al. 2001 by Hayden et al. (revision submitted) found that exposure to smoke from cooking fires increased the risk of contracting meningococcal meningitis. This increased risk suggests that exposure to elevated concentrations of air pollutants, such as carbon monoxide (CO) and particulate matter, may be linked to illness. More research is needed to clarify the impact of climate change on air quality and linkages with meningitis. Researchers have quantified the relationship between the environment and the location of the epidemics suggesting that there are connections between epidemics and regional climate variability (Molesworth *et al*., 2003; Sultan *et al*., 2005; Thomson *et al*., 2006). This will be beneficial in predicting location and onset of epidemics in Early Warning Systems.

Novel hantaviruses with unknown pathogenic potential have been identified in some insectivores (shrews and a mole) in Africa (Klempa, 2009). Climate change could alter the natural reservoirs of hantaviruses. 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). Exacerbated food insecurity due to climate change could further compromise the poor nutrition of people living with HIV/AIDs (Drimie and Gillespie, 2010). Laboratory studies suggest that the geographic range of the tsetse fly (Glossina species), the vector of human and animal trypanosomiasis in Africa, may be reduced under future scenarios (Terblanche *et al*., 2008).

Heat waves and heat-related health effects are only beginning to attract attention in Africa. Recent studies in West and southern Africa indicate heat-related health effects may be of concern (Dapi *et al*., 2010; Mathee *et al*., 2010).

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 in surface temperature, land cover, and lightning may alter natural sources of ozone precursor gases and consequently ozone levels over Africa (Stevenson *et al*., 2005; Brasseur *et al*., 2006; 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.

22.3.6. Human Security

Human security of people in Africa is particularly threatened by the impacts of climate variability. Adverse climate events impact all aspects of human security, either directly or indirectly (For more details see Chapter 12). Water stress, land use and food security, health security, violent conflicts, changing migration patterns, and human settlements are interrelating issues between climate change and human with particular relevance on the African continent.

22.3.6.1. Economic Security

The ultimate damages of climate change may significantly affect economic growth and the ability to trade (Lecocq and Shalizi, 2007; Ruppel and Ruppel-Schlichting, 2012). The impacts on the agricultural sector in Africa are probably of the most direct and profound nature. In Tanzania, climate volatility could have severe implications for poverty as agriculture accounts for about half of gross production, and employs about 80% of the labor force (Ahmed *et al*., 2011). For Namibia, 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 (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). Ghana's agricultural and economic sector with cocoa being the single most important export product is particularly vulnerable, since cocoa is particularly prone to the effects of a changing climate, which has been central to the country's debates on development and poverty alleviation strategies (WTO Trade Policy Review, 2008; Black *et al*., 2011c). A decline in lake levels in Ghana caused by reduced rainfall over the last 40 years, is another critical aspect with regard to economic development because the demand for power is increasing due to economic growth and hydroelectric power stations generate 80% of Ghana's total national power production (Kuuzegh, 2007; Black *et al*., 2011c).

22.3.6.2. Violent Conflicts

While there seems to be consensus that the environment is only one of several interconnected 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. In sub-Saharan Africa, climate variability is a poor predictor of armed conflict. Instead, African civil wars can be explained by generic structural and contextual conditions: prevalent ethno-political exclusion, poor national economies, and the collapse of the Cold War system (Buhaug, 2010). Other 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). Strong historical linkages exist 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 populations 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) while short-term causes may trigger the outbreak of conflict (Hendrix and Glaser, 2007). Distributional conflicts will arise due to the degradation of natural resources as a result of overexploitation and global warming (Kumssa and Jones, 2010). Such distributional conflicts are, for example, occurring in Somalia, and armed conflict may exacerbate the drought. An important part of the war economy in Somalia, namely the commercial production and export of charcoal resulting in deforestation, is one example of environmental degradation contributing to drought (Kolmannskog, 2010).

22.3.6.3 Migration

Human migration in Africa has social, political, demographic, economic, and environmental drivers, which may operate independently or in combination(Perch-Nielsen *et al.*, 2008; Piguet, 2010; Foresight, 2011; Piguet *et al.*, 2011; Black *et al.*, 2011a; Ruppel, 2012). People migrate either temporarily or permanently, within their country or across borders (Warner *et al.*, 2010; Kälin and Schrepfer, 2012). The evidence base in the field of migration in Africa is both varied and patchy. 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, including 697,066 people 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). 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 (UN-OCAH and IDMC, 2009). With regard to forced migration in sub-Saharan Africa, 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). Even if Africa’s population doubles by 2050 to 2 billion (Lutz and Kc, 2010) and the potential for displacement rises as a consequence of the impact of rapid-onset climate events, recent analyses (Foresight, 2011; Black *et al.*, 2011b) show that 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.

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 emphasize the interaction of climate change, disaster, conflict, displacement, and migration (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 (Black *et al.*, 2011a). The floods of the Zambezi River in Mozambique in 2008 have displaced 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 (Jäger *et al.*, 2009; Warner *et al.*, 2010).

The empirical base for major migration consequences is very weak (Lilleør and Van den Broeck, 2011; Black *et al.*, 2011a; Gemenne, 2011b) and non-existent for international migration (Marchiori *et al.*, 2011). Even across the same climate disaster, the response can vary (Findlay, (2011); Gray, (2011) for Kenya and Uganda; Raleigh, (2011) for the African Sahel States). Mobility is indeed a strategy (not a reaction) to high levels of climatic variation that is characteristic of Africa (Tacoli, 2011) and the specifics of the response are determined by the economic context of the specific communities.

22.3.7. Urbanization

Climate change affects the size and characteristics of rural and urban human settlements in Africa. Urbanization through migration is also leading to new vulnerabilities as new migrants face significant ecological issues including floods, etc. (Seto, 2011). The problems associated with voluntary or involuntary environmentally induced migration to Africa's large and intermediate cities will be exacerbated as a result of 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). African inland cities are threatened by the potential risk of water shortages, damage to infrastructure, and desiccating vegetation due to the impacts of climate change.

The urban population in Africa will treble by 2050, increasing by 0.8 billion (UN DESA, 2010). African countries are experiencing some of the world's highest urbanization rates (UN-Habitat, 2008a). Many of Africa's evolving cities are unplanned and have been associated with the uncontrolled growth of informal settlements, inadequate housing and basic services, and increasing urban poverty (Yuen and Kumssa, 2011).[6]

[FOOTNOTE 6: However, community-driven upgrading may contribute to reducing the vulnerability of such informal areas (for more details see Chapter 8).]

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, may 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 the economies of African urban areas, due to the massive investments needed to create job opportunities and provide infrastructure and services. Basic infrastructure services are not keeping up with urban growth, which has resulted in a decline in the coverage of many services, compared to 1990 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 (Boko *et al.*, 2007; Diagne, 2007; Dossou and Gléhouenou-Dossou, 2007; Douglas *et al.*, 2008; Adelekan, 2010; Kithiia, 2011). The impacts of climate change, which could be seen as one of the key systematic shocks, have the potential to disrupt entire urban systems as well as their sustainability (UN-Habitat, (2010); for further details see Chapter 8).

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 on 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 to 60% of the continent's total GDP, a massive 43% of its urban populations live below the poverty line (Eriksen *et al.*, 2010). Moreover, sub-Saharan African countries have the highest levels of urban poverty in the world (Eriksen *et al.*, 2010).

Squatter and poor areas typically lack provisions to reduce flood risks or to manage 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 sea level rise along coastal zones, which is likely to disrupt economic activities such as tourism, fisheries, and mining. More than a quarter of Africa's population lives within 100 km of the coast and about 12% of the urban population lives in low-elevation coastal zones. 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 *et al*., 2010). Despite being the most developed of Africa's urban areas, coastal cities are particularly vulnerable to sea level rise. Nearly 60% of Africa's total population living in low-elevation coastal zones is urban, representing 11.5% of the region's total urban population (UN-Habitat, 2008a). Because of their large adaptation deficit, African coastal cities are poorly equipped to deal with sea level rise and will be among the most adversely affected, leading to devastating consequences (UN-Habitat, 2008a). All of these climate change impacts affect the poor and vulnerable most severely (Douglas *et al*., 2008; Kithiia, 2011), making climate change one of the greatest developmental challenges facing the continent's cities.[7]

[FOOTNOTE 7: For more details see Chapter 8.]

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). In other words, they have a high adaptation deficit (Satterthwaite et al., (2009); for more details see Chapter 7 and Chapter 8). 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). It is also important to question the appropriateness of hard infrastructural responses such as seawalls and channelized drainage lines that are costly and often maladaptive (Dossou and Gléhouenou-Dossou, 2007; Douglas *et al*., 2008; Kithiia and Lyth, 2011).

The reason for the high level of vulnerability and low adaptive capacity has less to do with climate change (Kithiia, 2011) and more to do with structural factors, particularly local governments with poor capacities and resources. 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 a lack of coordination among government agencies (AMCEN and UNEP, 2006; Diagne, 2007; Dossou and Gléhouenou-Dossou, 2007; Mukheibir and Ziervogel, 2007; Douglas *et al*., 2008; Roberts, 2008; Adelekan, 2010; Kithiia and Dowling, 2010; Kithiia, 2011).

22.4. Adaptation

22.4.1. Introduction

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 (sections 22.4.4 and 22.4.5). However, across the continent, most of the adaptation to climate variability and change is reactive in response to short-term motivations, is occurring autonomously at the individual / household level, and lacks support from government stakeholders and policies (Vermuelen et al., 2008; Ziervogel et al., 2008; Berrang-Ford et al., 2011; Thorn, forthcoming).

22.4.2. Adaptation Needs, Gaps, and Adaptive Capacity

Africa's urgent adaptation needs stem from the continent's foremost vulnerability to climate change and its overall low levels of adaptive capacity (section 22.3). The literature does also highlight a number of inherent adaptation-related strengths in Africa: the continent's wealth in natural resources, well-developed social networks, and longstanding traditional mechanisms of managing variability through, for example, crop and livelihood diversification, migration and small-scale enterprises, all of which are underpinned by local or indigenous knowledge systems for sustainable resource management (Cooper et al., 2008; Nielson, 2010; UNFCCC, 2007; Nyong et al, 2007; Macchi et al., 2008; Castro et al., 2012; Eyong, 2007). However, it is uncertain to what extent these strategies will be capable of dealing with future changes, among them climate change and its interaction with other development processes (van Aalst et al., 2008; Leary et al, 2007; Paavola, 2008; Conway, 2009; Jones, 2011b). Since Africa is extensively exposed to a range of multiple stressors (section 22.3) that interact in complex ways with longer term climate change, adaptation needs are broad, encompassing institutional, social, physical and infrastructure needs, ecosystem services and environmental needs, and financial and capacity needs. Towards elucidating these needs, least developed countries in Africa have used the National Adaptation Plan of Action (NAPA) process to assess vulnerabilities, explore impacts, and identify adaptation priorities (UNFCCC, 2002), and many African countries have conducted technology needs assessments , including Cote d'Ivoire, Ethiopia, Kenya, Ghana, Mali, Morocco, Mauritius, Rwanda, Senegal, Sudan, and Zambia (GEF Evaluation Office, 2011).

Analyses reveal that making climate change information more reliable and accessible is one of the most pressing and cross-cutting adaptation needs. As noted in the AR4 and emphasised in subsequent 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., 2009b; Ziervogel & Zermoglio, 2009; Jalloh, Sarr et al., 2011). Adding to this is the shortage of relevant information and skills, in particular for downscaling climate models and using scenario outputs for development and adaptation planning, which is exacerbated by under-resourcing of Meteorological Agencies and related organisations; and the capacity of civil society and government organisations' to access, interpret and use climate information for planning and decision making (Ziervogel & Zermoglio, 2009; Brown et al., 2010; Ndegwa et al., 2010; Jalloh, Sarr et al., 2011). Information-related needs include additional vulnerability and impact assessments with greater continuity in countries , country-specific socio-economic scenarios, and greater knowledge on costs and benefits of different adaptation measures (UNFCCC, 2007; AAP, 2012).

Given its dependence on natural-resource based economies, most research on strengthening adaptive capacity in Africa is focused on natural resource-based livelihoods, such as agriculture, forestry or fisheries (Collier et al., 2008; Berrang-Ford et al., 2011). In this regard, many African countries have prioritised the following knowledge needs: comprehensive programmes that promote adaptation through a more holistic development approach, including integrated programmes on desertification, water management and irrigation; promoting sustainable agricultural practices and the use of appropriate technologies and innovations to address shorter growing seasons, extreme temperatures, droughts, and floods; developing alternative sources of energy; and approaches to deal with water shortages, food security and loss of livelihoods (AAP, 2012; Sissoko et al 2011; Jalloh and Roy-Macauley, 2011; Bryan et al., 2009; Chikozho, 2010; Eriksen & Silva, 2009, Gbetibouo et al., 2010). The rural emphasis is now being expanded through a growing focus on requirements for enhancing urban adaptive capacity (Lwasa, 2013). 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).

Despite significant data and vulnerability assessment gaps, there is consensus that this should not be used as an excuse to delay action on adaptation (UNFCCC, 2007; Jobbins, 2011). Recent analyses emphasise the significant resources and increased financial, technical and technological support needed to both address Africa's current adaptation deficit and to protect rural and urban livelihoods, societies and economies from climate change impacts at different local scales, with estimates of adaptation costs between US$20-30 billion per annum over the next couple of decades (LDC Expert Group, 2011; Parry et al, 2009a; Fankhauser and Schmidt-Traub, 2010; Watkiss et al, 2010; AfDB, 2011; Dodman and Carmin, 2011; Smith et al, 2011).

22.4.3. Adaptation, Equity, and Sustainable Development

Multiple uncertainties in the African context mean that successful adaptation will depend upon developing resilience in the face of uncertainty (Conway, 2011). 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 (high confidence) (Bauer and Scholz, 2010; Smith et al., 2011). As adaptation and local adaptive capacity are affected by inequalities, an effective adaptation response necessitates differentiated and targeted actions from the local to national levels, given the differentiated social impacts based on gender, age, disability, ethnicity, geographical location, livelihood, and migrant status of climate change (Tanner and Mitchell, 2008; IPCC, 2012). While adaptation efforts in Africa have not sufficiently prioritized equity and social justice, including the differential distribution of adaptation benefits and costs (Burton et al, 2002;

Thomas and Twyman, 2005; Madzwamuse, 2010), some valuable experience has been gained recently on gender equity in adaptation, human rights based-approaches, and involvement of vulnerable or marginalized groups such as indigenous peoples and children, aged and disabled people, internally displaced persons and refugees (Unicef, 2010; Unicef, 2011; Tanner and Seballos, 2012; Romero González et al., 2011; IDS, 2012; African Development Forum, 2010; Levine et al., 2011) (Table 22-4).

[INSERT TABLE 22-4 HERE
Table 22-4: Cross-cutting approaches for equity and social justice in adaptation.]

22.4.4. Experiences in Building the Governance System for Adaptation, and Lessons Learned

22.4.4.1. Introduction

Section 22.4 assesses progress made in developing policy, planning and institutional systems for climate adaptation at regional, national and sub-national levels in Africa. This includes an assessment of community-based adaptation, as an important local level response, and a consideration of adaptation decision making and monitoring.

22.4.4.2. Regional and National Adaptation Planning

While regional policies and strategies for adaptation, as well as transboundary adaptation, are still in their infancy, sub-regional institutions have begun to formulate strategies for climate change. For example, the Southern African Development Community and the Lake Victoria Basin Committee are developing Climate Change Strategies and Action Plans, and efforts are being made by six highly-forested Congo basin countries (Cameroon, Central African Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon, and the Republic of Congo) to coordinate conservation and sustainable forest management of the Central African forest ecosystem, and obtain payments for ecosystem services (Harmeling et al, 2011; African Development Bank, 2012).

At the national level, African countries have initiated comprehensive planning processes for adaptation by developing National Adaptation Programmes of Action (NAPAs) or National Climate Change Response Strategies (NCCRS); implementation is, however, lagging and integration with economic and development planning is limited but growing (high confidence). As of December 2011, 32 Least Developed Countries in Africa had developed NAPAs, with the exception of Equatorial Guinea and Somalia. Prioritized adaptation measures in the NAPAs tend to focus on agriculture, food security, water resources, forestry, and disaster management; and on technical solutions, education and capacity development, although some do include ecosystem response measures (Madzwamuse, 2010; Mamouda, 2011; Pramova et al, 2012). Constraints identified with the NAPAs and some of the NCCRS include a relatively narrow focus on biophysical vulnerabilities and sectoral or project approaches, which limits an integrated cross-sectoral adaptation response; inadequate inclusion of the adaptation needs of vulnerable societal sectors; no or little inclusion of energy adaptation; de-linkage from economic planning and poverty reduction processes; and little facilitation of investment funding - only a small percentage of the NAPA activities have been funded (Romero Gonzalez et al, 2011; Mamouda, 2011; Prowse et al, 2009; Madzwamuse, 2010).

Subsequent to the NAPAs and early experience with the NCCRS, there is some evidence of evolution to a more integrated, multi-level and multi-sector approach to adaptation planning (medium confidence): Ethiopia's Programme of Adaptation to Climate Change deals with adaptation at sectoral, regional, national and local community levels (Hunde, 2012); Lesotho is developing a coordinated policy framework involving all ministries and stakeholders (Corsi et al., 2012); and cross-sectoral adaptation planning and risk management is occurring through mainstreaming initiatives like the twenty country Africa Adaptation Programme (AAP), initiated in 2008 (UNDP, 2009; UNDP, 2010). Examples of the more programmatic approach of national climate resilient development strategies include Rwanda's National Strategy on Climate Change and Low Carbon Development, under development in 2012, and the Pilot Programmes for Climate Resilience in Niger, Zambia and Mozambique (Climate Investment Fund, 2009). Inter-sectoral climate risk management approaches can be detected in integrated water resources management, disaster risk reduction, and land use planning initiatives, while studies have highlighted the role of integrated coastal zone management in reducing the vulnerability of coastal towns to climate change and particularly coastal flooding (Koch et al, 2007; Boateng, 2006; Cartwright *et al.*, 2008; Awuor *et al.*, 2008; Kebede *et al.*, 2012; Kebede and Nicholls, 2011). Concerning spatial planning, climate change design principles have been incorporated into existing systematic biodiversity planning to guide land use planning in South Africa (Petersen and Holness, 2011).

Adaptation planning is occurring within efforts to construct enabling national policy environments for adaptation in many countries. Examples include Namibia's National Policy on Climate Change (IIED, 2011b); Zambia's National Climate Change Response Strategy and Policy, and South Africa's Draft National Climate Change Response Green Paper in November 2010. Ten countries were developing new climate change laws or formal policies at the end of 2012, including the proposed National Coastal Adaptation Law in Gabon (Corsi et al., 2012).

Despite this progress in mainstreaming climate risk in policy and planning, significant disconnects still exist at the national level, and implementation of a more integrated adaptation response remains tentative (high confidence) (Koch et al, 2007; Madzwamuse, 2010; Fankhauser and Schmidt-Traub, 2010; Oates et al, 2011; UNDP-UNEP Poverty-Environment Initiative, 2011b). 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). While climate resilience is starting to be mainstreamed into economic planning documents - for example, Zambia's Sixth National Development Plan 2011-2015, and the new Economic and Social Investment Plan in Niger (Corsi et al., 2012) - 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),while poor business environments impede both foreign direct investment and adaptation (Collier et al, 2008). National policies are often at odds with autonomous local adaptation strategies, which can act as a barrier to adaptation, especially where cultural, traditional and context-specific factors are ignored (Stringer et al., 2009; Patt and Schroter, 2008; Dube and Sekhwela, 2008; Hisali et al, 2011). National adaptation planning has placed little attention on integrating forests into programmes and strategies compared to mitigation (Bele et al. 2010; Kalame et al. 2011; Sonwa et al. 2012), despite opportunities for enhancing adaptation through forest governance reforms to improve community access to forest resources (Kalame et al. 2008).

22.4.4.3. Institutional Frameworks for Adaptation

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 (Chapter 14). Regional institutions focused on specific ecosystems rather than on political groupings, such as the Commission of Central African Forests (COMIFAC), present an opportunity to strengthen the institutional framework for adaptation. National frameworks include a number of institutions that cover all aspects of climate change, not just adaptation: most countries have inter-ministerial coordinating bodies and inter-sectoral technical working groups, while an increasing number of countries have established multi-stakeholder co-ordinating bodies, including Kenya, South Africa, Senegal and Tanzania (Harmeling et al, 2011). National institutions for climate finance are being established to manage international and domestic funding and encourage mainstreaming into national plans, including the National Implementing Entities in terms of the Adaptation Fund, and national funds to serve as conduits for all sources of climate change funding (Gomez-Echeverri, 2010; Smith et al, 2011).

Under uncertain climatic futures, hierarchical governance systems that operate within siloes 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., 2010a; Plummer, 2012). Despite some progress with developing the institutional framework for governing adaptation, there are significant problems with both transversal and vertical coordination, including institutional duplication with other inter-sectoral platforms, such as those set up for disaster risk reduction; while in fragile states, institutions for reducing climate risk and promoting adaptation may be extremely weak or almost non-existent

(Bettencourt, 2011; Belay Simane et al, 2012; Sietz et al, 2011; Hartmann and Sugulle, 2009). Facilitating institutional linkages and coordinating responses across all boundaries of government, private sector and civil society would enhance adaptive capacity (Brown et al., 2010).

22.4.4.4. Sub-National Adaptation Governance

Since AR4, there has been additional effort on adaptation planning at sub-national and local levels in African countries, but adaptation strategies at provincial and municipal levels are mostly still under development, with many local governments lacking the capacity and resources for the necessary decentralised adaptation response (high confidence). Provinces or states in some countries have developed policies and strategies on climate change: for example, in Nigeria, Delta State developed a Climate Change Policy in 2010, and Lagos State an Adaptation Strategy in 2012 (BNRCC, 2012). Adaptation has been integrated into five district development plans in Ghana, and Morocco's government has approved four communal climate change resilience plans (Corsi et al., 2012). Promising approaches include sub-national strategies that integrate adaptation and mitigation in a low-carbon climate resilient development approach, as is being done in Delta State in Nigeria, Mbale Region in Uganda, and several regions in Senegal, with similar plans for regions of Kenya, South Africa, Burkina Faso, Ivory Coast, Namibia and Egypt (UNDP, 2011b). In response to the identified institutional weaknesses, capacity development has been implemented in many cities and towns, including initiatives in Lagos, Nigeria, Durban and Cape Town in South Africa: notable examples include Maputo's specialized local government unit to implement climate change response, ecosystem-based adaptation and improved city wetlands; and participatory skills development in integrating community-based disaster risk reduction and climate adaptation into local development planning in Ethiopia (Madzwamuse, 2010; ACCRA, 2012; Broto, Vaesa, et al. 2013).

22.4.4.5. Community-Based Adaptation

Since AR4, there has been considerable progress in Africa in implementing and researching community-based adaptation (high confidence), with broad agreement that support to local-level adaptation is best achieved by starting with existing local adaptive capacity, and incorporating and building upon present coping strategies, including indigenous practices (Archer et al, 2008; Dube & Sekhwela, 2007; Huq, 2011). Some relevant initiatives include the Community-based Adaptation in Africa (CBAA) project, which supported three-year climate change adaptation pilot projects at community level in eight African countries (Sudan, Tanzania, Uganda, Zambia, Malawi, Kenya, Zimbabwe, South Africa), implemented as a learning-by-doing approach; and the Adaptation Learning Program, implemented in Ghana, Niger, Kenya and Mozambique (Care International, 2012). The literature includes a wide range of case studies detailing involvement of local communities in adaptation initiatives and projects facilitated by NGOs and researchers (for example, Leary et al, 2008; CCAA, 2011; Care International, 2012); these and other initiatives have generated process-related lessons (section 22.4.5), with positive assessments of effectiveness in improving adaptive capacity of African communities, local organisations and researchers (Lafontaine et al, 2012). Local adaptation planning using participatory scenario development workshops in Mozambique, Ghana, and Ethiopia has revealed the following priorities for pro-poor adaptation: social protection, services and safety nets; better water and land governance; enhanced water storage and harvesting; better post-harvest services; strengthened civil society and greater involvement in planning; and more attention to urban and peri-urban areas heavily affected by migration of poor people (Bizikova et al, 2010).

22.4.4.6. Adaptation Decisionmaking and Monitoring

Emerging patterns regarding adaptation decision-making in Africa include limited inclusive governance at the national level, while some local level initiatives have achieved greater involvement, including of vulnerable and exposed people, in assessing and choosing adaptation responses (high confidence). Civil society institutions and communities have to date played a limited role in formulation of national adaptation policies and strategies, highlighting the need for governments to widen the political space for citizens and institutions to participate in decision-making, for both effectiveness and to ensure rights are met (Madzwamuse, 2010; Castro et al, 2012).

Building African leadership for climate change may assist with this (Climate Change Adaptation in Africa Programme, 2011; Chandani, 2011; Corsi et al., 2012). 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; Conway, 2011). The importance of understanding how local knowledge forms the "knowledge frame" through which scientific forecasts are interpreted has been emphasised (Roncoli *et al.* 2009; Ifejika Speranza *et al.*, 2010; Newsham and Thomas, 2011).

The range of tools used in adaptation planning in Africa includes vulnerability assessment using various mapping techniques (section 22.4.5), risk assessment, cost-benefit analysis, cost-effectiveness, multi-criteria analysis, and participatory scenario planning. In Ghana, the Akropong Approach was developed to assess inter-relationships between sectoral adaptation options; multi-criteria analysis was used to evaluate and rank the options in the development of the National Climate Change Adaptation Strategy (Kemp-Benedict and Agyemang-Bonsu, 2008). Cost-benefit analysis was used to inform water management decisions for the Berg River basin in South Africa (Callaway et al, 2008) and in uplands of The Gambia to evaluate increased fertilizer use against adoption of irrigation in cereal cultivation (Njie et al, 2008). Adaptation decision making in the coastal zone in South Africa has encompassed cost benefit analysis decision tools, and modeling and mapping the combined effects of sea level rise and coastal storm surge (Cartwright *et al.*, 2008; Mather and Stretch, 2012). Innovative approaches include using participatory scenario planning in Ghana and Kenya (CARE, 2012), and developing an online interactive disaster management decision support system as part of the national adaptation response in Mozambique (Corsi et al., 2012).

Monitoring and assessing adaptation is still in its infancy in Africa, with national coordinating systems for collating data and synthesizing lessons not in place. Local-level monitoring of adaptation actions takes place at the project level: a positive community-based adaptation example in the Koue Bokkeveld, South Africa, approaches monitoring through a participatory action research framework, combined with integrating climate projections, local monitoring of climate variables and collaborative assessment of coping/adaptation actions (Archer et al., 2008).

22.4.5. Experiences with Adaptation Measures in Africa and Lessons Learned

22.4.5.1. Overview

Section 22.4.5 provides a cross-cutting assessment of experience gained in Africa with a range of adaptation approaches, encompassing climate risk reduction measures; processes for participatory learning and knowledge development and sharing; communication, education and training; ecosystem-based measures; and technological and infrastructural approaches; concluding with a discussion of maladaptation.

Common priority sectors across countries for implementing adaptation measures since 2008 include agriculture, food security, forestry, energy, water, and education (Corsi et al., 2012), which reflect a broadening of focus since the AR4. While there has been little planning focus on regional adaptation (Sections 22.4.4.2 and 22.4.4.3), the potential has been recognized for regional approaches to adaptation, such as the West African program on coastline change and adaptation (Niang, 2012) and the Congo Basin Forest and Climate Change Adaptation initiative (Sonwa et al., 2009) to catalyze effective collaboration between African countries (UNFCCC, 2007).

Research has highlighted that no single adaptation strategy exists to meet the needs of all communities and contexts in Africa (high confidence). In recognition of the socioeconomic dimensions of vulnerability (Bauer and Scholz, 2010), the previous focus on technological solutions to directly address specific impacts is now evolving toward 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 multiple livelihood–vulnerability risks faced by many people in Africa (Tschakert and Dietrich, 2010) . 'Soft path' measures are seen as holding promise for adaptation strategies (Martens et al., 2009).

Attention is increasing on identifying opportunities inherent in the continent's adaptation needs, as well as delineating key success factors for adaptation. A number of studies identify the opportunity inherent in implementing relatively low-cost and simple low-regrets adaptation measures that reduce people's vulnerability to current climate variability, have multiple developmental benefits, and are likely to reduce vulnerability to longer-term climate change as well (UNFCCC, 2007; Conway and Schipper, 2011; see also Section 22.4.3). Responding to climate change provides an opportunity to enhance awareness that maintaining ecosystem functioning underpins human survival and development in a most fundamental way (Shackleton and Shackleton, 2011), and to motivate for new development trajectories (section 22.4.6). While it is difficult to assess adaptation success, given temporal and spatial scale issues, and local specificities, Osbahr et al. (2010) highlight the role of social networks and institutions, social resilience, and innovation as possible key success factors for adaptation in small-scale farming livelihoods in southern Africa.

The following discussion of adaptation approaches under discrete headings does not imply that these are mutually exclusive – adaptation initiatives usually employ a range of approaches simultaneously.

22.4.5.2. Climate Risk Reduction, Risk Transfer, and Livelihood Diversification

African countries have gained experience in a range of approaches to offset the impacts of natural hazards on individual households, communities, and the wider economy, through the following risk reduction strategies: early warning systems, emerging risk transfer schemes, social safety nets, disaster risk contingency funds and budgeting, livelihood diversification, and migration as an adaptive response (World Bank, 2010; UNISDR, 2011). Figure 22-7 shows an assessment of Africa’s present and near term risks and risks at the end of the century for 2 temperatures (2°C and 4°C for 2080-2100), and the role of adaptation in reducing those risks.

[INSERT FIGURE 22-7 HERE
Figure 22-7: Risks for the present (blue line), for the near-term (2°C for 2030-2040) and for the end of the century for 2 temperatures (2°C and 4°C for 2080-2100). Risks are depicted for low adaptation and high adaptation.]

Disaster risk reduction (DRR) platforms are being built at national and local levels (Westgate, 2010), with the synergies between DRR and adaptation to climate change being increasingly recognized in Africa (UNISDR, 2011). At the policy level, the shift toward more proactive risk management can be seen in Ethiopia’s updated Disaster Risk Management policy, which also emphasizes decentralized and community-based actions (Hunde, 2012), although Conway and Schipper (2011) find that additional effort is needed for a longer-term vulnerability reduction perspective in disaster management institutions.

Early warning systems (EWS) are gaining prominence as multiple stakeholders strengthen capabilities to assess and monitor risks and warn communities of a potential crisis. The operation of regional systems such as the Permanent Inter-States Committee for Drought Control in the Sahel (CILSS) and the Famine Early Warning System Network (FEWS-NET) are seen as crucial for adaptation (Sissoko et al., 2011) . National, local, and community-based EWS on food and agriculture, such as in Niger, Mauritania, Ethiopia, and Burkina Faso, aim to support an effective response to food, nutritional, and pastoral crises (FAO, 2012; Pantuliano and Wekesa 2008). Some of the recent EWS emphasise a gendered approach, and may incorporate local knowledge systems used for making short-, medium-, and long-term decisions about farming and livestock-keeping, as in Kenya (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 example, conditions expected to lead to an outbreak of Rift Valley fever were predicted and a 2 to 6 week warning provided, prior to the occurrence in the Horn of Africa from December 2006 to May 2007(Ayamba, 2006), and progress has been made in prediction of meningitis and in linking climate/weather variability and extremes to the disease, which will be useful in adaptation planning and implementation (Thomson et al., 2006: Cuevas et al., 2007; Irving et al., 2011).

Local projects often use participatory vulnerability assessment methods in the design of adaptation activities (Van Vliet, 2010; GEF Evaluation Office, 2011), but vulnerability assessment at the local government level is often lacking, and assessments to develop national adaptation plans and strategies have not always been conducted in a participatory fashion (Madzwamuse, 2010). Lessons from vulnerability analysis highlight that the highest exposure and risk do not always correlate with vulnerable ecosystems, socially marginalized groups, and areas with at-risk infrastructure, but may also lie in unexpected segments of the population (Moench, 2011).

Various community-level DRR initiatives have focused on resilience-building activities that highlight the links between strengthening food security and household resilience, and delivery of environmental conservation, asset creation, and infrastructure development objectives and co-benefits (Parry et al., 2009b; UNISDR, 2011; Frankenberger et al., 2012). Food security and nutrition-related safety nets and social protection mechanisms can mutually reinforce each other to enhance disaster risk management and climate adaptation, as is being carried out in the Karamoja Productive Assets Programme in Uganda (Government of Uganda and WFP 2010; WFP, 2011). 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). Haan et al. (2012) highlight the need for increased donor commitment to the resilience-building agenda within the framework of DRR, based on lessons from the Somalia 2011 famine.

Implementation of effective national and local instruments to offset the impact of natural hazards in Africa, notably concerning social protection and insurance, has been increased. Social protection, a key element of the African Union social policy framework, can include social transfers (cash or food), minimum standards such as for child labor, and social insurance, and is being used in Ethiopia, Rwanda, Malawi, Mozambique, South Africa, and other countries to buffer against the impacts of shocks and disasters by building assets and increasing household resilience of both chronically and transiently poor people (Brown et al., 2007; Heltberg et al. 2009). Examples of social protection systems aimed at moving beyond repeated relief interventions to address *inter alia* slower onset climate shocks are Ethiopia's Productive Safety Net Program (PSNP), the largest social protection program in Africa (Brown et al., 2007), and Rwanda's Vision 2020 Umurenge Program (VUP). There is evidence that social protection is helping with *ex post* and *ex ante* DRR, and that such systems will be increasingly important as a safety net and for securing livelihoods under increasing climate variability, but less evidence exists for the effectiveness of social protection against the most extreme climatic shocks, which requires adaptive strategies that reduce dependence on climate sensitive livelihood activities (Davies et al., 2009; Wiseman et al., 2009; Pelham et al., 2011; Béné et al., 2012). Social protection initiatives could contribute more to building adaptive capacity if based on improved understanding of the structural causes of poverty, including political interests and institutional dimensions (Brown et al., 2007; Davies et al., 2009; Levine et al., 2011).

A number of different mechanisms are used by communities and individuals to spread risk in the African context: kinship networks; community funds; and disaster relief and insurance, which can provide financial security against extreme events such as droughts, floods, and tropical cyclones, and concurrently reduce poverty and enhance adaptive capacity[8] (Leary et al., 2008; Linnerooth-Bayer et al. 2010; Coe and Stern, 2011). Contingency planning at national and local levels, for example for drought, is an important element of risk reduction processes, although this may be hampered by not being linked to sustainable contingency funds (Lesukat, 2012). In Ethiopia, an integrated national risk management framework is being developed through the Livelihoods, Early Assessment and Protection (LEAP) project, an innovative early warning–early action tool that supports the PSNP, including a US$ 160 million contingency fund, which will promote drought risk management. Recent developments in the insurance sector in Africa include the emergence of index-based insurance contracts (Box 22-1), which pay out not with the actual loss, but with a measurable event that causes loss.

[FOOTNOTE 8: Climate (or disaster) risk financing instruments include contingency funds; agricultural and property (private) insurance; sovereign insurance; reallocation of program expenditures; weather derivatives; and bonds.]

_____ START BOX 22-1 HERE _____

Box 22-1. 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 1,710 farmers and stimulating interest among banks, financiers, and supply chain participants such as processing and trading companies and input suppliers. 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. 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 that 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), which makes insurance affordable to the most marginalized and resource-poor sectors of society.

_____ END BOX 22-1 HERE _____

The challenges associated with current risk reduction strategies include communication challenges related to EWS: conveying useful information in local languages; communicating EWS in remote areas; national-level mistrust of locally collected data, which are perceived to be inflated to leverage more relief resources (Hellmuth et al., 2007; Pantuliano and Wekesa, 2008; Cartwright, 2008b; FAO, 2011); the call for improved user-friendliness of early warning information; and the need for better linkages between early warning, response, and prevention (Haan et al., 2012).

Evidence is increasing that livelihood diversification, long used by African households to cope with climate shocks, can also assist with building resilience for longer term climate change by spreading risk. 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; IIED, 2011a). Motsholapheko et al. (2011) show how livelihood diversification is used as an adaptation to flooding in the Okavango Delta, Botswana, and Badjeck et al. (2010) recommend private and public insurance schemes to help fishing communities rebuild after extreme events, and education and skills upgrading to enable broader choices when fishery activities can no longer be sustained..

While livelihood diversification is an important adaptation strategy, it may replace formerly sustainable practices with livelihood activities that have negative environmental impacts (Section 23.4.5.8). Diversification at the national level is also required, especially where there is dependence on a single cash crop, such as cocoa cultivation in Ghana, which is highly vulnerable to the negative effects of climate change (UNFCCC, 2007).

Rural finance and micro-credit are seen as enabling activities for adaptive response, which are also used by women for resilience-building activities (e.g., as documented in Sudan by Osman-Elasha et al., 2006). Credit and storage systems are instrumental to support families during the lean period, to prevent the sale of assets to buy food when market prices are higher (Romero Gonzalez et al., 2011). Long seen as a fundamental process for most African families to incorporate choice into their risk profile and adapt to climate variability (Goldstone, 2002; Urdal, 2005; Reuveny, 2007; Fox and Hoeshler, 2010), there is evidence in some areas of the increased importance of migration and trade for livelihood strategies, as opposed to subsistence agriculture, as shown by Mertz et al. (2011) for the Sudano-Sahelian region of West Africa. Migration involves complex decision making and often supports adaptation to climate change, and may unlock diverse and innovative responses through the role of migrant social institutions (Scheffran et al., 2011; McLeman and Smit, 2006; Scheffran et al., 2012). However, climate-forced migration can exacerbate environmental degradation (e.g., on the Sahel margins) and accelerate land use changes with potential feedbacks to local climate, which can in return increase vulnerability (citations).

22.4.5.3. Adaptation as a Participatory Learning Process

Since AR4, there has been more focus on the importance of flexible and iterative learning approaches for effective adaptation (medium evidence, medium agreement). Learning approaches under investigation in Africa include action research, participatory adaptation planning, and adaptive management. Due to the variety of intersecting social, environmental, and economic factors that affect societal adaptation, governments, communities, and individuals (Jones et al., 2010; Jones 2011), adaptation is increasingly recognized as a complex process involving multiple linked steps at several scales, rather than a series of simple planned technical interventions (Moser and

Ekstrom 2010). Implementing adaptation as a participatory learning process enables people to adopt a proactive or anticipatory stance to avoid 'learning by shock' (Tschakert and Dietrich, 2010).

A number of adaptation initiatives in Africa emphasize the importance of iterative and experiential learning for a flexible adaptation planning, required to deal with the uncertainty inherent in climate projections, compounded by other sources of flux that affect populations in Africa, and the desirability of adjusting approaches based on lessons learned, through a participatory learning-by-doing or experiential learning modality (Suarez et al., 2008; Koelle and Annecke, undated; Dodman and Carmin, 2011; Huq, 2011). Many studies have highlighted the utility of participatory action research, multi-stakeholder dialogue, and experiential learning for managing uncertainty and leading to the social and behavioral change required for adaptation (e.g., Ziervogel and Opere, 2010; Bizikova et al., 2010); CCAA, 2011; Ebi et al., 2011; Faysse et al., 2012; Thorn, forthcoming). Transdisciplinary approaches are also starting to be adopted, as for example in the urban context (Evans, 2011). Learning approaches for adaptation may involve co-production of knowledge – such as combining local and traditional knowledge with science (Section 22.4.5.4).

Recent analyses highlight the importance of social learning and collective action to promote adaptation, and the need to create safe or enabling spaces for multi-stakeholder civic engagement for the adaptation learning process (UNDP/UNEP Poverty-Environment Initiative, 2011a; Tompkins and Adger, 2003). 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. Plummer (2012) points out the potential for adaptive co-management[9] to develop capacity to deal with change, which is relevant for climate change adaptation. Some experience is being gained on the implications of the strategic adaptive management approach for adaptation in aquatic protected areas in South Africa (Kingsford et al., 2011).

[FOOTNOTE 9: Adaptive co-management is understood as "a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of learning-by-doing" (Folke et al., 2002).]

Caveats and constraints to viewing adaptation as a participatory learning process include the time and resources required from both local actors and external facilitators, the challenges of multidisciplinary research, the politics of stakeholder participation and the effects of power imbalances, and the need to consider not only the consensus approach but also the role of conflicts (Tschakert and Dietrich 2010; Aylett, 2010; Shankland and Chambote, 2011; Jobbins, 2011; Beardon and Newman, 2011). Learning throughout the adaptation process necessitates additional emphasis on ways of sharing experiences between communities and other stakeholders, both horizontally and vertically (Section 22.4.5.4).

The increased emphasis on the importance of innovation for successful adaptation, in both rural and urban contexts, relates to interventions that employ innovative methods, as well as the innovation role of institutions (Tschakert and Dietrich, 2010; Scheffran et al., 2012; Dodman and Carmin, 2011; Rodima-Taylor, 2012). While relevant, high-quality data is important as a basis for adaptation planning, innovative methods are being used to overcome data gaps, particularly local climatic data and analysis capability (Tschakert and Dietrich, 2010; GEF Evaluation Office, 2011). Scheffran et al. (2012) show the role of institutional innovation triggered by migration in response to climate threats in the western Sahel, in which communities and migrants are seen as active social agents, with migrant social organizations initiating innovations across regions by transferring technology and knowledge, as well as remittances and resources. Innovative indigenous adaptation measures on the part of Niger Delta communities are documented by Nzeadibe et al. (2012).

22.4.5.4. Knowledge Development and Sharing

Since AR4, attention to the importance of knowledge development and sharing for enhancing adaptation responses has increased. Key areas investigated include bridging the gap between scientific knowledge and policy; the potential of local and traditional knowledge for informing climate risk management in Africa; and developing multi-stakeholder platforms for knowledge sharing, including regional collaboration**.** Recent literature has confirmed the positive role of local and traditional knowledge in building resilience and adaptive capacity, and shaping responses to climatic variability and change in Africa. Despite 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).

Because adaptation in most African contexts is autonomous, choosing specific adaptation actions needs to be informed by farmer's perceptions and be supported by accurate climate information, relevant to the scale where decisions are made (Vogel and O'Brien, 2006; Ziervogel et al., 2008; Bryan et al., 2009; Godfrey et al., 2010). Key problems regarding how science can inform decisionmaking 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 decisionmaking; and how to support scientists to provide information that is accessible by practitioners (Vogel et al., 2007; Hirsch Hadorn et al., 2008). Institutional innovation is one solution: for example, Nigeria established the Science Committee on Climate Change to develop strategies to bridge the gap between increasing scientific knowledge and policy to support Nigeria's goals of economic transformation (Corsi et al., 2012).

Interest is increasing and information is growing 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. The recent report on extreme events and disasters (IPCC, 2012) supports this view, finding high agreement and robust evidence of the positive impacts of integrating indigenous and scientific knowledge for adaptation. Local knowledge continues to play an important role in adaptation to climate variability and change in Africa, helping communities to select the most appropriate adaptive or coping mechanisms (Nyong et al., 2007; Osbahr et al., 2007; Ifejika Speranza et al., 2010; Goulden et al., 2009b; Jalloh and Roy-Macauley, 2011; Newsham and Thomas, 2011). Concerns about the future adequacy of local knowledge to respond to climate impacts within the multi-stressor context include the decline in intergenerational transmission; a perceived decline in the reliability of local indicators for variability and change, as a result of socio-cultural, environmental, and climate changes (Hitchcock 2009; Jennings and Magrath 2009); and challenges of the emerging and anticipated climatic changes seeming to overrun indigenous knowledge and coping mechanisms of farmers (Berkes, 2009; Ifejika Speranza et al., 2010; Jalloh and Roy-Macauley, 2011). Based on analysis of the responses to the Sahel droughts during the 1970s and 1980s, Mortimore (2010) argues that local knowledge systems are more dynamic and robust than what is often acknowledged.

Linking indigenous and conventional climate observations can add value to climate change adaptation within different local communities in Africa (Nyong et al., 2007; Chang'a et al., 2010; Roncoli et al., 2002). In Western Kenya, scientists work with local rainmakers to develop consensus forecasts, developed by harmonizing downscaled seasonal forecasts with traditional predictions, which are then disseminated in local languages by radio and at community events (Guthiga and Newsham, 2011). 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).

Evidence is growing of the importance of multi-stakeholder platforms for sharing experiences and developing collaborative adaptation responses. Drawing on a transboundary project in the Congo Basin, Tata et al. (2012) highlight the importance of encouraging and monitoring multi-actor negotiation and collaboration processes in order to infer and mitigate future complexities in the process. In Kenya and Ghana, participatory scenario planning has been used as a multi-stakeholder platform for adaptation dialogue, and has been effective in achieving local ownership of flexible adaptation decisionmaking, including through improved relationships between local actors and meteorologists (CARE, 2012).

Knowledge sharing between the many innovative adaptation management programs and projects in Africa is hampered by the lack of platforms to share knowledge on adaptation practices within and between countries. While knowledge management in adaptation interventions has evolved (AAP, 2012), and includes a number of web-based platforms, more comprehensive and proactive systems for knowledge sharing are needed, including institutionalized platforms at the national level (GEF Evaluation Office, 2011).

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; Ensor and Berger, 2009; Nielsen and Reenberg, 2010; Jones, 2011).

Studies show that integrating cultural components such as stories, myths, and oral history into initiatives to document local and traditional knowledge is a key to better understanding how climate vulnerability and adaptation are framed and experienced (Urquhart, 2009; Ford et al.,.2011; Beardon and Newman, 2011). 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 labor 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, limiting women's adaptive capacity in many parts of Africa (Davis, 2010; Roncoli et al., 2009; see also section 22.4.5.9).

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, appropriate and equitable processes of participation and communication between scientists and local people are required (Nyong et al., 2007; Orlove et al., 2010; Crane, 2010).

22.4.5.5.Communication, Education, and Training

Enhanced support for communication, education, and training is required to raise awareness and empower people to understand the manifestations of climate change and for behavioral change. Systemic causes of knowledge gaps have been identified in parliamentarian's understanding of climate threats and responses, such as limited access to parliamentary researchers and even to the internet (IIED, 2011b). There has been additional experience with civil society-driven approaches to advocacy and raising awareness about climate change and the need for adaptation (Reid et al., 2010; CCAA, 2011), with examples including youth ambassadors in Lesotho and civil society organizations in Tanzania (Corsi et al., 2012). Some evidence exists of the effectiveness of children as communicators and advocates for behavioral and policy change for adaptation to climate change (Section 22.4.3).

Capacity development to enhance understanding of climate impacts and adaptation measures has been undertaken by a range of institutions, such as regional and national research institutes, international and national programs and non-governmental organizations, and agencies of the United Nations (UNFCCC, 2007; START, 2011). Training and capacity development components are usually included in most adaptation interventions, sometimes within a gender-sensitive approach, and targeting youth (e.g., Figueiredo and Perkins, 2012). However, progress on inclusion of climate change into formal education is mixed. A number of countries have integrated climate change into educational curricula to increase awareness, while in Nigeria, climate change adaptation is becoming an educational priority (UNFCCC, 2007; Corsi et al., 2012), and this has been pursued through project-level approaches. However, integration of climate change into educational curricula occurs within the relatively low priority given to environmental and sustainable development education in most countries, as documented for the SADC (Mukute et al., 2012).

Innovative methods are being used to understand and communicate climate change: photo stories, oral history videos, drama, radio, television, festivals, involvement of youth, the use of participatory video in communicating community-based adaptation within and between communities, and influencing policy decisions. Harvey (2011) showed the usefulness of public education using community radio, video, and participation approaches to provide information about community-level adaptation initiatives, while Chikapa (2012) found that radio, cinema, and vernacular publications were critically important in enhancing community-based adaptation to climate change in Malawi. In Malawi and Mozambique, video and participatory approaches increased the accessibility of health risk management to local decisionmakers (Suarez et al., 2008). The role of the media in communication and awareness raising has been highlighted, including through a media capacity building project across 20 countries (Corsi et al., 2012).

Considerable effort is still required to raise awareness of the diverse range of stakeholders at all levels on the different aspects of climate change (Niang, 2007; Simane et al., 2012). Better evidence-based communication processes will enhance awareness of climate change and available responses for both policymakers and community-level development workers. This requires bringing together multiple users and producers of both scientific and local knowledgein a trans-disciplinary process (Hirsch Hadorn et al., 2008; Koné et al., 2012; Ziervogel et al., 2008) to achieve a better understanding of the dimensions of the problem, including its multiple causes and political context (Vogel et al., 2007).

22.4.5.6. Ecosystem Services, Biodiversity, and Natural Resource Management

There is increasing evidence that Africa's longstanding experiences with natural resource management and utilization of biodiversity can be harnessed for effective adaptation responses (high confidence). Relevant experiences include using mobile grazing to deal with both spatial and temporal rainfall variability in the Sahel (Djoudi et al., 2012); reducing the negative impacts of drought and floods on agricultural and livestock-based livelihoods through forest goods and services in Mali, Tanzania, and Zambia (Robledo et al., 2011); ensuring food security and improved livelihoods for indigenous and local communities in West and Central Africa through the rich diversity of plant and animal genetic resources (Jalloh and Roy-Macauley, 2011). Different ecosystem-based responses of value for reducing vulnerability include coastal and inland afforestation, rangeland regeneration, catchment rehabilitation, community forestry, and other forms of community-based natural resource management (CBNRM).

The responsibility placed on local stakeholder institutions for CBNRM, which enables a more flexible response to changing climatic conditions, embodies a supportive approach for local adaptation strategies; CBNRM is also a vehicle for for improving links between ecosystem services and poverty reduction, to enable sustainable adaptation approaches (Shackleton et al., 2010; Chishakwe et al, 2012; Girot et al, 2012). Forests provide valuable safety nets for women: when drought affects agriculture, vulnerable women in many African countries assure their livelihoods by using different forest products such as charcoal and non-timber forest products (Brown, 2011; Paavola, 2008). Based on an analysis of lessons learned in Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe, Chishakwe et al (2012) point out the synergies between CBNRM and adaptation at the community level.

Natural resource management practices that address desertification can also serve as adaptation measures 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 (Box 22-2) and water harvesting. Water harvesting practices[10] have increased soil organic matter, improved soil structure, and increased agricultural yields at sites in Burkina Faso, Mali, Niger, and elsewhere, and are used by 60% of farmers in one area of Burkina Faso (Fatondji et al., 2009; Vohland and Barry, 2009; Barbier et al., 2009; Larwanou and Saadou, 2011). Although these and other practices serve as adaptations to climate change, revenue generation and other concerns may outweigh climate change as a motivating factor in their adoption (Nielsen and Reenberg, 2010; Mertz et al., 2009). While destocking of livestock during drought periods may also address desertification and adaptation, the lack of individual incentives to destock and other cultural barriers inhibit their widespread adoption in the Sahel (Hein et al., 2009; Nielsen and Reenberg, 2010).

[FOOTNOTE 10: 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).]

_____ START BOX 22-2 HERE _____

Box 22-2. African Success Story: Integrating Trees into Annual Cropping Systems

Recent success stories from smallholder systems in Africa illustrate the potential for transforming degraded agricultural landscapes into more productive, sustainable, and resilient systems through the integration of trees into annual cropping systems. Trees in croplands reduce exposure of crops to wind and heavy rainfall, enhance moisture retention and rainwater capture, increase yields of grain crops, and expand livelihoods through production of fruits, animal fodder, and fuelwood. 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 the Sahel, natural regeneration, or the traditional selection and protection of small trees to maturity by farmers and herders has, 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). 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, and to decreased sensitivity to drought of the production systems, compared to other regions in Niger (Reij et al., 2009; Tougiani et al., 2009; Sendzimir et al., 2011). Devolvement of tree ownership from the state to the farmer catalysed farmer-managed natural regeneration, which has subsequently spread through community-based efforts, including partnerships between farmers and NGOs, improving food security while reducing exposure to climate risks.

_____ END BOX 22-2 HERE _____

Intact ecosystem services and biodiversity are recognized as critical components of successful human adaptation to climate change that may be more effective and incur lower costs than ‘hard’ or engineered solutions, and are often the first line of defence for poor people in Africa (Abramovitz et al., 2002; Petersen and Holness, 2011; UNDP/UNEP Poverty-Environment Initiative, 2011a; Girot et al, 2012; Pramova et al, 2012; Box 22-2). This understanding provides a compelling reason for linking biodiversity, developmental, and social goals, which is taken up in some NAPA projects that aim to support local livelihoods through ecosystem services provision that explicitly contributes to adaptation; for instance, Djibouti targets mangrove restoration to reduce salt water intrusion and coastal production losses due to climate hazards (Pramova et al., 2012).

Differentiation in the literature is growing, 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 – for example, using intact wetlands for flood risk management, sometimes equated with ‘low regrets’ approaches to adaptation, as contrasted with ‘hard path’ approaches like embankments and dams for flood control (International Rivers Network, 2007; Kundzewicz, 2011). While ecosystem-based adaptation (EbA) is an emerging global concept, ecosystem-based strategies are not new in many African local contexts (Figure 22-8). There has been additional experience in Africa with flood risk management as an adaptive response, 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, 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 and wave and tidal power) (citations).

[INSERT FIGURE 22-8 HERE
Figure 22-8: Ecosystem-based adaptation - Farmer Managed Natural Regeneration (FMNR): Benefits of ecosystem management for livelihoods and resilience (Garrity et al. 2010; Haglund et al. 2011; Reij et al. 2009; Sendzimir et al. 2011).]

Despite the evidence from studies cited in this section, scaling-up to prioritize ecosystem responses and EbA in plans and policy has been slow. Additional efforts will be required for a broad understanding that EbA is an integral component of the developmental agenda, rather than a competing 'green' agenda. Adaptive environmental governance represents one of the future challenges for the implementation of EbA strategies in Africa, together with sustainable use of resources, secure access to meet needs under climate change, and strong local institutions to enable this (Robledo et al., 2011). Ecosystem-based adaptation could be an important approach to consider for the globally significant Congo Basin forests, particularly given the predominance of REDD+ approaches for this region that risk neglecting adaptation responses (Somorin et al., 2012; Sonwa et al., 2012).

22.4.5.7. Technological and Infrastructural Adaptation Responses

Since AR4, experience has been gained on technological and infrastructural adaptation, with an emphasis on options being used in agricultural and water management responses, and for climate-proofing infrastructure, which has encompassed construction of submersible roads, raising homesteads, retrofitting or designing buildings, and building sea and flood defenses.

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, 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).

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 crop 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 sub-Saharan 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). Embedding irrigation expansion within systems-level planning that considers the multi-stressor context in 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). Suitable approaches to expand irrigation in Africa include the use of low-pressure drip irrigation technologies, which is becoming more widely available, and construction of small reservoirs, both of which can help to foster diversification toward irrigated high-value horticultural crops (Karlberg et al., 2007; Woltering et al., 2011; Biazin et al., 2011;). Adapting agricultural water management to increased drought risk and changes in rainfall patterns requires a 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).

Experience has been gained since the AR4 on adaptation of infrastructure (transportation, buildings, food storage, coastal), with evidence that this can sometimes be achieved at low cost, and additional implementation of soft measures such as building codes and zone planning. Examples of adaptation actions for road and transportation infrastructure include submersible roads in Madagascar and building dikes to avoid flooding in Djibouti (UNFCCC, 2007; Urquhart, 2009). Infrastructural climate change impact assessments and 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; Corsi et al., 2012). Mainstreaming adaptation into infrastructure development can be achieved at low cost, as has been shown for flood-prone roads in Mozambique (Halsnæs and and Trarup, 2009). Softer measures, such as building codes and zone planning are being implemented and are needed to complement and/or provide strategic guidance for hard infrastructural climate proofing, for example, the adoption of cyclone-resistant standards for public buildings in Madagascar (AfDB, 2011). Research in Durban (Naidu et al., 2006) and in the city of Umhlathuze (Zitholele Consulting, 2009) proposed the integration of climate change and especially those changes affecting the coastline into urban development plans, and recognized that the best option for adaptation in the coastal zone is not to combat coastal erosion in the long term, but rather to allow progression of the natural processes.

The potential for adaptation to reduce the risks associated with sea level rise is estimated at 10- to 27- fold, with adaptation costs 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 to sea level rise are estimated to be between US$ 25 and 62 million per year by 2030 (Figure 22-9).

[INSERT FIGURE 22-9 HERE
Figure 22-9: Total costs of adaptation per year from 2000 to 2100 for Tanzania (including beach nourishment and sea and river dikes) Source: Kebede et al., 2010.]

Reducing post-harvest losses through improved food storage, food preservation, greater access to processing facilities, and improved systems of transportation to markets are important means to enhance food security (Brown et al., 2009; Codjoe and Owusu 2011; Godfray et al., 2010). Low cost farm-level storage options, such as metal silos (Tefera et al., 2011), and triple-sealed plastic bags (Baoua et al., 2012) are effective for reducing post-harvest losses from pests and pathogens. Better storage allows farmers greater flexibility in when they sell their grain, with related income benefits (Brown et al., 2009), and reduces post-harvest infection of grain by aflatoxins, which is widespread in Africa and increases with drought stress and high humidity during storage (Shephard, 2008; Cotty and Jaime-Garcia, 2007).

22.4.5.8. Maladaptation Risks

The literature increasingly highlights the need, when designing development or adaptation research, policies and initiatives, to adopt a longer-term view and to consider the multi-stressor context in which people live, in order to avoid maladaptation, or outcomes that may serve short-term goals but come with future costs to society. The short-term nature of policy and other interventions, especially if they favor economic growth and modernization over resilience and human security, may themselves act as stressors or allow people to only react to short-term climate variability (Bryan et al., 2009; Brooks et al., 2009; Bunce et al., 2010a; Levine et al, 2011). The political context can also undermine autonomous adaptation and lead to maladaptation; for instance, Smucker and Wisner (2008) found that political and economic changes in Kenya meant that farmers could no longer use traditional strategies for coping with climatic shocks and stressors, with the poorest increasingly having to resort to coping strategies that undermined their long-term livelihood security, such as more intensive grazing of livestock and shorter crop rotations. In a case from the Simiyu wetlands in Tanzania, Hamisi et al. (2012) find that coping and reactive adaptation strategies may lead to maladaptation – for instance, through negative impacts on natural vegetation because of increased intensity of farming in wetter parts of the floodplain, where farmers have moved to exploit the higher soil water content.

Some diversification strategies, such as charcoal production and artisanal mining, may increase risk through promoting ecological change and the loss of ecosystem services to fall back on (Paavola, 2008; Adger et al, 2011; Shackleton and Shackleton, 2012). Studies also highlight risks that traditional adaptive pastoralism systems may be replaced by maladaptive activities. For example, charcoal burning has become a major source of income for 70% of poor and middle-income pastoralists in some areas of Somaliland, with resultant deforestation (Hartmann and Sugulle, 2009).

Another example of maladaptation provided in the literature is the long-term hydro-dependency risks and threats to ecosystem health and community resilience as a result of increased dam building in Africa, which may be underpinned by policies of multi-lateral donors (add citations; Jones et al, 2012). Additional substantive review of such international development projects is required to ensure that these do not result in maladaptation.

22.4.6. Barriers and Limits to Adaptation in Africa

A complex web of interacting barriers to local-level adaptation exists that manifests from national to local scales to block adaptation, which includes institutional, political, social, cultural, biophysical, cognitive and behavioral, and gender-related (high confidence). While relatively few studies from Africa have focused specifically on barriers and limits to adaptation, perceived and experienced constraints distilled from the literature encompass 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 but not others (Roncoli et al., 2010; Bryan et al.,. 2011; Nyanga et al., 2011; Ludi et al., 2012).

Institutional barriers can hamper adaptation through elite capture and corruption; poor survival of institutions without social roots; and the lack of attention to the institutional requirements of new technological interventions (Ludiet al., 2012). Tenure security over land and vital assets 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 (Brown et al., 2010; Bryan et al., 2009; Romero Gonzalez et al., 2011). In addition to unclear land tenure, legislation forbidding ecosystem use is one of the issues strengthening underlying conflicts over resources in Africa, which will have to be resolved if ecosystems are to contribute to adaptation beyond short-term coping (Robledo et al., 2011). There is also evidence that innovation may be suppressed if the dominant culture disapproves of departure from the 'normal way of doing things' (Ludiet et al., 2012; Jones 2011b).

Characteristics such as wealth, gender, ethnicity, religion, class, caste, 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 and 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. Restrictive institutions can block attempts to enhance local adaptive capacity by maintaining structural inequities related to gender and ethnic minorities (Jones, 2011b). Constraints faced by women, often through customs and legal barriers, include lack of access to land and natural resources,; lack of credit and input in decisionmaking, lack of ability to take financial risk, lack of confidence, limited access to information and new ideas, and lack of value for women's opinions (McFerson, 2008; Jones 2011b; Peach Brown, 2011, Djoudi and Brockhaus 2011; Ludi et al., 2012; Goh, 2012; Codjoe et al. 2012).

Only a portion of small-scale farmers across Africa is able to adapt to perceived climatic changes, while others are restricted by a suite of overlapping barriers (high agreement, robust evidence). Constraints identified in Kenya, South Africa, Ethiopia, Zimbabwe, Zambia, and Ghana included poverty and a lack of cash or credit (financial barriers); lack of access to water and land, poor soil quality, land fragmentation, poor roads, and pests and diseases (biophysical and infrastructural barriers); lack of access to inputs, shortage of labor, poor quality of seed and inputs attributed to a lack of quality controls by government and corrupt business practices by traders, lack of tenure, and poor market access (institutional, technological, and political barriers); and finally a lack of information on agroforestry/afforestation, different crop varieties, climate change predictions and weather, and adaptation strategies (informational barriers) (Nhemachena and Hassan, 2008; Bryan et al. 2009, 2011; Barbier et al., 2009; Clover and Eriksen, 2009; Deressa et al., 2009; Roncoli et al., 2010; Mandeleni and Anim, 2011; Nyanga et al.,2011).

Recognition is increasing that understanding psychological factors such as mindsets and risk perceptions is crucial for supporting adaptation (Jones, 2011b; Patt and Schroter, 2008; Grothman and Patt, 2005). Cognitive barriers to adaptation include alternative explanations of extreme events and weather such as religion (God's will), the ancestors, and witchcraft, or seeing these changes as out of people's own control (Artur and Hilhorst, 2012; Mubaya et al. 2012, Jones 2011b). Perceptions studies from Africa do show that most rural farmers perceive changes in weather patterns and acknowledge the associated risks, although the cause of the changes are not always known or are attributed to supernatural forces (Mandleni and Anim, 2011; Roncoli et al., 2010; Byran et al., 2009).

Climate uncertainty, high levels of variability, lack of access to appropriate real-time and future climate information, and poor predictive capacity at a local scale are commonly cited barriers to adaptation from the individual to national level (Repetto, 2008; Mather and Stretch, 2012; Jones, 2011b). Despite the cultural and psychological barriers noted above, several studies have shown that farmers with access to weather information are more likely to be aware of changes and to make adjustments accordingly (Mubaya et al., 2012). Dinku et al. (2011) point out that the current monitoring system is not sufficient for supporting sustainable development, being oriented more toward meteorology than climate, and more toward global interests and the presumed needs of government sectoral managers than the needs of local communities.

At a policy level, studies have detected political, institutional, and discursive barriers to adaptation. Adaptation options in southern Africa have been blocked by political and institutional inefficiencies, lack of prioritization of climate change, and the dominance of other discourses, such as the mitigation discourse in South Africa and short-term disaster-focused views of climate variability (Madzwamuse, 2010; Bele et al., 2011; Berrang-Ford et al., 2011; Chevalier, 2011; Conway and Schipper, 2011; Toteng, 2011; Kalame et al., 2011, Toteng, 2011; Leck et al., 2011). Lack of local participation in policy formulation, the neglect of social and cultural context, and the inadvertent undermining of local coping and adaptive strategies have also been identified by several commentators as barriers to appropriate national policies and frameworks that would support local-level adaptation (e.g., Brockhaus and Djoudi, 2008; Bele et al., 2011; Chevalier, 2011).

Many of these constraints to adaptation are well entrenched and will be far from easy to overcome; some may act as limits to adaptation for particular social groups. Biophysical barriers to adaptation in the arid areas could present as limits for more vulnerable groups if current climate change trends continue (Leary et al., 2007; Sallu et al., 2010; Roncoli et al., 2010). Traditional and autonomous adaptation strategies, particularly in the drylands, have been constrained by social-ecological change and drivers such as population growth, land privatization, land degradation, widespread poverty, HIV/AIDS, poorly conceived policies and modernization, 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 (Leary et al., 2007; UNCCD et al., 2009; Dabi et al., 2008; Paavola, 2008; Smucker and Wisner, 2008; Conway, 2009; Clover and Eriksen, 2009; Bunce et al., 2010b; Jones, 2011b; Quinn et al., 2011). As a result of these multiple stressors working together, the number of response options has decreased and traditional coping strategies are no longer sufficient (Dube and Sekhwela, 2008). 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, without which many poor groups in Africa may face real limits to adaptation.

These findings highlight the need for transformational change in situations where high levels of vulnerability and low adaptive capacity detract from the possibility for systems to adapt sustainably. This is in agreement with the Special Report on Extreme Events, which additionally found high agreement and robust evidence for a needed spectrum of actions ranging from incremental steps to transformational changes in order to reduce climate risks (IPCC, 2012). In support of such solutions, Moench (2011) has called for distilling common principles for building adaptive capacity at different stages, and adaptive management and learning are seen as critical approaches for facilitating transformation (Section 22.4.5.3; IPCC, 2012).

22.5. Case Studies

22.5.1. Climate Change Impacts on Kilimanjaro

Changing weather conditions, large-scale habitat conversion, agricultural intensification, and rapid human population growth have reached a critical stage at Kilimanjaro (Sala *et al.*, 2000; Jetz *et al.*, 2007; Lovett and Hemp, 2010). Decreasing precipitation is the main driver of increasing forest fires in combination with illegal logging activities affecting, for example, fog water-collecting capacity and with this, the water balance of the whole mountain. This endangers its function as the water tower for northern Tanzania, with potential to affect 10 million people. 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 (McDonald *et al.*, 2005; Huntingford *et al.*, 2005; Christensen *et al.*, 2007), causing a dangerous combination of decreasing adaptive capacity of many of the systems and increasing threats.

Kilimanjaro's glaciers have lost over 80% of their extent since 1912 (Thompson *et al.*, 2002; Cullen *et al.*, 2006) and annual precipitation has decreased by over 30% (Hemp, 2005). This declining trend in precipitation and humidity rather than increasing temperature is increasingly held responsible for the retreat of glaciers since 1880 (Kaser *et al.*, 2004; Mölg *et al.*, 2008; Mölg *et al.*, 2009a; Mölg *et al.*, 2009b; Kaser *et al.*, 2010). 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 and writers but also a large number of tourists. Today, the Kilimanjaro National Park (KINAPA) is a major attraction, generating more foreign currency earnings for Tanzania than any other national park (Hemp *et al.*, in press). Since the park was established in 1972, the number of visitors to KINAPA has increased five-fold (Hemp *et al.*, in press). 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, marking the final chapter in an important paleoclimatic archive (Thompson *et al.*, 2002; Hemp *et al.*, in press).

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

Impact

Fires: Loss of natural habitats due to land cover changes and fires is most severe in the foothills of Kilimanjaro. For 10,000 years, fires occurred with various intensities on Kilimanjaro, as suggested by old charcoal horizons in the soil (Hemp and Beck, 2001; Verschuren *et al.*, 2009; Zech *et al.*, 2011; Schüler *et al.*, 2012). However, due to a drier and warmer climate and higher anthropogenic impacts, fires have played an increasingly 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 km^2 (nearly 15%) of high-altitude forests, and the upper closed forest line dropped by 900 m (Hemp, 2005; Hemp, 2006a; Hemp, 2009). A high frequency of fires in the upper regions has caused typical alpine *Helichrysum* heath to extend downslope, replacing subalpine forests (Körner, 2003; Pauli *et al.*, 2012). In addition, losses due to clear cutting of lower elevation forests amount to 450 km^2 since 1929 (i.e., Kilimanjaro lost about 40% of its forests; Hemp(2006b); Hemp et al., (in press)). An increase in the migration of elephants from the Amboseli ecosystem via the so-called Kitendeni Corridor into the forests of Kilimanjaro due to rising temperatures and other factors like expansion of indigenous communities also have negative consequences on forest cover (impeded forest regeneration and increasing the risk of fire; Hemp et al., (in press)).

The average annual water yield of the entire forest belt is estimated to be about 500 million m^3 (Hemp, 2005). The loss since 1976 of 150 km^2 of cloud forests, which have an important function of fog water collecting in addition to the normal rainwater input, corresponds to an estimated loss of 20 million m^3 of fog water per year (Hemp, 2005). 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 (Hemp *et al.*, in press). 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. 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). The traditional Chagga home gardens, covering an area of about 1,000 km^2, represent a special type of coffee–banana agro-forestry that are also dependent on runoff from the montane forest and are now limited to a lowland field where maize, beans, and sunflower are grown to ensure food security (Hemp, 2006c; Liniger *et al.*, 2011).

Striking examples for an upward movement of organisms on Kilimanjaro can be found among the grasshopper fauna. In contrast to alpine flora, savanna grasshoppers are spreading from lower elevations to the sub-montane, montane, and even afro-alpine zone due to anthropogenic opening of the closed forest and a warmer microclimate (Figure 22-10; Hemp and Hemp, (2008)).

[INSERT FIGURE 22-10 HERE
Figure 22-10: Upward movement of grasshoppers and bushcrickets at Kilimanjaro. Left circles giving numbers of species which are typical for this zone; right circles giving numbers of species that are additionally found to the typical species of the respective zone, arrows indicating area from which they migrated upwards. Yellow: openland forms, green: forest forms; blue: afroalpine forms. A: colline lowland savanna area, B: submontane and lower montane zone, C: montane zone, D: (sub) alpine zone. Source: Hemp and Hemp, 2008).]

22.5.2. Coastal Zones and Urbanization

Case Studies – Lagos, Dakar, Saint Louis, and Beira

Coastal cities, Africa's most developed urban areas, host 11.5% of the total urban population (UN-Habitat, 2008b). Lagos, Nigeria; Dakar; and Saint Louis, Senegal, all in the low-lying coastal zone of West Africa, as well as Beira, Mozambique, exemplify the state of Africa's coastal cities that are naturally vulnerable to flood hazards from climate change and sea level rise by reason of their location. Moreover, rapid urbanization in these cities has caused migration of large numbers of people into slum or informal communities, often located in flood-prone and risky areas. For instance, between 1984 and 1992, migration resulted in an average increase of 91% in Beira's population, where 75% of the buildings are located in low-lying areas and most immigrants reside in unplanned settlements (Kusangaya, no date). In Saint Louis, the urban poor settle in watersheds and valley bottoms, altering drainage patterns and destabilizing slopes (Diagne, 2007). Similarly, in the Yeumbeul district in the north of Dakar, flood risk is high due to the occupation of depressions by the urban poor that are normally occupied by streams and natural vegetation (Mbow *et al.*, 2008). In Lagos, large sections of poor urban coastal communities have been built on land reclaimed by sand infill, which cannot support solid structures (Adelekan, 2010).

Changes in the intensity and pattern of rain storms, land use changes, and subsequent changes in the hydrological fluxes of the urban watershed associated with urban growth, compounded by inadequate or lack of drainage infrastructure, poor urban planning, and poor development control have consequently increased flood risks in these cities (Mbow *et al.*, 2008; Adelekan, 2010). In coastal Lagos, significant wetland loss of 38 to 100% was reported in four coastal local government areas between 1986 and 2006 (Taiwo, 2009). Okude and Ademiluyi (2006) showed that developed land comprising residential, industrial, commercial, transportation, and other uses increased from 85.4 km^2 (43.36%) to 111.9 km^2 (56.8%) between 1986 and 2002. Natural vegetation cover, including mangrove and swamp thicket, was also reduced from 59.2 km^2 (30.1%) to 38.3 km^2 (19.4%). In Beira, dryland vegetated areas (3.55 %) were converted to built-up areas followed by alteration of permanently waterlogged areas (1.53%) and finally bare surfaces (0.54%) between 1999 and 2010 (Kusangaya, no date). Urbanization processes and drivers are therefore the strongest cause of floods in Dakar, Lagos, and Saint Louis (Diagne, 2007; Mbow *et al.*, 2008; Adelekan, 2010).

Most African coastal cities have limited capacity and infrastructure to cope with the impacts of climate change and sea level rise. Lagos provides a case study of the possible impacts of trends in precipitation behavior in a vulnerable urban setting. Analyses of rainstorms for Lagos Island from 1971 to 2005 show that in latter years (1996–2005), heavier rainstorms resulting in flooding were recorded. While mean annual rainfall is similar (1,697.8 mm for 1971–1995 and 1,647.3 mm for 1996–2005), fewer rain days were recorded during the latter 10-year period, indicating that rainstorms were much heavier than those of the earlier period and resulted in more flooding (Adelekan, 2010). The range of impacts experienced in affected communities includes damage to roads, flooding of houses, and disruption of movement. Although the severity of impacts varies within communities, the functioning of affected communities and those of its members are affected (Adelekan, 2010). 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. About 91% of households in affected poor urban communities made regular visits to health centers because of ill health, and incurred increased medical expenses and income loss due to inability to work as a result of illness.

Residents of the Makoko community who had benefited from an improved drainage system experienced less flooding than areas where the drainage system was poor (Douglas *et al.*, 2008; Adelekan, 2010). Furthermore, potable water shortages, due to water pollution and damage to water pipes following flood events and cleaning and repair costs, were also experienced by households affected by floods.

At the individual level, flooding of homes and communities deters 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% 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 the majority depends on wages earned from daily work.

22.5.3. Case Study on Migration

[to be added]

22.6. New Emerging Issues

22.6.1. Integrated Adaptation / Mitigation Approaches

Since AR4, the literature has increasingly recognized that integrated adaptation–mitigation responses need to be implemented within a pro-poor orientation that leverages developmental benefits. Relevant experience gained in Africa on integrated adaptation–mitigation responses encompasses some participation of farmers and local communities in carbon offset systems, increasing the use of technologies that can promote adaptation and mitigation, such as agroforestry and farmer-assisted tree regeneration, emerging policy response within the context of Green Economy discussions and enhanced utilization of renewable energy resources. The recognition that adaptation and mitigation should not be viewed as tradeoffs, but rather as complementary elements of the global response to climate change, is gaining traction in Africa (Nyong *et al.*, 2007; Goklany, 2007; Woodfine, 2009; UNCCD et al., 2009; Milder et al., 2011). Many adaptation activities can contribute significantly to mitigation, provided the expected synergies are capitalized on (Jalloh and Roy-Macauley, 2011).

While the suitability of on- and off-farm techniques for an integrated adaptation-mitigation response depends on local physical conditions as well as political and institutional factors, the literature highlights that sustainable land management techniques particularly beneficial for an integrated response in Africa include agroforestry, including through farmer-managed natural regeneration and conservation agriculture (Woodfine, 2009; Milder *et al.*, 2011; Mutonyi and Fungo, 2011). An emerging area is multiple-benefit initiatives that aim to reduce poverty, promote adaptation through restoring local ecosystems, and deliver benefits from carbon markets. An example is a community-based project in Humbo, Ethiopia, which is facilitating adaptation and generating temporary certified emissions reductions under the Clean Development Mechanism (Brown *et al.*, 2011). Degraded native forests (2,728 ha) are being restored through farmer-managed natural regeneration, which is found to be low-cost and replicable, with benefits to communities of fodder and firewood within a year, and wild fruits and other non-timber forest products within three years. Local cooperatives and establishing user rights were important enabling conditions.

The important role of local communities in carbon offset systems through community forestry 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 by drawing from locally appropriate options (Nyong *et al.*, 2007; Ogden and Innes, 2009). Integrated approaches are constrained by the lack of supportive policy environments – for example, for conservation agriculture (Milder et al., 2011).

The literature has highlighted the need to pursue integrated adaptation–mitigation approaches in the implementation of REDD+ in Africa, and to use spatial planning to find integrated solutions (Bwango *et al.*, 2000; Biesbroek *et al.*, 2009). Given the significant contribution to food security and livelihoods of communities in Africa, such as the over 30 million indigenous forest people in the Congo Basin Forest of the Central African Region (Nasi *et al.*, 2008; Dudley *et al.*, 2008; Somorin *et al.*, 2012), adaptation and mitigation are inseparable as climate change responses in forest systems (Guariquata et al., 2007; Nkem *et al.*, 2007). However, the use of forests for anticipatory adaptation is limited and predominantly serves for reactive coping (Fisher *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 for adaptation (Somorin *et al.*, 2012). Flexible REDD+ models that include agriculture and adaptation may widen the scope for pro-poor participation (Wertz-Kanounnikoff *et al.*, 2011), given food security and adaptation priorities (Nkem *et al.*, 2008). This is crucial in avoiding the undesirable tradeoffs 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+ (Richard *et al.*, 2011). Harnessing the full potential and cost-effectiveness of REDD+ depends on the opportunity cost (Kremen *et al.*, 2000), which in the case of Africa, links to the tradeoffs in social benefits for local communities as well as support for national development efforts in addressing demands for food, fuel, and fiber that underly the decisionmaking process for land use change (Thomson *et al.*, 2010). The additional experience being gained on generating co-benefits for poverty reduction through a five-year project launched in 2010 to investigate synergies between adaptation and mitigation in the Congo Basin, with an emphasis on safeguarding local rights, livelihoods, and traditions, is also relevant (CIFOR, 2011).

There have been a number of studies 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). Options explored include solar, wind, small hydro and improved biomass technologies. Insufficient electricity to meet domestic and industrial needs has been the main driver of the increased focus on exploiting Africa's substantial renewable energy sources, rather than reduction in carbon emissions; however, mitigation and broader environmental reasons are seen as increasingly important (Foster-Pedley et al., 2006; Nwofor et al., 2007). An excellent example of integrating renewable energy generation into a national utility service is available from Mauritius (UNIDO, 2007). The three major barriers to the adoption of renewable energy in Africa are policy/legal, technical and financial barriers; other studies have pointed to the need for enhanced political will and continual lobbying for better policy uptake (Legros et al., 2009; Chineke and Ezike, 2010).

Integrated adaptation–mitigation responses are being considered within the context of the emerging Green Economy discussions at both regional and national levels. African leaders agreed in 2011 to develop an African Green Growth Strategy to guide low-carbon growth and climate resilient development. This will build a shared medium and long-term vision to promote sustainable and low-carbon growth in Africa through a linked adaptation–mitigation approach, with adaptation seen as an urgent priority. At the national level, Ethiopia launched its Climate Resilient Green Economy Facility in 2012 (Corsi *et al.*, 2012). Given Africa's ongoing development needs, questions to ask include how adaptation programs can be designed to meet 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 tradeoffs between approaches – for instance, in the agriculture sector, between various practices for food security and for mitigation of greenhouse gas emissions (Chambwera and Anderson, 2011).

22.6.2. Climate Finance and Management

At the UN climate negotiations in Copenhagen (2009), developed countries pledged to mobilize new and additional financial resources for climate change adaptation and mitigation in developing countries, approaching US$ 30 billion for the period 2010 to 2012, and US$ 100 per annum from 2020 onward (UNFCCC, 2009; UNFCCC, 2011). Historically, less than 20% of the global climate finance was directed to adaptation (Buchner *et al.*, 2012). However, in line with increasing international impetus for adaptation (Persson *et al.*, 2009) the Parties agreed on providing “adequate, predictable and sustainable financial resources” for adaptation in developing countries, and, within this context, paid special attention to Africa which is considered “particularly vulnerable” to the adverse effects of climate change (UNFCCC, 2009; UNFCCC, 2011).

The need for climate finance led to a proliferation of climate funds (Caravani *et al.*, 2010). Adaptation funding currently comes from the domestic budgets of developing countries; bilateral and multilateral development assistance; and funds situated under the UNFCCC (Klein, 2010). The Copenhagen Accord states that it should also come from the private sector (UNFCCC, 2009). The UN secretary general’s high-level advisory committee considered private finance necessary to meet the US$ 100 billion per annum target (AGF, 2010). However, doubts remain about how private sector financing can be effectively mobilized and channeled toward adaptation in developing countries (Atteridge, 2011; Naidoo *et al.*, 2012). The 2012 Landscape of Climate Finance Report (Buchner *et al.*, 2012) stated that private climate finance represents 63% of the total climate finance flows, of which close to two- thirds come from developed countries. It also estimates that mitigation activities attracted US$ 350 billion, mostly related to renewable energy and energy efficiency, while adaptation activities attracted US$ 14 billion.

Approximately 30% of the global distributed adaptation finance went to Africa (Nakhooda *et al.*, 2011) and seems to prioritize the continent (Naidoo *et al.*, 2012). However, there is general consensus that adaptation funding that is currently delivered does not fulfill demonstrated needs, neither globally (Flåm and Skjærseth, 2009; Denton, 2010) nor in sub-Saharan Africa (Nakhooda *et al.*, 2011).

Effective adaptation requires more than sufficient levels of funding. It requires developing country ‘readiness,’ which includes abilities to plan and access finances; the capacity to deliver adaptation projects and programs, and to monitor, report, and evaluate their effectiveness (Vandeweerd *et al.*, 2012). Particularly serious challenges are associated with directing finance to the sectors and people most vulnerable to climate change (Denton, 2010; Nakhooda *et al.*, 2011; Pauw *et al.*, 2012). Mismanagement and misuse of funds eventually puts at risk the rights of those most vulnerable to the negative effects of climate change. (Transparency International 2011:xxvi). 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. Solving these problems would, inter alia, require a focus on longer-term and integrated programs rather than isolated projects; building capacity and institutions in African countries (Nakhooda *et al.*, 2011; Pauw *et al.*, 2012); identifying priorities, processes, and knowledge needs at the local level (Haites, 2011; Pauw, forthcoming); and, accordingly, developing grassroots projects (Fankhauser and Burton, 2011).

22.7. Research Gaps

Research has a key role to play in providing information for informed decisionmaking at local to national levels (Fankhauser, 1997; Ziervogel *et al.*, 2008; Arendse and Crane, 2010). While there is significant activity in African research institutions on adaptation, much African research capacity is spent on foreign-led research that may not relate to national knowledge gaps about climate change (Madzwamuse, 2010), and African research may lack merited policy uptake or global recognition as it is often not published in peer-reviewed literature (Denton *et al.*, 2011).

The following data and research gaps have been identified:

- A 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
- Development of African capacity and leadership on climate change, including through strengthening and reorienting climate science and policy institutions to harness synergies for translation of new climate change science into policy and/or decisionmaking tools
- Clements 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.
- Methodologies and "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 climate change adaptation and disaster risk reduction with social protection.
- Approaches to further develop a more equitable approach to adaptation, including gender equity, human rights- based approaches, and involvement of vulnerable or marginalized groups such as indigenous peoples and children
- How to effectively combine social protection measures to mitigate vulnerability to climate change in different contexts
- 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 decisionmaking could address the inequitable distribution of climate impacts, and could improve adaptive decisionmaking 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 to climate change and variability.
- Monitoring adaptation
- The ethical and political dimensions of engaging with local and traditional knowledge on climate change adaptation are an important but under-examined issue in Africa. While the concept of indigeneity is debated in Africa, the claims for active participation of marginalized groups in global climate deliberations described above are significant for a wide range of communities in Africa.

Frequently Asked Questions

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

Migration was considered as a negative impact in the last decade, but a perception of the potential positive role of migration in climate change adaptation now exists. Even if classical literature tends to ignore the 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 of 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. Environmental change will affect livelihoods, making migration a primary answer or the only response. Better management of African migration and displacement is a core issue to avoid humanitarian emergencies and the risk of jeopardizing necessary population mobility due to environmental 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. Strong consensus exists 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 by an 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, although 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 impede the ability of the poor and middle class in Africa to purchase food, hence their reduced access to food. The impact of climate change on food quality could occur through increased risk of spoilage of fresh food and pest and pathogen damage to stored foods (cereals, pulses, tubers) 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.

FAQ 22.3: What role does climate change play with regard to violent conflict in Africa?

Wide consensus exists that violent conflicts are based on a variety of interconnected causes, of which the environment is considered to be one, but rarely the most decisive factor. Whether or not the changing climate increases the risk of civil war in Africa remains disputed and there exists a lack of robust findings related thereto. A risk of an increase of violent competition over scarce resources exists with a view to the impacts of climate change on renewable resources such as freshwater and arable land on the one side and population growth on the other. Increased distributional conflicts due to the degradation of natural resources as a result of overexploitation and global warming will arise. The outbreak of armed conflict with climate change as one of various interacting reasons, however, depends on country-specific sociopolitical and economic factors among others.

References

AAP, 2012: *AAP knowledge management needs survey report 2012*. United Nations Development Programme (UNDP) Africa Adaptation Programme (AAP), pp. 110.

Abdo, K.S., B.M. Fiseha, T.H.M. Rientjes, A.S.M. Gieske, and A.T. Haile, 2009: Assessment of climate change impacts on the hydrology of Gilgel Abay catchment in Lake Tana basin, Ethiopia. *Hydrological Processes,* **23(26)**, 3661-3669.

Abouabdillah, A., O. Oueslati, A.M. De Girolamo, and A. Lo Porto, 2010: Modeling the impact of climate change in a mediterranean catchment (Merguellil, Tunisia). *Fresenius Environmental Bulletin,* **19(10 A)**, 2334-2347.

Abou-Hadid, A.F., 2006: *Assessment of Impacts, Adaptation, and Vulnerability to Climate Change in North Africa: Food Production and Water Resources, A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. AF 90. AIACC Final Reports*. International START Secretariat, Washington, DC, pp. 148.

Abramovitz, J., Banuri, T., Girot, P., Orlando, B., Schneider, N., Spanger-Siegfried, E., et al. (2002). Adapting to Climate Change: Natural Resource Management and Vulnerability Reduction. Background Paper to the Task Force on Climate Change, Adaptation and Vulnerable Communities, 1, 1-37. http://www.iisd.org/pdf/2002/envsec_cc_bkgd_paper.pdf

ACCRA (2012) From local to national: supporting local government action in climate change adaptation, disaster risk reduction and development planning. ACCRA policy brief, http://community.eldis.org/.5a3ed4a1/ACCRA_Policy_Brief_Ethiopia_Local_Government.pdf

Achten, W.M.J., L. Verchot, Y.J. Franken, E. Mathijs, V.P. Singh, R. Aerts, and B. Muys, 2008: Jatropha bio-diesel production and use. *Biomass and Bioenergy,* **32(12)**, 1063-1084.

Adam, A.A., M.S. Karsany, and I. Adam, 2010: **Manifestations of severe Rift Valley fever in Sudan**. *International Journal of Infectious Diseases,* **14(2)**, 179-180.

Adano, W.R., T. Dietz, K. Witsenburg, and F. Zaal, 2012: Climate change, violent conflict and local institutions in kenya's drylands. *Journal of Peace Research,* **49(1)**, 65-80.

ADB and IFPRI, 2009: *Building climate resilience in the agriculture sector in Asia and the Pacific*. Asian Development Bank (ADB) and International Food Policy Research Institute (IFPRI), Mandaluyong City, Philippines, pp. 304.

ADB, 2011: *Climate change and migration in Asia and the Pacific*. Asian Development Bank, Metro Manila, Philippines, pp. 77.

Adelekan, I.O., 2010: Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. *Environment and Urbanization,* **22(2)**, 433-450.

Adesina, A.A., 2010: Conditioning trends shaping the agricultural and rural landscape in Africa. *Agricultural Economics,* **41(SUPPL. 1)**, 73-82.

Adger W. N., K. Brown, D. R. Nelson, F. Berkes, H. Eakin, C. Folke, K. Galvin, L. Gunderson, M. Goulden, K. O'Brien, J. Ruitenbeek and E. L. Tompkins, 2011: Resilience implications of policy responses to climate change. *Climatic Change* 2, 757–766.

AfDB, 2011: *The cost of adaptation to climate change in Africa*. African Development Bank (AfDB), pp. 41.

Afrane, Y.A., A.K. Githeko, and G. Yan, 2012: *The ecology of Anopheles mosquitoes under climate change: Case studies from the effects of deforestation in East African highlands* pp. 204-210.

African Development Bank, Economic Commission for Africa, African Union, and United Nations Development Programme, 2010: *Assessing progress in Africa towards the Millennium Development Goals*. MDG Report 2010, pp. 103.

African Development Bank, 2012: *Congo Basin MRV Regional Progect - Phase 1 Multinational: Project Appraisal Report*. ADB/BD/WP/2012/47/Approval.

African Development Forum, 2010: Climate change and human development.Proceedings of Seventh African Development Forum (ADF VII) - Acting on climate change for sustainable development in Africa, 10-15 October 2010, Addis Ababa, Ethiopia, pp. 6.

AGF, 2010: *Report of the secretary-general's high-level advisory group on climate change financing*. United Nations, New York, NY, USA, pp. 80.

Ahmed, S.A., N.S. Diffenbaugh, T.W. Hertel, D.B. Lobell, N. Ramankutty, A.R. Rios, and P. Rowhani, 2011: Climate volatility and poverty vulnerability in Tanzania. *Global Environmental Change,* **21(1)**, 46-55.

Ahmedou, O.C.A., R. Nagasawa, A.E. Osman, and K. Hattori, 2008: Rainfall variability and vegetation dynamics in the Mauritanian Sahel. *Climate Research,* **38(1)**, 75-81.

Ahrends, A., N.D. Burgess, S.A.H. Milledge, M.T. Bulling, B. Fisher, J.C.R. Smart, G.P. Clarke, B.E. Mhoro, and S.L. Lewis, 2010: Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. *Proceedings of the National Academy of Sciences of the United States of America,* **107(33)**, 14556-14561.

Akullo, D., R. Kanzikwer, P. Birungi, W. Akum, L. Aliguma, and M. Barwogeza, 2007: Indigenous Knowledge in Agriculture: A case study of the challenges in sharing knowledge of past generations in a globalized context in Uganda.[World Library and Information congress: 73rd IFLA General Conference and Council (ed.)]. Proceedings of World Library and Information Congress: 73rd IFLA General Conference and Council, 19-23, August 2007, Durban, South Africa, pp. 14.

Alcamo, J., M. Flörke, and M. Märker, 2007: Future long-term changes in global water resources driven by socio-economic and climatic changes. *Hydrological Sciences Journal,* **52(2)**, 247-275.

Alem, Y. and M. Söderbom, 2012: Household-Level Consumption in Urban Ethiopia: The Effects of a Large Food Price Shock. *World Development,* **40(1)**, 146-162.

Al-Gamal, S. and A.K. Dodo, 2009: Impacts of climate changes on water resources in africa with emphasis on groundwater. *Journal of Environmental Hydrology,* **17**, 1-11.

Allen, C.D., A.K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D.D. Breshears, E.H.(.). Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.-. Lim, G. Allard, S.W. Running, A. Semerci, and N. Cobb, 2010: A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management,* **259(4)**, 660-684.

Allison, E.H., A.L. Perry, M.-. Badjeck, W. Neil Adger, K. Brown, D. Conway, A.S. Halls, G.M. Pilling, J.D. Reynolds, N.L. Andrew, and N.K. Dulvy, 2009: Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries,* **10(2)**, 173-196.

Alo, C.A. and G. Wang, 2008: Hydrological impact of the potential future vegetation response to climate changes projected by 8 GCMs. *Journal of Geophysical Research G: Biogeosciences,* **113(3)**.

Alonso, D., M.J. Bouma, and M. Pascual, 2011: Epidemic malaria and warmer temperatures in recent decades in an East African highland. *Proceedings of the Royal Society B: Biological Sciences,* **278(1712)**, 1661-1669.

AMCEN and UNEP, 2006: *Africa Environment Outlook 2: Our environment, our wealth*. United Nations Environment Programme and African Ministerial Conference on the Environment, Nairobi, Kenya, pp. 542.

Amigun, B., J.K. Musango, and W. Stafford, 2011: Biofuels and sustainability in Africa. *Renewable and Sustainable Energy Reviews,* **15(2)**, 1360-1372.

Andriamandimby, S.F., A.E. Randrianarivo-Solofoniaina, E.M. Jeanmaire, L. Ravololomanana, L.T. Razafimanantsoa, T. Rakotojoelinandrasana, J. Razainirina, J. Hoffmann, J.-. Ravalohery, J.-.

Rafisandratantsoa, P.E. Rollin, and J.-. Reynes, 2010: Rift valley fever during rainy seasons, Madagascar, 2008 and 2009. *Emerging Infectious Diseases,* **16(6)**, 963-970.

Annez, P., R. Buckley, and J. Kalarickal, 2010: African urbanization as flight? Some policy implications of geography. *Urban Forum,* **21(3)**, 221-234.

Anthony, K.R.N., D.I. Kline, G. Diaz-Pulido, S. Dove, and O. Hoegh-Guldberg, 2008: Ocean acidification causes bleaching and productivity loss in coral reef builders. *Proceedings of the National Academy of Sciences of the United States of America,* **105(45)**, 17442-17446.

Anthony, K.R.N., J.A. Maynard, G. Diaz-Pulido, P.J. Mumby, P.A. Marshall, L. Cao, and O. Hoegh-Guldberg, 2011: Ocean acidification and warming will lower coral reef resilience. *Global Change Biology,* **17(5)**, 1798-1808.

Anyah, R.O. and W. Qiu, 2012: Characteristic 20th and 21st century precipitation and temperature patterns and changes over the Greater Horn of Africa. *International Journal of Climatology,* **32(3)**, 347-363.

Anyamba, A. and C.J. Tucker, 2005: Analysis of Sahelian vegetation dynamics using NOAA-AVHRR NDVI data from 1981-2003. *Journal of Arid Environments,* **63(3)**, 596-614.

Anyamba, A., J.-. Chretien, J. Small, C.J. Tucker, P.B. Formenty, J.H. Richardson, S.C. Britch, D.C. Schnabel, R.L. Erickson, and K.J. Linthicum, 2009: Prediction of a Rift Valley fever outbreak. *Proceedings of the National Academy of Sciences of the United States of America,* **106(3)**, 955-959.

Anyamba, A., K.J. Linthicum, J.L. Small, K.M. Collins, C.J. Tucker, E.W. Pak, S.C. Britch, J.R. Eastman, J.E. Pinzon, K.L. Russell, 2012: Climate Teleconnections and Recent Patterns of Human and Animal Disease Outbreaks. *PLoS Neglected Tropical Diseases,* **6(1)**.

Aoun, K., F. Amri, E. Chouihi, N. Haouas, K. Bedoui, R. Benikhlef, J. Ghrab, H. Babba, M.K. Chahed, Z. Harrat, and A. Bouratbine, 2008: Epidemiology of Leishmania (L.) infantum. L major and L. killicki in Tunisia: Results and analysis of the identification of 226 human and canine isolates. *Bulletin De La Societe De Pathologie Exotique,* **101(4)**, 323-328.

Appeaning Addo, K., M. Walkden, and J.P. Mills, 2008: Detection, measurement and prediction of shoreline recession in Accra, Ghana. *ISPRS Journal of Photogrammetry and Remote Sensing,* **63(5)**, 543-558.

Archer, E.R.M., N.M. Oettlé, R. Louw, and M.A. Tadross, 2008: 'Farming, on the edge' in arid western South Africa: Climate change and agriculture in marginal environments. *Geography,* **93(2)**, 98-107.

Armah, F.A., J.O. Odoi, G.T. Yengoh, S. Obiri, D.O. Yawson, and E.K.A. Afrifa, 2011: Food security and climate change in drought-sensitive savanna zones of Ghana. *Mitigation and Adaptation Strategies for Global Change,* **16(3)**, 291-306.

Armitage, D. and R. Plummer (eds.), 2010: Springer Series on Environmental Management. In: *Adaptive Capacity and Environmental Governance*. Springer, Heidelberg, Dordrecht, London, New York, pp. 308.

Arndt, C., S. Msangi, and J. Thurlow, 2011: Are biofuels good for African development? An analytical framework with evidence from Mozambique and Tanzania. *Biofuels,* **2(2)**, 221-234.

Arthurton, R., K. Korateng, T. Forbes, M. Snoussi, J. Kitheka, J. Robinson, N. Shah, S. Taljaard, and P. Monteiro, 2006: Chapter 5: Coastal and marine environments. In: *Africa Environment Outlook : Our environment, our wealth*. United Nations Environment Programme and African Ministerial Conference on the Environment, Nairobi, Kenya, pp. 155-195.

Artur, L and Hilhosrt, D. 2012. Everyday realities of climate change adaptation in Mozambique. Global Environmental Change 22: 526-536.

Artzy-Randrup, Y., D. Alonso, and M. Pascual, 2010: Transmission intensity and drug resistance in malaria population dynamics: Implications for climate change. *PLoS ONE,* **5(10)**.

Atteridge, A., 2011: *Will private finance support climate change adaptation in developing countries? Historical investment patterns as a window on future private climate finance*. SEI Working Paper No. 2011-05. Stockholm Environment Institute, Stockholm, Sweden, pp. 35.

Awange, J.L., M.A. Sharifi, G. Ogonda, J. Wickert, E.W. Grafarend, and M.A. Omulo, 2008: The falling lake Victoria water level: GRACE, TRIMM and CHAMP satellite analysis of the lake basin. *Water Resources Management,* **22(7)**, 775-796.

Awuor, C.B., V.A. Orindi, and A. Ochieng Adwera, 2008: Climate change and coastal cities: The case of Mombasa, Kenya. *Environment and Urbanization,* **20(1)**, 231-242.

Aylett, A. (2010), Conflict, Collaboration and Climate Change: Participatory Democracy and Urban Environmental Struggles in Durban, South Africa. International Journal of Urban and Regional Research, 34: 478–495. doi: 10.1111/j.1468-2427.2010.00964.x

Babiker, S.M., H.D. Blankespoor, M. Wassila, A. Fenwick, and A.A. Daffalla, 1985: Transmission of Schistosoma haematobium in North Gezira, Sudan. *Journal of Tropical Medicine and Hygiene,* **88(2)**, 65-73.

Badjeck, M.-., E.H. Allison, A.S. Halls, and N.K. Dulvy, 2010: Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy,* **34(3)**, 375-383.

Banerjee, S., A. Diallo, and Q. Wodon, 2007: *Measuring trends in access to modern infrastructure in sub-Saharan Africa: Results from demographic and health surveys*. World BankFindings No. 281: Poverty Data, Measurement and Policy Special Expanded Edition. The World Bank.

Barbier, B., H. Yacouba, H. Karambiri, M. Zoromé, and B. Somé, 2009: Human vulnerability to climate variability in the sahel: Farmers' adaptation strategies in northern burkina faso. *Environmental Management,* **43(5)**, 790-803.

Barrios, S., L. Bertinelli, and E. Strobl, 2006: Climatic change and rural-urban migration: The case of sub-Saharan Africa. *Journal of Urban Economics,* **60(3)**, 357-371.

Batisani, N., 2011: Spatio-temporal ephemeral streamflow as influenced by climate variability in Botswana. *Journal of Geographical Sciences,* **21(3)**, 417-428.

Battersby, J., 2012: Urban food security and climate change: A system of flows. In: *Climate Change, Assets and Food Security in Southern African Cities*. [Frayne, B., C. Moser, and G. Ziervogel(eds.)]. Earthscan, Abingdon, pp. 35-56.

Battisti, D.S. and R.L. Naylor, 2009: Historical warnings of future food insecurity with unprecedented seasonal heat. *Science,* **323(5911)**, 240-244.

Bauer, S. and I. Scholz, 2010: Adaptation to climate change in Southern Africa: New boundaries for sustainable development? *Climate and Development,* **2(2)**, 83-93.

Baumann, H., S.C. Talmage, and C.J. Gobler, 2012: Reduced early life growth and survival in a fish in direct response to increased carbon dioxide. *Nature Climate Change,* **2(1)**, 38-41.

Baoua, I.B., L. Amadou, V. Margam, L.L. Murdock, 2012: Comparative evaluation of six storage methods for postharvest preservation of cowpea grain. *Journal of Stored Products Research* **49**, 171-175.

Beardon and Newman (2011) How wide are the ripples? From local participation to international organisational learning. Participatory learning and action notes, 63. London: IIED.

Beck, L. and T. Bernauer, 2011: How will combined changes in water demand and climate affect water availability in the Zambezi river basin? *Global Environmental Change,* **21(3)**, 1061-1072.

Bégué, A., E. Vintrou, D. Ruelland, M. Claden, and N. Dessay, 2011: Can a 25-year trend in Soudano-Sahelian vegetation dynamics be interpreted in terms of land use change? A remote sensing approach. *Global Environmental Change,* **21(2)**, 413-420.

Bele, M.Y., O. Somorin, D.J. Sonwa, J.N. Nkem, and B. Locatelli, 2011: Forests and climate change adaptation policies in Cameroon. *Mitigation and Adaptation Strategies for Global Change,* **16(3)**, 369-385.

Bellotti, A., B.V.H. Campo, and G. Hyman, 2012: Cassava Production and Pest Management: Present and Potential Threats in a Changing Environment. *Tropical Plant Biology,* **5(1)**, 39-72.

Béné, C., S. Devereux, and R. Sabates-Wheeler, 2012: *Shocks and social protection in the Horn of Africa: Analysis from the Productive Safety Net Programme in Ethiopia*. CSP Working Paper Number 005 / IDS Working Paper Number 395. Centre for Social Protection (CSP), Institute of Development Studies (IDS), Brighton, UK, pp. 120.

Berchie, J.N., M. Opoku, H. Adu-Dapaah, A. Agyemang, J. Sarkodie-Addo, E. Asare, J. Addo, and H. Akuffo, 2012: Evaluation of five bambara groundnut (Vigna subterranea (L.) Verdc.) landraces to heat and drought stress at Tono-Navrongo, Upper East Region of Ghana. *African Journal of Agricultural Research,* **7(2)**, 250-256.

Berg, A., N. De Noblet-Ducoudré, B. Sultan, M. Lengaigne, and M. Guimberteau, 2013: Projections of climate change impacts on potential C4 crop productivity over tropical regions. *Agricultural and Forest Meteorology,* **170**, 89-102.

Bergengren, J.C., D.E. Waliser, and Y.L. Yung, 2011: Ecological sensitivity: A biospheric view of climate change. *Climatic Change,* **107(3)**, 433-457.

Berkes, F., 2002: Epilogue: Making Sense of Arctic Environmental Change? In: *The Earth Is Faster Now: Indigenous Observations of Arctic Environmental Change*. [Krupnik, I. and D. Jolly(eds.)]. Arctic Research Consortium of U.S., Fairbanks, Alaska, USA, pp. 334-349.

Berkes, F., 2009. Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. Journal of Environmental Management 90(5), 1692-1702.

Berrang-Ford, L., J.D. Ford, and J. Paterson, 2011: Are we adapting to climate change? *Global Environmental Change,* **21(1)**, 25-33.

Beyene, T., D.P. Lettenmaier, and P. Kabat, 2010: Hydrologic impacts of climate change on the Nile River Basin: Implications of the 2007 IPCC scenarios. *Climatic Change,* **100(3)**, 433-461.

Biasutti, M. and A.H. Sobel, 2009: Delayed Sahel rainfall and global seasonal cycle in a warmer climate. *Geophysical Research Letters,* **36(23)**.

Biazin, B., G. Sterk, M. Temesgen, A. Abdulkedir, and L. Stroosnijder, 2012: Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa - A review. *Physics and Chemistry of the Earth,* **47-48**, 139-151.

Biesbroek, G.R., R.J. Swart, and W.G.M. van der Knaap, 2009: The mitigation-adaptation dichotomy and the role of spatial planning. *Habitat International,* **33(3)**, 230-237.

Bizikova, L., S. Boardley, and S. Mead, 2010: *Participatory scenario development approaches for identifying pro-poor adaptation options*. In: Economics of adaptation to climate change. Discussion Paper Number 18, December 2010. The World Bank, Washington, DC, USA, pp. 67.

Black, R., W.N. Adger, N.W. Arnell, S. Dercon, A. Geddes, and D. Thomas, 2011a: The effect of environmental change on human migration. *Global Environmental Change,* **21(SUPPL. 1)**, S3-S11.

Black, R., S.R.G. Bennett, S.M. Thomas, and J.R. Beddington, 2011b: Climate change: Migration as adaptation. *Nature,* **478(7370)**, 447-449.

Black, R., D. Kniveton, and K. Schmidt-Verkerk, 2011c: Migration and climate change: Towards an integrated assessment of sensitivity. *Environment and Planning A,* **43(2)**, 431-450.

BNRCC, 2012: *Towards a Lagos State Climate Change Adaptation Strategy*. Report prepared for the Commissioner of Environment, Lagos State, January 2012. Building Nigeria's Response to Climate Change (BNRCC) project, pp. 46.

Boateng, I., 2006: Shoreline management planning: can it benefit Ghana? A case study of UK SMPs and their potential relevance in Ghana.Proceedings of 5th FIG Regional Conference: Promoting Land Administration and Good Governance, 8-11, March 2006, Accra, pp. 17.

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

Bomblies, A. and E.A.B. Eltahir, 2010: Assessment of the Impact of Climate Shifts on Malaria Transmission in the Sahel. *EcoHealth,* , 1-12.

Bootsma, H.A. and S.E. Jorgensen, 2006: Lake Malawi/ Nyasa: Experience and Lessons Learned Brief . http://iwlearn.net/iw-projects/1665/experience-notes-and-lessons-learned/lake_malawi_nyasa_2005.pdf/view

Born, K., M. Christoph, A.H. Fink, P. Knippertz, H. Paeth, and P. Speth, 2008: Moroccan Climate in the Present and Future: Combined View from Observational Data and Regional Climate Scenarios. In: [Zereini, F. and H. Hötzl(eds.)]. Springer Berlin Heidelberg, pp. 29-45.

Bouchaou, L., J.L. Michelot, A. Vengosh, Y. Hsissou, M. Qurtobi, C.B. Gaye, T.D. Bullen, and G.M. Zuppi, 2008: Application of multiple isotopic and geochemical tracers for investigation of recharge, salinization, and residence time of water in the Souss-Massa aquifer, southwest of Morocco. *Journal of Hydrology,* **352(3-4)**, 267-287.

Bouma, M.J., A. Baeza, A. terVeen, and M. Pascual, 2011: Global malaria maps and climate change: A focus on East African highlands. *Trends in Parasitology,* **27(10)**, 421-422.

Branchu, P., L. Bergonzini, E. Pons-branchu, E. Violier, M. Dittrich, M. Massault, and B. Ghaleb, 2010: Lake Malawi sediment and pore water chemistry: Proposition of a conceptual model for stratification intensification since the end of the Little Ice Age. *Global and Planetary Change,* **72(4)**, 321-330.

Brander, K.M., 2007: Global fish production and climate change. *Proceedings of the National Academy of Sciences of the United States of America,* **104(50)**, 19709-19714.

Brasseur, G.P., M. Schultz, C. Granier, M. Saunois, T. Diehl, M. Botzet, E. Roeckner, and S. Walters, 2006: Impact of climate change on the future chemical composition of the global troposphere. *Journal of Climate,* **19(16)**, 3932-3951.

Braune, E. and Y. Xu, 2010: The role of ground water in sub-Saharan Africa. *Ground Water,* **48(2)**, 229-238.

Brockhaus, M. and Djoudi, H. 2008. Adaptation at the interface of forest and ecosystem goods and services and livestock production systems in Northern Mali. CIFOR Info Brief No. 19. CIFOR, Bogor.

Brooks, N., S. Anderson, J. Ayers, I. Burton, and I. Tellam, 2011: *Tracking adaptation and measuring development.* IIED Climate Change Working Paper No. 1, November 2011. International Institute for Environment and Development (IIED), London, UK, pp. 36.

Brooks, N., N. Grist, and K. Brown, 2009: Development futures in the context of climate change: Challenging the present and learning from the past. *Development Policy Review,* **27(6)**, 741-765.

Broto, Vaesa, et al. 2013. "Climate change adaption, local governance and poverty alleviation in Maputo". Local Environment: The International Journal of Justice and Sustainability. Forthcoming

Brown, T., S. Gibson, and S. Ashley, 2007: *Building consensus for social protection: Insights from Ethiopia's Productive Safety Net Programme (PSNP).* The IDL Group, pp. 10.

Brown, D.R., P. Dettmann, T. Rinaudo, H. Tefera, and A. Tofu, 2011: Poverty alleviation and environmental restoration using the clean development mechanism: A case study from Humbo, Ethiopia. *Environmental Management,* **48(2)**, 322-333.

Brown, M.E., B. Hintermann, and N. Higgins, 2009: Markets, climate change, and food security in West Africa. *Environmental Science and Technology,* **43(21)**, 8016-8020.

Brown C., J. Nkem, D. Sonwa and Y. Bele, 2010. Institutional adaptive capacity and climate change response in the Congo Basin forests in Cameroon. Mitigation and Adaptation Strategies for Global Change, 15(3), 263-282.

Bryan, E., C. Ringler, B. Okoba, C. Roncoli, S. Silvestri, and M. Herrero, 2011: *Adapting agriculture to climate change in Kenya: Household and community strategies and determinants* Unpublished report from the World Bank Project “Adaptation of smallholder agriculture to climate change in Kenya”, pp. 30.

Bryan, E., T.T. Deressa, G.A. Gbetibouo, and C. Ringler, 2009: Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science and Policy,* **12(4)**, 413-426.

Buchner, B., A. Falconer, M. Hervé-Mignucci, and C. Trabacchi, 2012: *The landscape of climate finance 2012.* A CPI Report. Climate Policy Initiative, San Francisco, CA, USA, pp. 84.

Bucini, G. and N.P. Hanan, 2007: A continental-scale analysis of tree cover in African savannas. *Global Ecology and Biogeography,* **16(5)**, 593-605.

Buhaug, H., 2010: Climate not to blame for African civil wars. *Proceedings of the National Academy of Sciences of the United States of America,* **107(38)**, 16477-16482.

Bunce, M., K. Brown, and S. Rosendo, 2010a: Policy misfits, climate change and cross-scale vulnerability in coastal Africa: how development projects undermine resilience. *Environmental Science and Policy,* **13(6)**, 485-497.

Bunce, M., Rosendo, S. and Brown, K. 2010b. Perceptions of climate change, multiple stressors and livelihoods on marginal African coasts. Environment, Development and Sustainability 12: 407-440.

Burke, L., K. Reytar, M. Spalding, and A. Perry, 2011: *Reefs at risk revisited. Executive Summary.* World Resources Institute (WRI), Washington, D.C., pp. 10.

Burke, M.B., D.B. Lobell, and L. Guarino, 2009a: Shifts in African crop climates by 2050, and the implications for crop improvement and genetic resources conservation. *Global Environmental Change,* **19(3)**, 317-325.

Burke, M.B., E. Miguel, S. Satyanath, J.A. Dykema, and D.B. Lobell, 2009b: Warming increases the risk of civil war in Africa. *Proceedings of the National Academy of Sciences of the United States of America,* **106(49)**, 20670-20674.

Burney, J.A. and R.L. Naylor, 2012: Smallholder Irrigation as a Poverty Alleviation Tool in Sub-Saharan Africa. *World Development,* **40(1)**, 110-123.

Bwango, A., J. Wright, C. Elias, and I. Burton, 2000: Reconciling national and global priorities in adaptation to climate change: With an illustration from Uganda. *Environmental Monitoring and Assessment,* **61(1)**, 145-159.

Callaway, J.M., D.B. Louw, J.C. Nkomo, M.E. Hellmuth, and D.A. Sparks, 2008: Benefits and costs of adapting water planning and management to climate change and water demand growth in the Western Cape of South Africa. In: *Climate change and adaptation.* [Leary, N., J. Adejuwon, V. Barros, I. Burton, J. Kulkarni, and R. Lasco(eds.)]. Earthscan, London, UK and Sterling, VA, USA, pp. 53-70.

Calow, R. and A. MacDonald, 2009: *What will climate change mean for groundwater supply in Africa?*. ODI Background Notes. Overseas Development Institute:, London, UK, pp. 8.

Caminade, C. and L. Terray, 2010: Twentieth century sahel rainfall variability as simulated by the ARPEGE AGCM, and future changes. *Climate Dynamics,* **35(1)**, 75-94.

Caminade, C., J.A. Ndione, C.M.F. Kebe, A.E. Jones, S. Danuor, S. Tay, Y.M. Tourre, J.-. Lacaux, C. Vignolles, J.B. Duchemin, I. Jeanne, and A.P. Morse, 2011: Mapping Rift Valley fever and malaria risk over West Africa using climatic indicators. *Atmospheric Science Letters,* **12(1)**, 96-103.

Caravani, A., N. Bird, and L. Schalatek, 2010: *Evolving global climate finance architecture*. Climate Finance Fundamentals Brief 2. Heinrich Böll Stiftung North America and Overseas Development Institute, pp. 4.

Cardona, O.D., M.K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R.S. Pulwarty, E.L.F. Schipper, and B.T. Sinh, 2012: Determinants of risk: exposure and vulnerability. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC).* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi *et al.*(eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65-108.

CARE, 2012: *
Decision-making for climate resilient
livelihoods and risk reduction: a participatory scenario planning approach

* . CARE International - Adaptation Learning Programme for Africa, pp. 12.

Care International (2012) Community-based adaptation: lessons from Africa. Jotoafrica Special Issue. Issue 11, December 2012.

Carneiro, J.F., M. Boughriba, A. Correia, Y. Zarhloule, A. Rimi, and B.E. Houadi, 2010: Evaluation of climate change effects in a coastal aquifer in Morocco using a density-dependent numerical model. *Environmental Earth Sciences,* **61(2)**, 241-252.

Carter, R.C. and A. Parker, 2009: Climate change, population trends and groundwater in Africa. *Hydrological Sciences Journal,* **54(4)**, 676-689.

Cartwright, A., 2008a: *
Coastal vulnerability in the context of climate change: a South African perspective* pp. 12.

Cartwright, A., 2008b: *Coastal vulnerability in the context of climate change: a South African perspective* pp. 12.

Cartwright, A., G. Brundrit, and L. Fairhurst, 2008: *A sea-level rise risk assessment for the City of Cape Town. Phase 4. Global Climate Change and Adaptation.* Sea-Level Rise Adaptation and risk mitigation measures for the City of Cape Town. LaquaR Consultants CC, Cape Town, South Africa, pp. 42.

Castro, A. P., D. Taylor, and D. W. Brokensha (eds) (2012) Climate Change and Threatened Communities. Practical Action.

CCAA, 2011: ***Extending our reach: Climate Change Adaptation in Africa program annual report 2010-11*** . Climate Change Adaptation in Africa program.

Chandani, A., 2011: *Improving leadership on climate change*. IIED Reflect & Act series, March 2011. International Institute for Environment and Development (IIED) Climate Change Group, pp. 2.

Chambwera, M. and S. Anderson (2011) Integrating climate change into agricultural research for development in Africa. IIED Briefing Paper, September 2011, available at http://pubs.iied.org/pdfs/17099IIED.pdf?

Chang'a, L.B., P.Z. Yanda, and James Ngana (2010) Indigenous knowledge in seasonal rainfall prediction in Tanzania: A case of the South-western Highland of Tanzania. Journal of Geography and Regional Planning Vol. 3(4), pp. 66-72, April 2010.

Chaves, L.F., A. Kaneko, G. Taleo, M. Pascual, and M.L. Wilson, 2008: Malaria transmission pattern resilience to climatic variability is mediated by insecticide-treated nets. *Malaria Journal,* **7**.

Chaves, L.F. and C.J.M. Koenraadt, 2010: Climate change and highland malaria: Fresh air for a hot debate. *Quarterly Review of Biology,* **85(1)**, 27-55.

Chaves, L.F., M. Hashizume, A. Satake and N. Minakawa, 2011: Regime shifts and heterogeneous trends in malaria time series from Western Kenya Highlands. *Parasitology*, **139**, 14–25.

Chevalier, R. 2011. Political barriers to climate change adaptation implementation in SADC. In: Masters, L. and Duff, L. 2011. Overcoming barriers to climate change adaptation implementation in Southern Africa. Africa Institute of South Africa, Pretoria. Pp 1- 19.

Chevalier, V., T. Rakotondrafara, M. Jourdan, J.M. Heraud, H.R. Andriamanivo, B. Durand, J. Ravaomanana, P.E. Rollin, and R. Rakotondravao, 2011: An unexpected recurrent transmission of rift valley fever virus in cattle in a temperate and mountainous area of madagascar. *PLoS Neglected Tropical Diseases,* **5(12)**.

Chia, E.L. (ed.), 2011: *Climate change adaptation and mitigation in the Congo Basin forest of Cameroon: strategies for synergy*. Diss. MSc, Norwegian University of Life Sciences, Department of International Environment and Development Studies, 104 pp.

Chidumayo, E., D. Okali, G. Kowero, and M. Larwanou, 2011: *Climate change and African forest and wildlife resources*. [Chidumayo, E., Okali, D., Kowero, G. and Larwanou, M. (eds.)]. The African Forest Forum, Nairobi, Kenya, pp. 249.

Chikapa, C., 2012: Impact of radio, cinema and vernacular publications in enhancing community based adaptation to climate change.16-22, April 2012, Hanoi, Vietnam, pp. 64-64.

Chikozho, C., 2010: Applied social research and action priorities for adaptation to climate change and rainfall variability in the rainfed agricultural sector of Zimbabwe. *Physics and Chemistry of the Earth,* **35(13-14)**, 780-790.

Chineke, T.C., S.S. Jagtap, and O. Nwofor, 2010: West African monsoon: Is the August break "breaking" in the eastern humid zone of Southern Nigeria? *Climatic Change,* **103(3)**, 555-570.

Chishakwe, N., Murray, L. and Chambwera M., 2012: Building climate change adaptation on community experiences: Lessons from community-based natural resource management in southern Africa, International Institute for Environment and Development. London. Available online at http://pubs.iied.org/pdfs/10030IIED.pdf?

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton, 2007: Regional climate projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt *et al.*(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 847-940.

CIFOR, 2011: *
Climate change and forests in the Congo Basin:

Synergy between adaptation and mitigation
*. COBAM Project Information number 1. Center for International Forestry Research, pp. 2.

Cinner, J.E., T.R. McClanahan, N.A.J. Graham, T.M. Daw, J. Maina, S.M. Stead, A. Wamukota, K. Brown, and O. Bodin, 2012: Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. *Global Environmental Change,* **22(1)**, 12-20.

Clark, B.M., 2006: Climate change: A looming challenge for fisheries management in southern Africa. *Marine Policy,* **30(1)**, 84-95.

Clements, R., J. Haggar, A. Quezada, and J. Torres, 2011: *Technologies for climate change adaptation: agriculture sector*. In: TNA Guidebook Series [Zhu, X. (ed.)]. UNEP Risø Centre, Roskilde, Denmark, pp. 198.

Climate Investment Fund, 2009: *Programming and financing modalities for the SCF targeted program, the Pilot Program for Climate Change Resilience (PPCR)*. Climate Investment Funds, pp. 27.

Clover, J. and Eriksen, S. The effects of land tenure change on sustainability: human security and environmental change in southern African savannas. Environmental Science and Policy 12: 53-70.

Cochrane, K., C. De Young, D. Soto, and T. Bahri (eds.), 2009: *Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge*. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 212.

Codjoe, S.N.A. and G. Owusu, 2011: Climate change/variability and food systems: evidence from the Afram Plains, Ghana. *Regional Environmental Change,* , 1-13.

Codjoe, S. N. A., Atidoh, L.K., and Burkett, V. 2012. Gender and occupational perspectives on adapation to climate extremes in the Afram Plain of Ghana. Climatic Change 110: 432-454.

Coe, R. and R.D. Stern, 2011: Assessing and addressing climate-induced risk in sub-Saharan rainfed agriculture: Lessons learned. *Experimental Agriculture,* **47(2)**, 395-410.

Cohen, M.J. and J.L. Garrett, 2010: The food price crisis and urban food (in)security. *Environment and Urbanization,* **22(2)**, 467-482.

Collier, P., G. Conway, and T. Venables, 2008: Climate change and Africa. *Oxford Review of Economic Policy,* **24(2)**, 337-353.

Collins, J.M., 2011: Temperature variability over Africa. *Journal of Climate,* **24(14)**, 3649-3666.

Conway, G. 2009. The science of climate change in Africa: impacts and adaptation. Grantham Institute for Climate Change, Discussion Paper No. 1. Imperial College, London.

Conway, D., 2011: Adapting climate research for development in Africa. *Wiley Interdisciplinary Reviews: Climate Change,* **2(3)**, 428-450.

Conway, D. and E.L.F. Schipper, 2011: Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environmental Change,* **21(1)**, 227-237.

Cook, K.H. and E.K. Vizy, 2012: Impact of climate change on mid-twenty-first century growing seasons in Africa. *Climate Dynamics,* **39(12)**, 2937-2955.

Cooper, P.J.M., J. Dimes, K.P.C. Rao, B. Shapiro, B. Shiferaw, and S. Twomlow, 2008: Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems and Environment,* **126(1-2)**, 24-35.

Corsi, M., S. Hagemann, and C. Salgado Silva, 2012: *Africa Adaptation Programme third quarterly report 2012. Prepared by the AAP Inter-Regional Technical Support Component.* UNDP Africa Adaptation Programme, pp. 54.

Cotter, M., R. de la Pena-Lavander, and J. Sauerborn, 2012: Understanding the present distribution of the parasitic weed*Striga hermonthica*and predicting its potential future geographic distribution in the light of climate change. *Julius-Kühn-Archiv,* **2(434)**, 630-636.

Cotty, P.J. and R. Jaime-Garcia, 2007: Influences of climate on aflatoxin producing fungi and aflatoxin contamination. *International Journal of Food Microbiology,* **119(1-2)**, 109-115.

Crane, T.A. (2010) Of models and meanings: cultural resilience in social-ecological systems. Ecology and Society. 15(4)19 online

Crush, J. and B. Frayne, 2010: *Pathways to Insecurity: Urban Food Supply and Access in Southern African Cities.* Urban Food Security Series No. 3. African Food Security Urban Network (AFSUN), pp. 46.

Cuevas, L.E., I. Jeanne, A. Molesworth, M. Bell, E.C. Savory, S.J. Connor, and M.C. Thomson, 2007: Risk mapping and early warning systems for the control of meningitis in Africa. *Vaccine,* **25(SUPPL. 1)**, A12-A17.

Cullen, N.J., T. Mölg, G. Kaser, K. Hussein, K. Steffen, and D.R. Hardy, 2006: Kilimanjaro Glaciers: Recent areal extent from satellite data and new interpretation of observed 20th century retreat rates. *Geophysical Research Letters,* **33(16)**.

Dabi, D D., Nyong, A. O., Adeptu, A. and Ihemegbulem, V. I. 2008. Pat, present and future adaptation by rural households of northern Nigeria. In: Leary, N., Adejuwon, J., Barros, V., Burton, I., Kulkarni, J. and Lasco, R. Climate change and adaptation. Earthscan Climate, London.

Dapi, L.N., J. Rocklöv, G. Nguefack-Tsague, E. Tetanye, and T. Kjellstrom, 2010: Heat impact on schoolchildren in Cameroon, Africa: potential health threat from climate change. *Global Health Action,* **3(5610)**, 8.

Darwall, W., K. Smith, D. Allen, R. Holland, I. Harrison, and E. Brooks (eds.), 2011: *The Diversity of life in African freshwaters: under water, under threat. An analysis of the status and distribution of freshwater species throughout mainland Africa.* IUCN, Gland, Switzerland and Cambridge, UK, pp. 348.

Davies, M., B. Guenther, J. Leavy, T. Mitchell, and T. Tanner, 2009: *Climate change adaptation, disaster risk reduction and social protection: complementary roles in agriculture rural growth?.* IDS Working Paper No. 320, February 2009. Institute of Development Studies (IDS), Brighton, UK, pp. 37.

Dayamba, S.D., M. Tigabu, L. Sawadogo, and P.C. Oden, 2008: Seed germination of herbaceous and woody species of the Sudanian savanna-woodland in response to heat shock and smoke. *Forest Ecology and Management,* **256(3)**, 462-470.

de Jong, R., S. de Bruin, A. de Wit, M.E. Schaepman, and D.L. Dent, 2011: Analysis of monotonic greening and browning trends from global NDVI time-series. *Remote Sensing of Environment,* **115(2)**, 692-702.

de Magny, G.C., J.-. Guégan, M. Petit, and B. Cazelles, 2007: Regional-scale climate-variability synchrony of cholera epidemics in West Africa. *BMC Infectious Diseases,* **7**.

De Silva, S.S. and D. Soto, 2009: Climate change and aquaculture: potential impacts, adaptation and mitigation. In: *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530.* [Cochrane, K., C. De Young, D. Soto, and T. Bahri(eds.)]. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 151-212.

Debsu, D.N., 2012: Community based coping mechanisms and adaptations to droughts in the Borana Pastoral area of southern Ethiopia.16-22, April 2012, Hanoi, Vietnam, pp. 42-42.

del Ninno, C., K. Subbarao, and A. Milazzo, 2009: *How to make public works work: A review of the experiences.* Social Protection Discussion Paper No. 0905. The World Bank, Washington, DC, USA, pp. 78.

Delire, C., A. Ngomanda, and D. Jolly, 2008: Possible impacts of 21st century climate on vegetation in Central and West Africa. *Global and Planetary Change,* **64(1-2)**, 3-15.

Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S. Ramachandran, P.L. da Silva Dias, S.C. Wofsy, and X. Zhang, 2007: Couplings Between Changes in the Climate System and Biogeochemistry. In: [Solomon, S., D. Qin, M.

Manning, Z. Chen, M. Marquis, K.B. Averyt *et al.*(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 499-587.

Denton, F., S. Anderson, and J. Ayers, 2011: *Getting African climate change research recognised*. IIED Briefing, Lessons from Adaptation in Practice, November 2011. International Institute for Environment and Development (IIED), London, UK, pp. 4.

Denton, F., 2010: Financing adaptation in Least Developed Countries in West Africa: Is finance the 'real deal'? *Climate Policy,* **10(6)**, 655-671.

Deressa, T.T., Hassan, R. M., Ringler, C., Alemu, T. and Yesuf, M. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change 19: 248-255.

Desanker, P., C. Magdaza, A. Allalli, C. Basalirwa, M. Boko, G. Dieudonne, T.E. Downing, P.O. Dube, A. Githeko, M. Githendu, P. Gonzalez, D. Gwary, B. Jallow, J. Nwafa, and R. Scholes, 2001: Africa. In: *Climate Change 2001. Impacts, Adaptation, and Vulnerability*. [Mc Carthy, J.J., O.F. Canziani, N.A. Leary, and D.J. Dokken(eds.)]. Cambridge University Press, Cambridge, UK, pp. 487-531.

Descheemaeker, K., T. Amede, A. Haileslassie, and D. Bossio, 2011: Analysis of gaps and possible interventions for improving water productivity in crop livestock systems of Ethiopia. *Experimental Agriculture,* **47(S1)**, 21-38.

Descheemaeker, K., E. Mapedza, T. Amede, and W. Ayalneh, 2010: Effects of integrated watershed management on livestock water productivity in water scarce areas in Ethiopia. *Physics and Chemistry of the Earth,* **35(13-14)**, 723-729.

Dessu, S.B. and A.M. Melesse, 2012: Impact and uncertainties of climate change on the hydrology of the Mara River basin, Kenya/Tanzania. *Hydrological Processes,* .

Diagne, K., 2007: Governance and natural disasters: Addressing flooding in Saint Louis, Senegal. *Environment and Urbanization,* **19(2)**, 552-562.

Diallo, I., M.B. Sylla, M. Camara, and A.T. Gaye, 2012: Interannual variability of rainfall over the Sahel based on multiple regional climate models simulations. *Theoretical and Applied Climatology,* , 1-12.

Dillon, A., 2011: The effect of irrigation on poverty reduction, asset accumulation, and informal insurance: Evidence from Northern Mali. *World Development,* **39(12)**, 2165-2175.

Dinku, T., T. Arivelo, S.B. Awulachew, A.F. Kamgaf, S.A. Moges, B.S. Nyenzi, and Y. Sileshi, 2011: *
Climate science, information, and services in Africa: Status, gaps and policy implications*. Working Paper 1, November 2011. United Nations Economic Commission for Africa, African Climate Policy Centre, pp. 26.

Diop, S., R. Arthurton, P. Scheren, J. Kitheka, K. Koranteng, and R. Payet, 2011: The coastal and marine environment of Western and Eastern Africa: challenges to sustainable management and socioeconomic development. In: *Treatise on Estuarine and Coastal Science*. Academic Press, Amsterdam, pp. 315-335.

Djoudi, H. and M. Brockhaus, 2011: Is adaptation to climate change gender neutral? Lessons from communities dependent on livestock and forests in northern Mali. *International Forestry Review,* **13(2)**, 123-135.

Djoudi, H., M. Brockhaus, and B. Locatelli, 2011: Once there was a lake: vulnerability to environmental changes in northern Mali. *Regional Environmental Change,* , 1-16.

Dodman, D. and J. Carmin, 2011: *Urban adaptation planning: the use and limits of climate science*. . IIED Briefing: Lessons from adaptation in practice. International Institute for Environment and Development (IIED), London, UK, pp. 4.

Dondji, B., 2001: Leishmaniasis and phlebotomine sandflies of Cameroon: A review. *Bulletin De La Societe De Pathologie Exotique,* **94(3)**, 277-279.

Dondorp, A.M., S. Yeung, L. White, C. Nguon, N.P.J. Day, D. Socheat, and L. Von Seidlein, 2010: Artemisinin resistance: Current status and scenarios for containment. *Nature Reviews Microbiology,* **8(4)**, 272-280.

Dossou, K.M.R. and B. Gléhouenou-Dossou, 2007: The vulnerability to climate change of Cotonou (Benin): The rise in sea level. *Environment and Urbanization,* **19(1)**, 65-79.

Dougill, A.J., E.D.G. Fraser, and M.S. Reed, 2010: Anticipating vulnerability to climate change in dryland pastoral systems: Using dynamic systems models for the Kalahari. *Ecology and Society,* **15(2)**, 14.

Douglas, I., K. Alam, M. Maghenda, Y. Mcdonnell, L. Mclean, and J. Campbell, 2008: Unjust waters: Climate change, flooding and the urban poor in Africa. *Environment and Urbanization,* **20(1)**, 187-205.

Drimie, S. and S. Gillespie, 2010: Adaptation to climate change in Southern Africa: Factoring in AIDS. *Environmental Science and Policy,* **13(8)**, 778-784.

Drine, I., 2011: *Climate change compounding risks in North Africa*. UNU-WIDER Working Paper No. 2011/32. United Nations University, World Institute for Development Economics Research, pp. 19.

Driouech, F., M. Déqué, and E. Sánchez-Gómez, 2010: Weather regimes-Moroccan precipitation link in a regional climate change simulation. *Global and Planetary Change,* **72(1-2)**, 1-10.

Droogers, P., W.W. Immerzeel, W. Terink, J. Hoogeveen, M.F.P. Bierkens, L.P.H. Van Beek, and B. Debele, 2012: Water resources trends in Middle East and North Africa towards 2050. *Hydrology and Earth System Sciences,* **16(9)**, 3101-3114.

Dube, O.P. and M.B.M. Sekhwela, 2007: *Community Coping Strategies in Semiarid Limpopo Basin Part of Botswana: Enhancing Adaptation Capacity to Climate Change, AIACC Working Paper No. 47. AIACC Working Papers*. International START Secretariat, Washington, DC, pp. 42.

Dube, O. P. and Sekhwela, B. M. 2008. Indigenous knowledge, institutions and practices for coping with variable climate in the Limpopo Basin of Botswana. In: Leary, N., Adejuwon, J., Barros, V., Burton, I., Kulkarni, J. and Lasco, R. Climate change and adaptation. Earthscan Climate, London.

Dukić, V., M. Hayden, A.A. Forgor, T. Hopson, P. Akweongo, A. Hodgson, A. Monaghan, C. Wiedinmyer, T. Yoksas, M.C. Thomson, S. Trzaska, and R. Pandya, 2012: The Role of Weather in Meningitis Outbreaks in Navrongo, Ghana: A Generalized Additive Modeling Approach. *Journal of Agricultural, Biological, and Environmental Statistics,* **17(3)**, 442-460.

Easterly, W., 2009: Can the west save Africa? *Journal of Economic Literature,* **47(2)**, 373-447.

Ebi,K. L.;Padgham,J.;Doumbia,M.;Kergna,A.;Smith,J.;Butt,T.;McCarl,B., 2011: Smallholders adaptation to climate change in Mali. *Climatic Change,* **108(3),** 423-436.

Economic Commission for Africa, African Union, African Development Bank, and United Nations Development Programme, 2012: *MDG Report 2012: Assessing progress in Africa toward the Millennium Development Goals. Emerging perspectives from Africa on the post-2015 development agenda.*, pp. 160.

Edlund, S., M. Davis, J.V. Douglas, A. Kershenbaum, N. Waraporn, J. Lessler, and J.H. Kaufman, 2012: A global model of malaria climate sensitivity: Comparing malaria response to historic climate data based on simulation and officially reported malaria incidence. *Malaria Journal,* **11**.

Egbendewe-Mondzozo, A., M. Musumba, B.A. McCarl, and X. Wu, 2011: Climate change and vector-borne diseases: An economic impact analysis of malaria in Africa. *International Journal of Environmental Research and Public Health,* **8(3)**, 913-930.

Eid, H.M., S.M. El-Marsafawy, and S.A. Ouda, 2007: *Assessing the Economic Impacts of Climate Change on Agriculture in Egypt: A Ricardian Approach*. In: Policy Research Working Paper 4342. The World Bank, pp. 39.

Eitzinger, A., P. Läderach, A. Quiroga, A. Pantoja, and J. Gordon, 2011a: *Future climate scenarios for Kenya's tea growing areas*. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, pp. 27.

Eitzinger, A., P. Läderach, A. Quiroga, A. Pantoja, and J. Gordon, 2011b: *Future climate scenarios for Uganda's tea growing areas*. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, pp. 23.

Ellis, E.C., K.K. Goldewijk, S. Siebert, D. Lightman, and N. Ramankutty, 2010: Anthropogenic transformation of the biomes, 1700 to 2000. *Global Ecology and Biogeography,* **19(5)**, 589-606.

Elshamy, M.E., I.A. Seierstad, and A. Sorteberg, 2008: Impacts of climate change on Blue Nile flows using bias-corrected GCM scenarios. *Hydrology and Earth System Sciences Discussions,* **5(3)**, 1407-1439.

Elshamy, M.E., I.A. Seierstad, and A. Sorteberg, 2009: Impacts of climate change on Blue Nile flows using bias-corrected GCM scenarios. *Hydrology and Earth System Sciences,* **13(5)**, 551-565.

Engelbrecht, F.A., J.L. McGregor, and C.J. Engelbrecht, 2009: Dynamics of the conformal-cubic atmospheric model projected climate-change signal over southern Africa. *International Journal of Climatology,* **29(7)**, 1013-1033.

Eriksen, S., C. Vogel, G. Ziervogel, F. Steinbruch, and F. Nazare, 2010: Vulnerability assessments in the developing world: Mozambique and South Africa. In: *Assessing Vulnerability to Global Environmental Change: Making Research Useful for Adaptation Decision Making and Policy*. [Patt, A., D. Schröder, R. Klein, and A.C. de la Vega-Leinert(eds.)]. Earthscan, London, UK, pp. 61-78.

Eriksen, S. and J.A. Silva, 2009: The vulnerability context of a savanna area in Mozambique: household drought coping strategies and responses to economic change. *Environmental Science and Policy,* **12(1)**, 33-52.

Ermert, V., A.H. Fink, A.P. Morse, and H. Paeth, 2012: The impact of regional climate change on malaria risk due to greenhouse forcing and land-use changes in tropical Africa. *Environmental Health Perspectives,* **120(1)**, 77-84.

Evans, J.P. (2011) Resilience, ecology and adaptation in the experimental city. Trans Inst Br Geogr NS 36 223–237 2011.

Eyong, C.T., 2007: Indigenous knowledge and sustainable development in Africa: case study on central Africa. In: *Indigenous knowledge systems and sustainable development: relevance for Africa. Tribes and Tribals, Special Volume No. 1*. [Boon, E.K. and L. Hens(eds.)]. Kamla-Raj Enterprises, Dheli, India, pp. 121-139.

Fankhauser, S. and I. Burton, 2011: *Spending adaptation money wisely*. Working Paper No. 47 and No. 37. Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment, London, UK, pp. 22.

Fankhauser, S. and G. Schmidt-Traub, 2010: *From adaptation to climate-resilient development: the costs of climate-proofing the Millennium Development Goals in Africa*. Centre for Climate Change Economics and Policy (CCCEP) and Grantham Research Institute on Climate Change and the Environment, London, UK, pp. 26.

Fankhauser, S., 1997: The social costs of climate change: The IPCC second assessment report and beyond. *Mitigation and Adaptation Strategies for Global Change,* **1(4)**, 385-403.

FAO, 2011: *State of the World's Forests 2011*. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 164.

Fatondji, D., C. Martius, R. Zougmore, P.L.G. Vlek, C.L. Bielders, and S. Koala, 2009: Decomposition of organic amendment and nutrient release under the zai technique in the Sahel. *Nutrient Cycling in Agroecosystems,* **85(3)**, 225-239.

Favier, C., J. Aleman, L. Bremond, M.A. Dubois, V. Freycon, and J.-. Yangakola, 2012: Abrupt shifts in African savanna tree cover along a climatic gradient. *Global Ecology and Biogeography,* **21(8)**, 787-797.

Fensholt, R., K. Rasmussen, T.T. Nielsen, and C. Mbow, 2009: Evaluation of earth observation based long term vegetation trends - Intercomparing NDVI time series trend analysis consistency of Sahel from AVHRR GIMMS, Terra MODIS and SPOT VGT data. *Remote Sensing of Environment,* **113(9)**, 1886-1898.

Fensholt, R. and K. Rasmussen, 2011: Analysis of trends in the Sahelian 'rain-use efficiency' using GIMMS NDVI, RFE and GPCP rainfall data. *Remote Sensing of Environment,* **115(2)**, 438-451.

Fermont, A.M., P.J.A. van Asten, and K.E. Giller, 2008: Increasing land pressure in East Africa: The changing role of cassava and consequences for sustainability of farming systems. *Agriculture, Ecosystems and Environment,* **128(4)**, 239-250.

Ferrari, M.C.O., D.L. Dixson, P.L. Munday, M.I. Mccormick, M.G. Meekan, A. Sih, and D.P. Chivers, 2011: Intrageneric variation in antipredator responses of coral reef fishes affected by ocean acidification: Implications for climate change projections on marine communities. *Global Change Biology,* **17(9)**, 2980-2986.

Figueiredo, P. and P.E. Perkins, 2012: Women and water management in times of climate change: participatory and inclusive processes. *Journal of Cleaner Production,* .

Findlay, A.M., 2011: Migrant destinations in an era of environmental change. *Global Environmental Change,* **21(SUPPL. 1)**, S50-S58.

Fisher, M., M. Chaudhury, and B. McCusker, 2010: Do forests help rural households adapt to climate variability? Evidence from Southern Malawi. *World Development,* **38(9)**, 1241-1250.

Flåm, K.H. and J.B. Skjærseth, 2009: Does adequate financing exist for adaptation in developing countries? *Climate Policy,* **9(1)**, 109-114.

Foden, W., G.F. Midgley, G. Hughes, W.J. Bond, W. Thuiller, M.T. Hoffman, P. Kaleme, L.G. Underhill, A. Rebelo, and L. Hannah, 2007: A changing climate is eroding the geographical range of the Namib Desert tree Aloe through population declines and dispersal lags. *Diversity and Distributions,* **13(5)**, 645-653.

Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C. S. Holling, B. Walker, J. Bengtsson, F. Berkes, J. Colding, K. Danell, M. Falkenmark, M. Moberg, L. Gordon, R. Kaspersson, N. Kautsky, A. Kinzig, S. A. Levin, K.-G. Mäler, L. Ohlsson, P. Olsson, E. Ostrom, W. Reid, J. Rockstöm, S. Savenije, and U. Svedin. 2002.Resilience and sustainable development: building adaptive capacity in a world of transformations. Report for the Swedish Environmental Advisory Council 2002. Ministry of the Environment, Stockholm, Sweden.

Folke, C., T. Hahn, P. Olsson, and J. Norberg, 2005: *Adaptive governance of social-ecological systems* pp. 441-473.

Ford, J.D., W. Vanderbilt, and L. Berrang-Ford, 2012: Authorship in IPCC AR5 and its implications for content: Climate change and Indigenous populations in WGII. *Climatic Change,* **113(2)**, 201-213.

Foresight, 2011: *Migration and global environmental change: future challenges and opportunities*. Final Project Report. The Government Office for Science, London, UK, pp. 234.

Fox, S. and K. Hoelscher, 2010: *The political economy of social violence: theory and evidence from a cross-country study*. Crisis States Working Papers Series No. 2, April 2010. Crisis States Research Centre, London School of Economics, London, UK, pp. 24.

Franke, A. and C. Clemmesen, 2011: Effect of ocean acidification on early life stages of Atlantic herring (Clupea harengus L.). *Biogeosciences,* **8(12)**, 3697-3707.

Frankel-Reed, J. and N.C. Brooks, 2008: *Proposed framework for monitoring and evaluation of adaptation to climate change*. UNDP Working Paper, June 2008. United Nations Development Programme.

Frankenberger, T.R., T. Spangler, S. Nelson and M. Langworthy, 2012: *Enhancing Resilience to Food Insecurity amid Protracted Crisis*. High Level Expert Forum on food insecurity in protracted crisis, 13-14 September 2012, Rome, 16pp.

Freier, K.P., R. Bruggemann, J. Scheffran, M. Finckh, and U.A. Schneider, 2012: Assessing the predictability of future livelihood strategies of pastoralists in semi-arid Morocco under climate change. *Technological Forecasting and Social Change,* **79(2)**, 371-382.

Friedman, J. and N. Schady, 2009: *How many more infants are likely to die in Africa as a result of the global financial crisis?*. Policy Research Working Paper No. 5023. Development Reserach Group, The World Bank, Washington, D.C., pp. 16.

Frommel, A.Y., R. Maneja, D. Lowe, A.M. Malzahn, A.J. Geffen, A. Folkvord, U. Piatkowski, T.B.H. Reusch, and C. Clemmesen, 2012: Severe tissue damage in Atlantic cod larvae under increasing ocean acidification. *Nature Climate Change,* **2(1)**, 42-46.

Funk, C., G. Eilerts, J. Verdin, J. Rowland, and M. Marshall, 2011: *A climate trend analysis of Sudan*. U.S. Geological Survey Fact Sheet 2011-3072, pp. 6.

Funk, C., J. Michaelsen, and M. Marshall, 2012: Mapping recent decadal climate variations in precipitation and temperature across Eastern Africa and the Sahel. In: ***Remote Sensing of Drought: Innovative Monitoring Approaches***. [Wardlow, B.D., M.C. Anderson, and J.P. Verdin(eds.)]. CRC Press, Boca Raton, FL, USA, pp. 331-358.

Funk, C., M.D. Dettinger, J.C. Michaelsen, J.P. Verdin, M.E. Brown, M. Barlow, and A. Hoell, 2008: Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. *Proceedings of the National Academy of Sciences of the United States of America,* **105(32)**, 11081-11086.

Galloway McLean, K., 2010: *dvance Guard: Climate Change Impacts, Adaptation, Mitigation and Indigenous Peoples – A Compendium of Case Studies*. United Nations University, Institute of Advanced Studies - Traditional Knowledge Initiative, Darwin, Australia, pp. 124.

Galvin, K.A., 2009: *Transitions: Pastoralists living with change* pp. 185-198.

García-Ruiz, J.M., J.I. López-Moreno, S.M. Vicente-Serrano, T. Lasanta-Martínez, and S. Beguería, 2011: Mediterranean water resources in a global change scenario. *Earth-Science Reviews,* **105(3-4)**, 121-139.

Garrity, D.P., F.K. Akinnifesi, O.C. Ajayi, S.G. Weldesemayat, J.G. Mowo, A. Kalinganire, M. Larwanou, and J. Bayala, 2010: Evergreen Agriculture: A robust approach to sustainable food security in Africa. *Food Security,* **2(3)**, 197-214.

Gbetibou, G.A., 2009: *Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa*. IFPRI Discussion Paper 00849. International Food Policy Research Institute (IFPRI) Environment and Production Technology Division, Washington, DC, pp. 43.

Gbetibouo, G.A., Hassan, R.M., Ringler, C., 2010. Modelling farmers' adaptation strategies for climate change and variability: The case of the Limpopo Basin, South Africa, Agrekon: Agricultural Economics Research, Policy and Practice in Southern Africa, 49, 217-234

GEF Evaluation Office, 2011: *Evaluation of the Special Climate Change Fund (SCCF)*. Unedited Version of Final Report. Global Environmental Facility (GEF), pp. 62.

Gemenne, F., 2011a: Climate-induced population displacements ina4°C+ world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* **369(1934)**, 182-195.

Gemenne, F., 2011b: Why the numbers don't add up: A review of estimates and predictions of people displaced by environmental changes. *Global Environmental Change,* **21(SUPPL. 1)**, S41-S49.

German, L., G.C. Schoneveld, and D. Gumbo, 2011: The local social and environmental impacts of smallholder-based biofuel investments in Zambia. *Ecology and Society,* **16(4)**.

Gething, P.W., D.L. Smith, A.P. Patil, A.J. Tatem, R.W. Snow, and S.I. Hay, 2010: Climate change and the global malaria recession. *Nature,* **465(7296)**, 342-345.

Girot, P., C. Ehrhart and J.Oglethorpe, 2012: Integrating Community and Ecosystem-Based Approaches in Climate Change Adaptation Responses. Briefing paper prepared by the Ecosystem and Livelihoods Adaptation Network (ELAN), available at http://www.elanadapt.net

Gijsbers, H.J.M., J.J. Kessler, and M.K. Knevel, 1994: Dynamics and natural regeneration of woody species in farmed parklands in the Sahel region (Province of Passore, Burkina Faso). *Forest Ecology and Management,* **64(1)**, 1-12.

Gilioli, G. and L. Mariani, 2011: Sensitivity of Anopheles gambiae population dynamics to meteo-hydrological variability: A mechanistic approach. *Malaria Journal,* **10**.

Githeko, A.K., E.N. Ototo, and Y. Guiyun, 2012: Progress towards understanding the ecology and epidemiology of malaria in the western Kenya highlands: Opportunities and challenges for control under climate change risk. *Acta Tropica,* **121(1)**, 19-25.

Godfrey, A., E. Le Roux-Rutledge, S. Cooke, and M. Burton, 2010: *Africa Talks Climate: The public understanding of climate change in ten countries*. Executive Summary. BBC World Service Trust and British Council, London, UK, pp. 11.

Goerner, A., E. Jolie, and R. Gloaguen, 2009: Non-climatic growth of the saline Lake Beseka, Main Ethiopian Rift. *Journal of Arid Environments,* **73(3)**, 287-295.

Goh, A. H. X. 2012. A literature review of the gender-differentiated imapcts of climate change on women's and men's assets and well-being in developing countries. CAPRi Working Paper No. 106. CAPRi, IFPRI, Washington DC.

Goklany, I.M. (2007) Integrated strategies to reduce vulnerability and advance adaptation, mitigation, and sustainable development. Mitig Adapt Strat Glob Change. DOI 10.1007/s11027-007-9098-1

Goldstone, J.A., 2002:
Population and security: how demographic change can lead to violent conflict. *Journal of International Affairs,* **56(1)**, 3-22.

Gomez-Echeverri, L., 2010: National Funding Entities. Their role in the transition to a new paradigm of global cooperation on climate change. European Capacity building Initiative Policy report. http://www.oxfordclimatepolicy.org/publications/documents/NFEsPolicyReport.pdf

Gonzalez, P., 2001: Desertification and a shift of forest species in the West African Sahel. *Climate Research,* **17(2 SPECIAL 8)**, 217-228.

Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek, 2010: Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography,* **19(6)**, 755-768.

Gonzalez, P., C.J. Tucker, and H. Sy, 2012: Tree density and species decline in the African Sahel attributable to climate. *Journal of Arid Environments,* **78**, 55-64.

Good, S.P. and K.K. Caylor, 2011: Climatological determinants of woody cover in Africa. *Proceedings of the National Academy of Sciences of the United States of America,* **108(12)**, 4902-4907.

Goreau, T., T. McClanahan, R. Hayes, and A. Strong, 2000: Conservation of coral reefs after the 1998 global bleaching event. *Conservation Biology,* **14(1)**, 5-15.

Goulden, M., D. Conway, and A. Persechino, 2009a: Adaptation to climate change in international river basins in Africa: A review. *Hydrological Sciences Journal,* **54(5)**, 805-828.

Goulden, M., L.O. Naess, K. Vincent and W.N. Adger, 2009b: Accessing Diversification, Networks and Traditional Resource Management as Adaptations to Climate Extremes. In: Adapting to Climate Change: Thresholds, Values, Governance [Adger, W.N., Lorenzoni, I. And K.O'Brien (eds.)] . Cambridge University Press.

Government of Uganda and WFP, 2010: *Project Document on Partnership between the Office of the Prime Minister of Uganda and the United Nations World Food Programme in the Implementation of the Livelihoods Program under the Framework of the Second Northern Uganda Social Action Fund (NUSAF2) in Karamoja Sub-Region.*

Grab, S. and A. Craparo, 2011: Advance of apple and pear tree full bloom dates in response to climate change in the southwestern Cape, South Africa: 1973-2009. *Agricultural and Forest Meteorology,* **151(3)**, 406-413.

Gray, C.L., 2011: Soil quality and human migration in Kenya and Uganda. *Global Environmental Change,* **21(2)**, 421-430.

Greene, A.M., A. Giannini, and S.E. Zebiak, 2009: Drought return times in the Sahel: A question of attribution. *Geophysical Research Letters,* **36(12)**.

Greve, M., A.M. Lykke, A. Blach-Overgaard, and J.-. Svenning, 2011: Environmental and anthropogenic determinants of vegetation distribution across Africa. *Global Ecology and Biogeography,* **20(5)**, 661-674.

Grimmer, A. (ed.), 2011: *Accretion versus bioerosion on the Maputaland reefs in South Africa – The major processes*. Diss. MSc, University of KwaZulu-Natal, 69 pp.

Groen, T.A., F. van Langevelde, C.A.D.M. van de Vijver, A.L. de Raad, J. de Leeuw, and H.H.T. Prins, 2011: A continental analysis of correlations between tree patterns in African savannas and human and environmental variables. *Journal of Arid Environments,* **75(8)**, 724-733.

Grothmann, T. and Patt, A. 2005. Adaptive capacity and human cognition: The process of individual adaptation to climate change. Global Environmental Change 15: 199-213.

Guthiga, P. and A. Newsham, 2011: Meteorologists Meeting Rainmakers: Indigenous Knowledge and Climate Policy Processes in Kenya. *IDS Bulletin,* **42(3)**, 104-109.

Haan, N., S. Devereux, and D. Maxwell, 2012: Global implications of Somalia 2011 for famine prevention, mitigation and response. *Global Food Security,* **1**, 74-79.

Haande, S., T. Rohrlack, R.P. Semyalo, P. Brettum, B. Edvardsen, A. Lyche-Solheim, K. Sørensen, and P. Larsson, 2011: Phytoplankton dynamics and cyanobacterial dominance in Murchison Bay of Lake Victoria (Uganda) in relation to environmental conditions. *Limnologica,* **41(1)**, 20-29.

Hadley, C., D.A. Linzer, T. Belachew, A.G. Mariam, F. Tessema, and D. Lindstrom, 2011: Household capacities, vulnerabilities and food insecurity: Shifts in food insecurity in urban and rural Ethiopia during the 2008 food crisis. *Social Science and Medicine,* **73(10)**, 1534-1542.

Haglund, E., J. Ndjeunga, L. Snook, and D. Pasternak, 2011: Dry land tree management for improved household livelihoods: Farmer managed natural regeneration in Niger. *Journal of Environmental Management,* **92(7)**, 1696-1705.

Haites, E., 2011: Climate change finance. *Climate Policy,* **11(3)**, 963-969.

Halsnæs, K. and J. Verhagen, 2007: Development based climate change adaptation and mitigation - Conceptual issues and lessons learned in studies in developing countries. *Mitigation and Adaptation Strategies for Global Change,* **12(5)**, 665-684.

Halsnas, K. and S. Trarup, 2009: Development and climate change: A mainstreaming approach for assessing economic, social, and environmental impacts of adaptation measures. *Environmental Management,* **43(5)**, 765-778.

Hamisi, H.I., M. Tumbo, E. Kalumanga, and P. Yanda, 2012: Crisis in the wetlands: Combined stresses in a changing climate - Experience from Tanzania. *Climate and Development,* **4(1)**, 5-15.

Hanff, E., M.-. Dabat, and J. Blin, 2011: Are biofuels an efficient technology for generating sustainable development in oil-dependent African nations? A macroeconomic assessment of the opportunities and impacts in Burkina Faso. *Renewable and Sustainable Energy Reviews,* **15(5)**, 2199-2209.

Hanspach, J., I. Kühn, O. Schweiger, S. Pompe, and S. Klotz, 2011: Geographical patterns in prediction errors of species distribution models. *Global Ecology and Biogeography,* **20(5)**, 779-788.

Harmeling, S., S. Kreft, and S.C. Rai, 2011: *Institutions for adaptation: towards an effective multi-level interplay.* Germanwatch e.V. and WWF International, Bonn, Germany and Gland, Switzerland, pp. 44.

Hartmann, I. and A.J. Sugulle, 2009: *The impact of climate change on pastoral societies of Somaliland.* Candlelight for Health, Education & Environment, pp. 62.

Harvey, B., 2009: Indigenous knowledges, sustainable development and the environment: Implications for research, education and capacity building. In: *Indigenous knowledges, development and education.* [Langdon, J. (ed.)]. Sense Publishers, Rotterdam, The Netherlands, pp. 57-72.

Harvey, B., 2011: Climate airwaves: Community radio, action research, and advocacy for climate justice in Ghana. *International Journal of Communication,* **5(1)**, 2035-2058.

Hecky, R.E., R. Mugidde, P.S. Ramlal, M.R. Talbot, and G.W. Kling, 2010: Multiple stressors cause rapid ecosystem change in Lake Victoria. *Freshwater Biology,* **55(SUPPL. 1)**, 19-42.

Hegazy, A.K., M.A. Medany, H.F. Kabiel, and M.M. Maez, 2008: Spatial and temporal projected distribution of four crop plants in Egypt. *Natural Resources Forum,* **32(4)**, 316-326.

Heidecke, C. and T. Heckelei, 2010: Impacts of changing water inflow distributions on irrigation and farm income along the Drâa River in Morocco. *Agricultural Economics,* **41(2)**, 135-149.

Hein, L. and N. De Ridder, 2006: Desertification in the Sahel: A reinterpretation. *Global Change Biology,* **12(5)**, 751-758.

Hein, L.G., M.J. Metzger, R. Leemans (2009) The local impacts of climate change in the Ferlo, Western Sahel. Climatic change 93:465-483.

Hein, L., N. De Ridder, P. Hiernaux, R. Leemans, A. De Wit, and M. Schaepman, 2011: Desertification in the Sahel: Towards better accounting for ecosystem dynamics in the interpretation of remote sensing images. *Journal of Arid Environments,* **75(11)**, 1164-1172.

Hellmuth, M., D.E. Osgood, U. Hess, A. Moorhead, and H. Bhojwani (eds.), 2009: Climate and Society No. 2. In: *Index insurance and climate risk: prospects for development and disaster management.* International Research Institute for Climate and Society (IRI), Columbia University, New York, USA, .

Hellmuth, M.E., A. Moorhead, M.C. Thomson, and J. Williams (eds.), 2007: *Climate Risk Management in Africa: Learning from Practice*. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA, pp. 104.

Heltberg, R., P.B. Siegel, and S.L. Jorgensen, 2009: Addressing human vulnerability to climate change: Toward a 'no-regrets' approach. *Global Environmental Change,* **19(1)**, 89-99.

Hély, C., L. Bremond, S. Alleaume, B. Smith, M.T. Sykes, and J. Guiot, 2006: Sensitivity of African biomes to changes in the precipitation regime. *Global Ecology and Biogeography,* **15(3)**, 258-270.

Hemp, A., 2006a: The impact of fire on diversity, structure and composition of the vegetation on Mt. Kilimanjaro. In: *Land use change and mountain biodiversity*. [Spehn, E.M., M. Liberman, and C. Körner(eds.)]. CRC Press, Boca Raton, FL, USA, pp. 51-68.

Hemp, A., C. Lambrechts, and C. Hemp, in press: *Global trends and Africa. The case of Mt. Kilimanjaro*. UNEP, Nairobi.

Hemp, C. and A. Hemp, 2008: The Chagga Homegardens on Kilimanjaro. Diversity and refuge function for indigenous fauna and flora in anthropogenically influenced habitats in tropical regions under global change on Kilimanjaro, Tanzania. *IHDP Update,* **2**, 12-17.

Hemp, A. and E. Beck, 2001: Erica excelsa as a fire-tolerating component of Mt. Kilimanjaro's forests. *Phytocoenologia,* **31(4)**, 449-475.

Hemp, A., 2005: Climate change-driven forest fires marginalize the impact of ice cap wasting on Kilimanjaro. *Global Change Biology,* **11(7)**, 1013-1023.

Hemp, A., 2006b: Vegetation of Kilimanjaro: Hidden endemics and missing bamboo. *African Journal of Ecology,* **44(3)**, 305-328.

Hemp, A., 2006c: The banana forests of Kilimanjaro: Biodiversity and conservation of the Chagga homegardens. *Biodiversity and Conservation,* **15(4)**, 1193-1217.

Hemp, A., 2009: Climate change and its impact on the forests of Kilimanjaro. *African Journal of Ecology,* **47(SUPPL. 1)**, 3-10.

Hendrix, C.S. and S.M. Glaser, 2007: Trends and triggers: Climate, climate change and civil conflict in Sub-Saharan Africa. *Political Geography,* **26(6)**, 695-715.

Hertel, T.W., M.B. Burke, and D.B. Lobell, 2010: The poverty implications of climate-induced crop yield changes by 2030. *Global Environmental Change,* **20(4)**, 577-585.

Hession, S.L. and N. Moore, 2011: A spatial regression analysis of the influence of topography on monthly rainfall in East Africa. *International Journal of Climatology,* **31(10)**, 1440-1456.

Heubes, J., I. Kühn, K. König, R. Wittig, G. Zizka, and K. Hahn, 2011: Modelling biome shifts and tree cover change for 2050 in West Africa. *Journal of Biogeography,* **38(12)**, 2248-2258.

Heumann, B.W., J.W. Seaquist, L. Eklundh, and P. Jönsson, 2007: AVHRR derived phenological change in the Sahel and Soudan, Africa, 1982-2005. *Remote Sensing of Environment,* **108(4)**, 385-392.

Hewitson, B.C. and R.G. Crane, 2006: Consensus between GCM climate change projections with empirical downscaling: Precipitation downscaling over South Africa. *International Journal of Climatology,* **26(10)**, 1315-1337.

Hiernaux, P., L. Diarra, V. Trichon, E. Mougin, N. Soumaguel, and F. Baup, 2009: Woody plant population dynamics in response to climate changes from 1984 to 2006 in Sahel (Gourma, Mali). *Journal of Hydrology,* **375(1-2)**, 103-113.

Himeidan, Y.E. and E.J. Kweka, 2012: Malaria in East African highlands during the past 30 years: Impact of environmental changes. *Frontiers in Physiology,* **3**, 315.

Hirsch Hadorn, G., S. Biber-Klemm, W. Grossenbacher-Mansuy, H. Hoffmann-Riem, D. Joye, C. Pohl, U. Wiesmann, and E. Zemp, 2008: The Emergence of Transdisciplinarity as a Form of Research. In: *Handbook of Transdisciplinary Research*. [Hirsch Hadorn, G., H. Hoffmann-Riem, S. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Pohl *et al.*(eds.)]. Springer Netherlands, Dordrecht, pp. 19-39.

Hisali, E., P. Birungi, and F. Buyinza, 2011: Adaptation to climate change in Uganda: Evidence from micro level data. *Global Environmental Change,* **21(4)**, 1245-1261.

Hitchcock, R.K., 2009:
From local to global: perceptions and realities of environmental change among Kalahari San. In: *Anthropology and climate change: from encounters to actions*. [Crate, S.A. and M. Nuttall(eds.)]. Left Coast Press, Walnut Creek, CA, USA, pp. 250-264.

Hockey, P.A.R. and G.F. Midgley, 2009: Avian range changes and climate change: A cautionary tale from the Cape Peninsula. *Ostrich,* **80(1)**, 29-34.

Hockey, P.A.R., C. Sirami, A.R. Ridley, G.F. Midgley, and H.A. Babiker, 2011: Interrogating recent range changes in South African birds: Confounding signals from land use and climate change present a challenge for attribution. *Diversity and Distributions,* **17(2)**, 254-261.

Hoegh-Guldberg, O., P.J. Mumby, A.J. Hooten, R.S. Steneck, P. Greenfield, E. Gomez, C.D. Harvell, P.F. Sale, A.J. Edwards, K. Caldeira, N. Knowlton, C.M. Eakin, R. Iglesias-Prieto, N. Muthiga, R.H. Bradbury, A. Dubi, and M.E. Hatziolos, 2007: Coral reefs under rapid climate change and ocean acidification. *Science (New York, N.Y.),* **318(5857)**, 1737-1742.

Hoerling, M., J. Hurrell, J. Eischeid, and A. Phillips, 2006: Detection and attribution of twentieth-century northern and southern African rainfall change. *Journal of Climate,* **19(16)**, 3989-4008.

Hoffman, M.T., M.D. Cramer, L. Gillson, and M. Wallace, 2011: Pan evaporation and wind run decline in the Cape Floristic Region of South Africa (1974-2005): implications for vegetation responses to climate change. *Climatic Change,* , 1-16.

Huang, Y. and L. Manderson, 1992: Schistosomiasis and the social patterning of infection. *Acta Tropica,* **51(3-4)**, 175-194.

Huang, S.-., Z.-. Deng, Q.-. Zhang, R.-. Lin, X.-. Zhang, L.-. Huo, J.-. Wang, and C.-. Ruan, 2011: Endemic situation of schistosomiasis in Guangdong Province from 2004 to 2009. *Chinese Journal of Schistosomiasis Control*, **23(2)**, 197-198+201.

Hunde, M., 2012: Integrating community based disaster risk reduction and climate change adaptation into local development planning.Proceedings of Presentation at the Sixth International Conference on Community-Based Adaptation, 16-22, April 2012, Hanoi, Vietnam, pp. 20-21.

Hunter, J.M., L. Rey, K.Y. Chu, E.O. Adekolu-John, and K.E. Mott, 1993: *Parasitic diseases in water resources development: The need for intersectoral negotiation*. World Health Organization (WHO), Geneva, Switzerland, pp. 152.

Huntingford, C., F.H. Lambert, J.H.C. Gash, C.M. Taylor, and A.J. Challinor, 2005: Aspects of climate change prediction relevant to crop productivity. *Philosophical Transactions of the Royal Society B: Biological Sciences,* **360(1463)**, 1999-2009.

Huq, S., 2011: *Improving information for community-based adaptation*. IIED Opinion: Lessons from adaptation in practice, October 2011. International Institute for Environment and Development (IIED), London, UK, pp. 2.

IDMC, 2011: *Displacement due to natural hazard-induced disaster: Global estimates for 2009 and 2010*. Internal Displacement Monitoring Centre (IDMC), Geneva, Switzerland, pp. 30.

IDRC, 2010: *Improving accessibility and usability of seasonal forecasts for food security in Africa: Lessons from CCAA participatory action research projects*. Background Paper, First CCAA Learning Forum, 8-12 March, 2010. International Developoment Research Centre (IDRC) and Department for International Development (DFID), Nairobi, Kenya, pp. 25.

IDS, 2012: *Innovative approaches to gender and food security: changing attitudes, changing behaviours*. Food Security Insights Issue 82, January 2012. IDS Knowledge Services, Brighton, UK, pp. 8.

IFAD, 2010: *Rural poverty report 2011. New realities, new challenges: new opportunities for tomorrow's generations*. International Fund for Agricultural Development (IFAD), Rome, Italy, pp. 317.

Ifejika Speranza, C., 2010: Drought coping and adaptation strategies: Understanding adaptations to climate change in agro-pastoral livestock production in makueni district, Kenya. *European Journal of Development Research,* **22(5)**, 623-642.

Ifejika Speranza, C., B. Kiteme, P. Ambenje, U. Wiesmann, and S. Makali, 2010: Indigenous knowledge related to climate variability and change: Insights from droughts in semi-arid areas of former Makueni District, Kenya. *Climatic Change,* **100(2)**, 295-315.

Ijang, T.P., N. Cleto, N.W. Ewane, A. Chicaia, and R. Tamar, 2012: Transboundary dialogue and cooperation: First lessons from igniting negotiations on joint management of the Mayombe Forest in the Congo Basin. *International Journal of Agriculture and Forestry,* **2(3)**, 121-131.

Interim Technical Report, 2011: *Rapport technique n°5 du projet de recherche ATCT/ONMNE/CRDI « Analyse des modalités d'adaptation aux effets sur la santé des changements climatiques : Cas de la leishmaniose cutanée zoonotique en Tunisie ». [French; Interim Technical Report no.5 « Analysis of adaptation modalities to the effects of climate change on health: the case of zoonotic cutaneous leishmaniasis in Tunisia]. .*

IPCC, 2012: Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of

Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19.

Jackson, M.C., L. Johansen, C. Furlong, A. Colson, and K.F. Sellers, 2010: Modelling the effect of climate change on prevalence of malaria in western Africa. *Statistica Neerlandica,* **64(4)**, 388-400.

Jäger, J., J. Frühmann, S. Grünberger, and A. Vag, 2009: *EACH-FOR. Environmental Change and Forced Migration Scenarios: D.3.4. Synthesis Report* pp. 81.

Jalloh, A., Roy-Macauley, H., 2011. Climate change research and development orientation framework: A CORAF/WECARD strategy for guiding climate change research and development in West and Central Africa. Conseil Ouest et Centre Africain pour la Recherche et le Development Agricoles/West and Central African Council for Agricultural Research and Development (CORAF/WECARD). CORAF/WECARD, Dakar, Senegal.

Jalloh, A., B. Sarr, J. Kuiseu, H. Roy-Macauley, and P. Sereme, 2011: *Review of climate in West and Central Africa to inform farming systems research and development in the sub-humid and semi-arid agroecologies of the region*. Conseil Ouest et Centre Africain pour la Recherche et le Development Agricoles/West and Central African Council for Agricultural Research and Development (CORAF/WECARD), Dakar, Senegal, pp. 53.

James, R. and R. Washington, 2012: Changes in African temperature and precipitation associated with degrees of global warming. *Climatic Change,* , 1-14.

Jaramillo, J., E. Muchugu, F.E. Vega, A. Davis, C. Borgemeister, and A. Chabi-Olaye, 2011: Some like it hot: The influence and implications of climate change on coffee berry borer (Hypothenemus hampei) and coffee production in East Africa. *PLoS ONE,* **6(9)**.

Jarvis, A., J. Ramirez-Villegas, B.V.H. Campo, and C. Navarro-Racines, 2012: Is Cassava the Answer to African Climate Change Adaptation? *Tropical Plant Biology,* **5(1)**, 9-29.

Jennings, S. and J. Magrath, 2009: *What happened to the seasons?*. Oxfam GB Research Report. Oxfam GB, pp. 26.

Jetz, W., D.S. Wilcove, and A.P. Dobson, 2007: Projected impacts of climate and land-use change on the global diversity of birds. *PLoS Biology,* **5(6)**, 1211-1219.

Jima, D., M. Wondabeku, A. Alemu, A. Teferra, N. Awel, W. Deressa, A. Adissie, Z. Tadesse, T. Gebre, A.W. Mosher, F.O. Richards, and P.M. Graves, 2012: Analysis of malaria surveillance data in Ethiopia: What can be learned from the Integrated Disease Surveillance and Response System? *Malaria Journal,* **11**.

Jobbins, G., 2011: *Managing uncertainty in adaptation*. CCAA Perspectives series. International Development Research Centre (IDRC) and Department for International Development (DFID), Ottawa, Canada, pp. 10.

Jobin, W., 1999: *Dams and disease: ecological design and health impacts of large dams, canals and irrigation systems*. Taylor & Francis, London, UK and New York, NY, USA, pp. 600.

Jones, L. 2011b. Social barriers to adaptation. Exploring the implications and identifying options for adaptation policy across the SADC region. In: Masters, L. and Duff, L. 2011. Overcoming barriers to climate change adaptation implementation in Southern Africa. Africa Institute of South Africa, Pretoria. Pp 41-58.

Jones, L., E. Ludi, and S. Levine, 2010: *Towards a characterisation of adaptive capacity: a framework for analysing adaptive capacity at the local level*. ODI Background Note, December 2010. Overseas Development Institute (ODI), London, UK, pp. 8.

Jones, L., 2011: Social barriers to adaptation: exploring implications and identifying options for adaptation policy across the SADC Region. In: *Overcoming barriers to climate change adaptation implementation in Southern Africa*. [Masters, L. and L. Duff(eds.)]. Africa Institute of South Africa, Pretoria, South Africa, pp. 41-60.

Jones, L. and E. Boyd, 2011: Exploring social barriers to adaptation: Insights from Western Nepal. *Global Environmental Change,* **21(4)**, 1262-1274.

Jones, P.G. and P.K. Thornton, 2009: Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science and Policy,* **12(4)**, 427-437.

Jones, H.P., D.G. Hole ad E.S. Zavaleta (2012) Harnessing nature to help people adapt to climate change. Nature Climate Change Perspective, published online: 26 June 2012 | DOI: 10.1038/NCLIMATE1463

Kabubo-Mariara, J., 2008: Climate change adaptation and livestock activity choices in Kenya: An economic analysis. *Natural Resources Forum,* **32(2)**, 131-141.

Kalame, F.B., Nkem, J., Brockhaus, M., Idinoba, M. and Kanninen, M. 2008. Using forest ecosystem goods and services for climate change adaptation in Burkina Faso and Ghana: Policy gaps and constraints (abstract). International conferences on forests and climate change Adaptation. August 25-28 2008, Umea, Sweden

Kalame, F.B., O. Luukkanen, and M. Kanninen, 2011: Making the national adaptation programme of action (NAPA) more responsive to the livelihood needs of tree planting farmers, drawing on previous experience in Dryland Sudan. *Forests,* **2(4)**, 948-960.

Kälin, W. and N. Schrepfer, 2012: *Protecting people crossing borders in the context of climate change: normative gaps and possible approaches*. Legal and Protection Policy Research Series. UN High Commissioner for Refugees, pp. 80.

Kandji, S.T., L. Verchot, and J. Mackensen, 2006: *Climate change and variability in the Sahel region: impacts and adaptation strategies in the agricultural sector*. United Nations Environment Programme (UNEP) and World Agroforestry Centre, Nairobi, Kenya, pp. 48.

Karlberg, L., J. Rockström, J.G. Annandale, and J.M. Steyn, 2007: Low-cost drip irrigation-A suitable technology for southern Africa?. An example with tomatoes using saline irrigation water. *Agricultural Water Management,* **89(1-2)**, 59-70.

Kaser, G., D.R. Hardy, T. Mölg, R.S. Bradley, and T.M. Hyera, 2004: Modern glacier retreat on Kilimanjaro as evidence of climate change: Observations and facts. *International Journal of Climatology,* **24(3)**, 329-339.

Kaser, G., T. Mölg, N.J. Cullen, D.R. Hardy, and M. Winkler, 2010: Is the decline of ice on kilimanjaro unprecedented in the holocene? *Holocene,* **20(7)**, 1079-1091.

Kassam, A., T. Friedrich, R. Derpsch, R. Lahmar, R. Mrabet, G. Basch, E.J. González-Sánchez, and R. Serraj, 2012: Conservation agriculture in the dry Mediterranean climate. *Field Crops Research,* **132**, 7-17.

Kay, G. and R. Washington, 2008: Future southern African summer rainfall variability related to a southwest Indian Ocean dipole in HadCM3. *Geophysical Research Letters,* **35(12)**.

Kebede, A.S. and R.J. Nicholls, 2011a: *Population and assets exposure to coastal flooding in Dar es Salaam (Tanzania): Vulnerability to climate extremes. Report siûbmitted to Global Climate Adaptation Partnership (GCAP).*, pp. 26.

Kebede, A.S., S. Brown, and R.J. Nicholls, 2010: *Synthesis Report: The Implications of Climate Change and Sea-Level Rise in Tanzania - The Coastal Zones*. Report submitted to the Stockholm Environment Institute, 5 November 2010, pp. 32.

Kebede, A.S. and R.J. Nicholls, 2011b: *Population and asset exposure to coastal flooding in Dar es Salaam (Tanzania): vulnerability to climate extremes*. Report submitted to Global Climate Adaptation Partnership (GCAP), pp. 26.

Kebede, A.S., R.J. Nicholls, S. Hanson, and M. Mokrech, 2012: Impacts of climate change and sea-level rise: A preliminary case study of Mombasa, Kenya. *Journal of Coastal Research,* **28(1 A)**, 8-19.

Kelly-Hope, L.A., J. Hemingway, and F.E. McKenzie, 2009: Environmental factors associated with the malaria vectors Anopheles gambiae and Anopheles funestus in Kenya. *Malaria Journal,* **8(1)**.

Kemp-Benedict, E. and W.K. Agyemang-Bonsu, 2008: The Akropong approach to multi-sector project planning. *Futures,* **40(9)**, 834-840.

Kerrou, J., P. Renard, and J. Tarhouni, 2010: Status of the Korba groundwater resources (Tunisia): Observations and three-dimensional modelling of seawater intrusion. *Hydrogeology Journal,* **18(5)**, 1173-1190.

Kimutai, A., P. Kamau Ngure, W. Kiprotich Tonui, M. Muita Gicheru, and L. Bonareri Nyamwamu, 2006: Leishmaniasis in Northern and Western Africa: A review. *African Journal of Infectious Diseases,* **3(1)**, 14-25.

Kingsford, R.T., H.C. Biggs, and S.R. Pollard, 2011: Strategic Adaptive Management in freshwater protected areas and their rivers. *Biological Conservation,* **144(4)**, 1194-1203.

Kingston, D.G. and R.G. Taylor, 2010: Sources of uncertainty in climate change impacts on river discharge and groundwater in a headwater catchment of the Upper Nile Basin, Uganda. *Hydrology and Earth System Sciences,* **14(7)**, 1297-1308.

Kithiia, J. and R. Dowling, 2010: An integrated city-level planning process to address the impacts of climate change in Kenya: The case of Mombasa. *Cities,* **27(6)**, 466-475.

Kithiia, J., 2011: Climate change risk responses in East African cities: Need, barriers and opportunities. *Current Opinion in Environmental Sustainability,* **3(3)**, 176-180.

Kithiia, J. and A. Lyth, 2011: Urban wildscapes and green spaces in mombasa and their potential contribution to climate change adaptation and mitigation. *Environment and Urbanization,* **23(1)**, 251-265.

Klein, R.J.T., 2010: Linking adaptation and development finance: A policy dilemma not addressed in Copenhagen. *Climate and Development,* **2(3)**, 203-206.

Klempa, B., 2009: Hantaviruses and climate change. *Clinical Microbiology and Infection,* **15(6)**, 518-523.

Kniveton, D.R., R. Layberry, C.J.R. Williams, and M. Peck, 2009: Trends in the start of the wet season over Africa. *International Journal of Climatology,* **29(9)**, 1216-1225.

Koch, I.C., C. Vogel and Z. Patel (2007) Institutional Dynamics and climate change adaptation in South Africa. Mitig Adapt Strat Glob Change 12: 1323-1339

Koelle, K., X. Rodó, M. Pascual, M. Yunus, and G. Mostafa, 2005: Refractory periods and climate forcing in cholera dynamics. *Nature,* **436(7051)**, 696-700.

Koelle, B., W. Annecke, undated: Community Based climate change adaptation (CBA). Adaptation and Beyond. Lessons learnt from the Community Based Adaptation in Africa (CBAA). IDRC. http://www.indigo-dc.org/documents/Adaptationandbeyond01small.pdf

Kolmannskog, V., 2010: Climate change, human mobility, and protection: Initial evidence from Africa. *Refugee Survey Quarterly,* **29(3)**, 103-119.

Koné, B., M. Feagan, Y.A. Houenou, N. Brou, P.V. Houenou, B. Fayomi, E. Ngnikam, G. Cissé, J. Spiegel, and E. Kouassi, 2012: Facilitating the Relationship Between Researchers and Policy-Makers: Experiences from Three Ecohealth Projects in West and Central Africa. *EcoHealth,* , 1-5.

Körner, C., 2003: *Alpine Plant Life. Functional Plant Ecology of High Mountain Ecosystems.* Springer, Berlin, Heidelberg, 2nd ed., pp. 350.

Kremen, C., J.O. Niles, M.G. Dalton, G.C. Daily, P.R. Ehrlich, J.P. Fay, D. Grewal, and R.P. Guillery, 2000: Economic incentives for rain forest conservation across scales. *Science,* **288(5472)**, 1828-1832.

Krishnamurty, J., 2011: *Employment policies and disaster risk reduction.* Global Assessment Report on Disaster Risk Reduction. UNISDR and ILO, Geneva, Switzerland, pp. 27.

Kronik, J. and D. Verner, 2010: The role of indigenous knowledge in crafting adaptation and mitigation strategies for climate change in Latin America. In: *Social dimensions of climate change: equity and vulnerability in a warming world.* [Mearns, R. and A. Norton(eds.)]. The World Bank, Washington, DC, USA, pp. 145-169.

Kruger, A.C. and S.S. Sekele, 2012: Trends in extreme temperature indices in South Africa: 1962-2009. *International Journal of Climatology,* .

Kuffner, I.B., A.J. Andersson, P.L. Jokiel, K.S. Rodgers, and F.T. MacKenzie, 2008: Decreased abundance of crustose coralline algae due to ocean acidification. *Nature Geoscience,* **1(2)**, 114-117.

Kulkarni, M.A., R.E. Desrochers, and J.T. Kerr, 2010: High resolution niche models of malaria vectors in Northern Tanzania: A new capacity to predict malaria risk? *PLoS ONE,* **5(2)**.

Kumar, N. and A.R. Quisumbing, 2011: *Gendered Impacts of the 2007–08 Food Price Crisis: Evidence Using Panel Data from Rural Ethiopia.* IFPRI Discussion Paper 01093. International Food Policy Research Institute (IFPRI), Poverty, Health, and Nutrition Division, Washington, D.C., USA, pp. 24.

Kumssa, A. and J.F. Jones, 2010: Climate change and human security in Africa. *International Journal of Sustainable Development and World Ecology,* **17(6)**, 453-461.

Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen, and I.A. Shiklomanov, 2007: Freshwater resources and their management. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson(eds.)]. Cambridge University Press, Cambridge, UK, pp. 173-210.

Kundzewicz, Z.W., 2011: *Comparative assessment: fact or fiction?.* Paper to be presented at the Workshop “Including longterm climate change in hydrologic design", pp. 17.

Kung'u, J., A. Gichu, and D. Mugendi, 2011: Helping small scale tree farmers in Africa participate in carbon trade. *In: World Soil Resources Reports No. 105* [Bombelli, A. and R. Valentini(eds.)]. Proceedings of Africa and the carbon cycle: Proceedings of the Open Science Conference on "Africa and Carbon Cycle: the CarboAfrica project", 25-27, November 2008, Accra, Ghana, pp. 177-183.

Kunz, M.J., A. Wüest, B. Wehrli, J. Landert, and D.B. Senn, 2011: Impact of a large tropical reservoir on riverine transport of sediment, carbon, and nutrients to downstream wetlands. *Water Resources Research,* **47(12)**.

Kusangaya, S., no date: *An assessment of the potential effects of climate induced sea level rise on land uses and land cover in Beira, Mozambique.* Department of Scientific Services, Gorongosa Restoration Project, Gorongosa National Park.

Kuuzegh, R.S., 2007: *Ghana's experience at integrating climate change adaptation into national planning* pp. 5.

Läderach, P., A. Eitzinger, O. Ovalle, J. Ramirez, and A. Jarvis, 2010: *Climate change adaptation and mitigation in the Kenyan coffee sector.* International Center for Tropical Agriculture, Cali, Colombia.

Läderach, P., A. Eitzinger, A. Martinez, and N. Castro, 2011a: *Predicting the impact of climate change on cashew growing regions in Ghana and Cote d'Ivoire*. Climate Change, Agriculture and Food Security Programme (CCAFS) and International Center for Tropical Agriculture (CIAT), Managua, Nicaragua, pp. 29.

Läderach, P., A. Eitzinger, A. Martinez, and N. Castro, 2011b: *Predicting the impact of climate change on cotton growing regions in Ghana and Cote d'Ivoire*. Climate Change, Agriculture and Food Security Programme (CCAFS) and International Center for Tropical Agriculture (CIAT), Cali, Colombia.

Läderach, P., A. Eitzinger, A. Martinez, and N. Castro, 2011c: *Predicting the impact of climate change on the cocoa-growing regions in Ghana and Cote d'Ivoire*. Climate Change, Agriculture and Food Security Programme (CCAFS) and International Center for Tropical Agriculture (CIAT), Managua, Nicaragua, pp. 29.

Lam, V.W.Y., W.W.L. Cheung, W. Swartz, and U.R. Sumaila, 2012: Climate Change Impacts on Fisheries in West Africa: Implications for Economic, Food and Nutritional Security. *African Journal of Marine Science,* **34(1)**, 103-117.

Larson, A.M., 2011: Forest tenure reform in the age of climate change: Lessons for REDD+. *Global Environmental Change,* **21(2)**, 540-549.

Larwanou, M. and M. Saadou, 2011: The role of human interventions in tree dynamics and environmental rehabilitation in the Sahel zone of Niger. *Journal of Arid Environments,* **75(2)**, 194-200.

Laube, W., B. Schraven, and M. Awo, 2012: Smallholder adaptation to climate change: Dynamics and limits in Northern Ghana. *Climatic Change,* **111(3)**, 753-774.

LDC Expert Group, 2011: *Best practices and lessons learned in addressing adaptation in the least developed countries through the national adaptation programme of action process*. Volume 1. United Nations Climate Change Secretariat, Bonn, pp. 78.

Leary, N et al. 2007. A stitch in time: Lessons for climate change adaptation from the AIACC project. AIACC Working Paper No. 48. www.aiaccproject.org.

Leary, N., J. Adejuwon, V. Barros, I. Burton, J. Kulkarni, and R. Lasco (eds.), 2008: *Climate change and adaptation*. Earthscan, London, UK and Sterling, VA, USA, pp. 398.

Leck, H., Sutherland, C., Soctt, D. and Oelofse, G. 2011. Social and cultural barriers to adaptation implementation. The case of South Africa. In: Masters, L. and Duff, L. 2011. Overcoming barriers to climate change adaptation implementation in Southern Africa. Africa Institute of South Africa, Pretoria. Pp 61-82.

Lecocq, F. and Z. Shalizi, 2007: *How Might Climate Change Affect Economic Growth in Developing Countries? A Review of the Growth Literature with a Climate Lens*. In: Policy Research Working Paper 4315. The World Bank, pp. 54.

Lericollais, A., 1989: La mort des arbres à Sob, en pays Sereer (Sénégal). In: *Tropiques: Lieux et Liens*. [Benoît, A., C. Blanc-Pamard, J.L. Chaléard, A. Dubresson, V. Lassailly-Jacob, J.M. Marchal *et al.*(eds.)]. Éditions ORSTOM, Paris, France, .

Lesukat, M., 2012: *Drought contingency plans and planning in the Greater Horn of Africa: A desktop review of the effectiveness of drought contingency plans and planning in Kenya, Uganda and Ethiopia*. United Nations International Strategy for Disaster Reduction (UNISDR) Regional Office for Africa, Nairobi, Kenya, pp. 23.

Levine, S., E. Ludi, and L. Jones, 2011: *Rethinking support for adaptive capacity to climate change: the role of development interventions. Findings from Mozambique, Uganda and Ethiopia*. A report for the Africa Climate Change Resilience Alliance. Overseas Development Institute (ODI), London, UK, pp. 38.

Levine, S., 2012: The 2007/2008 food price acceleration in Namibia: an overview of impacts and policy responses. *Food Security,* , 1-13.

Lilleør, H.B. and K. Van den Broeck, 2011: Economic drivers of migration and climate change in LDCs. *Global Environmental Change,* **21(SUPPL. 1)**, S70-S81.

Liniger, H.P., R.M. Studer, C. Hauert, and M. Gurtner, 2011: *Sustainable land management in practice: guidelines and best practices for Sub-Saharan Africa
*. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO), pp. 243.

Linnerooth-Bayer, J., K. Warner, C. Bals, P. Höppe, I. Burton, T. Loster, and A. Haas, 2009:
Insurance, developing countries and climate change. *The Geneva Papers on Risk and Insurance - Issues and Practice,* **34**, 381-400.

Linthicum, K.J., A. Anyamba, C.J. Tucker, P.W. Kelley, M.F. Myers, and C.J. Peters, 1999: Climate and satellite indicators to forecast Rift Valley fever epidemics in Kenya. *Science,* **285(5426)**, 397-400.

Liu, J., S. Fritz, C.F.A. van Wesenbeeck, M. Fuchs, L. You, M. Obersteiner, and H. Yang, 2008: A spatially explicit assessment of current and future hotspots of hunger in Sub-Saharan Africa in the context of global change. *Global and Planetary Change,* **64(3-4)**, 222-235.

Lloyd, S.J., R. Sari Kovats, and Z. Chalabi, 2011: Climate change, crop yields, and undernutrition: Development of a model to quantify the impact of climate scenarios on child undernutrition. *Environmental Health Perspectives,* **119(12)**, 1817-1823.

Lobell, D.B., M. Bänziger, C. Magorokosho, and B. Vivek, 2011: Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nature Climate Change,* **1**, 42-45.

Lobell, D.B., M.B. Burke, C. Tebaldi, M.D. Mastrandrea, W.P. Falcon, and R.L. Naylor, 2008: Prioritizing climate change adaptation needs for food security in 2030. *Science,* **319(5863)**, 607-610.

Lockwood, M., 2012: *Adaptation policy, governance and politics in sub-Saharan Africa. Paper to be presented at an international symposium on the Governance of Adaptation, Amsterdam, March 22-23 2012*. Institute of Development Studies (IDS), Sussex, UK, pp. 29.

Loha, E. and B. Lindtjørn, 2010: Model variations in predicting incidence of Plasmodium falciparum malaria using 1998-2007 morbidity and meteorological data from south Ethiopia. *Malaria Journal,* **9(1)**.

Lou, Y. and X.-. Zhao, 2010: A climate-based malaria transmission model with structured vector population. *SIAM Journal on Applied Mathematics,* **70(6)**, 2023-2044.

Lovett, J. and A. Hemp, 2010: Is climate change making plants go up mountains? *Frontiers of Biogeography,* **2.1**, 5-7.

Ludi, E., L. Jones, and S. Levine, 2012: *Changing focus? How to take adaptive capacity seriously. Evidence from Africa shows that development interventions could do more*. ODI Briefing Paper 71. Overseas Development Institute (ODI), London, UK, pp. 4.

Luseno, W.K., J.G. McPeak, C.B. Barrett, P.D. Little, and G. Gebru, 2003: Assessing the value of climate forecast information for pastoralists: Evidence from Southern Ethiopia and Northern Kenya. *World Development,* **31(9)**, 1477-1494.

Lutz, W. and S. Kc, 2010: Dimensions of global population projections: What do we know about future population trends and structures? *Philosophical Transactions of the Royal Society B: Biological Sciences,* **365(1554)**, 2779-2791.

Lwasa, S., 2010: Adapting urban areas in Africa to climate change: The case of Kampala. *Current Opinion in Environmental Sustainability,* **2(3)**, 166-171.

Lwasa, Shuaib. 2013. "Bridging adaptation to climate change across city scales in Kampala". Local Environment: The International Journal of Justice and Sustainability. Forthcoming.

Lyon, B., 2009: Southern Africa summer drought and heat waves: Observations and coupled model behavior. *Journal of Climate,* **22(22)**, 6033-6046.

Lyon, B. and D.G. Dewitt, 2012: A recent and abrupt decline in the East African long rains. *Geophysical Research Letters,* **39(2)**.

Lyons, C.L., M. Coetzee, J.S. Terblanche, and S.L. Chown, 2012: Thermal limits of wild and laboratory strains of two African malaria vector species, Anopheles arabiensis and Anopheles funestus. *Malaria Journal,* , 226.

Lyons, R.P., C.N. Kroll, and C.A. Scholz, 2011: An energy-balance hydrologic model for the Lake Malawi Rift Basin, East Africa. *Global and Planetary Change,* **75(1-2)**, 83-97.

Mabaso, M.L.H., I. Kleinschmidt, B. Sharp, and T. Smith, 2007: El Niño Southern Oscillation (ENSO) and annual malaria incidence in Southern Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **101(4)**, 326-330.

Macchi, M., G. Oviedo, S. Gotheil, K. Cross, A. Boedhihartono, C. Wolfangel, and M. Howell, 2008: *Indigenous and traditional peoples and climate change*. IUCN Issues Paper. International Union for Conservation of Nature (IUCN), Gland, Switzerland, pp. 64.

MacDonald, A.M., R.C. Carlow, D.M.J. MacDonald, W.G. Darling, and B.ÉÓ Dochartaigh, 2009: What impact will climate change have on rural groundwater supplies in Africa? *Hydrological Sciences Journal,* **54(4)**, 690-703.

MacDonald, A.M., H.C. Bonsor, B.ÉÓ Dochartaigh, and R.G. Taylor, 2012: Quantitative maps of groundwater resources in Africa. *Environmental Research Letters,* **7(2)**.

Madzwamuse, M., 2010: *Drowning voices: the climate change discourse in South Africa*. Policy Brief 05/2010. Heinrich-Böll-Foundation Southern Africa, Cape Town, South Africa, pp. 8.

Magadza, C.H.D., 2006: Kariba reservoir: Experience and lessons learned. *Lakes and Reservoirs: Research and Management,* **11(4)**, 271-286.

Magadza, C.H.D., 2008: Limnology News from Zimbabwe. *SIL News,* **52**, 12 October 2009.

Magadza, C.H.D., 2010: Environmental state of Lake Kariba and Zambezi River Valley: Lessons learned and not learned. *Lakes and Reservoirs: Research and Management,* **15(3)**, 167-192.

Magadza, C.H.D., 2011: Indications of the effects of climate change on the pelagic fishery of Lake Kariba, Zambia-Zimbabwe. *Lakes and Reservoirs: Research and Management,* **16(1)**, 15-22.

Mamouda, M.N.A., 2011: *Africa's National Adaptation Programmes of Action.* In: Joto Africa - adapting to climate change in Africa [Denton, F. (ed.)]. Issue 8. Arid Lands Information Network, Nairobi, Kenya, pp. 8-8.

Mandeleni, B. and Anim, F.D.K. 2011. Perceptions of cattle and sheep farmers on climate change and adaptation in the Eastern Cape Province of South Africa. Journal of Human Ecology 34: 107-112.

Manyatsi, A.M. and E.T. Hlophe, 2010: Contribution of sale of firewood towards rural livelihood in Swaziland, and its environmental sustainability. *Current Research Journal of Social Sciences,* **2(4)**, 226-232.

Maranz, S., 2009: Tree mortality in the African Sahel indicates an anthropogenic ecosystem displaced by climate change. *Journal of Biogeography,* **36(6)**, 1181-1193.

Marchiori, L., J.-. Maystadt, and I. Schumacher, 2011: Paper presented at CSAE 25th Anniversary Conference 2011: Economic Development in Africa, Oxford, UK. In: *The impact of climate variations on migration in sub-Saharan Africa* pp. 33.

Marchiori, L., J.-. Maystadt, and I. Schumacher, 2012: The impact of weather anomalies on migration in sub-Saharan Africa. *Journal of Environmental Economics and Management,* **63(3)**, 355-374.

Mariotti, L., E. Coppola, M.B. Sylla, F. Giorgi, and C. Piani, 2011: Regional climate model simulation of projected 21st century climate change over an all-Africa domain: Comparison analysis of nested and driving model results. *Journal of Geophysical Research D: Atmospheres,* **116(15)**.

Marongwe, L.S., K. Kwazira, M. Jenrich, C. Thierfelder, A. Kassam, and T. Friedrich, 2011: An African success: The case of conservation agriculture in Zimbabwe. *International Journal of Agricultural Sustainability,* **9(1)**, 153-161.

Marshall, B., C. Ezekiel, J. Gichuki, O. Mkumbo, L. Sitoki, and F. Wanda, 2009: Global warming is reducing thermal stability and mitigating the effects of eutrophication in Lake Victoria (East Africa). *Nature Precedings*.

Marshall, B.E., 2012: **Does climate change really explain changes in the fisheries productivity of Lake Kariba (Zambia-Zimbabwe)?**. *Transactions of the Royal Society of South Africa,* **67(1)**, 45-51.

Martens, P., D. McEvoy, and C. Chang, 2009: The climate change challenge: linking vulnerability, adaptation, and mitigation. *Current Opinion in Environmental Sustainability,* **1(1)**, 14-18.

Martínez-Vilalta, J., F. Lloret, and D.D. Breshears, 2012: Drought-induced forest decline: Causes, scope and implications. *Biology Letters,* **8(5)**, 689-691.

Masike, S. and P.B. Urich, 2009: **The projected cost of climate change to livestock water supply and implications in Kgatleng District, Botswana**. *World Journal of Agricultural Sciences,* **5(5)**, 597-603.

Masike, S. and P. Urich, 2008: Vulnerability of traditional beef sector to drought and the challenges of climate change: The case of Kgatleng District, Botswana. *Journal of Geography and Regional Planning,* **1(1)**, 12-18.

Mason, N.M., T.S. Jayne, A. Chapoto, and C. Donovan, 2011: Putting the 2007/2008 global food crisis in longer-term perspective: Trends in staple food affordability in urban Zambia and Kenya. *Food Policy,* **36(3)**, 350-367.

Mason, P.R., 2009: Zimbabwe experiences the worst epidemic of cholera in Africa. *Journal of Infection in Developing Countries,* **3(2)**, 148-151.

Mathee, A., J. Oba, and A. Rose, 2010: Climate change impacts on working people (the HOTHAPS initiative): findings of the South African pilot study. *Global Health Action,* **3**, 5612.

Mather, A.A. and D.D. Stretch, 2012: A perspective on sea level rise and coastal storm surge from Southern and Eastern Africa: A case study near Durban, South Africa. *Water,* **4**, 237-259.

Mbow, C., A. Diop, A. Diaw, and C.I. Niang, 2008: **Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal)** . *African Journal of Environmental Science and Technology,* **2(4)**, 75-88.

McCartney, M.P. and M. Menker Girma, 2012: Evaluating the downstream implications of planned water resource development in the Ethiopian portion of the Blue Nile River. *Water International,* **37(4)**, 362-379.

McClanahan, T.R. and J. Maina, 2003: Response of Coral Assemblages to the Interaction between Natural Temperature Variation and Rare Warm-Water Events. *Ecosystems,* **6(6)**, 551-563.

McClanahan, T.R., M. Ateweberhan, C.A. Muhando, J. Maina, and M.S. Mohammed, 2007: Effects of climate and seawater temperature variation on coral bleaching and mortality. *Ecological Monographs,* **77(4)**, 503-525.

Mcclanahan, T.R., N.A. Muthiga, J. Maina, A.T. Kamukuru, and S.A.S. Yahya, 2009: Changes in northern Tanzania coral reefs during a period of increased fisheries management and climatic disturbance. *Aquatic Conservation: Marine and Freshwater Ecosystems,* **19(7)**, 758-771.

McCully, P., 2007: *Before the Deluge: Coping with floods in a changing climate*. IRN Dams, Rivers and People Report 2007. International River Network, Berkeley, CA, USA, pp. 24.

McDonald, R.E., D.G. Bleaken, D.R. Cresswell, V.D. Pope, and C.A. Senior, 2005: Tropical storms: Representation and diagnosis in climate models and the impacts of climate change. *Climate Dynamics,* **25(1)**, 19-36.

McFerson, H.M., 2010: Poverty among women in Sub-Saharan Africa: A review of selected issues. *Journal of International Women's Studies,* **11(4)**, 50-72.

McGinley, M., 2008: Lake Turkana National Parks, Kenya. In: *Encyclopedia of Earth*. [Cleveland, C.J. (ed.)]. Environmental Information Coalition, National Council for Science and the Environment, Washington D.C., USA, .

McLeman, R. and B. Smit, 2006: Migration as an adaptation to climate change. *Climatic Change,* **76(1-2)**, 31-53.

McManus, J.W., 1997: Tropical marine fisheries and the future of coral reefs: A brief review with emphasis on Southeast Asia. *Coral Reefs,* **16(SUPPL. 1)**, S121-S127.

Mertz, O., C. Mbow, A. Reenberg, and A. Diouf, 2009: Farmers' perceptions of climate change and agricultural adaptation strategies in rural sahel. *Environmental Management,* **43(5)**, 804-816.

Mertz, O., Mbow, C., Reenberg, A., Genesio, L., Lambin, E. F., D'haen, S., Zorom, M., Rasmussen, K., Diallo, D., Barbier, B., Moussa, I. B., Diouf, A., Nielsen, J. Ø. and Sandholt, I. (2011), Adaptation strategies and climate vulnerability in the Sudano-Sahelian region of West Africa. Atmosph. Sci. Lett., 12: 104–108. doi: 10.1002/asl.314

Milder, J., Majanen, T., Scherr, S., (2011) Performance and Potential of Conservation Agriculture for Climate Change Adaptation and Mitigation in Sub-Saharan Africa: An Assessment of WWF and CARE Projects in Support of the WWF-CARE Alliance's Rural Future Initiative.

Milzow, C., V. Burg, and W. Kinzelbach, 2010: Estimating future ecoregion distributions within the Okavango Delta Wetlands based on hydrological simulations and future climate and development scenarios. *Journal of Hydrology,* **381(1-2)**, 89-100.

Min, S.-. and A. Hense, 2007: A Bayesian assessment of climate change using multimodel ensembles. Part II: Regional and seasonal mean surface temperatures. *Journal of Climate,* **20(12)**, 2769-2790.

Mkutu, K.A., 2008: *Guns and governance in the Rift Valley: Pastoralist conflict and small arms*. Indiana University Press, Oxford, pp. 178.

Moench, M., 2011: *Aren't we all vulnerable: why do vulnerability analysis?*. IIED Opinion: Lessons from adaptation in practice, November 2011. International Institute for Environment and Development (IIED), London, UK, pp. 2.

Mohamed, A.B., 2011: Climate change risks in Sahelian Africa. *Regional Environmental Change,* **11(SUPPL. 1)**, 109-117.

Moise, A.F. and D.A. Hudson, 2008: Probabilistic predictions of climate change for Australia and southern Africa using the reliability ensemble average of IPCC CMIP3 model simulations. *Journal of Geophysical Research D: Atmospheres,* **113(15)**.

Molesworth, A.M., L.E. Cuevas, S.J. Connor, A.P. Morse, and M.C. Thomson, 2003: Environmental risk and meningitis epidemics in Africa. *Emerging Infectious Diseases,* **9(10)**, 1287-1293.

Mölg, T., N.J. Cullen, D.R. Hardy, G. Kaser, and L. Klok, 2008: Mass balance of a slope glacier on Kilimanjaro and its sensitivity to climate. *International Journal of Climatology,* **28(7)**, 881-892.

Mölg, T., N.J. Cullen, D.R. Hardy, M. Winkler, and G. Kaser, 2009a: Quantifying climate change in the tropical midtroposphere over East Africa from glacier shrinkage on Kilimanjaro. *Journal of Climate,* **22(15)**, 4162-4181.

Mölg, T., N.J. Cullen, and G. Kaser, 2009b: Solar radiation, cloudiness and longwave radiation over low-latitude glaciers: Implications for mass-balance modelling. *Journal of Glaciology,* **55(190)**, 292-302.

Mölg, T., M. Großhauser, A. Hemp, M. Hofer, and B. Marzeion, 2012: Limited forcing of glacier loss through land-cover change on Kilimanjaro. *Nature Climate Change,* **2(4)**, 254-258.

Mordecai, E.A., K.P. Paaijmans, L.R. Johnson, C. Balzer, T. Ben-Horin, E. de Moor, A. Mcnally, S. Pawar, S.J. Ryan, T.C. Smith, and K.D. Lafferty, 2013: Optimal temperature for malaria transmission is dramatically lower than previously predicted. *Ecology Letters,* **16(1)**, 22-30.

Mortimore, M., 2010: Adapting to drought in the Sahel: Lessons for climate change. *Wiley Interdisciplinary Reviews: Climate Change,* **1(1)**, 134-143.

Morton, J. and F. Mousseau, 2010: *Adressing chronic food insecurity in the Horn of Africa: Good practice identified, but commitment needed.* Policy Brief. Regional Learning & Advocacy Programme for Vulnerable Dryland Communities (REGLAP), pp. 5.

Moser, S.C. and J.A. Ekstrom, 2010: A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America,* **107(51)**, 22026-22031.

Mosha, A.C., 2011: The Effects of Climate Change on Urban Human Settlements in Africa. In: [Yuen, B. and A. Kumssa(eds.)]. Springer, Dordrecht, Heidelberg, London, New York, pp. 69-100.

Moss, B., 2010: Climate change, nutrient pollution and the bargain of Dr Faustus. *Freshwater Biology,* **55(SUPPL. 1)**, 175-187.

Motsholapheko,M. R.;Kgathi,D. L.;Vanderpost,C. 2011 Rural livelihoods and household adaptation to extreme flooding in the Okavango Delta, Botswana. Phys.Chem.Earth 36 (14-15)984-995

Mougou, R., M. Mansour, A. Iglesias, R.Z. Chebbi, and A. Battaglini, 2011: Climate change and agricultural vulnerability: A case study of rain-fed wheat in Kairouan, Central Tunisia. *Regional Environmental Change,* **11(SUPPL. 1)**, 137-142.

Moustadraf, J., M. Razack, and M. Sinan, 2008: Evaluation of the impacts of climate changes on the coastal Chaouia aquifer, Morocco, using numerical modeling. *Hydrogeology Journal,* **16(7)**, 1411-1426.

Moyo, D., 2009: *Dead Aid: Why aid is not working and how there is a better way for Africa.* Penguin Books, London, .

Mubaya, C. P., Njuki, J., Mutsvangwa, E. P., Mugabe, F. T., Nanja, D. 2012. Climate variability an change or multiple stressors? Farmers' perceptions regarding threats to livelihoods in Zimbabwe and Zambia. Journal of Environmental Management 102: 9 – 17.

Muchena, F.N., D.D. Onduru, G.N. Gachini, and A. de Jager, 2005: Turning the tides of soil degradation in Africa: Capturing the reality and exploring opportunities. *Land use Policy,* **22(1)**, 23-31.

Mukheibir, P., 2007: Possible climate change impacts on large hydroelectricity schemes in Southern Africa. *Journal of Energy in Southern Africa,* **18(1)**, 4-9.

Mukheibir, P. and G. Ziervogel, 2007: Developing a Municipal Adaptation Plan (MAP) for climate change: The city of Cape Town. *Environment and Urbanization,* **19(1)**, 143-158.

Mukute, M., T. Marange, C. Masara, H. Sisitka, and T. Pesanayi, 2012: *Future capacity building: Capacity assessment for environmental policy implementation.* SADC REEP, Howick.

Murray, V., G. McBean, M. Bhatt, S. Borsch, T.S. Cheong, W.F. Erian, S. Llosa, F. Nadim, M. Nunez, R. Oyun, and A.G. Suarez, 2012: Case studies. In: [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi *et al.*(eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 487-542.

Murray-Hudson, M., P. Wolski, and S. Ringrose, 2006: Scenarios of the impact of local and upstream changes in climate and water use on hydro-ecology in the Okavango Delta, Botswana. *Journal of Hydrology,* **331(1-2)**, 73-84.

Mutonyi, S. and B. Fungo, 2011: Patterns of agroforestry practices among small-holder farmers in the Lake Victoria Crescent Zone (LVCAEZ) of Uganda. *Research Journal of Applied Sciences,* **6(4)**, 251-257.

Mutuku, F.M., C.H. King, A.L. Bustinduy, P.L. Mungai, E.M. Muchiri, and U. Kitron, 2011: Impact of drought on the spatial pattern of transmission of Schistosoma haematobium in coastal Kenya. *American Journal of Tropical Medicine and Hygiene,* **85(6)**, 1065-1070.

Mwaura, P., 2008: *Indigenous Knowledge in Disaster Management in Africa.* United Nations Environment Programme (UNEP), Nairobi, Kenya, pp. 117.

Naess, L.O., E. Polack, and B. Chinsinga, 2011: Bridging Research and Policy Processes for Climate Change Adaptation. *IDS Bulletin,* **42(3)**, 97-103.

Naidoo, T., K. Vaz, and L. Byaba, 2012: *An introduction to adaptation in view of developing a private financing approach for adaptation related projects using the CTI PFAN model.* CTI PFAN Background Paper on Adaptation 02/2012. Climate Technology Initiative, pp. 51.

Naidu, S., R. Hounsome, and K. Iyer, 2006: *Climatic future for Durban: revised report.* Prepared for Ethekwini Municipality. CSIR Environmentek, pp. 202.

Nakhooda, S., A. Caravani, N. Bird, and L. Schalatek, 2011: *Climate Finance in Sub-Saharan Africa.* Climate Finance Policy Briefs. Heinrich Böll Stiftung North America and Overseas Development Institute, pp. 8.

Naude, W., 2010: Environment, Forced Migration and Social Vulnerability. In: *Forced Migration from Sub-Saharan Africa: The Conflict–Environment Link* [Afifi, T. and J. Jäger(eds.)]. Springer Berlin Heidelberg, pp. 43-55.

Ncube, S.P., H. Makurira, E. Kaseke, and A. Mhizha, 2011: Reservoir operation under variable climate: Case of Rozva Dam, Zimbabwe. *Physics and Chemistry of the Earth,* **36(14-15)**, 1112-1119.

Ndebele-Murisa, M.R. (ed.), 2011: *An analysis of primary and secondary production in Lake Kariba in a changing climate*. Diss. PhD, University of the Western Cape, South Africa, .

Ndebele-Murisa, M.R., M.C. Frank, and R.L. Miles, 2012: Phytoplankton biomass and primary production dynamics in Lake Kariba. *Lakes and Reservoirs: Research and Management,* **17(4)**, 275-289.

Ndebele-Murisa, M.R., E. Mashonjowa, and T. Hill, 2011a: The implications of a changing climate on the Kapenta fish stocks of Lake Kariba, Zimbabwe. *Transactions of the Royal Society of South Africa,* **66(2)**, 105-119.

Ndebele-Murisa, M.R., E. Mashonjowa, and T. Hill, 2011b: The decline of Kapenta fish stocks in Lake Kariba – a case of climate changing? *Transactions of the Royal Society of South Africa,* **66(3)**, 220-223.

Ndebele-Murisa, M.R., C.F. Musil, and L. Raitt, 2010: A review of phytoplankton dynamics in tropical African lakes. *South African Journal of Science,* **106(1-2)**, 13-18.

Ndegwa, W., K.P.C. Rao, R.K. Ngugi, and K. Kwena, 2010: *Improving farmer adaptive capacity by integrating local and indigenous knowledge in climate forecasting and adaptive response*. Adaptation Insights No. 4. IDRC anda CIFOR, pp. 3.

Nelson, G.C., M.W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes, R. Valmonte-Santos, M. Ewing, and D. Lee, 2009: *Climate change: Impact on agriculture and costs of adaptation*. Food Policy Report #19. International Food Policy Research Institute (IFPRI), Washington, D.C., pp. 30.

Neumann, R., G. Jung, P. Laux, and H. Kunstmann, 2007: Climate trends of temperature, precipitation and river discharge in the Volta Basin of West Africa. *International Journal of River Basin Management,* **5(1)**, 17-30.

New, M., B. Hewitson, D.B. Stephenson, A. Tsiga, A. Kruger, A. Manhique, B. Gomez, C.A.S. Coelho, D.N. Masisi, E. Kululanga, E. Mbambalala, F. Adesina, H. Saleh, J. Kanyanga, J. Adosi, L. Bulane, L. Fortunata, M.L. Mdoka, and R. Lajoie, 2006: Evidence of trends in daily climate extremes over southern and west Africa. *Journal of Geophysical Research D: Atmospheres,* **111(14)**.

Newsham, A.J. and D.S.G. Thomas, 2011: Knowing, farming and climate change adaptation in North-Central Namibia. *Global Environmental Change,* **21(2)**, 761-770.

Newton, K., I.M. Côté, G.M. Pilling, S. Jennings, and N.K. Dulvy, 2007: Current and Future Sustainability of Island Coral Reef Fisheries. *Current Biology,* **17(7)**, 655-658.

Ngigi, S.N., J. Rockström, and H.H.G. Savenije, 2006: Assessment of rainwater retention in agricultural land and crop yield increase due to conservation tillage in Ewaso Ng'iro river basin, Kenya. *Physics and Chemistry of the Earth,* **31(15-16)**, 910-918.

Nguku, P., S. Sharif, A. Omar, C. Nzioka, P. Muthoka, J. Njau, A. Dahiye, T. Galgalo, J. Mwihia, J. Njoroge, H. Limo, J. Mutiso, R. Kalani, A. Sheikh, J. Nyikal, D. Mutonga, J. Omollo, A. Guracha, J. Muindi, S. Amwayi, D. Langat, D. Owiti, A. Mohammed, J. Musaa, R. Sang, R. Breiman, K. Njenga, D. Feikin, M. Katz, H. Burke, P. Nyaga, M. Ackers, S. Gikundi, V. Omballa, L. Nderitu, N. Wamola, R. Wanjala, S. Omulo, J. Richardson, D. Schnabel, S. Martin, D. Hoel, H. Hanafi, M. Weiner, J. Onsongo, T. Kojo, M. Duale, A. Hassan, M. Dabaar, C. Njuguna, M. Yao, T. Grein, P. Formenty, B. Telfer, R. Lepec, H. Feldmann, A. Grolla, S. Wainwright, E. Lederman, E. Farnon, C. Rao, B.K. Kapella, and H. Gould, 2007: Rift Valley fever outbreak - Kenya, November 2006-January 2007. *Morbidity and Mortality Weekly Report,* **56(4)**, 73-76.

Nhemachena, C. and Hassan, R. M. 2008. How can African agriculture adapt to climate change? Insights from Ethiopia and South Africa. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Research Brief 15-7, IFPRI, Washington DC.

Niang, I., 2007: *Institutional Framework in Relation to Climate Change in West and Central Africa*. Climate Change Adaptation in Africa Programme, Dakar.

Niang, I., M. Dansokho, S. Faye, K. Gueye, and P. Ndiaye, 2010: Impacts of climate change on the Senegalese coastal zones: Examples of the Cap Vert peninsula and Saloum estuary. *Global and Planetary Change,* **72(4)**, 294-301.

Niang, I. (2012) Coastal erosion and the adaptation to climate change in coastal zones of West Africa project. http://www.undp-alm.org/sites/default/files/downloads/coastal_erosion_and_the_adaptation_to_climate_change_in_coastal_zones_of_west_africa_project_-_niang_2012.pdf

Nicholls, T., L. Norgrove, and G. Masters, 2008: Innovative solutions to new invaders: managing agricultural pests, diseases and weeds under climate change.[Brown, A.G. (ed.)]. Proceedings of Agriculture in a Changing Climate. Records of a conference conducted by the The ATSE Crawford Fund. Fourteenth Annual Development Conference, 3 September 2008, Parliament House, Canberra, Australia, pp. 9-14.

Nielsen J.Ø. (2010) The Outburst: climate change, gender relations and situational analysis. Social Analysis 54(3)76-89.

Nielsen J.Ø. and A. Reenberg, 2010. Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. Global Environmental Change, 20(1), 142-152.

Nilsson, A. and A. Schnell, 2010 Lessons learnt on HRBA in Sub-Saharan Africa. HRBA Helpdesk, Sida, April 2010. msc.st/docs/LessonsLearntHRBA-April2010.doc

Njaya, F., K.A. Snyder, D. Jamu, J. Wilson, C. Howard-Williams, E.H. Allison, and N.L. Andrew, 2011: The natural history and fisheries ecology of Lake Chilwa, southern Malawi. *Journal of Great Lakes Research,* **37(SUPPL. 1)**, 15-25.

Njie, M., B.E. Gomez, M.E. Hellmuth, J.M. Callaway, B.P. Jallow, and P. Droogers, 2008: Making economic sense of adaptation in upland cereal production systems in The Gambia. In: [Leary, N., J. Adejuwon, V. Barros, I. Burton, J. Kulkarni, and R. Lasco(eds.)]. Earthscan, London, UK and Sterling, VA, USA, pp. 131-146.

Njue, P.N. and M. Kimeu, 2010: " *Impenetrable' urban maze of east African coastal town: its implications on climate change*. Paper presented at 46th ISOCARP Congress 2010, pp. 11.

Nkem, J., H. Santoso, D. Murdiyarso, M. Brockhaus, and M. Kanninen, 2007: Using tropical forest ecosystem goods and services for planning climate change adaptation with implications for food security and poverty reduction. *SAT eJournal,* **4(1)**, 1-23.

Nkem, J., M. Idinoba, M. Brockhaus, F. Kalame, and A. Tas, 2008: *Adaptation to climate change in Africa: Synergies with biodiversity and forest.* CIFOR Environment Brief No. 3. Center for International Forestry Research (CIFOR), Bogor, Indonesia, pp. 4.

Notter, B., H. Hurni, U. Wiesmann, and J.O. Ngana, 2012: Evaluating watershed service availability under future management and climate change scenarios in the Pangani Basin. *Physics and Chemistry of the Earth,* .

Nwauche, E.S., 2009: Regional economic communities and human rights in West Africa and the African Arabic countries. In: [Bösl, A. and J. Diescho(eds.)]. Macmillan Education Namibia, Windhoek, Namibia, pp. 319-348.

Nyanga, P., Johnsen, F. H., Aune, J.B., and Kalinda, T. H. 2011. Smallholder farmers' perceptions of climate change and conservation agriculture: Evidence from Zambia. Journal of Sustainable Development 4: 73-85.

Nyenje, P.M. and O. Batelaan, 2009: Estimating the effects of climate change on groundwater recharge and baseflow in the upper Ssezibwa catchment, Uganda. *Hydrological Sciences Journal,* **54(4)**, 713-726.

Nyong, A., F. Adesina, and B. Osman Elasha, 2007: The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change,* **12(5)**, 787-797.

Nyssen, J., J. Poesen, D. Gebremichael, K. Vancampenhout, M. D'aes, G. Yihdego, G. Govers, H. Leirs, J. Moeyersons, J. Naudts, N. Haregeweyn, M. Haile, and J. Deckers, 2007: Interdisciplinary on-site evaluation of stone bunds to control soil erosion on cropland in Northern Ethiopia. *Soil and Tillage Research,* **94(1)**, 151-163.

Nzeadibe, T.C., C.L. Egbule, N.A. Chukwuone, A.E. Agwu, and V.C. Agu, 2012: Indigenous innovations for climate change adaptation in the Niger Delta region of Nigeria. *Environment, Development and Sustainability,* **14(6)**, 901-914.

Oates, N., Conway, D. and Calow, R. 2011. The 'mainstreaming' approach to climate change adaptation: insights from Ethiopia's water sector. ODI Background Note, April 2011, ODI, London.

Obura, D.O., 2005: Resilience and climate change: Lessons from coral reefs and bleaching in the Western Indian Ocean. *Estuarine, Coastal and Shelf Science,* **63(3)**, 353-372.

Odada, E.O., D.O. Olago, and W.O. Ochola (eds.), 2006: *Environment for Development: An ecosystems assessment of lake Victoria basin environmental and socio-economic status, trends and human vulnerabilities*. Pan African START Secretariat (PASS) and United Nations Environment Programme (UNEP), Nairobi, Kenya, pp. 192.

Odongo-Aginya, E.I., F.K. Kironde, N.B. Kabatereine, P. Kategere, and F. Kazibwe, 2008: Effect of seasonal rainfall and other environmental changes, on snail density and infection rates with schistosoma mansoni fifteen years after the last snails' study in kigungu, entebbe, uganda. *East African Medical Journal,* **85(11)**, 556-563.

Ogden, A.E. and J.L. Innes, 2009: Application of structured decision making to an assessment of climate change vulnerabilities and adaptation options for sustainable forest management. *Ecology and Society,* **14(1)**.

Oguntunde, P.G. and B.J. Abiodun, 2013: The impact of climate change on the Niger River Basin hydroclimatology, West Africa. *Climate Dynamics,* **40(1-2)**, 81-94.

Ogutu-Ohwayo, R. and J.S. Balirwa, 2006: Management challenges of freshwater fisheries in Africa. *Lakes and Reservoirs: Research and Management,* **11(4)**, 215-226.

Okude, A.S. and I.A. Ademiluyi, 2006: Implications of the changing pattern of land cover of the Lagos coastal area of Nigeria. *American-Eurasian Journal of Scientific Research,* **1(1)**, 31-37.

Olago, D., M. Marshall, S.O. Wandiga, M. Opondo, P.Z. Yanda, R. Kanalawe, A.K. Githeko, T. Downs, A. Opere, R. Kavumvuli, E. Kirumira, L. Ogallo, P. Mugambi, E. Apindi, F. Githui, J. Kathuri, L. Olaka, R. Sigalla, R. Nanyunja, T. Baguma, and P. Achola, 2007: Climatic, socio-economic, and health factors affecting human vulnerability to cholera in the Lake Victoria basin, east Africa. *Ambio,* **36(4)**, 350-358.

Olaka, L.A., E.O. Odada, M.H. Trauth, and D.O. Olago, 2010: The sensitivity of East African rift lakes to climate fluctuations. *Journal of Paleolimnology,* **44(2)**, 629-644.

Olsson, P., L. H. Gunderson, S. R. Carpenter, P. Ryan, L. Lebel, C. Folke, and C. S. Holling. 2006. Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. Ecology and Society 11(1): 18.

Olwoch, J.M., A.S. Van Jaarsveld, C.H. Scholtz, and I.G. Horak, 2007: Climate change and the genus rhipicephalus (Acari: Ixodidae) in Africa. *Onderstepoort Journal of Veterinary Research,* **74(1)**, 45-72.

Olwoch, J.M., B. Reyers, F.A. Engelbrecht, and B.F.N. Erasmus, 2008: Climate change and the tick-borne disease, Theileriosis (East Coast fever) in sub-Saharan Africa. *Journal of Arid Environments,* **72(2)**, 108-120.

Omumbo, J.A., B. Lyon, S.M. Waweru, S.J. Connor, and M.C. Thomson, 2011: Raised temperatures over the Kericho tea estates: Revisiting the climate in the East African highlands malaria debate. *Malaria Journal,* **10**.

O'Reilly, C.M., S.R. Alin, P.-. Piisnier, A.S. Cohen, and B.A. McKee, 2003: Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa. *Nature,* **424(6950)**, 766-768.

Orlove, B., C. Roncoli, M. Kabugo, and A. Majugu, 2010: Indigenous climate knowledge in southern Uganda: The multiple components of a dynamic regional system. *Climatic Change,* **100(2)**, 243-265.

Orlowsky, B. and S.I. Seneviratne, 2012: Global changes in extreme events: Regional and seasonal dimension. *Climatic Change,* **110(3-4)**, 669-696.

Osbahr, H., with E. Boyd and P. Ericksen. 2007. Resilience, realities and research in African environments.Report of workshop 18 June 2007. University of Oxford, Oxford, UK.

Osbahr, H., C. Twyman, W.N. Adger, and D.S.G. Thomas, 2010: Evaluating Successful Livelihood Adaptation to Climate Variability and change in Southern Africa. *Ecology and Society,* **15(2)**, 22.

Osbahr, H., P. Dorward, R. Stern, and S. Cooper, 2011: Supporting agricultural innovation in Uganda to respond to climate risk: Linking climate change and variability with farmer perceptions. *Experimental Agriculture,* **47(2)**, 293-316.

Osborne, P.L., 2012: *Tropical ecosystems and ecological concept*. Cambridge University Press, Cambridge, UK, Second ed., pp. 536.

Osman-Elasha, B., N. Goutbi, E. Spanger-Siegfried, W. Dougherty, S. Hanafi, S. Zakieldeen, A. Sanjak, H. Abdel, and H. M. Elhassan, 2006: Adaptation practices and policies to increase human resilience against climate variability and change: Lessons from the arid regions of Sudan. Working Paper 42. Washington, D.C.: Assessments of Impacts and Adaptations to Climate Change.

Ototo, E.N., A.K. Githeko, C.L. Wanjala, and T.W. Scott, 2011: Surveillance of vector populations and malaria transmission during the 2009/10 El Niño event in the western Kenya highlands: Opportunities for early detection of malaria hyper-transmission. *Parasites and Vectors,* **4(1)**.

Oweis, T. and A. Hachum, 2006: Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. *Agricultural Water Management,* **80(1-3 SPEC. ISS.)**, 57-73.

Paaijmans, K.P., A.F. Read, and M.B. Thomas, 2009: Understanding the link between malaria risk and climate. *Proceedings of the National Academy of Sciences of the United States of America,* **106(33)**, 13844-13849.

Paaijmans, K.P., S. Blanford, A.S. Bell, J.I. Blanford, A.F. Read, and M.B. Thomas, 2010a: Influence of climate on malaria transmission depends on daily temperature variation. *Proceedings of the National Academy of Sciences of the United States of America,* **107(34)**, 15135-15139.

Paaijmans, K.P., S.S. Imbahale, M.B. Thomas, and W. Takken, 2010b: Relevant microclimate for determining the development rate of malaria mosquitoes and possible implications of climate change. *Malaria Journal,* **9(1)**.

Paaijmans, K.P., S. Blanford, B.H.K. Chan, and M.B. Thomas, 2012: Warmer temperatures reduce the vectorial capacity of malaria mosquitoes. *Biology Letters,* **8(3)**, 465-468.

Paavola, J., 2008: Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science and Policy,* **11(7)**, 642-654.

Paeth, H. and H.-. Thamm, 2007: Regional modelling of future African climate north of 15°S including greenhouse warming and land degradation. *Climatic Change,* **83(3)**, 401-427.

Pahl-Wostl, C., 2009: A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change,* **19(3)**, 354-365.

Palmgren, H., 2009: Meningococcal disease and climate. *Global Health Action,* **2**, 8.

Pantuliano, S. and M. Wekesa, 2008: *Improving drought response in pastoral areas of Ethiopia: Somali and Afar regions and Borena Zone of Oromiya region*. Overseas Development Institute (ODI) - Humanitarian Policy Group, London, UK, pp. 39.

Parfitt, J., M. Barthel, and S. MacNaughton, 2010: Food waste within food supply chains: Quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences,* **365(1554)**, 3065-3081.

Parham, P.E. and E. Michael, 2010: Modeling the effects of weather and climate change on malaria transmission. *Environmental Health Perspectives,* **118(5)**, 620-626.

Parham, P.E., D. Pople, C. Christiansen-Jucht, S. Lindsay, W. Hinsley, and E. Michael, 2012: Modeling the role of environmental variables on the population dynamics of the malaria vector Anopheles gambiae sensu stricto. *Malaria Journal,* **11**.

Parry, M., N. Arnell, P. Berry, D. Dodman, S. Fankhauser, C. Hope, S. Kovats, R. Nicholls, D. Satterthwaite, R. Tiffin, T. Wheeler, 2009a Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates, International Institute for Environment and Development and Grantham Institute for Climate Change, London

Parry, M., A. Evans, M.W. Rosegrant, and T. Wheeler, 2009b: *Climate change and hunger: responding to the challenge*. World Food Programme, Rome, Italy, pp. 104.

Pascual, M., J.A. Ahumada, L.F. Chaves, X. Rodó, and M. Bouma, 2006: Malaria resurgence in the East African highlands: Temperature trends revisited. *Proceedings of the National Academy of Sciences of the United States of America,* **103(15)**, 5829-5834.

Passioura, J., 2006: Increasing crop productivity when water is scarce - From breeding to field management. *Agricultural Water Management,* **80(1-3 SPEC. ISS.)**, 176-196.

Patricola, C.M. and K.H. Cook, 2010a: Northern African climate at the end of the twenty-first century: An integrated application of regional and global climate models. *Climate Dynamics,* **35(1)**, 193-212.

Patricola, C.M. and K.H. Cook, 2010b: Sub-Saharan Northern African climate at the end of the twenty-first century: forcing factors and climate change processes. *Climate Dynamics,* , 1-24.

Patt, A. and Schroter , D. 2008. Perceptions of climate risk in Mozambique: Implications for the success of adapation strategies. Global Environmental Change 18: 458-467.

Patt, A., A. Dazé, P. Suarez (2009) Gender and climate change vulnerability: What's the problem, what's the solution? In Distributional Impacts of Climate Change and Disasters: Concepts and Cases, M. Ruth, M.E. Ibarraran (eds), Edward Elgar, Cheltenham, UK pp.82-102

Pauli, H., M. Gottfried, S. Dullinger, O. Abdaladze, M. Akhalkatsi, J.L.B. Alonso, G. Coldea, J. Dick, B. Erschbamer, R.F. Calzado, D. Ghosn, J.I. Holten, R. Kanka, G. Kazakis, J. Kollár, P. Larsson, P. Moiseev, D. Moiseev, U. Molau, J.M. Mesa, L. Nagy, G. Pelino, M. Puşcaş, G. Rossi, A. Stanisci, A.O. Syverhuset, J.-. Theurillat, M. Tomaselli, P. Unterluggauer, L. Villar, P. Vittoz, and G. Grabherr, 2012: Recent plant diversity changes on Europe's mountain summits. *Science,* **336(6079)**, 353-355.

Pauly, D., V. Christensen, S. Guénette, T.J. Pitcher, U.R. Sumaila, C.J. Walters, R. Watson, and D. Zeller, 2002: Towards sustainability in world fisheries. *Nature,* **418(6898)**, 689-695.

Paumgarten, F. and C.M. Shackleton, 2011: The role of non-timber forest products in household coping strategies in South Africa: The influence of household wealth and gender. *Population and Environment,* **33(1)**, 108-131.

Pauw, W.P., J. Ayers, and A. Kaere, 2012: The international architecture of climate adaptation finance and its implications for African institutions. In: *"Adapting" institutions to meet Climate Change Impacts: can Africa meet the Challenges?* [Denton, F. (ed.)]. IDRC/Springer, .

Pauw, W.P., forthcoming: The role of perception in subsistence farmer adaptation in Africa – enriching the climate finance debate. *International Journal of Climate Change Strategies and Management,* .

Peach Brown, H. C. 2011. Gender, climate change and REDD+ in the Congo Basin Forests of Central Africa. International Forestry Review 13: 136-176.

Peden, D., G. Taddesse, and A. Haileslassie, 2009: Livestock water productivity: Implications for sub-Saharan Africa. *Rangeland Journal,* **31(2)**, 187-193.

Pelham, L., E. Clay, and T. Braunholz, 2011: *Natural disasters: what is the role for social safety nets?*. Social Protection Discussion Paper No. 1102. The World Bank, Washington, DC, USA, pp. 142.

Pepin, N.C., W.J. Duane, and D.R. Hardy, 2010: The montane circulation on Kilimanjaro, Tanzania and its relevance for the summit ice fields: Comparison of surface mountain climate with equivalent reanalysis parameters. *Global and Planetary Change,* **74(2)**, 61-75.

Perch-Nielsen, S.L., M.B. Bättig, and D. Imboden, 2008: Exploring the link between climate change and migration. *Climatic Change,* **91(3-4)**, 375-393.

Persson, Å, R.J.T. Klein, C. Kehler Siebert, A. Atteridge, B. Müller, J. Hoffmaister, M. Lazarus, and T. Takama, 2009: *Adaptation finance under a Copenhagen agreed outcome*. Research Report. Stockholm Environment Institute, Stockholm, Sweden, pp. 187.

Peters, J. and S. Thielmann, 2008: Promoting biofuels: Implications for developing countries. *Energy Policy,* **36(4)**, 1538-1544.

Petersen, C. and S. Holness, 2011: *South Africa: Ecosystem-based planning for climate change*. World Resources Report Case Study. World Resources Report, Washington, DC, USA, pp. 18.

Peterson, A.T., 2009a: Shifting suitability for malaria vectors across Africa with warming climates. *BMC Infectious Diseases,* **9**.

Peterson, A.T., 2009b: Shifting suitability for malaria vectors across Africa with warming climates. *BMC Infectious Diseases,* **9**.

Piguet, É, A. Pécoud, and P. de Guchteneire (eds.), 2011: *Migration and Climate Change*. Cambridge University Press and UNESCO Publishing, New York, NY, USA, pp. 464.

Piguet, E., 2010: Linking climate change, environmental degradation, and migration: A methodological overview. *Wiley Interdisciplinary Reviews: Climate Change,* **1(4)**, 517-524.

Plummer, R., 2012: *Fostering governance and building capacity for climate change adaptation: can adaptive co-management help?*pp. 18.

Postigo, J.A.R., 2010: Leishmaniasis in the World Health Organization Eastern Mediterranean Region. *International Journal of Antimicrobial Agents,* **36(SUPPL. 1)**, S62-S65.

Pramova, E., B. Locatelli, M. Brockhaus, and S. Fohlmeister, 2012: Ecosystem services in the National Adaptation Programmes of Action. *Climate Policy,* **12(4)**, 393-409.

Prince, S.D., K.J. Wessels, C.J. Tucker, and S.E. Nicholson, 2007: Desertification in the Sahel: A reinterpretation of a reinterpretation. *Global Change Biology,* **13(7)**, 1308-1313.

Prowse, M., N. Grist, and C. Sourang, 2009: *Closing the gap between climate adaptation and poverty reduction frameworks*. ODI Policy Briefing No. 21, June 2009. Overseas Development Institute (ODI), London, UK, pp. 4.

Purdon, M., 2010: The clean development mechanism and community forests in Sub-Saharan Africa: reconsidering Kyoto's "moral position" on biocarbon sinks in the carbon market. *Environment, Development and Sustainability,* **12(6)**, 1025-1050.

Quinn, C.H., G. Ziervogel, A. Taylor, T. Takama, and F. Thomalla, 2011: Coping with multiple stresses in rural South Africa. *Ecology and Society,* **16(3)**, 10.

Ræbild, A., U.B. Hansen, and S. Kambou, 2012: Regeneration of Vitellaria paradoxa and Parkia biglobosa in a parkland in Southern Burkina Faso. *Agroforestry Systems,* **85(3)**, 443-453.

Rain, D., R. Engstrom, C. Ludlow, and S. Antos, 2011: *Accra Ghana: A city vulnerable to flooding and drought-induced migration. Case study prepared for the Cities and Climate Change: Global Report on Human Settlements 2011* pp. 21.

Raleigh, C., 2010: Political Marginalization, Climate Change, and Conflict in African Sahel States. *International Studies Review,* **12(1)**, 69-86.

Raleigh, C., 2011: The search for safety: The effects of conflict, poverty and ecological influences on migration in the developing world. *Global Environmental Change,* **21(SUPPL. 1)**, S82-S93.

Ramirez, J., A. Jarvis, I. Van den Bergh, C. Staver, and D. Turner, 2011: Changing Climates: Effects on Growing Conditions for Banana and Plantain (Musa spp.) and Possible Responses. In: *Crop Adaptation to Climate*

Change. [Yadav, S.S., R. Redden, J.L. Hatfield, H. Lotze-Campen, and A.J.W. Hall(eds.)]. Wiley-Blackwell, Oxford, UK, pp. 426-438.

Rao, K.P.C., W.G. Ndegwa, K. Kizito, and A. Oyoo, 2011: Climate variability and change: Farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya. *Experimental Agriculture,* **47(2)**, 267-291.

Raxworthy, C.J., R.G. Pearson, N. Rabibisoa, A.M. Rakotondrazafy, J.-. Ramanamanjato, A.P. Raselimanana, S. Wu, R.A. Nussbaum, and D.A. Stone, 2008: Extinction vulnerability of tropical montane endemism from warming and upslope displacement: A preliminary appraisal for the highest massif in Madagascar. *Global Change Biology,* **14(8)**, 1703-1720.

Reid, H., S. Huq, and L. Murray, 2010: *Community Champions: Adapting to Climate Challenges*. International Institute for Environment and Development, London, UK (IIED), pp. 106.

Reid, H., L. Sahlén, J. Stage, and J. MacGregor, 2008: Climate change impacts on Namibia's natural resources and economy. *Climate Policy,* **8(5)**, 452-466.

Reij, C., G. Tappan, and M. Smale, 2009: *Agroenvironmental transformation in the Sahel: another kind of "Green Revolution"*. IFPRI Discussion Paper 00914, November 2009. International Food Policy Research Institute, Washington, DC, USA., pp. 43.

Repetto, R., 2008: *The climate crisis and the adaptation myth*. Working Paper Number 13. Yale School of Forestry and Environmental Studies, New Haven, Conneticut, USA, pp. 20.

Research Institute for Groundwater, 2011: *Adaptation to the impact of sea level Rise in the Nile Delta Coastal zone, Egypt: Contribution of the Research Institute For Groundwater. Second Progress Report*. National Water Research Center, Egypt.

Reuveny, R., 2007: Climate change-induced migration and violent conflict. *Political Geography,* **26(6)**, 656-673.

Reynolds, M.P., J. Hellin, B. Govaerts, P. Kosina, K. Sonder, P. Hobbs, and H. Braun, 2012: Global crop improvement networks to bridge technology gaps. *Journal of Experimental Botany,* **63(1)**, 1-12.

Rhajaoui, M., 2011: Human leishmaniases in Morocco: A nosogeographical diversity. *Pathologie Biologie,* **59(4)**, 226-229.

Richard, K., D.M. Mwayafu, and H. Smith, 2011: *REDD+ and adaptation to climate change in East Africa*. Networking for equity in forest climate policy. REDD-net programme, pp. 8.

Roberts, D., 2008: Thinking globally, acting locally - Institutionalizing climate change at the local government level in Durban, South Africa. *Environment and Urbanization,* **20(2)**, 521-537.

Roberts, D., R. Boon, N. Diederichs, E. Douwes, N. Govender, A. Mcinnes, C. Mclean, S. O'Donoghue, and M. Spires, 2012: Exploring ecosystem-based adaptation in Durban, South Africa: "learning-by-doing" at the local government coal face. *Environment and Urbanization,* **24(1)**, 167-195.

Roberts, L., 2010: The beginning of the end for Africa's devastating meningitis outbreaks? *Science,* **330(6010)**, 1466-1467.

Robledo, C., N. Clot, A. Hammill, and B. Riché, 2012: The role of forest ecosystems in community-based coping strategies to climate hazards: Three examples from rural areas in Africa. *Forest Policy and Economics,* **24**, 20-28.

Rocha, A., P. Melo-Gonçalves, C. Marques, J. Ferreira, and J.M. Castanheira, 2008: High-frequency precipitation changes in southeastern Africa due to anthropogenic forcing. *International Journal of Climatology,* **28(9)**, 1239-1253.

Rodima-Taylor, D., 2012: Social innovation and climate adaptation: Local collective action in diversifying Tanzania. *Applied Geography,* **33(1)**, 128-134.

Rodó, X., M. Pascual, G. Fuchs, and A.S.G. Faruque, 2002: ENSO and cholera: A nonstationary link related to climate change? *Proceedings of the National Academy of Sciences of the United States of America,* **99(20)**, 12901-12906.

Rogers, D.J. and S.E. Randolph, 2006: *Climate Change and Vector-Borne Diseases* pp. 345-381.

Romero González, A.M., A. Belemvire, and S. Saulière, 2011: *Climate Change and Women Farmers in Burkina Faso: Impact and adaptation policies and practices*. Oxfam Research Reports. Oxfam International, Oxford, UK, pp. 45.

Roncoli, C., K. Ingram, and P. Kirshen. 2002. Reading the rains: Local knowledge and rainfall forecasting among farmers of Burkina Faso. Society and Natural Resources 15: 411–30.

Roncoli, C., Crane, T. and Orlove, B. 2009. Fielding Climate Change in Cultural Anthropology. pp.87-115. In: Anthropology & Climate Change: From Encounters to Actions [Crate, S.A. and Nuttall, M. (Eds.)]. Left Coast Press, Walnut Creek, U.S.

Roncoli, C., B. Okoba, V. Gathaara, J. Ngugi, and T. Nganga, 2010: *Adaptation to climate change for smallholder agriculture in Kenya: community-based perspectives from five districts*. IFPRI Note. International Food Policy Research Institute (IFPRI), Washington, DC, USA, pp. 4.

Rosenthal, D.M. and D.R. Ort, 2011: Examining Cassava's Potential to Enhance Food Security Under Climate Change. *Tropical Plant Biology,* , 1-9.

Roudier, P., B. Sultan, P. Quirion, and A. Berg, 2011: The impact of future climate change on West African crop yields: What does the recent literature say? *Global Environmental Change,* **21(3)**, 1073-1083.

Rowhani, P., O. Degomme, D. Guha-Sapir, and E.F. Lambin, 2011: Malnutrition and conflict in East Africa: The impacts of resource variability on human security. *Climatic Change,* **105(1)**, 207-222.

Ruelland, D., A. Tribotte, C. Puech, and C. Dieulin, 2011: Comparison of methods for LUCC monitoring over 50 years from aerial photographs and satellite images in a Sahelian catchment. *International Journal of Remote Sensing,* **32(6)**, 1747-1777.

Ruelland, D., S. Ardoin-Bardin, L. Collet, and P. Roucou, 2012: Simulating future trends in hydrological regime of a large Sudano-Sahelian catchment under climate change. *Journal of Hydrology,* **424-425**, 207-216.

Ruppel, O.C., 2009: Regional economic communities and human rights in East and southern Africa. In: *Human Rights in Africa. Legal Perspectives on their Protection and Promotion*. [Bösl, A. and J. Diescho(eds.)]. Macmillan Education Namibia, Windhoek, Namibia, pp. 275-317.

Ruppel, O.C., 2011: Trade, environment and sustainable development. In: *Environmental Law and Policy in Namibia*. [Ruppel, O.C. and K. Ruppel-Schlichting(eds.)]. Hans Seidel Foundation, Windhoek, Namibia, pp. 241-282.

Ruppel, O.C., 2012: Climate change policy positions and related developments in the AU and SADC. *SADC Law Jounal,* **2(1)**, 14-35.

Ruppel, O.C. and K. Ruppel-Schlichting, 2012: Climate change and human security: relevant for regional integration in SADC? In: *Monitoring Regional Integration in Southern Africa 2011: Yearbook for Regional Integration*. [Hartzenberg, T., G. Erasmus, and A. Du Pisani(eds.)]. Trade Law Centre for Southern Africa, Stellenbosch, South Africa, pp. 32-71.

Sala, O.E., F.S. Chapin III, J.J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L.F. Huenneke, R.B. Jackson, A. Kinzig, R. Leemans, D.M. Lodge, H.A. Mooney, M. Oesterheld, N.L. Poff, M.T. Sykes, B.H. Walker, M. Walker, and D.H. Wall, 2000: Global biodiversity scenarios for the year 2100. *Science,* **287(5459)**, 1770-1774.

Salah, A.B., Y. Kamarianakis, S. Chlif, N.B. Alaya, and P. Prastacos, 2007: Zoonotic cutaneous leishmaniasis in central Tunisia: Spatio-temporal dynamics. *International Journal of Epidemiology,* **36(5)**, 991-1000.

Sallu, S. M., C. Twyman, and L. C. Stringer. 2010. Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. Ecology and Society 15(4): 3.

Sanchez, A.C., P.E. Osborne, and N. Haq, 2011: Climate change and the African baobab (Adansonia digitata L.): The need for better conservation strategies. *African Journal of Ecology,* **49(2)**, 234-245.

Sankaran, M., J. Ratnam, and N. Hanan, 2008: Woody cover in African savannas: The role of resources, fire and herbivory. *Global Ecology and Biogeography,* **17(2)**, 236-245.

Sarmento, H., M. Isumbisho, and J.-. Descy, 2006: Phytoplankton ecology of Lake Kivu (eastern Africa). *Journal of Plankton Research,* **28(9)**, 815-829.

Sarvala, J., V.T. Langenberg, K. Salonen, D. Chitamwebwa, G.W. Coulter, T. Huttula, P. Kotilainen, N. Mulimbwa, and H. Mölsä, 2006a: Changes in dissolved silica and transparency are not sufficient evidence for decreased primary productivity due to climate warming in Lake Tanganyika. Reply to comment by Verburg, Hecky and Kling. *Verhandlungen Internationale Vereiningung Für Limnologie,* **29**, 2339-2342.

Sarvala, J., V.T. Langenberg, K. Salonen, D. Chitamwebwa, G.W. Coulter, T. Huttula, R. Kanyaru, P. Kotilainen, S. Makasa, N. Mulimbwa, and H. Molsa, 2006b: Fish catches from Lake Tanganyika mainly reflect changes in fishery practices, not climate. *Verhandlungen Internationale Vereinigung Für Theoretische Und Angewandte Limnologie,* **29**, 1182-1188.

Satterthwaite, D., S. Huq, H. Reid, P. Pelling, and P. Romero Lankao, 2009: Adapting to climate change in urban areas: the possibilities and constraints in low- and middle-income nations. In: ***Adapting Cities to Climate***

Change. Understanding and Addressing the Development Challenges. [Bicknell, J., D. Dodman, and D. Satterthwaite(eds.)]. Routledge, London, .

Saugeon, C., T. Baldet, M. Akogbeto, and M.C. Henry, 2009: Will climate and demography have a major impact on malaria in sub-Saharan Africa in the next 20 years? *Médecine Tropicale : Revue Du Corps De Santé Colonial,* **69(2)**, 203-207.

Scheffran, J., E. Marmer, and P. Sow, 2012: Migration as a contribution to resilience and innovation in climate adaptation: Social networks and co-development in Northwest Africa. *Applied Geography,* **33(1)**, 119-127.

Scheiter, S. and S.I. Higgins, 2009: Impacts of climate change on the vegetation of Africa: An adaptive dynamic vegetation modelling approach. *Global Change Biology,* **15(9)**, 2224-2246.

Schilling, J., K.P. Freier, E. Hertig, and J. Scheffran, 2012: Climate change, vulnerability and adaptation in North Africa with focus on Morocco. *Agriculture, Ecosystems and Environment,* **156**, 12-26.

Schlenker, W. and D.B. Lobell, 2010: Robust negative impacts of climate change on African agriculture. *Environmental Research Letters,* **5(1)**.

Schleyer, M.H. and L. Celliers, 2003: Biodiversity on the marginal coral reefs of South Africa: What does the future hold? *Zoologische Verhandelingen,* **345**, 387-400.

Scholze, M., W. Knorr, N.W. Arnell, and I.C. Prentice, 2006: A climate-change risk analysis for world ecosystems. *Proceedings of the National Academy of Sciences of the United States of America,* **103(35)**, 13116-13120.

Schoneveld, G.C., L.A. German, and E. Nutako, 2011: Land-based investments for rural development? A grounded analysis of the local impacts of biofuel feedstock plantations in Ghana. *Ecology and Society,* **16(4)**.

Schüler, L., A. Hemp, W. Zech, and H. Behling, 2012: Vegetation, climate and fire-dynamics in East Africa inferred from the Maundi crater pollen record from Mt Kilimanjaro during the last glacial-interglacial cycle. *Quaternary Science Reviews,* **39**, 1-13.

Seaquist, J.W., L. Olsson, J. Ardö, and L. Eklundh, 2006: Broad-scale increase in NPP quantified for the African Sahel, 1982-1999. *International Journal of Remote Sensing,* **27(22)**, 5115-5122.

Seballos, F., T. Tanner, M. Tarazona and J. Gallegos (2011) Children and disasters: understanding impact and enabling agency. Brighton: Children in a Changing Climate/Institute of Development Studies. http://resourcecentre.savethechildren.se/content/library/documents/children-and-disasters-understanding-impact-and-enabling-agency

SEI, 2009: *The economics of climate change in Kenya*. Final Report submitted in advance of COP15. Stockholm Environment Institute, Stockholm, Sweden, pp. 82.

Sendzimir, J., C.P. Reij, and P. Magnuszewski, 2011: Rebuilding Resilience in the Sahel: Regreening in the Maradi and Zinder Regions of Niger. *Ecology and Society,* **16(3)**, 08.

Seo, S.N. and R. Mendelsohn, 2008: Measuring impacts and adaptations to climate change: A structural Ricardian model of African livestock management. *Agricultural Economics,* **38(2)**, 151-165.

Seneviratne, S.I., N. Nicholls, D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M. Reichstein, A. Sorteberg, C. Vera, and X. Zhang, 2012: Changes in climate extremes and their impacts on the natural physical environment. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 109-230.

Seth, A., S.A. Rauscher, M. Rojas, A. Giannini, and S.J. Camargo, 2011: Enhanced spring convective barrier for monsoons in a warmer world? *Climatic Change,* **104(2)**, 403-414.

Seto, K.C., 2011: Exploring the dynamics of migration to mega-delta cities in Asia and Africa: Contemporary drivers and future scenarios. *Global Environmental Change,* **21(SUPPL. 1)**, S94-S107.

Shackleton, C.M., S.E. Shackleton, J. Gambiza, E. Nel, K. Rowntree, P. Urquhart, C. Fabricius, and A. Ainslie, 2010: *Livelihoods and Vulnerability in the Arid and Semi-Arid Lands of Southern Africa: Exploring the Links Between Ecosystem Services & Poverty Alleviation*. Nova Science Publishers, New York, pp. 267.

Shackleton, S.E. and C.M. Shackleton, 2012: Linking poverty, HIV/AIDS and climate change to human and ecosystem vulnerability in southern Africa: consequences for livelihoods and sustainable ecosystem management. *International Journal of Sustainable Development & World Ecology,* **19(3)**, 275-286.

Shankland, A. and Chambote, R. 2011 Prioritising PPCR investments in Mozambique: the politics of ‘country ownership and ‘stakeholder participation’. IDS Bulletin 42.3. Publisher Wiley-Blackwell

Shephard, G.S., 2008: Impact of mycotoxins on human health in developing countries. *Food Additives and Contaminants,* **25(2)**, 146-151.

Sheppard, C.R.C., 2003: Predicted recurrences of mass coral mortality in the Indian Ocean. *Nature,* **425(6955)**, 294-297.

Shongwe, M.E., G.J. Van Oldenborgh, B.J.J.M. Van Den Hurk, B. De Boer, C.A.S. Coelho, and M.K. Van Aalst, 2009: Projected changes in mean and extreme precipitation in Africa under global warming. Part I: Southern Africa. *Journal of Climate,* **22(13)**, 3819-3837.

Shongwe, M.E., G.J. van Oldenborgh, B. van den Hurk, and M. van Aalst, 2011: Projected changes in mean and extreme precipitation in Africa under global warming. Part II: East Africa. *Journal of Climate,* **24(14)**, 3718-3733.

Sillmann, J. and E. Roeckner, 2008: Indices for extreme events in projections of anthropogenic climate change. *Climatic Change,* **86(1-2)**, 83-104.

Simane, B., B.F. Zaitchik, and D. Mesfin, 2012: Building climate resilience in the Blue Nile/Abay Highlands: A framework for action. *International Journal of Environmental Research and Public Health,* **9(2)**, 610-631.

Sissoko, K., H. van Keulen, J. Verhagen, V. Tekken, and A. Battaglini, 2011: Agriculture, livelihoods and climate change in the West African Sahel. *Regional Environmental Change,* **11(SUPPL. 1)**, 119-125.

Sitch, S., C. Huntingford, N. Gedney, P.E. Levy, M. Lomas, S.L. Piao, R. Betts, P. Ciais, P. Cox, P. Friedlingstein, C.D. Jones, I.C. Prentice, and F.I. Woodward, 2008: Evaluation of the terrestrial carbon cycle, future plant geography and climate-carbon cycle feedbacks using five Dynamic Global Vegetation Models (DGVMs). *Global Change Biology,* **14(9)**, 2015-2039.

Sitoki, L., J. Gichuki, C. Ezekiel, F. Wanda, O.C. Mkumbo, and B.E. Marshall, 2010: The environment of Lake Victoria (East Africa): Current status and historical changes. *International Review of Hydrobiology,* **95(3)**, 209-223.

Smith, J.B., T. Dickinson, J.D.B. Donahue, I. Burton, E. Haites, R.J.T. Klein, and A. Patwardhan (2011) Development and climate change adaptation funding: coordination and integration. CLIMATE POLICY 11 (2011) 987–1000. doi:10.1080/14693062.2011.582385

Smucker, T.A. and B. Wisner, 2008: Changing household responses to drought in Tharaka, Kenya: Vulnerability, persistence and challenge. *Disasters,* **32(2)**, 190-215.

Snoussi, M., T. Ouchani, A. Khouakhi, and I. Niang-Diop, 2009: Impacts of sea-level rise on the Moroccan coastal zone: Quantifying coastal erosion and flooding in the Tangier Bay. *Geomorphology,* **107(1-2)**, 32-40.

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood, and D. Wratt, 2007a: Technical Summary. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt *et al.*(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, .

Solomon, T.B., H.A. Snyman, and G.N. Smit, 2007b: Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management,* **82(4)**, 481-494.

Somorin, O.A., H.C.P. Brown, I. Visseren-Hamakers, D.J. Sonwa, B. Arts, and J. Nkem, 2012: The congo basin forests in a changing climate: Policy discourses on adaptation and mitigation (REDD+). *Global Environmental Change,* **22(1)**, 288-298.

Sonwa, D., Y. Bele, O. O. Somorin, C. Jum, and J. Nkem, 2009:
Adaptation for forests and communities in the Congo Basin. *ETFRN News,* **50**, 93-100.

Sonwa, D.J., J.N. Nkem, M.E. Idinoba, M.Y. Bele, and C. Jum, 2012: Building Regional Priorities in Forests for Development and Adaptation to Climate Change in the Congo Basin. *Mitigation and Adaptation Strategies for Global Change,* **17(4)**, 441-450.

Sovacool, B.K. (2011) Hard and soft paths for climate change adaptation. Climate Policy 11(2011)1177-1183.

START, 2011: START Annual Report 2010-2011: Enhancing scientific capacity to inspire informed action on global environmental change. International START Secretariat, Washington, DC, USA.

Staver, A.C., S. Archibald, and S.A. Levin, 2011: The global extent and determinants of savanna and forest as alternative biome states. *Science,* **334(6053)**, 230-232.

Stenuite, S., S. Pirlot, M.-. Hardy, H. Sarmento, A.-. Tarbe, B. Leporcq, and J.-. Descy, 2007: Phytoplankton production and growth rate in Lake Tanganyika: Evidence of a decline in primary productivity in recent decades. *Freshwater Biology,* **52(11)**, 2226-2239.

Stenuite, S., A.-. Tarbe, H. Sarmento, F. Unrein, S. Pirlot, D. Sinyinza, S. Thill, M. Lecomte, B. Leporcq, J.M. Gasol, and J.-. Descy, 2009: Photosynthetic picoplankton in Lake Tanganyika: Biomass distribution patterns with depth, season and basin. *Journal of Plankton Research,* **31(12)**, 1531-1544.

Stern, D.I., P.W. Gething, C.W. Kabaria, W.H. Temperley, A.M. Noor, E.A. Okiro, G. Dennis Shanks, R.W. Snow, and S.I. Hay, 2011: Temperature and malaria trends in highland East Africa. *PLoS ONE,* **6(9)**.

Stevenson, D., R. Doherty, M. Sanderson, C. Johnson, B. Collins, and D. Derwent, 2005: Impacts of climate change and variability on tropospheric ozone and its precursors. *Faraday Discussions,* **130**, 41-57.

Steynor, A.C., B.C. Hewitson, and M.A. Tadross, 2009: Projected future runoff of the Breede river under climate change. *Water SA,* **35(4)**, 433-440.

Stott, P.A., G.S. Jones, N. Christidis, F.W. Zwiers, G. Hegerl, and H. Shiogama, 2011: Single-step attribution of increasing frequencies of very warm regional temperatures to human influence. *Atmospheric Science Letters,* **12(2)**, 220-227.

Stringer, L., Dyer, J.C., Reed, M.S., Dougill, A. J., Twyman, C., Mkwambisi, D. 2009. Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. Environmental Science and Policy 12: 748-765.

Suarez, P., F. Ching, G. Ziervogel, I. Lemaire, D. Turnquest, J.M. de Suarez, and B. Wisner, 2008: Video-mediated approaches for community-level climate adaptation. *IDS Bulletin,* **39(4)**, 96-104.

Sultan, B., K. Labadi, J.-. Guégan, and S. Janicot, 2005: Climate drives the meningitis epidemics onset in West Africa. *PLoS Medicine,* **2**, 0043-0049.

Swiderska, K., Y. Song, J. Li, H. Reid, and D. Mutta, 2011: *Adapting agriculture with traditional knowledge*. IIED Briefing, October 2011. International Institute for Environment and Development (IIED), London, UK, pp. 4.

Syampungani, S., P.W. Chirwa, F.K. Akinnifesi, and O.C. Ajayi, 2010: The Potential of Using Agroforestry as a Win-Win Solution to Climate Change Mitigation and Adaptation and Meeting Food Security Challenges in Southern Africa. *Agricultural Journal,* **5(2)**, 80-88.

Tacoli, C., 2011: *Not only climate change: mobility, vulnerability and socio-economic transformations in environmentally fragile areas of Bolivia, Senegal and Tanzania*. Human Settlements Working Paper No. 28: Rural-Urban Interactions and Livelihood Strategies. International Institute for Environment and Development (IIED), London, UK.

Tacoli, C., 2009: Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and Urbanization,* **21(2)**, 513-525.

Tadross, M., P. Suarez, A. Lotsch, S. Hachigonta, M. Mdoka, L. Unganai, F. Lucio, D. Kamdonyo, and M. Muchinda, 2009: Growing-season rainfall and scenarios of future change in southeast Africa: Implications for cultivating maize. *Climate Research,* **40(2-3)**, 147-161.

Tadross, M.A., B.C. Hewitson, and M.T. Usman, 2005: The interannual variability on the onset of the maize growing season over South Africa and Zimbabwe. *Journal of Climate,* **18(16)**, 3356-3372.

Taiwo, O.J. (ed.), 2009: ***Socio-economic correlates of the spatio-temporal variations in wetland loss in Lagos State, Nigeria***. Diss. PhD, University of Ibadan, Nigeria, .

Tanner, T. and T. Mitchell, 2008: *Entrenchment or enhancement: could climate change adaptation help reduce poverty?*. Working Paper No. 106. Chronic Poverty Research Centre, Brighton, UK, pp. 18.

Tanner, T. and F. Seballos (2012) Children, climate change and disasters. IDS In Focus Policy Briefing, Issue 23, April 2012.

Tawodzera, G., 2011: Vulnerability in crisis: Urban household food insecurity in Epworth, Harare, Zimbabwe. *Food Security,* **3(4)**, 503-520.

Taylor, R.G., A.D. Koussis, and C. Tindimuguya, 2009: Groundwater and climate in Africa - A review. *Hydrological Sciences Journal,* **54(4)**, 655-664.

Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl, 2006: Going to the extremes: An intercomparison of model-simulated historical and future changes in extreme events. *Climatic Change,* **79(3-4)**, 185-211.

Tefera, T., F. Kanampiu, H. De Groote, J. Hellin, S. Mugo, S. Kimenju, Y. Beyene, P.M. Boddupalli, B. Shiferaw, and M. Banziger, 2011: The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection,* **30(3)**, 240-245.

Terblanche, J.S., S. Clusella-Trullas, J.A. Deere, and S.L. Chown, 2008: Thermal tolerance in a south-east African population of the tsetse fly Glossina pallidipes (Diptera, Glossinidae): Implications for forecasting climate change impacts. *Journal of Insect Physiology,* **54(1)**, 114-127.

Theron, A. and M. Rossouw, 2008: Analysis of potential coastal zone climate change impacts and possible response options in the southern African region.Proceedings of Science real and relevant: 2nd CSIR Biennial Conference, 17 & 18 November 2008, CSIR International Convention Centre Pretoria, pp. 10.

Thierfelder, C. and P.C. Wall, 2010: Investigating conservation agriculture (CA) systems in Zambia and Zimbabwe to mitigate future effects of climate change. *Journal of Crop Improvement,* **24(2)**, 113-121.

Thomas, C.J. and J.O. Malala, 2009: Lake Turkana and Its Link to the Nile. In: *The Nile: Origin, Environments, Limnology and Human Use. Monographiae Biologicae Volume 89.* [Dumont, H.J. (ed.)]. Springer, pp. 287-304.

Thomas, D.S.G. and Twyman, C. 2005. Equity and justice in climate change adaptation amongst natural-resource-dependent societies. Global Environmental Change 15: 115-124.

Thomas, D.S.G., C. Twyman, H. Osbahr, and B. Hewitson, 2007: Adaptation to climate change and variability: Farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change,* **83(3)**, 301-322.

Thomas, R.J., 2008: Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. *Agriculture, Ecosystems and Environment,* **126(1-2)**, 36-45.

Thompson, L.G., E. Mosley-Thompson, M.E. Davis, K.A. Henderson, H.H. Brecher, V.S. Zagorodnov, T.A. Mashiotta, P.-. Lin, V.N. Mikhalenko, D.R. Hardy, and J. Beer, 2002: Kilimanjaro ice core records: Evidence of holocene climate change in tropical Africa. *Science,* **298(5593)**, 589-593.

Thomson, A.M., K.V. Calvin, L.P. Chini, G. Hurtt, J.A. Edmonds, B. Bond-Lamberty, S. Frolking, M.A. Wise, and A.C. Janetos, 2010: Climate mitigation and the future of tropical landscapes. *Proceedings of the National Academy of Sciences of the United States of America,* **107(46)**, 19633-19638.

Thomson, M.C., A.M. Molesworth, M.H. Djingarey, K.R. Yameogo, F. Belanger, and L.E. Cuevas, 2006: Potential of environmental models to predict meningitis epidemics in Africa. *Tropical Medicine and International Health,* **11(6)**, 781-788.

Thorn, J. (forthcoming) Urban climate adaptation in East Africa: the case of community-adaptation in Mathare Valley Slums, Nairobi. forthcoming in Urbanization and the Environment.

Thornton, P.K., P.G. Jones, G. Alagarswamy, and J. Andresen, 2009a: Spatial variation of crop yield response to climate change in East Africa. *Global Environmental Change,* **19(1)**, 54-65.

Thornton, P.K., J. van de Steeg, A. Notenbaert, and M. Herrero, 2009b: The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural Systems,* **101(3)**, 113-127.

Thornton, P.K., P.G. Jones, G. Alagarswamy, J. Andresen, and M. Herrero, 2010: Adapting to climate change: Agricultural system and household impacts in East Africa. *Agricultural Systems,* **103(2)**, 73-82.

Thornton, P.K., P.G. Jones, P.J. Ericksen, and A.J. Challinor, 2011: Agriculture and food systems in sub-Saharan Africa in a 4°C+ world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* **369(1934)**, 117-136.

Tierney, J.E., M.T. Mayes, N. Meyer, C. Johnson, P.W. Swarzenski, A.S. Cohen, and J.M. Russell, 2010: Late-twentieth-century warming in Lake Tanganyika unprecedented since AD 500. *Nature Geoscience,* **3(6)**, 422-425.

Tingem, M. and M. Rivington, 2009: Adaptation for crop agriculture to climate change in Cameroon: Turning on the heat. *Mitigation and Adaptation Strategies for Global Change,* **14(2)**, 153-168.

Tol, R.S.J., 2008: Climate, development and malaria: An application of FUND. *Climatic Change,* **88(1)**, 21-34.

Tompkins, E.L., W.N. Adger, 2003: Building resilience to climate change throughadaptive management of natural resources. Tyndall Centre for Climate Change ResearchWorking Paper 27. http://www.academia.edu/189236/Building_resilience_to_climate_change_through_adaptive_management_of_natural_resources

Tonnang, H.E.Z., R.Y.M. Kangalawe, and P.Z. Yanda, 2010: Predicting and mapping malaria under climate change scenarios: The potential redistribution of malaria vectors in Africa. *Malaria Journal,* , 111.

Totneg, E. N. 2011. Political and state system barriers to the implementation of climate change adaptation in Botswana. In: Masters, L. and Duff, L. 2011. Overcoming barriers to climate change adaptation implementation in Southern Africa. Africa Institute of South Africa, Pretoria. Pp 22-28.

Tougiani, A., C. Guero, and T. Rinaudo, 2009: Community mobilisation for improved livelihoods through tree crop management in Niger. *GeoJournal,* **74(5)**, 377-389.

Tschakert, P. and K.A. Dietrich, 2010: Anticipatory learning for climate change adaptation and resilience. *Ecology and Society,* **15(2)**, 11.

Tschakert, P. and R. Tutu, 2010: Environment, Forced Migration and Social Vulnerability. In: *Solastalgia: Environmentally Induced Distress and Migration Among Africa's Poor Due to Climate Change* [Afifi, T. and J. Jäger(eds.)]. Springer Berlin Heidelberg, pp. 57-69.

Tshimanga, R.M. and D.A. Hughes, 2012: Climate change and impacts on the hydrology of the Congo Basin: The case of the northern sub-basins of the Oubangui and Sangha Rivers. *Physics and Chemistry of the Earth,* **50-52**, 72-83.

Tumbare, M.J., 2008: Managing Lake Kariba sustainably: Threats and challenges. *Management of Environmental Quality,* **19(6)**, 731-739.

UN DESA, 2010: *World Urbanization Prospects: The 2009 Revision*. United Nations Department of Economic and Social Affairs, Population Division, New York, pp. 47.

UNCCD, UNDP and UNEP (2009) Climate change in the African drylands: options and opportunities for adaptation and mitigation. Nairobi: UNON Publishing Services: 54pp.

UNDP, 2009: *Rapport mondial sur le développement humain 2009: Levers les barrières: Mobilité et développement humains*. Programme des Nations Unies pour le développement (PNUD), New York, NY, USA, pp. 237.

UNDP, 2011a: *Africa Adaptation Programme experiences. Gender and climate change: advancing development through an integrated gender perspective*. Discussion Paper Series, Vol. 1, March 2011. United Nations Development Programme (UNDP), New York, NY, USA, pp. 16.

UNDP, 2011b: *Down to earth: territorial approach to climate change. Low-emission and cliamte-resilient development strategies at the sub-national level. 2011 Update*. United Nations Development Programme, New York, NY, pp. 18.

UNDP, UNECA, AfDB, and AUC, 2011: *Assessing progress in Africa toward the Millennium Development Goals: MDG Report 2011*. Economic Commission for Africa; African Union Commission; African Development Bank; United Nation Development Programme-Regional Bureau for Africa, pp. 136.

UNDP-UNEP Poverty-Environment Initiative, 2011a: *Mainstreaming climate change adaptation into development planning: a guide for practitioners*. UNDP-UNEP Poverty-Environment Initiative, Nairobi, Kenya, pp. 86.

UNDP-UNEP Poverty-Environment Initiative, 2011b: *Enabling local success: a primer on mainstreaming local ecosystem-based solutions to poverty-environment challenges*. UNDP-UNEP Poverty-Environment Facility, Nairobi, Kenya, pp. 65.

UNEP, 2008: *Afrique. Atlas d'un environnement en mutation*. United Nations Environment Programme (UNEP), Nairobi, Kenya, pp. 374.

UNEP and IOC-UNESCO, 2009: Summary for decision makers. In: *An Assessment of Assessments, Findings of the Group of Experts. Start-up Phase of a Regular Process for Global Reporting and Assessment of the State of the Marine Environment including Socio-economic Aspects*. United Nations Environment Programme and Intergovernmental Oceanographic Commission of UNESCO, Nairobi, Kenya, pp. 44.

UNEP, 2012: *Global Environmental Outlook 5. Environment for the future we want*. United Nations Environment Programme, Nairobi, pp. 528.

UNFCCC, 2002: *Report of the Conference of the Parties on its Seventh Session, held at Marrakesh from 29 October to 10 November 2001. Addendum. Part two: Action taken by the Conference of Parties. Volume IV.* FCCC/CP/2001/13/Add.4 21 January 2002. United Nations Framework Convention on Climate Change (UNFCCC), pp. 44.

UNFCCC, 2007: *Report on the African regional workshop on adaptation: Note by the secretariat.* FCCC/SBI/2007/2, 12 February 2007. United Nations Framework Convention on Climate Change (UNFCCC), pp. 15.

UNFCCC, 2009: *Copenhagen Accord* .

UNFCCC, 2011: *The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention* .

UN-Habitat, 2008a: *State of the world's cities 2008/2009. Harmonious cities*. Earthscan, London, UK and Sterling, VA, USA, pp. 259.

UN-Habitat, 2008b: *The state of African cities: a framework for adressing urban challenges in Africa*. United Nations Human Settlements Programme (UN-Habitat), Nairobi, Kenya, pp. 207.

UN-Habitat, 2010: *State of the world's Cities 2010/2011: Bridging the urban divide*. Earthscan, London, UK and Sterling, VA, USA, pp. 220.

UN-Habitat and UNEP, 2010: *The state of African cities 2010: governance, inequality and urban land markets*. UN-Habitat and UNEP, Nairobi, Kenya, pp. 268.

UN-Habitat, 2011: *Cities and Climate Change: Global Report on Human Settlements 2011
*. United Nations Human Settlements Programme and Earthscan, London, UK and Nairobi, Kenya, pp. 279.

Unicef (2007) Climate change and children. New York: United Nations Children's Fund. http://www.unicef.org/publications/files/Climate_Change_and_Children.pdf

UNICEF and WHO, 2008: *Progress on Drinking Water and Sanitation: Special Focus on Sanitation*. Joint Monitoring Programme for Water Supply and Sanitation (JMP). United Nations Children's Fund (UNICEF) and World Health Organization (WHO), New York, NY, USA and Geneva, Switzerland, pp. 54.

UNICEF and WHO, 2009: *Diarrhoea: Why children are still dying and what can be done*. The United Nations Children's Fund (UNICEF) / World Health Organization (WHO), New York, NY, USA and Geneva, Switzerland, pp. 58.

UNICEF, 2010: *Climate change in Kenya: Focus on childrenU*. UNICEF UK, London, UK, pp. 28.

UNICEF, 2011: *Expliring the impact of climate change on children in South Africa*. UNICEF South Africa, Pretoria, South Africa, pp. 119.

UNICEF and WHO, 2012: *Progress on Drinking Water and Sanitation: 2012 Update*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. United Nations Children's Fund (UNICEF) and the World Health Organization (WHO), New York, NY, USA, pp. 59.

UNISDR, 2011: *Effective measures to build resilience in Africa to adapt to climate change*. Briefing Note 04. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland, pp. 8.

United Nations, African Development Bank, African Union, European Commission, International Monetary Fund, Islamic Development Bank, OECD, and The World Bank, 2008: *Achieving the Millennium Development Goals in Africa. Recommendations of the MDG Africa Steering Group*. United Nations, New York, pp. 39.

United Nations Department of Economic and Social Affairs, Population Division, 2011, World Population Prospects, The 2010 Revision, Highlights and Advance Tables, http://esa.un.org/wpp/Documentation/pdf/WPP2010_Highlights.pdf (accessed 12 March 2013)

UN-OCAH and IDMC, 2009: *Monitoring disaster displacement in the context of climate change*. United Nations Office for the Coordination of the Humanitarian Affairs (UN-OCHA) and Internal Displacement Monitoring Centre (IDMC), Geneva, Switzerland, pp. 30.

UNPFII, 2008: /C.19/2008/CRP. 3. In: *Conference on indigenous peoples and climate change, Copenhagen, 21-22 February 2008: Meeting Report* United Nations Permanent Forum on Indigenous Issues, pp. 11.

Unruh, J.D., 2008: Carbon sequestration in Africa: The land tenure problem. *Global Environmental Change,* **18(4)**, 700-707.

UNSCN, 2009: *Global recession increases malnutrition for the most vulnerable people in developing countries. Pregnant women and children are hardest hit*. United Nations Standing Committee on Nutrition, pp. 4.

Urama, K.C. and N. Ozor, 2010: *Impacts of climate change on water resources in Africa: the role of adaptation* African Technology Policy Studies Network (ATPS), pp. 29.

Urdal, Henrik (2005) People vs. Malthus: Population Pressure, Environmental Degradation, and Armed Conflict Revisited, *Journal of Peace Research* **42(4)**: 417–434.

Urquhart, P., 2009: *
IFAD's response to climate change through support to adaptation and related actions*. Comprehensive report: Final version. International Fund for Agricultural Development (IFAD), Rome.

Urquhart, P. (2013) (in press) Governing the ungovernable? Climate change and social justice in southern Africa. Book chapter in Sowman, M. and R. Wynberg (eds.) (2013, in press) Environmental governance for social justice: lessons across natural resources in southern Africa. (Final publication details to be provided.)

van Aalst, M.K., T. Cannon, and I. Burton, 2008: Community level adaptation to climate change: The potential role of participatory community risk assessment. *Global Environmental Change,* **18(1)**, 165-179.

van Breugel, P., M. Herrero, J. van de Steeg, and D. Peden, 2010: Livestock water use and productivity in the Nile basin. *Ecosystems,* **13(2)**, 205-221.

van de Giesen, N., J. Liebe, and G. Jung, 2010: Adapting to climate change in the Volta Basin, West Africa. *Current Science,* **98(8)**, 1033-1037.

van Vliet, N. 2010. Participatory vulnerability assessment in the context of conservation and development projects: a case study of local communities in Southwest Cameroon. Ecology and Society 15(2): 6. [online] URL: http://www.ecologyandsociety.org/vol15/iss2/art6/

Vandeweerd, V., Y. Glemarec, and S. Billett, 2012: *Readiness for Climate Finance. A framework for understanding what it means to be ready to use climate finance*. United Nations Development Programme, New York, NY, USA, pp. 27.

Vang Rasmussen, L., K. Rasmussen, T. Birch-Thomsen, S.B.P. Kristensen, and O. Traoré, 2012a: The effect of cassava-based bioethanol production on above-ground carbon stocks: A case study from Southern Mali. *Energy Policy,* **41**, 575-583.

Vang Rasmussen, L., K. Rasmussen, and T. Bech Bruun, 2012b: Impacts of Jatropha-based biodiesel production on above and below-ground carbon stocks: A case study from Mozambique. *Energy Policy,* .

Verburg, P. and R.E. Hecky, 2009: The physics of the warming of Lake Tanganyika by climate change. *Limnology and Oceanography,* **54(6 PART 2)**, 2418-2430.

Verchot, L.V., M. Van Noordwijk, S. Kandji, T. Tomich, C. Ong, A. Albrecht, J. Mackensen, C. Bantilan, K.V. Anupama, and C. Palm, 2007: Climate change: Linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change,* **12(5)**, 901-918.

Vermuelen, S., K. Dossou, D. Macqueen, D. Walubengo, and E. Nangoma, 2008: *Spring back: climate resilience at Africa's grassroots*. Sustainable Development Opinion. International Institute for Environment and Development (IIED), London, UK, pp. 2.

Verschuren, D., J.S. Sinninghe Damsté, J. Moernaut, I. Kristen, M. Blaauw, M. Fagot, and G.H. Haug, 2009: Half-precessional dynamics of monsoon rainfall near the East African Equator. *Nature,* **462(7273)**, 637-641.

Viatte, G., J. De Graaf, M. Demeke, T. Takahatake, and M. Rey de Arce, 2009: *Responding to the food crisis: synthesis of medium-term measures proposed in inter-agency assessments*. Food and Agriculture Organization of the United Nations (FAO), Rome, pp. 100.

Vié, J., C. Hilton-Taylor, and S.N. Stuart (eds.), 2009: *Wildlife in a changing world: An analysis of the 2008 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland, pp. 157.

Vincent, L.A., E. Aguilar, M. Saindou, A.F. Hassane, G. Jumaux, D. Roy, P. Booneeady, R. Virasami, L.Y.A. Randriamarolaza, F.R. Faniriantsoa, V. Amelie, H. Seeward, and B. Montfraix, 2011: Observed trends in indices of daily and extreme temperature and precipitation for the countries of the western Indian Ocean, 1961-2008. *Journal of Geophysical Research D: Atmospheres,* **116(10)**.

Vincke, C., I. Diédhiou, and M. Grouzis, 2010: Long term dynamics and structure of woody vegetation in the Ferlo (Senegal). *Journal of Arid Environments,* **74(2)**, 268-276.

Vogel, C. and K. O'Brien, 2006: Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. *Climate Research,* **33(1)**, 111-122.

Vogel, C., S.C. Moser, R.E. Kasperson, and G.D. Dabelko, 2007: Linking vulnerability, adaptation, and resilience science to practice: Pathways, players, and partnerships. *Global Environmental Change,* **17(3-4)**, 349-364.

Vohland, K. and B. Barry, 2009: A review of in situ rainwater harvesting (RWH) practices modifying landscape functions in African drylands. *Agriculture, Ecosystems and Environment,* **131(3-4)**, 119-127.

Walker, N.J. and R.E. Schulze, 2008: Climate change impacts on agro-ecosystem sustainability across three climate regions in the maize belt of South Africa. *Agriculture, Ecosystems and Environment,* **124(1-2)**, 114-124.

Warner, K., M. Hamza, A. Oliver-Smith, F. Renaud, and A. Julca, 2010: Climate change, environmental degradation and migration. *Natural Hazards,* **55(3)**, 689-715.

Washington, R., M. Harrison, D. Conway, E. Black, A. Challinor, D. Grimes, R. Jones, A. Morse, G. Kay, and M. Todd, 2006: African climate change: Taking the shorter route. *Bulletin of the American Meteorological Society,* **87(10)**, 1355-1366.

Watkiss, P., T.E. Downing, and J. Dyszynski, 2010: *ADAPTCost Project: Analysis of the economic costs of climate change adaptation in Africa*. United National Environment Programme (UNEP), Nairobi, Kenya, pp. 35.

Watterson, I.G., 2009: Components of precipitation and temperature anomalies and change associated with modes of the Southern Hemisphere. *International Journal of Climatology,* **29(6)**, 809-826.

Weiß, M., R. Schaldach, J. Alcamo, and M. Flörke, 2009: Quantifying the human appropriation of fresh water by african agriculture. *Ecology and Society,* **14(2)**.

Wertz-Kanounnikoff, S., A. Sitoe, and A. Salomão, 2011: *How is REDD+ unfolding in southern Africa's dry forests? A snapshot from Mozambique*. CIFOR Infobrief No. 37. Center for International Forestry Research (CIFOR), Maputo, Mozambique, pp. 8.

West, C.T., C. Roncoli, and F. Ouattara, 2008: Local perceptions and regional climate trends on the Central Plateau of Burkina Faso. *Land Degradation and Development,* **19(3)**, 289-304.

Westerhoff, L. and B. Smit, 2009: The rains are disappointing us: Dynamic vulnerability and adaptation to multiple stressors in the Afram Plains, Ghana. *Mitigation and Adaptation Strategies for Global Change,* **14(4)**, 317-337.

Westgate, K., 2010: *Toolkit for national platforms for disaster risk reduction in Africa: Contributing to the implementation of the Hyogo Framework for Action and the Africa Regional Strategy and Programme of Action for DRR*. United Nations International Strategy for Disaster Reduction (UNISDR) - Regional Office for Africa, Nairobi, Kenya, pp. 48.

Wezel, A. and A.M. Lykke, 2006: Woody vegetation change in Sahelian West Africa: Evidence from local knowledge. *Environment, Development and Sustainability,* **8(4)**, 553-567.

WFP, 2011: *Building resilience: Bridging food security, climate change adaptation and disaster risk reduction: An overview of workshop case studies*. World Food Programme Office for Climate Change and Disaster Risk Reduction, Rome, pp. 35.

WHO, 2007: Outbreaks of Rift Valley fever in Kenya, Somalia and United Republic of Tanzania, December 2006-April 2007. *Relevé Épidémiologique Hebdomadaire / Section D'Hygiène Du Secrétariat De La Société Des Nations = Weekly Epidemiological Record / Health Section of the Secretariat of the League of Nations,* **82(20)**, 169-178.

WHO, 2009:
Sommet africain sur les maladies tropicales négligées. Thème : Lutte contre la pauvreté et la maladie: donner de l'espoir aux mères et aux enfants [French: combatting poverty and illness. Report of the African summit on neglected tropical diseases].30 mars-3 avril 2009, Palais des Congrès, Cotonou, Bénin, pp. 5.

WHO, 2011: *World malaria report 2011*. World Health Organization Global Malaria Programme, Geneva, Switzerland, pp. 248.

WHO, 2013. Schistosomiasis Fact sheet N°115 available: http://www.who.int/mediacentre/factsheets/fs115/en/index.html Accessed: 1st March, 2013

Williams, A.P. and C. Funk, 2010: A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa. *Climate Dynamics,* , 1-19.

Williams, A.P., C. Funk, J. Michaelsen, S.A. Rauscher, I. Robertson, T.H.G. Wils, M. Koprowski, Z. Eshetu, and N.J. Loader, 2012: Recent summer precipitation trends in the Greater Horn of Africa and the emerging role of Indian Ocean sea surface temperature. *Climate Dynamics,* **39(9-10)**, 2307-2328.

Wiseman, W., J. Van Domelen, and S. Coll-Black, 2009: *Designing and implementing a rural safety net in a low income setting: Lessons learned from Ethiopia's Productive Safety Net Program 2005-2009*. The Productive Safety Net Program (PSNP), pp. 155.

Wolski, P., M.C. Todd, M.A. Murray-Hudson, and M. Tadross, 2012: Multi-decadal oscillations in the hydro-climate of the Okavango River system during the past and under a changing climate. *Journal of Hydrology,* **475**, 294-305.

Woltering, L., A. Ibrahim, D. Pasternak, and J. Ndjeunga, 2011: The economics of low pressure drip irrigation and hand watering for vegetable production in the Sahel. *Agricultural Water Management,* **99(1)**, 67-73.

Woodfine, A., 2009: *Using sustainable land management practices to adapt to and mitigate climate change in sub-Saharan Africa: Resource Guide Version 1.0*. TerrAfrica, pp. 79.

World Bank, 2010: *Report on the status of disaster risk reduction in sub-Saharan Africa*. The World Bank, Africa Disaster Risk Management Team, Washington, DC, USA, pp. 44.

World Bank and International Monetary Fund, 2010: *Global Monitoring Report 2010: The MDGs after the Crisis*. World Bank and International Monetary Fund, pp. 151.

World Bank, 2011: ***Migration and Remittances Factbook 2011***. The World Bank, 2nd ed., pp. 264.

WRI, 2009: *The National Adaptive Capacity Framework: Key Institutional Functions for a Changing Climate*. Pilot Draft. World Resources Institute (WRI), Washington, DC, USA, pp. 12.

WTO Trade Policy Review, 2008: *Trade policy review report by the Secretariat Ghana. WT/TPR/S/194*. World Trade Organziation Trade Policy Review Body, pp. 10.

Yabi, I. and F. Afouda, 2012: Extreme rainfall years in Benin (West Africa). *Quaternary International,* **262**, 39-43.

Yaka, P., B. Sultan, H. Broutin, S. Janicot, S. Philippon, and N. Fourquet, 2008: Relationships between climate and year-to-year variability in meningitis outbreaks: A case study in Burkina Faso and Niger. *International Journal of Health Geographics,* **7**.

Yaro, J.A., 2010: *The social dimensions of adaptation to climate change in Ghana*. In: Development and climate change discussion paper. The World Bank, pp. 104.

Yé, Y., V.R. Louis, S. Simboro, and R. Sauerborn, 2007: Effect of meteorological factors on clinical malaria risk among children: An assessment using village-based meteorological stations and community-based parasitological survey. *BMC Public Health,* **7**.

Yesuf, M., S. Di Falco, T. Deressa, C. Ringler, and G. Kohlin, 2008: *The impact of climate change and adaptation on food production in low-income countries: evidence from the Nile Basin, Ethiopia*. IFPRI Research Brief 15-11. International Food Policy Research Institute, Washington, DC, USA, pp. 2.

Yiougo, L., T. Sanon, and W.S. Ouedraogo, 2007: *Facteurs de recrudescence de la leishmaniose cutanee et ses consequences socio economiques et sanitaires dans le secteur 30 de la ville de Ouagadougou (English: Factors affecting the resurgence of cutaneous leishmaniasis and its socioeconomic and health implications in Sector 30 of Ouagadougou city)*. Rapport de recherche. 2iE groupe EIER-ETSHER, pp. 103.

You, L., C. Ringler, U. Wood-Sichra, R. Robertson, S. Wood, T. Zhu, G. Nelson, Z. Guo, and Y. Sun, 2011: What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. *Food Policy,* **36(6)**, 770-782.

Yuen, B. and A. Kumssa (eds.), 2011: *Climate Change and Sustainable Urban Development in Africa and Asia*. Springer, Dordrecht, Heidelberg, London, New York, pp. 278.

Zech, M., K. Leiber, W. Zech, T. Poetsch, and A. Hemp, 2011: Late Quaternary soil genesis and vegetation history on the northern slopes of Mt. Kilimanjaro, East Africa. *Quaternary International,* **243(2)**, 327-336.

Zelazowski, P., Y. Malhi, C. Huntingford, S. Sitch, and J.B. Fisher, 2011: Changes in the potential distribution of humid tropical forests on a warmer planet. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* **369(1934)**, 137-160.

Zeng, G., J.A. Pyle, and P.J. Young, 2008: Impact of climate change on tropospheric ozone and its global budgets. *Atmospheric Chemistry and Physics,* **8(2)**, 369-387.

Zeng, N. and J. Yoon, 2009: Expansion of the world's deserts due to vegetation-albedo feedback under global warming. *Geophysical Research Letters,* **36(17)**.

Zhou, L., R.E. Dickinson, A. Dai, and P. Dirmeyer, 2010: Detection and attribution of anthropogenic forcing to diurnal temperature range changes from 1950 to 1999: Comparing multi-model simulations with observations. *Climate Dynamics,* **35(7)**, 1289-1307.

Ziervogel, G. and A. Opere, 2010: *Integrating meteorological and indigenous knowledge-based seasonal climate forecasts for the agricultural sector: Lessons from participatory action research in sub-Saharan Africa*. Climate Change Adaptation in Africa Learning Paper Series. International Development Research Centre, Ottawa, Canada, pp. 19.

Ziervogel, G. 2004. Targeting seasonal climate forecasts for integration into household level decisions: the case of smallholder farmers in Lesotho. The Georgraphic Journal 170: 6-21.

Ziervogel, G., A. Taylor, S. Hachigonta, and J. Hoffmaister, 2008: *Climate adaptation in southern Africa: Addressing the needs of vulnerable communities*. Stockholm Environment Institute, Stockholm, Sweden, pp. 56.

Ziervogel, G., M. Bithell, R. Washington, and T. Downing, 2005: Agent-based social simulation: A method for assessing the impact of seasonal climate forecast applications among smallholder farmers. *Agricultural Systems,* **83(1)**, 1-26.

Ziervogel, G. and F. Zermoglio, 2009: Climate change scenarios and the development of adaptation strategies in Africa: Challenges and opportunities. *Climate Research,* **40(2-3)**, 133-146.

Zinyengere, N., O. Crespo, and S. Hachigonta, submitted: Crop response to climate change in Southern Africa: A scoping study. *Global and Planetary Change,* .

Zinyowera, M.C., B.P. Jallow, R.S. Maya, H.W.O. Okoth-Ogando, L.F. Awosika, E.S. Diop, T.E. Downing, M. El-Raey, D. Le Sueur, C.H.D. Magadza, S. Toure, and C. Vogel, 1997: Africa. In: *The Regional Impacts of Climate Change: An Assessment of Vulnerability. A Special Report of IPCC Working Group II*. [Watson, R.T., M.C. Zinyowera, R.H. Moss, and D.J. Dokken(eds.)]. Cambridge University Press, Cambridge, UK, pp. 29-84.

Zitholele Consulting, 2009: *Report on the city of Umhlathuze climate change vulnerability assessment*. Zitholele Consulting, Durban, South Africa, pp. 57.

Table 22-1: Changes and impacts observed in freshwater lakes of Africa.

Lake	Observed Impacts
Kivu	The upper (below 250 m) water layers warmed up by 0.5°C in the 55-year period between 1937 and 2002 in response to increased air temperatures (?)
Tanganyika	Reductions in phytoplankton biomass have been attributed to an average 0.2°C warming at 1 000 m and 1.3°C of the upper waters during the past century and an average 0.9°C warming across the lake. (Sources: (Sarvala *et al*., 2006a; Sarvala *et al*., 2006b; Stenuite *et al*., 2007; Stenuite *et al*., 2009; Verburg and Hecky, 2009))
Kariba	Warmed up by an average of 1.9°C between 1965 and 2009; thermocline has migrated upward by over 80% from the maximum thermocline depth of 30m reported during the late 1960s, and by over 60% from the maximum thermocline depth of 20m reported during the late 1980s.This warming is associated with an average of 0.34°C per decade increase in air temperature in the Zambezi Valley. (Sources: Ndebele-Murisa, 2012, Magadza, 2010) Consequences Observed: reduced fish production, e.g. exotic Tanganyika sardine, Limnothrissa miodon due to decline in the production of palatable Chlorophyceae, leading to decreased zooplankton production and a consequent decline in fish stocks; reduced phytoplankton biomass and has caused seasonal shifts in phytoplankton seasonality. (Sources: (Magadza, 2011; Ndebele-Murisa *et al*., 2011a; Ndebele-Murisa *et al*., 2011b; Ndebele-Murisa *et al*., 2012))
Turkana	Level has dropped 10m between 1975 and 1992 due to reduced river inflows. (Sources(McGinley, 2008; Thomas and Malala, 2009))
Victoria	Water level has dropped over 1.5m in five years. (Sources: Awange et al., 2008; Hecky et al., 2010) The upper (below 250 m) water layers warmed up by 0.5°C in the 55-year period between 1937 and 2002 and since the 1960s respectively in response to increased air temperatures resulting in sharper water-density gradient at depths below 250 m. (Sources: (Odada *et al*., 2006; Kunz *et al*., 2011))
Malawi	A 60-year (1930 to 2000) temperature record shows that the temperature of deep water above 300 m has increased by 0.78°C. Due to reduced cold-water intrusions associated with milder winters, rainfall and cold river inflow are critical factors in controlling thermal structure and the rate of deep-water recharge in this tropical lake. These findings are corroborated by geochemical records obtained from sediment cores of changes in Lake Malawi over the last 730 years, caused by natural climatic forcing and anthropogenic activities. (Sources: (Branchu *et al*., 2010; Lyons *et al*., 2011))
Chilwa	Dried up nine times in the 20th Century at 10-20 year intervals in relation to patterns in rainfall in the lake basin. (Source: (Njaya *et al*., 2011))

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

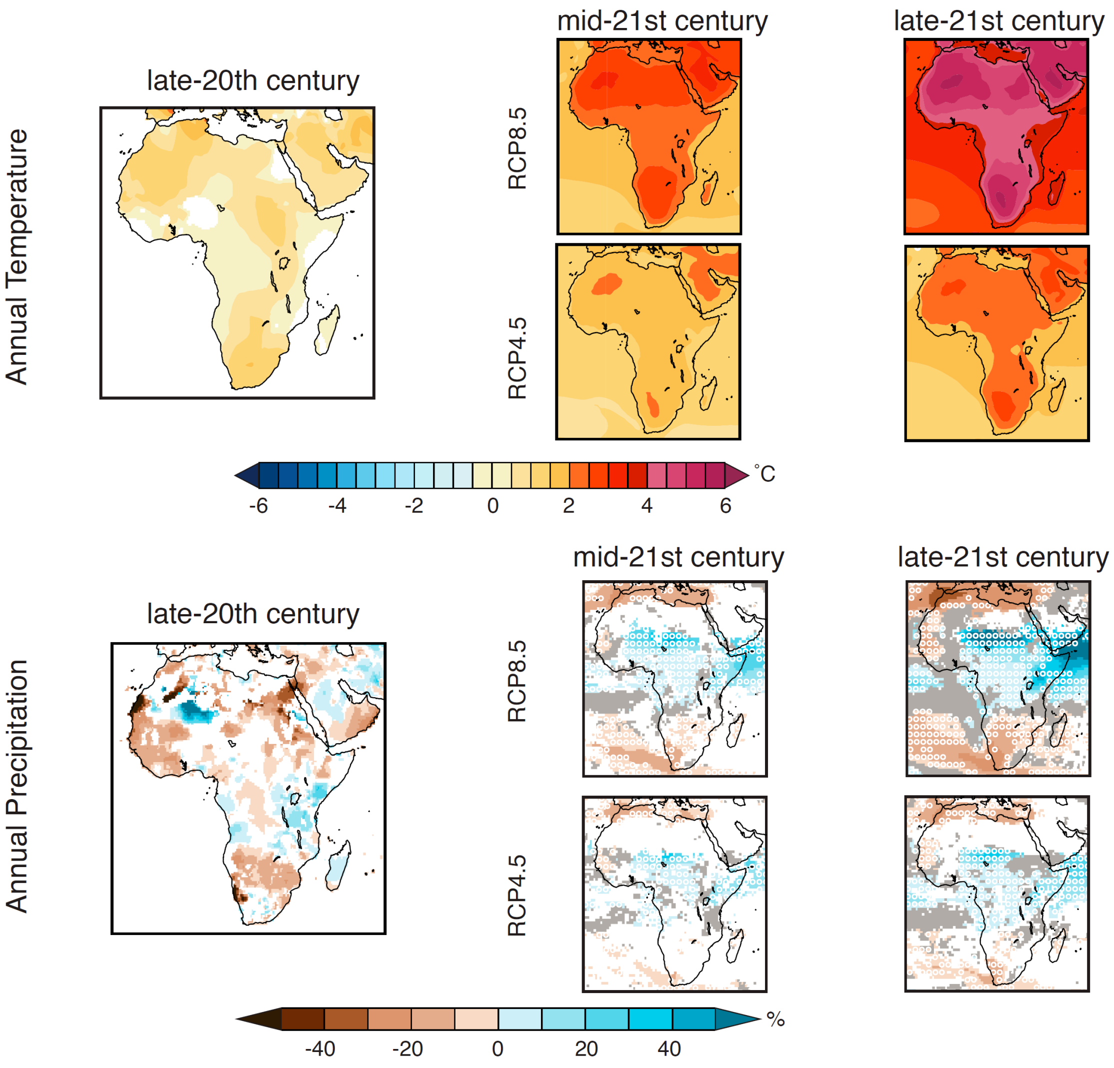
Note: The economic impacts are determined based on the value of properties, losses of touristic revenues and the cost of infrastructure replacement. The total geographical gross product for Cape Town in 2008 was 165 billion of Rands.

Table 22-3. Projected changes in agro-climatic suitability for perennial crops in Africa under an A2 scenario.

Crop	Suitability change	Country	Source
Coffee	Increased suitability at high latitudes; decreased suitability at low latitudes	Kenya	Läderach et al., 2010
Tea	Decreased suitability	Uganda	Eitzinger et al., 2011a,b
	Increased suitability at high latitudes; decreased suitability at low latitudes	Kenya	
Cocoa	Constant or increased suitability at high latitudes; decreased suitability at low latitudes	Ghana, Côte d'Ivoire	Läderach et al., 2011b
Cashew	Increased suitability	Ghana, Côte d'Ivoire	Läderach et al., 2011a
Cotton	Decreased suitability	Ghana, Côte d'Ivoire	Läderach et al., 2011c

Table 22-4: Cross-cutting approaches for equity and social justice in adaptation.

Equitable adaptation approach	**Key issues to address for adaptation**	**Factors that could cause maladaptation**	**Opportunities**	**Lessons learned**
Gender mainstreamed adaptation in Africa	Lack of empowerment and participation in decision-making (Patt et al, undated) Climate impacts increase women's household roles and may result in girls being kept out of school to assist (Raworth, 2008; UNDP, 2011; Romero Gonzalez et al, 2011) Male adaptation strategies e.g. migration may increase women's vulnerability (Djoudi and Brockhaus, 2011)	Employment opportunities are frequently not sufficiently extended to women in adaptation response frameworks (Madzwamuse, 2010). Failure to incorporate power relations in adaptation responses (Romero Gonzalez et al, 2011; Djoudi and Brockhaus, 2011)	Women's aptitude for long-term thinking, trusting and integrating scientific knowledge, and taking decisions in uncertain conditions (Patt et al, undated) Potential long-term positive changes in women's empowerments, roles and social and economic status (Djoudi and Brockhaus, 2011) Women opportunistically using development projects to adapt to climate change (Nielson, 2010)	Security of tenure over land and resource access is critical for enabling enhanced adaptive capacity of women (African Development Forum, 2010; add refs) Research on understanding different adaptive strategies of benefit for women and men is needed
Child-centered approaches to adaptation	Children and youth represent over 60% of Africa's population, yet their issues are largely absent from adaptation policy (African Development Forum, 2010) Children's differential vulnerability to projected climate impacts is high, particularly to hunger, malnutrition and disasters (Unicef, 2007)	Limits to children's agency related to power imbalances between children and adults, and different cultural contexts (Seballos et al, 2011)	Using approaches that stress agency and empowerment, and 'innovative energies' of youth; build on targeted adaptation initiatives, such as child-centred disaster risk reduction and adaptation (African Development Forum, 2010; Seballos et al., 2011)	Children and youth can play a positive role as change agents for climate adaptation, within an appropriate enabling environment Child-sensitive programmes and policies can reduce risks children face from disasters (Seballos et al, 2011) Funding for climate resilience programmes is necessary to protect children's basic rights (Unicef, 2010; Unicef, 2011)
Human rights-based approaches	Common critical rights issues for local communities are land/resource rights, gender equality, and political voice and fair adjudication of grievances for the poor and excluded (Castro et al, 2012).	Lack of recognition and promotion of their human rights blocks indigenous peoples' coping and adaptation capacities (UNPFII, 2008).	Using the HRBA lens to understand, for example, climate-related disaster risk, necessitates risk analysis to probe the root causes of the vulnerabilities that heighten disaster risk of certain groups, allowing for a structural and sustainable response (Urquhart, 2013)	Applying HRBA presents a framework for addressing conflicting rights and interests, necessary for equitable adaptation responses (Nilsson and Schnell, 2010)



Maps: Change in annual temperature and precipitation. For the CRU observations, differences are shown between the 1986-2005 and 1906-1925 periods, with white indicating areas where the difference between the 1986-2005 and 1906-1925 periods is less than twice the standard deviation of the 20 20-year periods beginning in the years 1906 through 1925. For CMIP5, white indicates areas where <66% of models exhibit a change greater than twice the baseline standard deviation of the respective model's 20 20-year periods ending in years 1986 through 2005. Gray indicates areas where >66% of models exhibit a change greater than twice the respective model baseline standard deviation, but <66% of models agree on the sign of change. Colors with circles indicate the ensemble-mean change in areas where >66% of models exhibit a change greater than twice the respective model baseline standard deviation and >66% of models agree on the sign of change. Colors without circles indicate areas where >90% of models exhibit a change greater than twice the respective model baseline standard deviation and >90% of models agree on the sign of change. The realizations from each model are first averaged to create baseline-period and future-period mean and standard deviation for each model, from which the multi-model mean and the individual model signal-to-noise ratios are calculated. The baseline period is 1986-2005. The late-21st century period is 2081-2100. The mid-21st century period is 2046-2065.

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

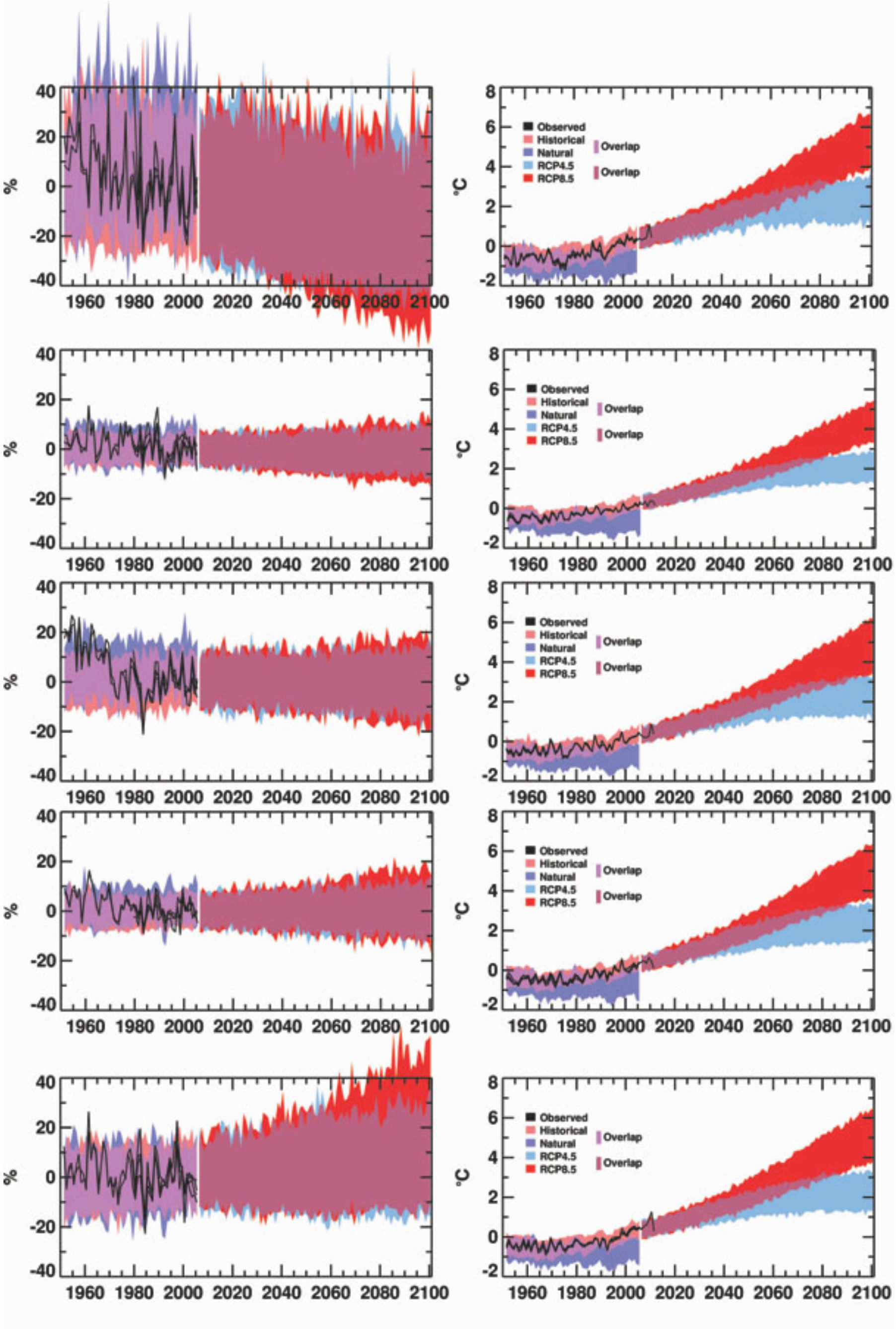


Figure 22-2: Observed and simulated variations in past and projected future annual average precipitation and temperature over five African regions (Arab Maghreb Union- AMU, Common Market for Eastern and Southern Africa – COMSEA, Southern African Development Community – SADC, Economic Community of West African States – ECOWAS, Economic Community of Central African States – ECCAS). Black lines show several estimates from observational measurements. Shading denotes the 5-95 percentile range of climate model simulations driven with "historical" changes in anthropogenic and natural drivers (68 simulations), historical changes in "natural" drivers only (30), the "RCP4.5" emissions scenario (68), and the "RCP8.5" (68). Data are anomalies from the 1986-2006 average of the individual observational data (for the observational time series) or of the corresponding historical all-forcing simulations. Further details are given in Box 21-3. The regions are described in 22.1.2, but COMESA-north covers COMESA north and inclusive of Rwanda, Uganda, and Kenya. Precipitation is included for land territories only, while temperature is included for both land and exclusive economic zone territories.

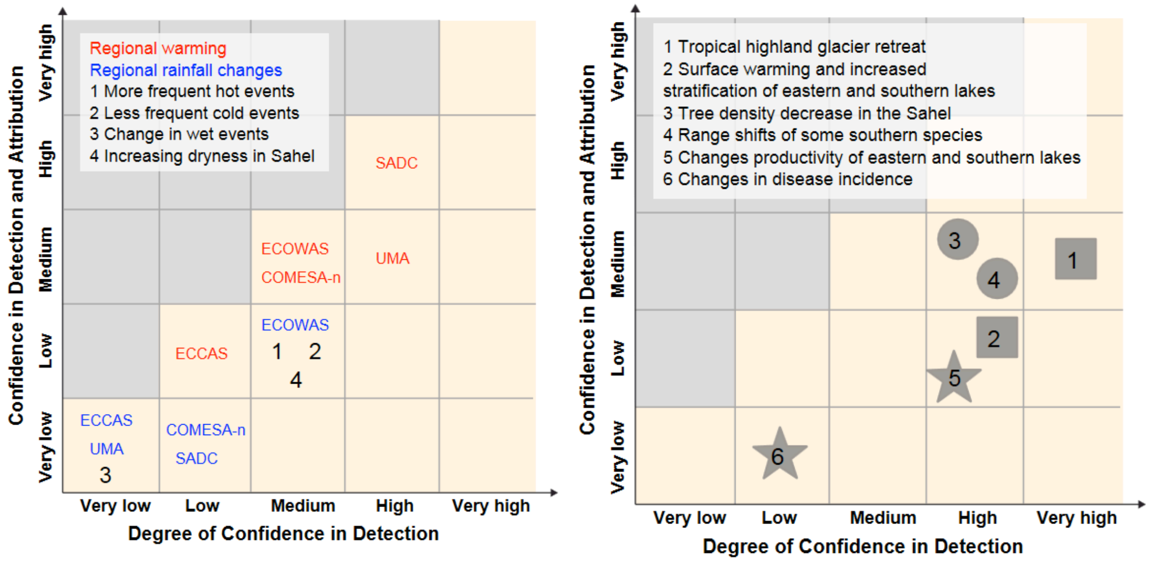


Figure 22-3: Summary of detection and attribution assessments of the relation of observed climate change over Africa with anthropogenic emissions (left) and of the relation of observed changes in natural and human systems with observed regional climate changes (right). All detection assessments are against a no-change reference and all attribution assessments for a major role of anthropogenic emissions (left) or observed regional climate change (right), except for "change in disease incidence" for which the detection assessment is relative to what would have been expected based on changes in livelihoods and health care and for which the attribution assessment is for a minor role of climate change in disease incidence. COMESA-n covers the half of COMESA north of and including Rwanda, Uganda, and Kenya. Discussion of these assessments are in 22.2, 22.3, 22.5.1, WGI AR5 Chapter 10, SREX 3.3, SREX 3.5, and 18.5.1. The detection and attribution assessments follow the specifications described in 18.2.

Figure 22-4: Number of undernourished people in Africa between 1994/1996 and 2010/2012
Source: www.fao.org/fileadmin/templates/ess/foodsecurity/Food_Security_Indicators.Xlsx.

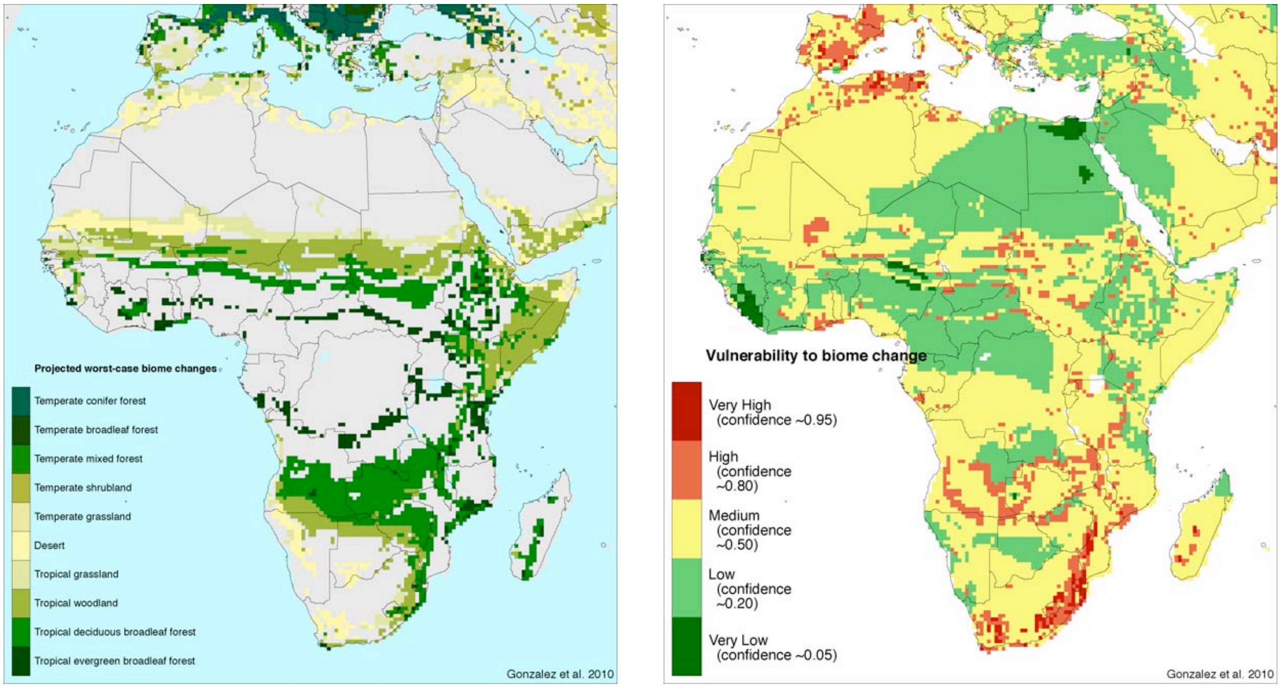


Figure 22-5: (a) Potential changes in vegetation between the periods 1961-1990 and 2071-2100, where any of nine combinations of three GCMs (CSIRO Mk3, HadCM3, MIROC 3.2 medres) and three emissions scenarios (B1, A1B, A2) project change. This is the worst case in comparison to the case of complete agreement of the nine combinations. (b) Vulnerability of ecosystems to biome shifts based on historical climate (1901-2002) and projected vegetation (2071-2100), where all nine GCM-emissions scenario combinations agree on the projected biome change. Source: Gonzalez *et al*. (2010).]

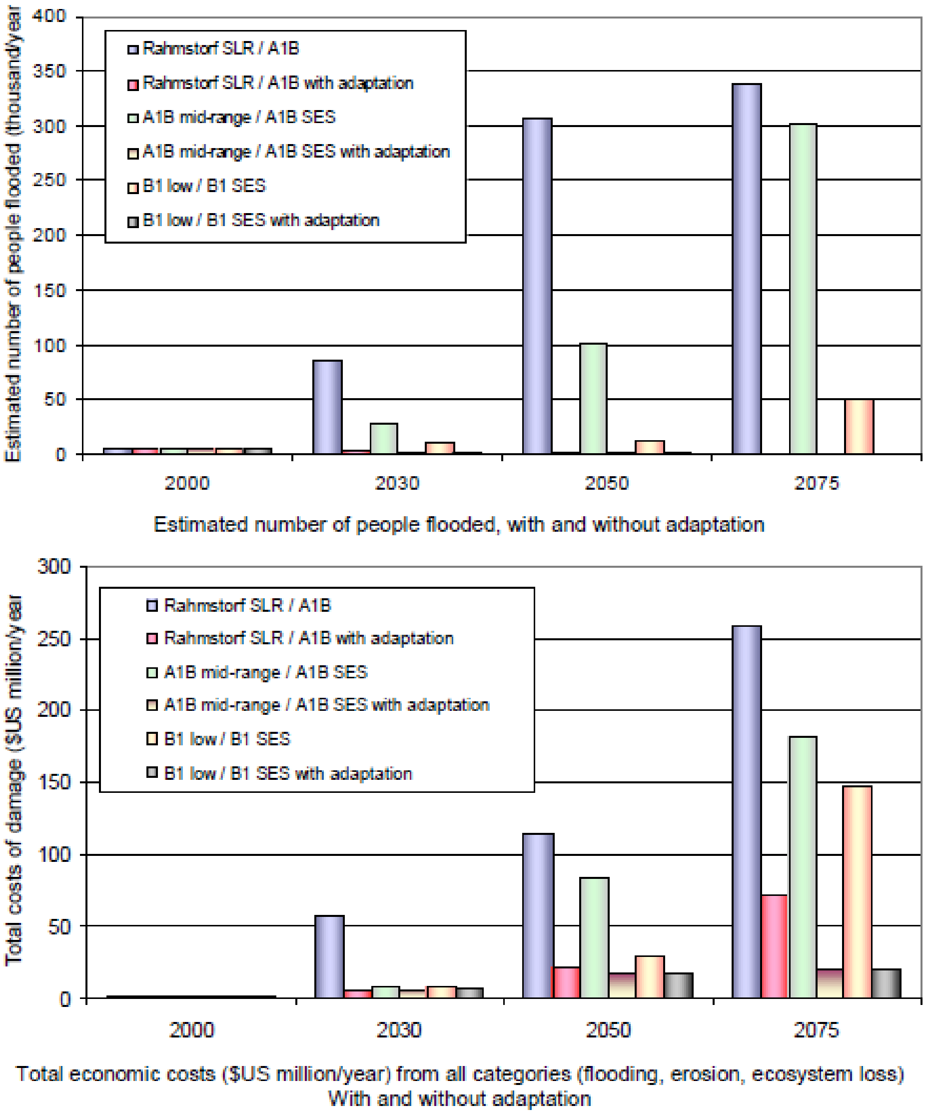


Figure 22-6: Population and economic losses in case of climate change for the whole Kenya coastal zone. Source: (SEI, 2009).

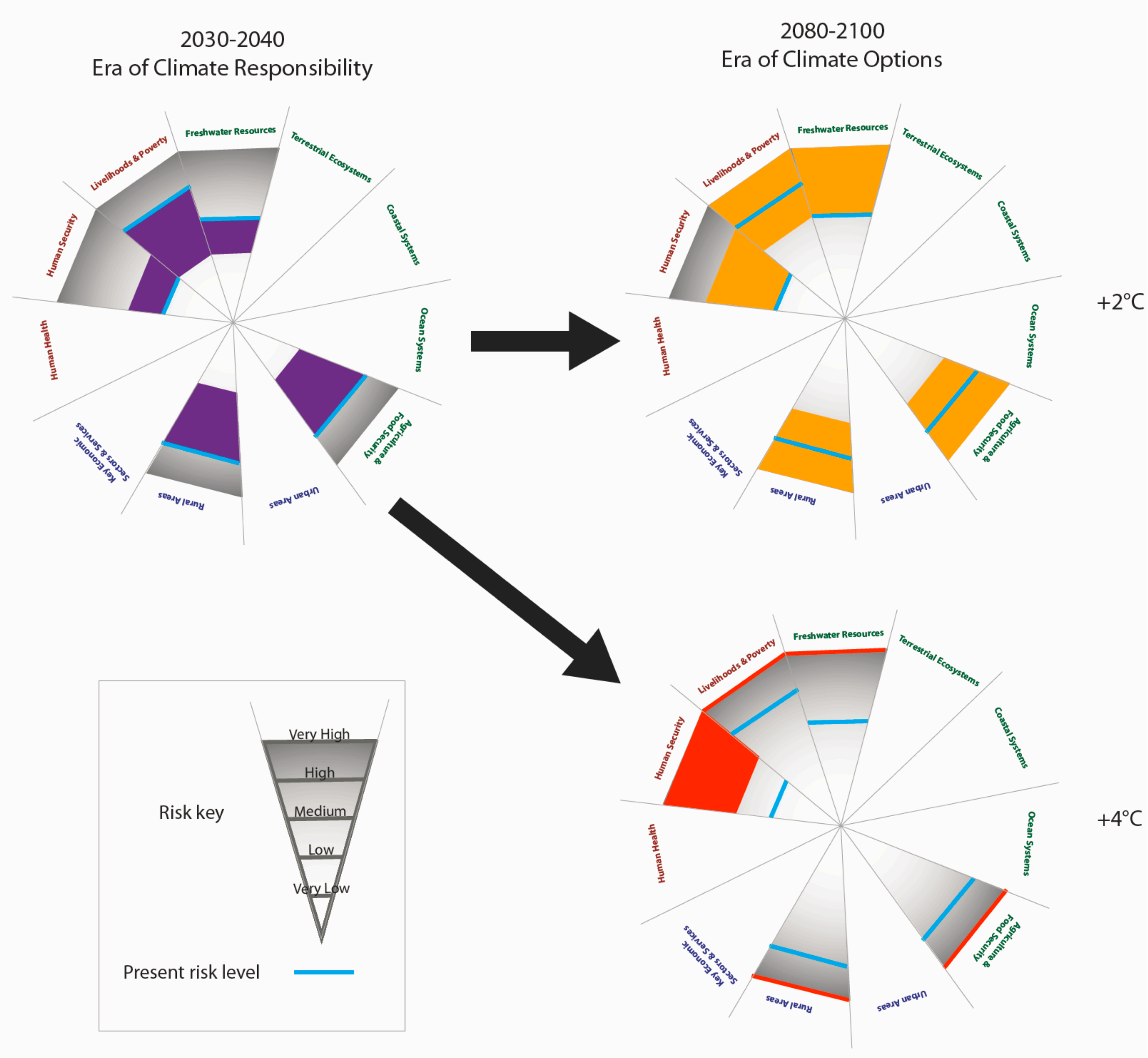


Figure 22-7: Risks for the present (blue line), for the near-term (2°C for 2030-2040) and for the end of the century for 2 temperatures (2°C and 4°C for 2080-2100). Risks are depicted for low adaptation and high adaptation.

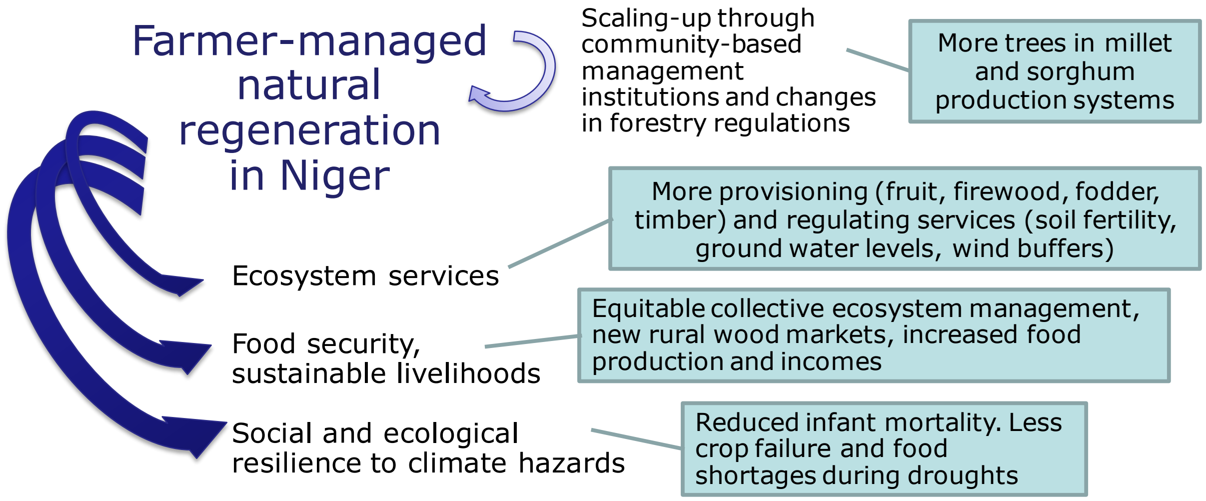


Figure 22-8: Ecosystem-based adaptation - Farmer Managed Natural Regeneration (FMNR): Benefits of ecosystem management for livelihoods and resilience (Garrity et al. 2010; Haglund et al. 2011; Reij et al. 2009; Sendzimir et al. 2011).

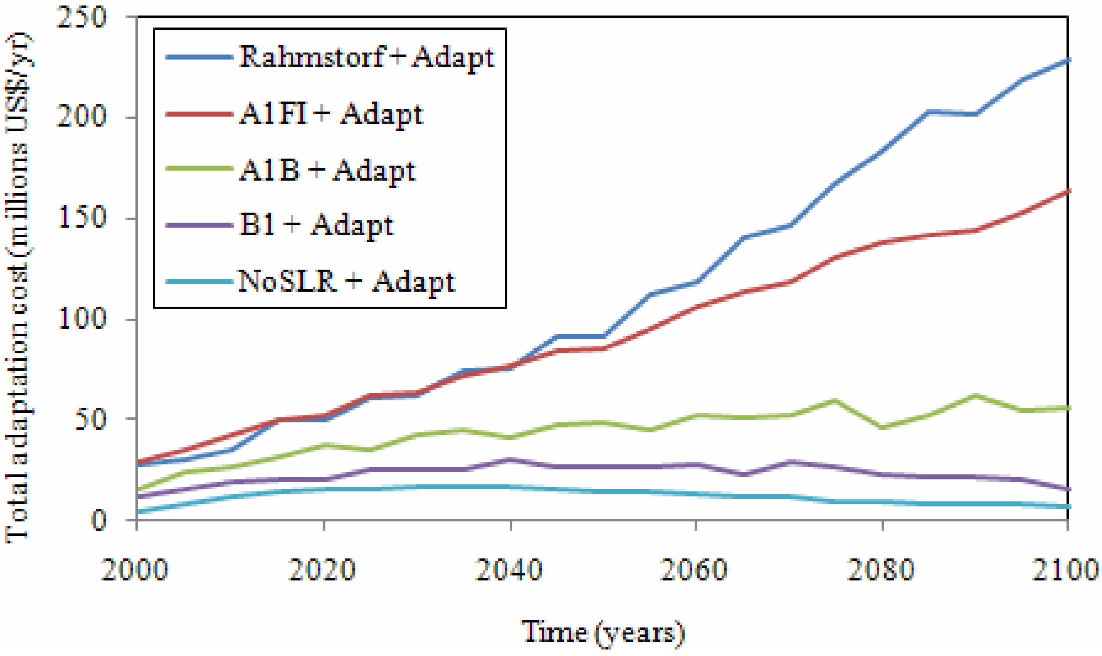


Figure 22-9: Total costs of adaptation per year from 2000 to 2100 for Tanzania (including beach nourishment and sea and river dikes) Source: Kebede et al., 2010.]

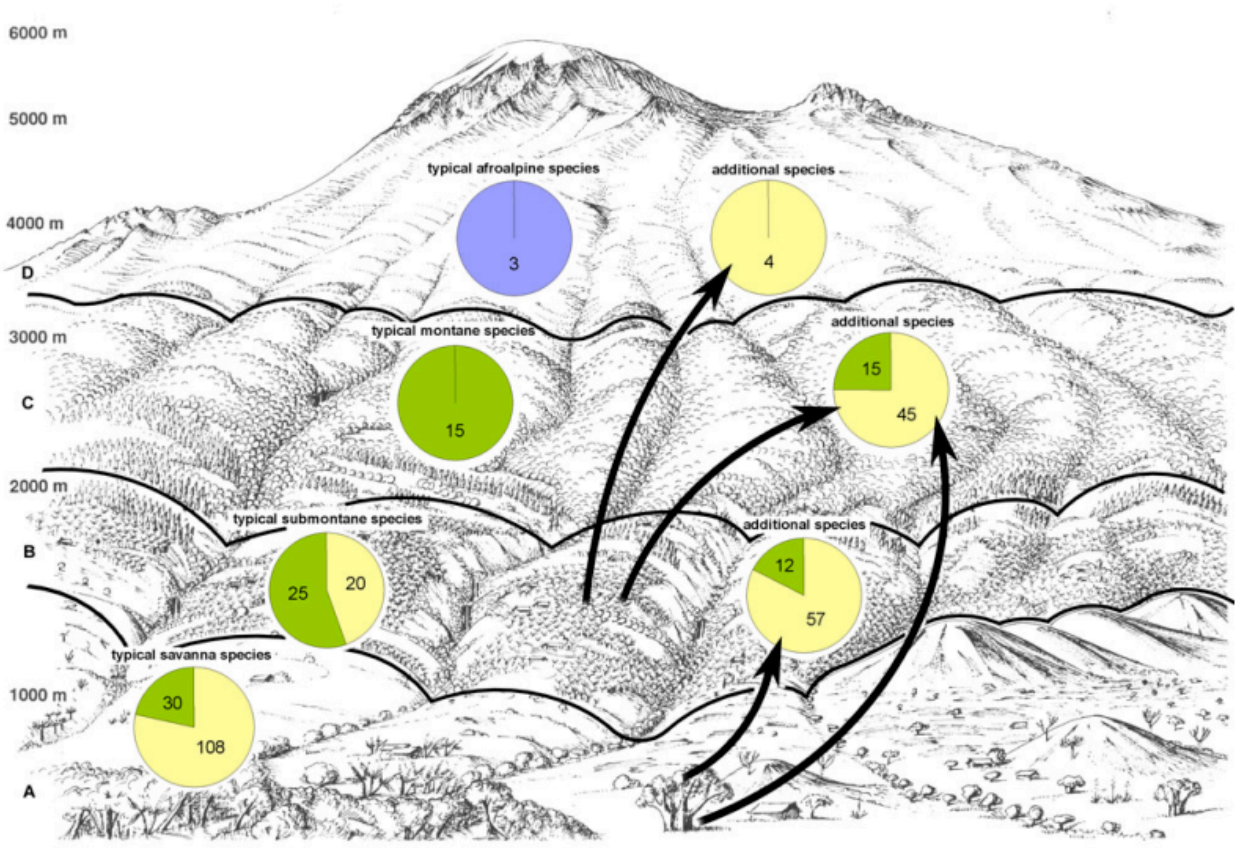


Figure 22-10: Upward movement of grasshoppers and bushcrickets at Kilimanjaro. Left circles giving numbers of species which are typical for this zone; right circles giving numbers of species that are additionally found to the typical species of the respective zone, arrows indicating area from which they migrated upwards. Yellow: openland forms, green: forest forms; blue: afroalpine forms. A: colline lowland savanna area, B: submontane and lower montane zone, C: montane zone, D: (sub) alpine zone. Source: Hemp and Hemp, 2008.