

THE IMPACTS OF CLIMATE CHANGE IN AFRICA

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EXECUTIVE SUMMARY

Introduction

Africa, the second largest continent, has a wide range of climates that range from the hyper-arid to the very humid. Africa's vulnerability to climate variability is generally well acknowledged. Africa's vulnerability to climate change largely depends on its current and future adaptive capacities. This in turn is influenced by such factors as the level of economic development, education, access to credit and adoption of technology. Because these factors are not uniform across Africa, it is difficult to have a uniform assessment of the impacts of climate on the continent. As a result, the impacts of climate change will be assessed at the sub-regional and national levels where data exist. This report is an attempt therefore at synthesising information on the cost of climate change in Africa. It reviews costs both in monetary and non-monetary terms. Understanding these potential impacts in Africa forms an important first step for any policy analysis of options to tackle climate change. Examining how the impacts change with differing degrees of climate change should inform the debate about the effectiveness of a range of policy options, e.g. delaying action, coordinated action to reduce greenhouse gas emissions (mitigation), and preparing for a changing climate (adaptation).

Approach and Scale of Analyses

This study adopts a vulnerability approach to assessing the implications of climate change on Africa, as opposed to adopting the bio-physical impacts approach. This is because the vulnerability to climate variability and change is stacked on an existing vulnerability, such that the impacts of climate variability and change are greatly exacerbated. Most studies that have assessed the impacts of climate change in Africa have used large-scale GCMs which provide very little information that is of practical use to decision-makers on the precise extent and impacts of climate change, especially for any specific location within a country in Africa. The few regional impacts are largely on Southern Africa where considerable capacity exists for regional climate modeling. It is acknowledged that making predictions of future climate change in Africa is problematic as a result of Africa's complex climate and the lack of data on the current climate to feed into models. This reduces confidence in projections of future change. However, available data are reviewed in this report.

Africa's Current Climate

Africa has a highly variable and unpredictable climate that is not fully understood by climatologists. However, observational records show that Africa has been warming through the 20th century at the rate of about 0.05°C per decade with slightly larger warming in the June-November seasons than in December-May. The most significant climatic change that has occurred in Africa has been a long-term reduction in rainfall in the semi-arid regions of West Africa. For example, in the Sahel there has been on average a 25% decrease in rainfall over the past 30 years – characterised by a decrease in the number of rainfall events. This reduction has been much more moderate in regions other than the Sahel.

Africa's Existing Non-Climate Vulnerabilities

Understanding the impacts of climate change in Africa requires that we first of all understand Africa's existing non-climate vulnerabilities. Africa's vulnerability to climate change is not only caused by climate change but through a combination of social, economic and other environmental factors that interact with climate change. It is the interaction of all these

multiple stressors that make Africa the most vulnerable region to climate change. These vulnerabilities include the region's high population growth rate (the highest in the world), pervasive and growing poverty, the high prevalence of malnutrition, low literacy rates, a high burden of disease, prevalence of environmental disasters such as floods and droughts, etc. The region is also characterised by poor governance, corruption, conflicts and weak institutions.

Vulnerability to and Impacts of Past and Current Climate Variability and Extreme Events

Climate variability: Africa's climate is highly variable and this variability manifest in climate extremes such as droughts and floods, both products of extreme rainfall events. Droughts and floods have increased in frequency and severity over the past 30 years. Droughts have largely occurred in the Sahel and in some parts of Southern Africa. During the Sahelian drought of the early 1970s, about 300,000 people and millions of animals died. Recurrent droughts are becoming very common in several parts of Africa with the impacts on the population increasing exponentially. Flooding, on the other hand, has also caused a lot of havoc particularly in southern and eastern Africa, around the coasts of the Indian Ocean. For instance, Mozambique, one of the poorest countries in the world, is highly vulnerable to disasters caused by climatic irregularities. In recent years it has seen frequent floods, and cyclones and these have had a negative impact on the country's economic and social development. For example, the floods in Mozambique in 2000 resulted in 2 million people being displaced with 350,000 jobs lost, impacting the livelihoods of up to 1.5 million people.

Water: Over 300 million people in Africa do not have reasonable access to safe drinking water and adequate sanitation, giving it the lowest water supply coverage of any region in the world. This access is much worse in the rural areas where only about 47% coverage, compared with 85% coverage in the urban areas. There are sub-regional variations in run-off which ultimately affect river flows, where the largest increases in runoff are found in the eastern areas of South Africa and Tanzania, south west Angola, northern Zambia and eastern Tanzania. The largest decreases of runoff are found in the wetter northern regions of Southern Africa. These declines in river flows have negative consequences on livelihoods, agriculture, fisheries and energy production.

Health: Africa has a heavy disease burden largely caused by vector-borne diseases that are influenced by climatic elements. About 90% of all malaria cases occur in Africa, and more than 110 million people in Africa live in regions prone to malaria epidemics with the most vulnerable populations located in the fringes of the current infected areas. Malaria is responsible for about 91% of all mortalities in Africa. Africa accounts for about 85% of all malaria-related deaths in the world. There is a significant increase in the occurrence of malaria in Africa, particularly in areas that did not have previous incidences of malaria, such as the east African highlands (Githeko and Ndegwa, 2001). With the high economic costs of malaria in Africa, it is expected that an increase in malaria incidence and prevalence could lead to an increase in poverty. For instance, a five-fold difference in GDP between malarious and non-malarious countries is noted. Other notable climate-related diseases in the region are meningitis and cholera.

Agriculture and Food Security: Agriculture accounts for 20-40% of GDP in Africa. Even without climate change, there are serious concerns about agriculture in Africa because of water supply variability, soil degradation, and recurring drought events. A number of

countries face semi-arid conditions that make agriculture challenging. African agriculture has the slowest record of productivity increase in the world, and the lowest share of irrigated cropland of any major region of the developing world. A significant fraction of cropland resides in Africa's driest regions, with 39% of the irrigation unsustainable. Sub-Saharan Africa is the world's only major region where food output per capita has been stagnant since 1980. One key factor in this stagnation is the declining availability of arable land per capita, which has shrunk dramatically from 0.38 to 0.25 hectare over the past twenty years, mainly because of population growth.

Environmental Conflicts and Migration: Africa is home to several resource scarcity-induced conflicts. These conflicts range from high intensity civil wars (Darfur-Sudan) to skirmishes between livelihood groups, as do often occur between the pastoralists and the sedentary farmers. Of all the climatic elements, precipitation is known to be the major factor that influences onset of conflicts in Africa. Instances of climate related conflicts in sub-Saharan Africa have been noted. As most climate models predict a decline in precipitation in several drylands in sub-Saharan Africa with consequent declines in biodiversity, there is a tendency that we might witness an increase in these scarcity-induced conflicts.

Projected Future Impacts

Climate change models and scenarios: Although the exact nature of the changes in temperature, precipitation, and extreme events is not known, there is consensus in literature about the following general trends: global mean surface temperature is projected to increase between 1.5 °C and 6 °C by 2100; sea levels are projected to rise by 15 to 95 centimetres (6 to 37 inches) by 2100 resulting in flooding and salt-water intrusion forcing people to abandon their land and homes; African countries will experience hotter and drier conditions, with warming greatest over the interior of semi-arid margins of the Sahara and central Southern Africa. The warming in Africa is likely to be somewhat larger than the global, annual mean warming throughout the continent and in all seasons, with drier subtropical regions (especially arid zones) warming more than the moister tropics. Annual rainfall is very likely to decrease in much of North Africa and Northern Sahara, while winter rainfall will very likely decrease in much of Southern Africa. There will likely be an increase in annual mean rainfall in tropical and East Africa, while it is uncertain how rainfall in the Sahel and the Southern Sahara will evolve in this century.

Although Africa will likely experience a modest increase in extreme wet and dry seasons, the probability of an increase in the occurrence of heat waves is high. In East Africa, the frequency of extremely wet seasons is projected to range between 9 and 24% in JJA and DJF respectively. Projections for West Africa are somewhat similar. In South Africa, we could see a 20% increase in the frequency of extremely dry austral winter and springs. While there is insufficient information on which to assess possible changes in the distribution of tropical cyclones impacting Africa, thermodynamic arguments for increases in intensity are applicable here as in other regions.

Socio-Economic Scenarios: Understanding the future impacts of climate change requires an understanding of the future socio-economic situations of the systems. It is the interaction of climate and socioeconomic conditions (usually population and GDP) that produces the final impacts. By 2030 the population growth rate of sub-Saharan Africa will be growing at 2.1 percent and it is estimated that the population of Africa will exceed 1 billion by 2010 and eventually stabilize after 2100 at about 2.85 billion, three and a half times today's population.

In sub-Saharan Africa, incomes are expected to grow very slowly and the numbers living in poverty is expected to rise from 240 million in 1990 to 345 million in 2015. By then, two out of five people in the region will be living in poverty. By 2030, all regions except sub-Saharan Africa should see the incidence of undernourishment decline to between 4 and 6 percent, down from the range of 9 to 24 percent today. In sub-Saharan Africa, 15 percent of the population or 183 million people will still be undernourished by 2030. This will be by far the highest total for any region, and is only 11 million less than in 1997-99.

Future Impacts:

Agriculture and food security: In aggregate, African agriculture will be worse off with climate change. Even though warming expands supply and reduces agricultural prices, the prices will be harmful to farmers in Africa. Areas that are currently marginal could find themselves unsuitable for agriculture in the future. Under a business as usual scenario, a 2°C increase could, by the 2050s, result in 12 million people at risk from hunger as a result of falling crop yields. Increases in temperature to 3.3°C and 3.4°C could result in about 60 million and 70 million people respectively at risk. Even though increases in temperature increase livestock revenues for small farmers, the overall effect is losses in billions of dollars from livestock revenues since large farmers dominate the sector. One explanation for this is that farmers shift into crops as rainfall increases, given rainfall increases crop productivity. Second, increased precipitation reduces the quality of grazing for animals as grassland become forests. Third, is an increase in animal diseases thereby reducing the population of livestock.

Glaciers and water supply: Projections show that the majority of the glaciers on Mount Kilimanjaro could vanish in the next 15 years if the recession of the icecap continues (an estimated 82 percent of the icecap surveyed in 1912 is now gone). By 2050s, northern and southern Africa will experience a general reduction in average annual runoff. In Southern Africa, the area having water shortages could increase by 29% annually by 2050 (against the current value of 9%), with Mozambique, Tanzania and South Africa being the most affected. By 2025 nine countries mainly in eastern and southern Africa will face water scarcity and twelve countries will face water stress. The Nile could witness a decrease in flow up to more than 75% by the year 2100, together with dramatic reductions in the Sudanese swamps. In these conditions, agriculture will be affected since normal irrigation practices cease when annual flow is reduced by more than 20%. The likelihood of such a situation occurring is greater than 50% by the year 2020.

Health: Climate change and small changes in temperature and precipitation will boost the population of disease-carrying mosquitoes and result in increased malaria epidemics. Increased flooding could facilitate the breeding of these malaria carriers in formerly arid areas (Warsame et al. 1995). The greatest burden for malaria is borne by the African continent, and remains unacceptably high. This contention is supported by the fact that over 60% and 90% of the clinical episodes and deaths from falciparum malaria occur in Africa south of the Sahara, where more than a million children mostly under the age of 5 years die from malaria each year. In Africa climate change could be responsible for an additional 21 million – 67 million people at risk of malaria by the 2080s. Previously unsuitable areas for malaria in Zimbabwe could become suitable for transmission with slight temperature and precipitations variations. Similarly, in South Africa the area suitable for malaria will double and 7.8 million people will be at risk by 2100. A 5-7% potential increase (mainly altitudinal) in malaria distribution with little increase in the latitudinal extent of the disease is estimated by 2100.

Ecosystem: The impact of climate change manifested by warmer and drier climates will

affect the ecosystem leading to a contraction of suitable habitats for endangered plant and animal species and even the loss of endemic species. This has implications for the well-being of the greater proportion of Africans who depend directly on the ecosystem for their livelihoods.

Urban Impacts: Sea level rise resulting from global climate change will pose a serious threat to coasts, lagoons and mangrove forests in countries such as Mozambique, Tanzania and Angola. Coastal infrastructure and settlements are also at risk. Flooding will claim millions of lives and coastal flooding will add to further losses as the tourism industry is adversely affected. Resulting diseases resulting will claim more lives and the plight of the poor will worsen.

Migration and conflicts: Climate change will create new environmental conflict hotspots that could lead to a significant increase in national and international conflicts over shared environmental resources, such as water and land (Vorosmarty et al., 2005).

Adaptation

The most viable option that is open to Africa to manage the impacts of climate change in the region is through adaptation. However, the continent's low adaptive capacity serves as a major constraint to her ability to adapt. This limited adaptive capacity results from the region's poor financial resources, low technical and technological capabilities, weak institutions and limited awareness of the devastating impacts of climate change.

However, despite this limited adaptive capacity, several adaptation strategies are currently being practiced to cope with present climate variability in the region. For instance, within the agricultural sector, these strategies range from the development and deployment of early warning systems, better agricultural management systems, improved crop cultivars, better and more efficient irrigation systems and good grain storage systems. Strategies used in the other sectors include the construction of sea retaining walls to stop coastal erosion and storm surges, the use of insecticide-treated nets to reduce the incidences of malaria, etc.

Efforts should be made by the more developed countries who contribute the bulk of the greenhouse gas responsible for the global warming to cut down on their emissions to acceptable limits as well as provide the funds and technical capability to enable Africa adapt to climate change.

Conclusion

Africa's contribution to the climate change problem is very insignificant and yet it is one of the hardest hit by the negative impacts. Africa is dominated by tropical weather patterns which make for highly variable climate under current climatic conditions. This increased climate variability, coupled with the high dependence of African economies on agriculture and the direct consumption of natural resources, creates the potential for dramatic negative consequences of global climate change. Warmer temperatures have a potential of facilitating the increased breeding of vector-borne disease such as malaria, and hygiene-related illnesses such as cholera, etc.

Climate change will also impose other costs to the economy, human development and the environment. The transport system could suffer because of destroyed roads and bridges, railway lines, waterways, affected harbors due to sea level rise, and disrupted air transport

due to increased precipitation or bad weather. Change in vegetation, lack of water, beach erosion, water sedimentation, high temperatures will have a negative impact on wildlife and tourism. The marine and fisheries industry could be affected by changes in water temperatures, flooding and drought. Climate change could also result in energy losses or changes in hydropower potential for electricity generation, effects of increased runoff (siltation) on hydrogeneration, as well as changes in the growth rates of trees used for fuel wood. The adverse impacts in some parts of the continent are likely to trigger spontaneous migration as an adaptive option.

1. INTRODUCTION

Africa, the second largest continent in terms of land mass occupies an area of over 30 million sq. km, slightly more than 20% of the world's landmass (Figure 1). It is the only continent that straddles the equator centrally. By its position, it is affected by all three ocean basins – the Atlantic, the Pacific and the Indian Ocean. The continent consists of 53 independent countries, with a total population of over 880 million in 2005.

Africa has a wide range of climate that spans from the moist humid regime through the semi-arid Sahel to the hyper-arid climate of the Sahara and Kalahari deserts. It also has a mild Mediterranean climate in the northern part and a temperate climate on the mountainous regions. However, about a third of the continent is classified as arid/semi-arid. The continent has experienced several extreme events such as floods and droughts, with significant

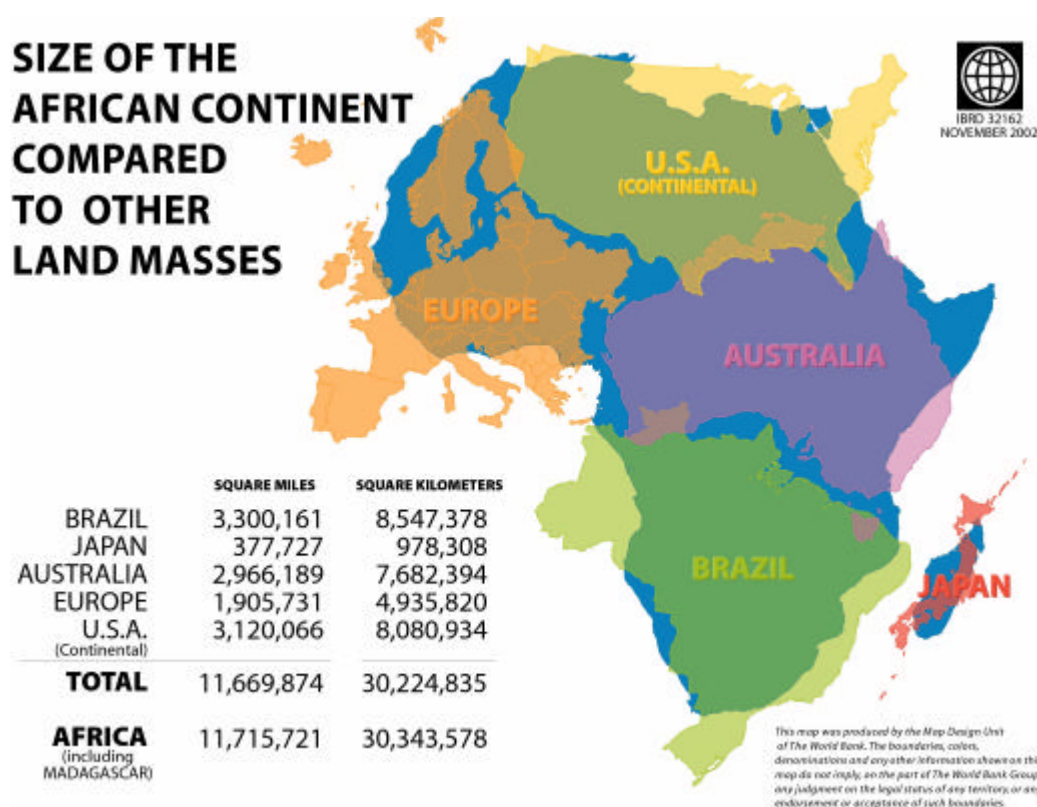


Figure 1: Size of the African Continent Compared to other Land Masses (Source: IBRD, 2002)

economic losses. Observational records in the past century show that Africa has been warming at the rate of about 0.5° per decade. This warming is projected to increase in the future with consequent rise in sea level and variable effects on precipitation. In some areas, the warming is associated with increased precipitation while in other areas it is projected to cause a significant decline in precipitation. This overall will have negative impacts on human development, income and the environment.

Several reports have noted that Africa is the most vulnerable continent to climate change. Africa's vulnerability to climate change largely depends on its current and future adaptive capacities. This in turn is influenced by such factors as the level of economic development, education, access to credit and adoption of technology. Because these factors are not uniform across Africa, it is difficult to have a uniform assessment of the impacts of climate on the continent. This report is an attempt at synthesising information from peer-reviewed literature on the economic impacts of climate change in Africa.

2. APPROACH AND SCALE OF ANALYSIS

Until recently, most assessments of the consequences of climate change have adopted an impacts approach. In this approach, emphasis is on the physical hazards associated with climate change. Present and future socio-economic conditions are given little consideration, except as part of global scenarios needed to project emissions and calculate impacts, based on the IPCC's SRES scenarios. Recent approaches have tried to understand the underlying factors that may enhance vulnerability to climate risks and stresses. This approach has highlighted the role of multiple stresses in exacerbating vulnerability to climate stress. Nowhere is the impact of multiple stresses on climate change as obvious as in Africa. Any attempt, therefore, to discuss the economic impacts of climate change on the continent without stressing the role that several other stresses play will be an exercise in futility.

While substantial information exists on the impacts of past and current climate variability, not much work has been done on the projected impacts of future climate change on Africa for various levels of warming. Most of the assessments for the continent are based on global models, with very poor resolutions capable of concealing local scale impacts. Africa has the least number of local-scale studies of the impacts of climate change in any region. Several factors have been identified as being responsible for the limited number of regional level assessments in Africa. The first is the lack of observational data with which to calibrate models. A recent report has noted that "the climate observing system in Africa is in a far worse state than that of any other continent and it is deteriorating. The density of weather stations is eight times lower than the minimum recommended by the World Meteorological Organization. This creates key gaps in our understanding of and ability to predict the global climate system" (Washington et al; 2004). The second is the lack of skilled African capacity to carry out these modelling assessments. Africa has the lowest number of peer-reviewed research publications emanating from the continent (Table 1).

Table 1: Affiliation of lead author of papers in two leading climate journals (2002-2004)

Regions	J. Climate		Int. J. Climatology	
	Number	%	Number	%
North America (USA)	416	66.7	40	17.4
North America (Canada)	30	4.8	10	4.3
South America	18	2.9	15	6.5
Europe (excluding UK)	62	9.9	78	33.9
UK	36	6.8	25	10.9
Africa	2	0.3	7	3.0
Middle East	2	0.3	8	3.6
Asia (east)	40	6.4	18	7.8
Asia (South)	6	0.8	11	4.8
Australasia	13	2.1	17	7.4

(Source: Washington et al., 2004)

3. AFRICA'S CURRENT CLIMATE.

Africa's climate has been described as both varied and varying: *varied* because they range from humid equatorial regimes, through seasonally-arid tropical and hyper-arid regimes, to sub-tropical Mediterranean-type climates, and *varying* because all these climates exhibit differing degrees of temporal variability, particularly with regard to rainfall (Hulme et al., 2005).

The north-south extent ensures a land mass that straddles the equator and extends polewards through sub-tropical latitudes to the fringe of climates that extend into mid-latitude regimes during their respective winters. This size of the African continent and its amplitude of climate variability make the region an important component of not only the climate system of surrounding regions but also of the global climate system itself.

The complexities of African climates are attributable to a number of factors, many of which are unique to Africa. The size of the tropical land mass ensures interaction between land surface and atmosphere can be expected to play a major role in the basic state, annual cycle and climate variability on timescales from intra-seasonal to decadal. This potential derives from the well established premise that the atmosphere in tropical latitudes is very sensitive to changes at its lower boundary (Charney and Shukla, 1981). The expanse of arid and semi-arid lands in tropical Africa makes atmosphere interaction with these land surface environments particularly important to understand. Changes in vegetation, hydrology and dust export from land surface to the atmosphere all modify large scale atmospheric properties in the region and have potential to impact climate variability. Might the land surface interactions with the atmosphere be contributing to the magnitude of climate variability seen in Africa Certainly the land surface can change considerably on interannual timescales, and we know African climates to be capable of dramatic paleo-change.

Some of the complexity of African climates is generated by the shape of the land mass. For example, the north-south gradient in landscape and climate in West Africa from Equatorial rain forest to savanna over less than 10 degrees latitude is in part generated by the juxtaposition of the Equatorial Atlantic Ocean with the land mass covering 5-35°N. In Southern Africa, the north-south elongated tropical land mass creates a complex of meridional and zonal intertropical convergence zones, leading to a unique triple point where three air masses converge. Further complexity is added by the variable terrain: snow capped mountains on the Equator, extensive low-lying swamp lands, huge inland lakes, rift valleys and two major deserts in northern and southern sub-tropics.

The African climate is governed by monsoon circulations extending across large parts of the Atlantic and Indian Oceans. Extra-tropical influences are also felt from both hemispheres. The potential for adequate rainfall depends: on the response of the African atmosphere to prevailing global patterns of seasonally varying surface wind, upper level jet structures (e.g., the African Easterly jet, the Tropical Easterly Jet), the Southern Oscillation, and seasonal to inter-decadal atmospheric fluctuations in the Atlantic and Indian Oceans. Even the stratospheric quasi-biennial oscillation (QBO) may play a role in modulating African rainfall (Mason and Tyson, 1992; Jury et al., 1994, Ogallo, et al 1994). For example during the QBO easterly phase, tropical cyclones are more frequent in the Indian Ocean and convection increases over Madagascar (Jury et al, 1995).

Observational records show that Africa has been warming through the 20th century at the rate about 0.5°C per decade (Figure 2) with slightly larger warming in the June-November seasons than in December-May (Hulme et al., 2001). A higher figure of 0.8°C for continental Africa has been reported by New *et al.* (2000). The six-warmest years in Africa have occurred since 1987, with 1998 being the warmest year. The observed warming trend is consistent with changes in the global climate and is likely to be caused by anthropogenic effect (IPCC, 2001).

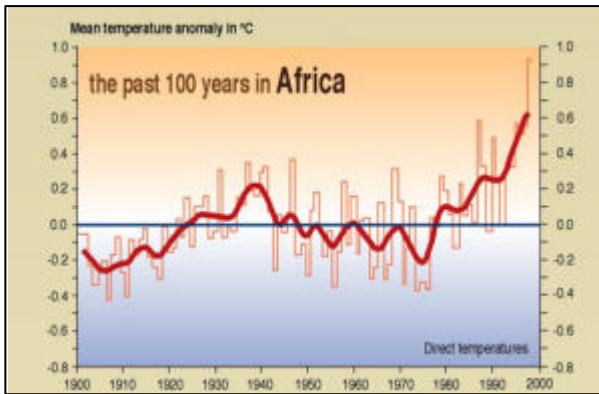


Figure 2: Mean temperature anomalies in Africa (Source UNEP, 2002)

The most significant climatic change that has occurred in Africa in the past century has been a long-term reduction in rainfall in the semi-arid regions of West Africa, particularly since the 1980s. In parts of the Sahel, the most seriously affected region, 30-year means have decreased by 20 to 40% between the periods 1931–60 and 1968–97 (Figure 3). In recent years Sahel rainfall has been stable around the 1961–1990 average of 371mm (Hulme at al., 2005).

Inter-annual variability is large over most parts of Africa, particularly in the Sahel where multi-decadal variability has been observed. In Eastern and Southern Africa, contrary to the Sahel, the rainfall variability is concentrated on short time scales (few years). In these regions, there is a strong ENSO signal in the rainfall variability. ENSO is noted as a major factor in the inter-annual variation in precipitation in eastern equatorial and south-eastern Africa (Hulme et al., 2001; Ropelewski and Halpert, 1996). There is little rainfall sensitivity to ENSO elsewhere in Africa. While climate change is often associated with global warming and rising temperatures, rainfall, and consequently water availability is a strong factor in Africa’s development. It could therefore be the strongest climatic determinant of Africa’s vulnerability.

4. AFRICA’S EXISTING NON-CLIMATE VULNERABILITIES

Africa’s vulnerability to climate change is not only caused by climate change but through a combination of socioeconomic factors that interact with climate change. It is the interaction of all these multiple stressors that make Africa the most vulnerable region to climate change. These vulnerabilities are discussed under social vulnerabilities and economic vulnerabilities.

4.1 Social Vulnerability

Africa’s population of about 887 million (2005) is growing at an annual rate of about 2.4%, almost twice the world average of 1.2 percent. Africa’s population, which is projected to double in 22 years, and with the high proportion of young people, the population momentum will probably continue for decades to come, even with AIDS reversing decades of gains in life expectancy. This growing population will exert pressure on the provision of safe water, education and health services, as well as threaten food security.

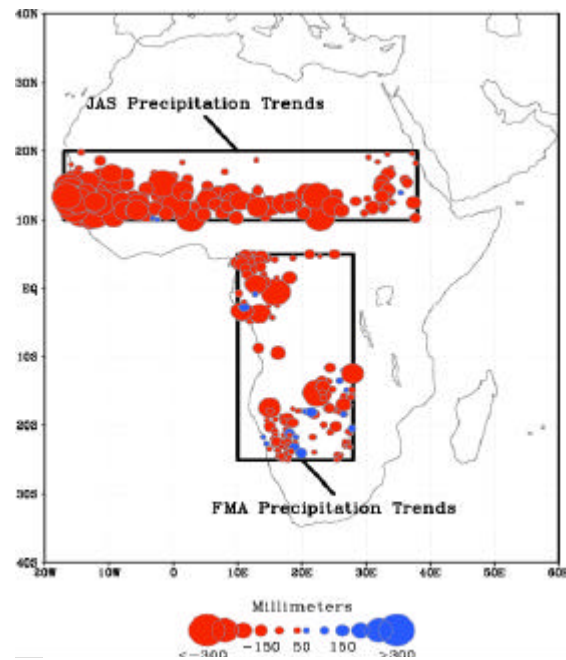
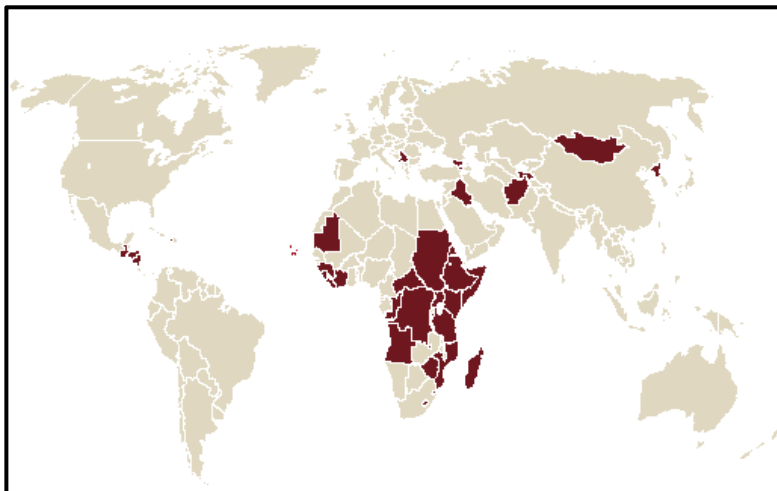


Fig. 3. Observed seasonal rainfall trends during 1950-1999 for all available stations within the northern and southern African monsoon index regions. Station locations indicated by circles, with dry (wet) trends denoted by red (blue), and the intensity of trends indicated by a circle’s size. Station values of monthly rainfall are based on the Global Historical Climate Network, and the circles denote all sites having at least 40 years of measurements during 1950-1999 (Source: Hoerling et al., 2005).

Migration particularly from the drier regions to the wetter sub-humid regions puts undue pressure on land resources both for farming and pasture, often resulting in environmental conflicts as in Darfur (Abdalla, 2006). These conflicts have become so frequent in Africa threatening livelihoods and creating environmental refugees. The economic costs of these conflicts are usually high and range from loss of human lives to loss of livelihoods (Nyong and Fiki, 2005).

A significant proportion of Africa's population (about 60%) over the age of 15 are illiterate (UNDP, 2003). The continent has a high under-5 mortality rate of 140 per 1000 (the highest in the world), and life expectancy at birth of only about 54 years (slightly higher for females than males). Almost all the African countries are classified as being in the low human development category.

Africa's health conditions are by far the worst on the planet (Sachs et al., 2004). A significant proportion of the population contends with the devastating consequences of diseases such as malaria, HIV/AIDS, cholera, typhoid and meningitis. The HIV/AIDS pandemic, which killed 2.3 million people in Africa in 2001, is having an impact on all aspects of human, social and economic development (UNAIDS, 2003). For example, the impact of HIV/AIDS on social development, economic growth and on health systems in Africa is projected to run to into billions of dollars. In South Africa the impact is anticipated to be equal to 0.4% of GDP over the next decade, while the impact on families, communities and societies is incalculable (UNAIDS 2000).



Sub-Saharan Africa has the highest percentage of undernourished – 40% of the total population. Most of the countries that are currently facing food emergency are in Africa (Figure 4). Hunger and poverty are closely related and are the main causes of human vulnerability in Africa.

Figure 4: Countries facing food emergency

4.2 Economic Vulnerability

Subsistence rain-fed agriculture is the mainstay of most African economies contributing GDPs that range from 10% to 70% and averaging about 21%. It employs about 70% of the labour force. Africa has the lowest share of irrigated cropland of any major region of the developing world. African agriculture has the slowest record of productivity increase in the world (Mendelsohn, 2000). It is the only major region with a decline in food production per capita during 1980–2000 (Sachs et al., 2004). One major factor in this decline is the declining availability of arable land per capita, which has shrunk dramatically from 0.38 to 0.25 hectare over the past twenty years. Africa's dependence on rain-fed agriculture means that production is vulnerable to climatic variability, which can severely affect food and human security, and exports.

Africa is by far the world's poorest inhabited continent, and it is, on average, poorer than it was 25 years ago. Not only is Africa the poorest region in the world, but it was also the only

major developing region with negative growth in income per capita during 1980–2000 (Sachs et al., 2004). Although some African countries recorded some modest growth during the 1990s, but for the most part this growth only recovered ground lost during the 1980s. Africa remains mired in poverty and a strangling debt portfolio. The number of Africans living

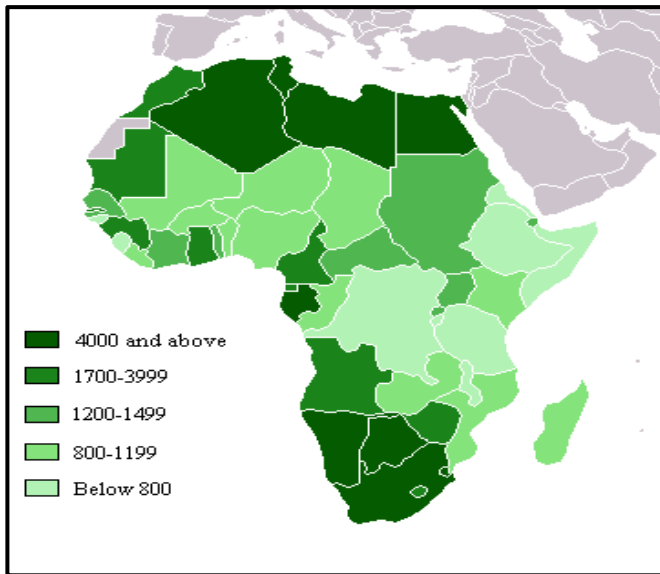


Figure 5: African States by GDP per Capita in US Dollars (2002): Source: Wikipedia

below the poverty line has increased by 50% over the last 14 years (Amoakoh, 2004).

However, the entire continent is not utterly impoverished and there is considerable variation in its wealth. The richest areas are the far north and south of the continent (Figure 5). There is also considerable internal variation in economic development within countries. Urban areas, especially capital cities, are generally wealthier than rural zones.

Some constraints to Africa's economic development have been identified by Sachs et al (2004). These include a very high transport costs and small market size, low-productivity agriculture, a very high disease

burden, adverse geopolitics and a very slow diffusion of technology from abroad.

5.0 VULNERABILITY TO AND IMPACTS OF PAST AND CURRENT CLIMATE VARIABILITY AND EXTREME EVENTS

Global mean temperatures have increased by about 0.6°C over the 20th century. In this section, we examine the social and economic impacts of these observed changes on Africa. Impacts in the near future, up to about 2010 are also noted.

5.1 Climate Variability and Extremes

Africa's climate is highly variable and this variability manifest in climate extremes such as droughts and floods which have increased in frequency and severity over the past 30 years (AMCEN/UNEP, 2002). For instance, the Sahel achieved international prominence during the catastrophic drought of the early 1970s, during which about 300,000 people and millions of animals died (de Waal, 1997; Mortimore, 1998). Dry conditions began in the late 1960s, and have persisted until the present day, with signs of increasing wetness during the 1990s (Figure 6). During the mid-1980s drought's economic losses in Africa totalled several hundred million US\$ (Tarhule and Lamb, 2003). Recurrent droughts are becoming very common in several parts of Africa with the impacts on the population increasing exponentially, as Table 3 illustrates. These increased impacts could be due to both population growth and the frequency and intensity of the droughts. More comprehensive climate-induced disasters (droughts) in Africa along with their costs and the number of people affected are presented in Appendix 1.

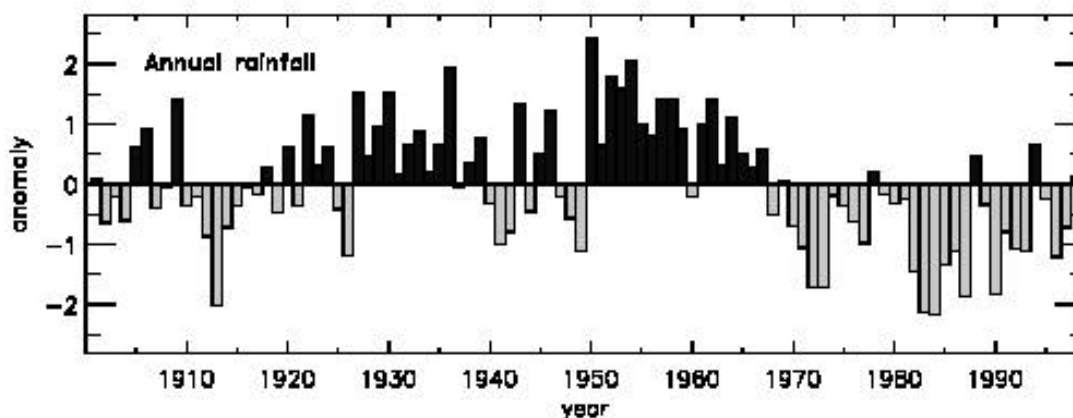


Figure 6: Spatially aggregated annual rainfall anomalies (in standard deviations) for the Sahel. Anomalies are calculated with respect to the mean for the entire series (1901-1998). (Source: Adger and Brookes, 2001.)

Table 3: Numbers affected by drought in Kenya, 1975-2006

Year	Estimated number of people affected
1975	16,000
1977	20,000
1980	40,000
1984	200,000
1992	1.5 million
1995-6	1.4 million
1999-2000	4.4 million
2004-2006	3.5 million

Source: Oxfam International (2006): Making the case: A national drought contingency fund for Kenya, Oxfam Briefing Paper, 89.

Table 4: World Bank Estimates of the 1999/2000 Flood Disaster in Mozambique (million USD)

Impacts	Direct	Indirect	Relief	Reconstruction
Food Aid				
Health				
Education				
Housing and private property	68.7		47.2	116.9
Government property				
Water & Sanitation				
Energy & Telecommunication	81.3	48.1	17.6	165.3
Roads and Railways				
Infrastructure				
Agriculture				
Livestock				
Fisheries				
Industry	117.7	163.4		123.3
Trade Tourism				
Environment subtotal	2.0			2.8
Subtotal disaster prevention	3.4			19.4
Grand Total	273.1	211.5	64.8	427.7

Source: Hirji, R et al 2002.

Flooding has also caused a lot of havoc particularly in southern and eastern Africa, around the coasts of the Indian Ocean. For instance, Mozambique, one of the poorest countries in the world, is highly vulnerable to disasters caused by climatic irregularities. In recent years it has seen frequent droughts, floods, and cyclones and these have had a negative impact on the country's economic and social development. The most significant of these disasters were the 1981-1984, 1991-1992 and 1994-1995 droughts, and the floods of 1977-1978, 1985 and 1988.

However, none of these phenomena have been as destructive or as abrupt, especially in the central and southern provinces, as the country's floods of 2000 and 2001, aggravated by the simultaneous occurrence of Cyclone Eline (Box 1). The estimated cost of the flood is presented in Table 4.

Box 1: The 1999/2000 Floods in Mozambique

From December 1999 there was heavy rainfall in both Mozambique and the neighbouring countries. In the first days of February, further heavy rainfall in the Maputo region and in neighbouring countries caused the Umbeluzi and Incomati rivers to reach levels not seen since 1937, and caused the Limpopo River to exceed all recorded levels, completely flooding the town of Chokwe and the lower part of Xai-Xai town. On 22 February, when the situation was still critical, the country was hit by Cyclone Eline that devastated in particular the provinces of Inhambane, Sofala and Manica. In addition to heavy direct damage in Mozambique, the cyclone quickly moved into neighbouring Zimbabwe, South Africa and Botswana, where it caused prolonged heavy rainfall, producing a new and rapid rise in the water levels of the rivers flowing into Mozambique.

About 27% of the country's population was affected by this disaster. Some 2 million people face severe economic difficulties. This included people who had lost their possessions, homes, shops, vehicles, animals, crops and fields, or people who have no access to their property or to any means of subsistence. This was not only due to the floods but also the destruction of land, communications and infrastructure. The direct economic costs of the floods were enormous. About 10% of the country's cultivated lands were destroyed, 90% of its operational irrigation structures were damaged, and over 20,000 cattle had disappeared, while public buildings, schools, health posts and hospitals have been destroyed. Water and energy supply systems were seriously damaged, as well as road networks, railways and telecommunications facilities.

There were also negative impacts on the economies of neighbouring countries, particularly Zimbabwe and South Africa. The breaching of the Limpopo railway forced Zimbabwe to export its goods through less economic routes. The energy situation in South Africa was seriously affected. As South Africa was unable to receive Cahora Bassa energy, it had to generate its own, more costly, thermal electricity to meet domestic needs. Due to the shortage of food products and the interruption of land communications inflation has re-appeared. From January to March there was a cumulative rise in the consumer price index of 9.7%.

Source: Carmo Vaz, A. (2000). "Coping with floods: The experience of Mozambique". First WARFSA/WaterNet Symposium on Sustainable use of water resources, Maputo, 15 pp.

5.2 Water

Over 300 million people in Africa still do not have reasonable access to safe drinking water. An even greater number of people lack adequate sanitation. Over 400 million people are expected to be living in at least 17 water-scarce African countries by the year 2010 (World Water Forum, 2000). Their lack of adequate water will severely constrain food production, ecosystem protection and socio-economic development.

Sub-regional variations in run-off associated with variations in rainfall which ultimately affect river flows have been observed in Africa. The largest increases in runoff for 1961-90 were in the eastern areas of South Africa and Tanzania and south west Angola (Hulme, 1996). The largest decreases in runoff were observed in the wetter northern regions of southern Africa where northern Angola, Zambia and Mozambique experienced decrease in excess of 30% (Schulze et al., 2001). In West Africa, it is noted that since the early 1970s, the average discharge in the region's major river systems have dropped by 40 to 60% (Niasse et al., 2004, Niasse, 2005). Only about 10% of Africans have access to abundant river corridor

discharge ($> 10 \text{ km}^3 \text{ y}^{-1}$), indicating that the vast majority of the population must rely on local run-off in small streams (Vorosmarty et al., 2005). The declines in river flows have negative consequences on livelihoods, agriculture, fisheries and energy production.

5.3 Health

Africa has a heavy disease burden largely caused by vector-borne diseases that are influenced by climatic elements (see Table 5). A study by Agyemang-Yeboah (2005) in Ghana confirms a positive correlation between malaria, cholera and meningitis, and climatic elements (Figures 7a-b). Malaria is widely-appreciated as the most important of the climate-sensitive diseases (IRI, 2005). The strong correlation between malaria epidemics and anomalously high rainfall is observed in both the east African highlands (Githeko and Ndegwa, 2001) and in semi-arid areas of Africa (Thomson et al., 2006). Agyemang-Yeboah (2005) estimated the cost of malaria treatment in only two provinces in Ghana in 2003 to be approximately US\$6,000,000/year. Besides the direct cost of treatment, other indirect costs include reduced income of affected individuals due to loss of productivity, increased expenditure of affected families, diminished quality of life, social disruption and reduction in Gross Domestic Product. With the high economic costs of malaria in Africa, it is expected that an increase in malaria incidence and prevalence could lead to an increase in poverty. For instance, Sachs and Malaney (2003) have noted a five-fold difference in GDP between malarious and non-malarious countries.

Table 5: Vector-borne diseases considered to be sensitive to climate change

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

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

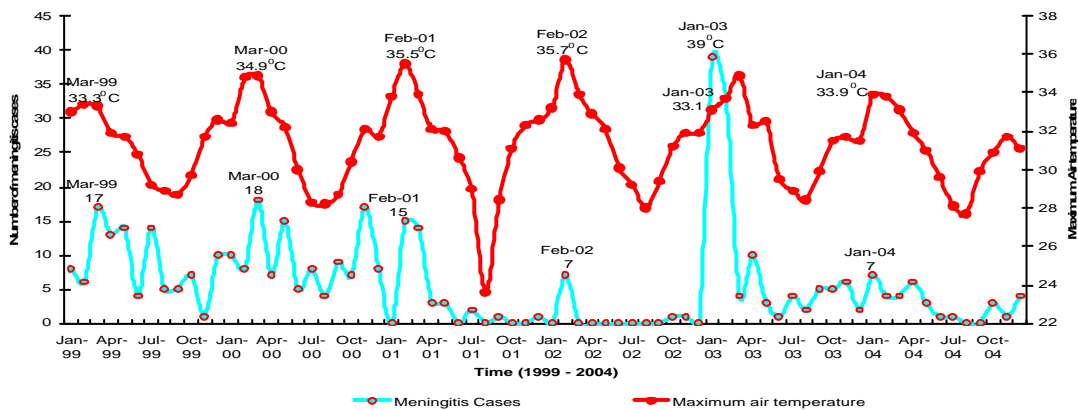


Figure 7 (a): Distribution of meningitis cases

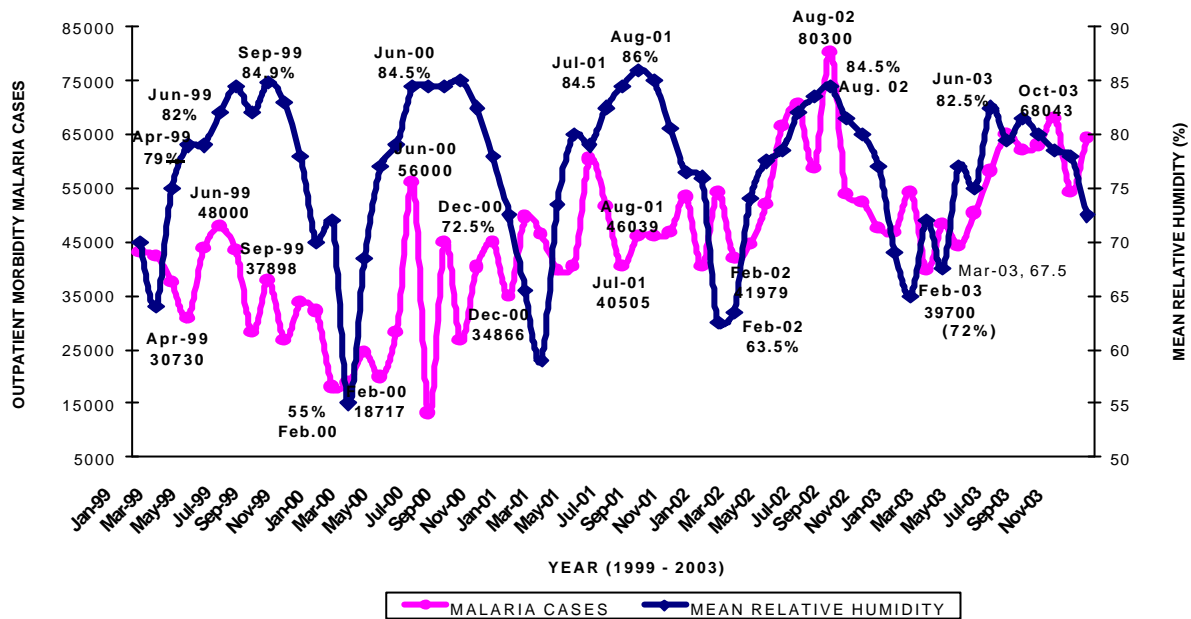


Figure 7 (b): Distribution of malaria cases and Relative Humidity

Africa also suffers from a number of other diseases that are sensitive to climatic parameters. For instance, vector-borne diseases such as Rift Valley Fever increase dramatically during periods of above normal temperature and rainfall. Cholera, a water and food-borne disease is associated with increase in sea and air temperatures and has been known to cause large scale severe epidemics during periods of strong El Nino. According to WHO disease outbreak reports, cholera outbreaks have continued in many countries in Africa with case fatality ranging from 0.2% in South Africa to 11.78% in Mali and the average for the continent being 3.5%. Meningitis is associated with increase in temperature and decrease in humidity, and is also related to dusts. Outbreaks of meningitis epidemics before the rains in West Africa, particularly the Sahel, and recently in Eastern Africa have been noted.

The rapid spread of the HIV/AIDS pandemic is partly blamed on climate events, even though indirectly. Studies have linked the spread of HIV/AIDS to population movement (Anarfi, 1993). In Africa, migration due to environmental factors occurs as people are displaced due to extreme weather events/natural disasters and sea-level rise, and also because of deteriorating agricultural productivity. These migrations are in response to the need to seek additional sources of income and food, and in some cases young girls from the rural areas with limited education become sex workers in the cities. These actions facilitate the spread of the infection, especially among women and children. For those already infected with the virus, malnutrition further debilitates the immune system, which makes people more susceptible to malaria, TB and other opportunistic diseases, and leads to a faster progression from HIV to AIDS (Thornton et al., 2006).

A study by the World Health Organization (McMichael, A. J. et al. (2004) indicates that the climatic changes that have occurred since the mid-1970s could already be causing over 150,000 deaths and approximately five million ‘disability-adjusted life years’ (DALYs) per year through increasing incidences of diseases such as diarrhoea (temperature effects only), malaria and malnutrition that occur mainly in developing countries. Most of these deaths are in the developing countries, particularly Africa (Figure 8).

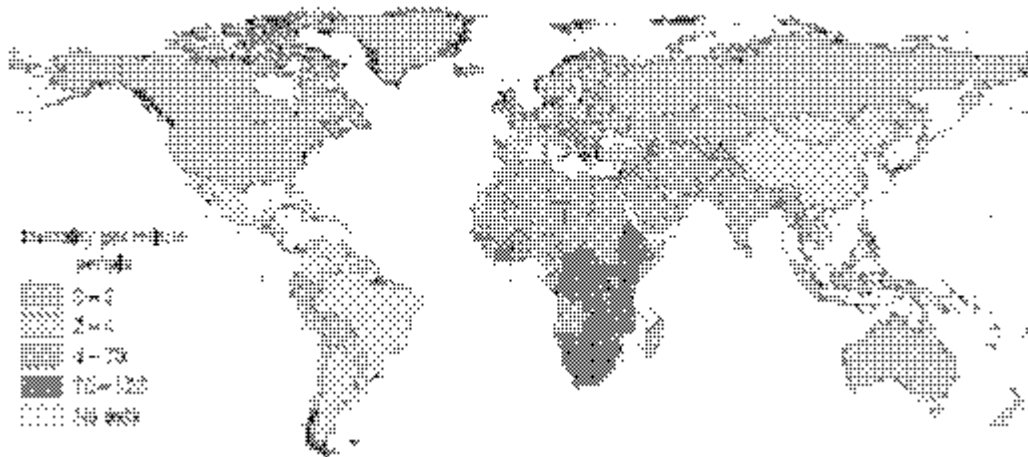


Figure 8: WHO estimated mortality (per million people) attributable to climate change by the year 2000. (Source, McMichael, A. J. et al. 2004)

Besides human health, climate also affects animal health in Africa. Livestock in Africa is an important economic activity, a critical form of food security and wealth. Although there's been little research on the impacts of climate change on pests and diseases of livestock in Africa, tsetse fly, the major African livestock pest, is associated with sub-humid regions, and may be further limited by increased aridity and expand into new wetter regions.

5.4 Agriculture and Food Security

Agricultural crop distribution and production is largely dependent on the geographical distribution of thermal and moisture regimes. Changes in rainfall patterns as observed in some parts of Africa, particularly the Sahel, in addition to shifts in thermal regimes, influence local seasonal and annual water balances, and in turn affect the distribution of periods during which temperature and moisture conditions permit agricultural crop production. Such characteristics are well reflected by the length of growing period (LGP). The drying of the Sahel that has been observed in the last century has been accompanied by a significant decline in LGP. An LGP of less than 120 days indicates hyper-arid, arid, and dry semi-arid lands with unsuitable or highly variable and unreliable conditions for crop agriculture. More than 180 million people in Africa alone are presently living in these vulnerable environments, relying to a large extent on agriculture for their livelihood (Fisher et al., 2002).

According to Vorosmarty et al (2005), a significant fraction of cropland resides in Africa's driest regions, with 39% of the irrigation unsustainable. As noted earlier, rainfall in much of the continent is erratic, vulnerable to high seasonal and year-to-year fluctuations, and the land is subject to high rates of evapotranspiration, due also to high temperatures. Indeed, of all major regions, Africa loses the largest share of its precipitation to evapotranspiration.

5.5 Environmental Conflicts and Migration

Africa is home to several resource scarcity-induced conflicts. These conflicts range high intensity civil wars to skirmishes between livelihood groups, as do often occur between pastoralists and sedentary farmers. Studies have also identified climate-induced resource

scarcity as the root cause of the present conflict in Darfur, Sudan (Abdalla, 2006). Of all the climatic elements, precipitation is known to be the major factor that influences onset of conflicts in Africa. For instance, Levy et al (2005) found a strong relationship between rainfall deviations below normal (droughts) and the likelihood of high intensity conflicts. Their explanations for these are that, first; droughts could decrease levels of capacity and increase levels of grievance. Second, droughts could reduce the return from agricultural labour and therefore improve the relative returns from rebellion. This is consistent with the study by Hendrix and Glaser (2005) which found that more temperate, fertile climates are associated with a decreased likelihood of conflict, while negative changes in rainfall are associated with an increased likelihood of conflict the following year. The study concluded that inter-annual variability matters more than the specter of changes in overall means and climate, which take place over long periods of time.

Instances of climate related conflicts in sub-Saharan Africa have been noted. A study by Meier and Bond (2005) of the environmental influences on pastoral conflict in the horn of Africa found that human deaths and livestock losses increased dramatically during the end of the dry season when both forage availability and rainfall were relatively low. Low forage availability during the end of the dry season prompts pastoralists to migrate in search of productive patches of land and water resources. Human casualties and livestock losses soared during this time period, just before the onset of the rainy season. As most climate models predict a decline in precipitation in several drylands in sub-Saharan Africa with consequent declines in biodiversity, there is a tendency that we might witness an increase in these scarcity-induced conflicts.

Climate change and the predicted warming have a potential of increasing risks of conflict over water. The West African countries, for example, have high degree of water interdependence making the region susceptible to tensions and conflicts over water resources. Niassé (2005) argues that the 17 West Africa countries share 25 transboundary watercourses and that (with the exception of Cape Verde) each of the countries shares at least an international watercourse. The region's major rivers (Niger, Senegal and Volta) have experienced declines in discharges of between 40 and 60% since the 1970s. This in turn, causes decreased water availability or altered water quality and creates tension, with communities and government authorities blaming upstream countries for phenomena caused by climate change and climate variability.

Dams in most cases are triggers of conflicts (Box 3). Nigeria, for instance, supplies Niger with the electricity the country needs to stop them from building a dam upstream of the Niger. This has worked well and prevented potential conflict between both countries.

When temperature increases in already hot areas it results in loss of livestock (the most valuable form of wealth to most households), reduces access to water as wells dry, and threatens the source of food supply as crops wither. Scarce resources that sustain life are affected leading to conflicts. In East Africa, for example, nomadic pastoralists have a history of disputes with each other that is exacerbated by increases drought and famine. The drying out of wells makes their livestock routes unsustainable leading to search for fodder and land in other territories. This intrusion and conflict over access to water and grazing land results in extreme violence and loss of human life. In Kenya, the violence between pastoralists in 2005 near the Ethiopian border left 56 people dead in some village, with another 20 people killed in revenge attacks. Such conflicts are now crossing international borders. Drought, for example, has caused conflict between Ugandan and Kenyan pastoralists, and has led the Ethiopian troops to move up north to stop the Somalis crossing the border in search of pasture and water for their livestock (Christian Aid Report, 2006).

Box 3: Mauritania-Senegal: from risks of open armed conflict to the “thickening” of the border line

In the Senegal River Basin, 8 of the top ten drought years (estimated on the basis of the volume of discharge in the middle reaches of the river) between 1904 and 1984 occurred in the 1970s and in the 1980s. It is in this context that the Senegal River Basin Development Authority (OMVS) was created by Mali, Mauritania and Senegal with the mandate of developing and implementing a major water infrastructure programme, which included the construction of the downstream Diama Dam and the upstream Manantali Dam. In the last quarter of 1988, two years after the commissioning of the Diama and few months after the completion of Manantali Dam (both dams meant to reduce the vulnerability of riparian countries to drought and climate variability), a conflict erupted between Senegal and Mauritania. The tension began when the river started to recede from adjacent floodplains. Senegalese farmers who went to the right bank of the river to prepare their fields were chased by Mauritanian border guards. Senegalese authorities retaliated by sending back to Mauritania camel herds which used to spend most of the dry season in the Sahelian region (of the northern Senegal known as the Ferlo region. Few months later, in April 1989, after a dispute between Senegalese farmers and Mauritanian herders in a territory claimed by the two countries, the Mauritanian border guards killed two Senegalese farmers and held in custody 13 others. The tension grew, and a series of skirmishes between Senegalese farmers and Mauritanian pastoralists took place along the river. Few days later, shops held by Mauritanians in small riverine towns and in Dakar are ransacked and looted by bands of youth. In response, hundreds of Senegalese residents are killed in Mauritania. The two Governments then decided to impose a curfew in their respective countries. By the end of June 1989, 75,000 Senegalese and 150,000 Mauritanians are repatriated. Thousands of black people whose Mauritanian nationality was denied were deported to Senegal. The two countries severed their diplomatic relationships, and the situation remained tense for the rest of the year. In 1992, diplomatic relationships between the two countries are restored, but the wounds of the crisis remained for a longer period. Since then, there has been a “thickening” of the border as a virtual wall seems to have been erected along the river. This marks a new era as the Senegal River used to be a communication highway regularly crossed by thousands of transboundary farmers residing in one bank of the river while having their farms on the other bank. The number of these transboundary farmers was estimated at 37,000 in the middle of the 1970s, with 21% residing on the right bank of the river (Mauritanian side) and 79% living on the left bank (Senegalese side) (Niasse, 2005).

These conflicts in addition to other direct environmental stresses such as droughts and floods lead to migrations, creating environmental refugees, who have been forced to flee their homes. The impact on farming could force people to leave their homelands. Although Africa’s farmers have proved skilled at adapting to changing rainfall patterns over decades, global warming threatens to stretch coping mechanisms beyond breaking point. With climate change, droughts and floods could become more frequent and as these worsen, more people are set to become both internally displaced and to flee across borders.

6. PROJECTED FUTURE IMPACTS

6.1 Climate Models and Scenarios

As rightly observed by Hulme et al., (2005), there has been relatively little work published on future climate change scenarios for Africa. Most assessments are based on global maps of climate change within which Africa has featured. Few climate scenarios have been developed for Africa based on the IPCC SRES scenarios. Details of the SRES scenarios can be found in IPCC (2000). The A scenarios have more of an emphasis on economic growth, the B scenarios on environmental protection. The 1 scenarios assume more globalisation, the 2 scenarios more regionalization. The SRES scenarios have come under heavy criticism, partly to do with the fact that the projections for human population have become out-of-date surprisingly rapidly. While some have criticized the population and economic details, the scenarios are generally internally consistent and constitute a very useful set of standards, and the range of future greenhouse gas emissions is undisputed (Tol et al., 2005). The most recent set of climate change scenarios for Africa are those presented in Hulme et al., (2001) (Table 6). Although there have been studies of GCM-simulated climate change for several regions in Africa, the downscaling of GCM outputs to finer spatial and temporal scales has received relatively little attention in Africa. It must be noted however that downscaled GCMs are still dependent on the large-scale forcing from the GCMs and only sample one-realization of the possible range of future possible climates (Hulme et al., 2005).

Table 6: The four global climate change scenarios for the 2050s adopted by Hulme et al. (2001)

Scenario/ Climate sensitivity	Population (billions)	C emissions from energy (GtC)	Total S emissions (TgS)	Global ΔT ($^{\circ}C$)	Global ΔSL (cm)	pCO ₂ (ppmv)
B1-low/ 1.5 $^{\circ}C$	8.76	9.7	51	0.9	13	479
B2-mid/ 2.5 $^{\circ}C$	9.53	11.3	55	1.5	36	492
A1-mid/ 2.5 $^{\circ}C$	8.54	16.0	58	1.8	39	555
A2-high/ 4.5 $^{\circ}C$	11.67	17.3	96	2.6	68	559

Source: Hulme et al., (2005)

6.1.1 Future temperature and precipitation.

The Hulme et al. (2001) scenarios suggest a future annual warming across Africa ranging from below 0.2 $^{\circ}C$ decade⁻¹ (B1-low scenario; to over 0.5 $^{\circ}C$ decade⁻¹ (A2-high scenario). This translates to a warming of between 2 $^{\circ}C$ and 6 $^{\circ}C$ by 2100. This warming is greatest over the interior semi-arid tropical margins of the Sahara and central southern Africa, and least in equatorial latitudes and coastal environments. Newer studies have shown that these figures could be much higher. Under the A1F1 scenario, constant warming of up to 9 $^{\circ}C$ and 7 $^{\circ}C$ was noted for northern and southern Africa respectively for the period 2070-2099 (Ruosteenoja *et*

al., 2003). Modelled results using HadCM2 GCM based on the IS92a scenario showing the effects of CO₂ stabilization at 550ppm (by 2150) and 750ppm (by 2250) indicate that for the Sahel region, the predicted reductions in warming are respectively 2.9° and 2.1°C.

While there is a general consistency in projected temperatures for Africa, future changes in mean seasonal rainfall in Africa are less well defined. Under the B1 scenario, Hulme et al., (2001) found that relatively few regions in Africa will likely experience a significant change in either December-January-February (DJF) or June-July-August (JJA) rainfall that exceeds the natural rainfall variability simulated by the HadCM2 model. The exceptions are parts of equatorial East Africa where rainfall increases by 5 to 30% in DJF and decreases by 5 to 10% in JJA. With more rapid global warming (A2 scenario), large areas of equatorial Africa experience significant increases in DJF rainfall of up to 100% particularly in eastern Africa, while West Africa could witness a significant decline in JJA by 2100. Rainfall pattern over the Sahel is less certain. In some models, the Sahel is projected to be wetter (Hoerling et al., 2005), other models project that it will experience 'significant' rainfall decreases in JJA season under the B1-low scenario.

Inter-annual fluctuations in rainfall over Africa are determined in part by global atmospheric circulation regimes which alter the preferred location of tropical deep convection (Harrison 1986) and of the inter-tropical convergence zone (ITCZ). Skilful predictions of rainfall depend largely upon our ability to model the atmospheric response over Africa to large-scale atmospheric features (Ward et al., 1993; Mason et al, 1996).

Two main reasons for the inconsistency in modelled precipitation as noted by Hulme et al., (2005) are: the ambiguous representation in most global climate models of ENSO-type climate variability in the tropics, itself a key determinant of African rainfall variability; and the omission in all global climate models of any representation of dynamic land cover-atmosphere interactions and dust and biomass aerosols. Such interactions are known to be important in determining African climate variability during the Holocene and may have contributed to the more recently observed desiccation of the Sahel.

Despite the lack of convergence in predicting future trends in precipitation in Africa, the following general conclusions can be drawn:

- In northern Africa, a decrease in precipitation in JJA (less 10-25%) is projected for the 2010-2039 period.
- In Western Africa, there is an agreement between models to of a progressive increase in precipitation (between 10 and 35%) for the DJF period (which is normally dry).
- In Eastern Africa, a net increase in precipitations is projected for DJF period (between 10 and 30%).
- In Southern Africa, a net trend towards decreased precipitations is predicted for the JJA (less 15 to 62%).

In summary, all of Africa is very likely to warm during this century. The warming is likely to be somewhat larger than the global, annual mean warming throughout the continent and in all seasons. Annual rainfall is very likely to decrease in much of North Africa and Northern Sahara, while winter rainfall will very likely decrease in much of Southern Africa. There will likely be an increase in annual mean rainfall in tropical and East Africa, while it is uncertain how rainfall in the Sahel and the Southern Sahara will evolve in this century.

6.2 Socio-Economic Scenarios

Understanding the future impacts of climate change requires an understanding of the future socio-economic situations of the systems. It is the interaction of climate and socioeconomic conditions (usually population and GDP) that produces the final impacts. Since 1950, Africa's population has quadrupled. By 2030 the population growth rate of sub-Saharan Africa will be growing at 2.1 percent. By 2030, every third person added to the world's population will be a sub-Saharan African. By 2050, this will rise to every second person. It is estimated that the population of Africa will exceed 1 billion by 2010 and eventually stabilize after 2100 at about 2.85 billion, three and a half times today's population (Openshaw, 2005).

In sub-Saharan Africa, incomes are expected to grow very slowly and the numbers living in poverty is expected to rise from 240 million in 1990 to 345 million in 2015. By then, two out of five people in the region will be living in poverty. The projected GDP per Capita for the different regions in Africa under the various SRES scenarios shows that average income is likely to rise throughout the century, though West and Central Africa consistently perform poorer than the other regions. With regards to projected population, all the scenarios assume a continued growth, with the Western Indian Ocean Islands having the lowest growth rates. West Africa is projected to have a consistently high population growth except for the A2 scenario where the population of North Africa is likely to outgrow that of West Africa by 2070. A caveat in using the SRES scenarios is that it assumes global growth convergence. This is an unlikely assumption for Africa as trend growth rates in Africa show that Africa's growth has been much slower than the convergence hypothesis would support.

By 2030, all regions except sub-Saharan Africa should see the incidence of undernourishment decline to between 4 and 6 percent, down from the range of 9 to 24 percent today. In sub-Saharan Africa, 15 percent of the population or 183 million people will still be undernourished by 2030. This will be by far the highest total for any region, and is only 11 million less than in 1997-99. The fate of sub-Saharan Africa is therefore cause for serious concern (FAO, 2002).

6.3 Future Impacts

A limited number of modelling studies on the impact of future climate change in Africa have been carried out. Most of the studies that have been conducted use large scale general circulation models with poor resolutions and the results are capable of concealing local scale variations in impacts. Most of the regional climate modelling activities have been restricted to southern Africa where there is considerable expertise in regional climate modelling. However, attempt is made here to review available impacts studies on the various socio-economic sectors in Africa.

6.3.1 Agriculture and food security

With the exception of oil-exporting countries, most of Africa relies on rain-fed agriculture. African agriculture will be highly vulnerable to changes in climate variability, seasonal shifts and precipitation patterns, so that continued increases in temperature will, apart from increasing water stress, threaten crop production and husbandry that so far account for a significant portion of household income. The poorest members of society, which tend to be those most dependent on agriculture for jobs and income, will be worst affected (Odingo 1990; FAO 1999). Worsening agricultural conditions usually lead to deteriorating food security conditions, increased risk of hunger, increased dependence on food imports and instability in prices.

A study commissioned by DFID to identify areas of sub-Saharan Africa where current and projected impacts of climate variability and change are likely to significantly showed among other things that the length of the growing period was one of the elements that would be affected by climate change (Thornton et al., 2006). The study used downscaled outputs of 2 GCMs (the ECHam4 GCM and the HADCM3) across 4 IPCC SRES scenarios (A1F1, A2, B1 and B2). Some of the conclusions from the study are that by 2020 some losses in LGP greater than 20% will occur in highly marginal areas for cropping. By 2050, some areas that showed gains in LGP in 2020 would have lost growing days. By 2050, projected increases in temperature and projected changes in precipitation patterns and amount would combine to suggest that LGP would decrease in many parts of sub-Saharan Africa. In the A1F1 world, (temperature range of between 1.5°C and 2.0°C) the hotspots are the more marginal areas such as the coastal systems of southern and eastern Africa, and the arid-semiarid livestock only systems, particularly in the Sahel. In the B1 scenario (temperature range of 1.0°C and 1.5°C), the general trend of marginal areas becoming more marginal is still apparent.

There are also a few places where the combination of increased temperature and rainfall changes may lead to an extension of the growing season, particularly in the highland areas. For instance BI scenario for the HADCM3 model projects that Kenya would likely experience an extension in LGP particularly for the arid-semi-arid livestock only system, the highland/temperate regions and the rainfed, mixed crop/livestock system.

An FAO (2000) study on the impact of future climate change and agriculture examines how much agriculture in developing countries will be hurt by likely warming scenarios. How badly Africa is affected depends on the climate change it can endure. The study makes the following assertions. First, that modest increase of less than 1 to 3.5°C is deleterious but manageable. Second, that adaptation and carbon fertilisation should mitigate most effects at the global level. The FAO study explores low, medium and high climate scenarios for 2100 of 1°C with CO₂ concentration of 700ppmv, 2°C of 800ppmv, and the 3.5°C global temperature scenario involving 1000 ppmv concentration. Country changes in temperature and precipitation changes are predicted using the UIUC II model for each of the climate scenarios. The study reports results of 6 possible outcomes, based on two climate sensitivities: a pessimistic prediction taken from agro-economic results and an optimistic prediction taken from cross sectional results. In aggregate, African countries will be left worse off. The study also notes that areas that are currently marginal could find themselves unsuitable for agriculture in the future. This supports new research which suggests that actual effect of CO₂ concentration is about half of that in the experiments used to develop climate change models (Long et al., 2005). Long et al. find that areas with modelled increases might actually see no change, and areas with no change (as in Africa) might actually experience crop failure.

Table 7. Agricultural impacts (000 million US\$)

	Pessimistic Sensitivity			Optimistic Sensitivity		
	1 ⁰ C	2 ⁰ C	3.5 ⁰ C	1 ⁰ C	2 ⁰ C	3.5 ⁰ C
Africa	-23	-85	-165	16	-1	-30

Note: negative numbers imply damages and the positive number shows benefits

Mendelsohn et al (1997) present two sets of results for a 2°C global warming projected for 2060 (i) using the Reduced-form response and (ii) using a Ricardian model functions. These empirical response functions (Reduced form and Ricardian) are used to assess the uncertainty of the climate impacts. These climate models are based on the Global Impacts Model (GIM) that combines: (i) detailed climate simulations of a general circulation model (GCM), (ii) sectoral data for different countries and (iii) climate-response functions to estimate climate

impacts. The market impacts using the Reduced-form model show that Africa is damaged by the warming while Europe and North America benefit. Table 8 shows Africa's market impacts (billions of dollars) for a 2°C global-mean warming in 2060. The net effect for Africa is a \$133 billion loss, which is about 4.7% of GDP. Most of these damages come from agriculture which suffers a \$132 billion loss. Water and energy contribute losses of \$2 and \$3 billion, respectively. Surprisingly, there is neither coastal damage nor benefit from sea-level rise. Forests contribute a \$4 billion gain. The results using the Ricardian response functions are similar to those using the Reduced-form model in that Africa is damaged by the warming. The Ricardian model predicts much smaller losses than its Reduced-form counterpart. According to the Ricardian model, while there will be a small gain in agriculture worldwide, Africa suffers losses of \$11 billion. The huge discrepancy in agricultural results can be attributed to different predictions in the models about agriculture. The damages in the energy sector are smaller, and the gains to forestry become losses (\$6 billion). The net result is that warming results in a \$22 billion loss for Africa (equal to 0.08% of Africa's GDP in 2060) for a 2°C global warming, with agriculture accounting for a large chunk of the losses.

Table 8. Africa's market impacts (billions of dollars) from the for a 2°C global-mean warming.

	Sector					Total	%GDP
	Agric	Forest	Coast	Energy	Water		
Reduced-form model	-132	4	-0	-3	-2	-133	-4.7
Ricardian model	-11	-6	-0	-2	-3	-22	-0.8

Source: Mendelsohn et al (1997)

Disaggregating these results to country effects shows Nigeria as the largest loser because of its present warm climates and large masses (Table 9). The reduced-form model shows that the damages from global warming are large, and that agriculturally dependent countries will suffer the worst losses. The losses predicted by the Ricardian model are smaller, but point to countries with extensive coastlines to be most the vulnerable (e.g. Mozambique and Nigeria), a situation worsened by their limited development and dependence on tourism. The Reduced form model shows large damages from global warming as a fraction of GDP and even predicts that agriculture will virtually disappear from most of Africa resulting in large losses in agriculturally dependent states. In contrast, the Ricardian model does not predict such dire results, but rather confirms that global warming is bad for Africa.

Table 9. Net market impacts (billions of dollars for a 2°C global-mean warming in 2060

Country	Reduced-form		Ricardian	
	Welfare	% GDP	Welfare	% GDP
Ethiopia	-9	-17.7	-1	-2.7
Mozambique	-2	-19.0	-0	-3.8
Nigeria	-27	-11.2	-5	-1.9

Source: Mendelsohn et al (1997)

Mendelson et al (2000) report country-level results based on 14 different climate models in terms of percentage of GDP, again focusing on the agricultural sector. Their results show climate sensitivity of agriculture as an important factor. According to their pessimistic climate model, University of Illinois at Urbana-Champaign (UIUC), climate change impacts for the African continent can range from a potential loss of \$25 billion to a loss of \$194 billion per year, depending on climate sensitivity used. Up to 47% of the continent's revenue may be lost because of global warming. This assumption, however, takes into account limited adaptation and the models do not incorporate tropical crops. Their cross-sectional forecasts are less pessimistic, suggesting losses of 6% of agricultural GDP. For this reason, they argue that with expected growth in other sectors of the economy, agriculture is likely to be a small fraction of GDP in Africa by 2100. Country-level results vary. Countries predicted to suffer the largest losses in the agricultural sector in their descending order are: Nigeria, Sudan, Algeria, Cameroon, South Africa, Morocco and Gambia. These countries account for 47% of the damages in Africa. Expressed as a fraction of agricultural GDP, countries that are severely impacted are, in their descending order: Zambia, Niger, Chad, Burkina Faso, Togo, Botswana, Guinea Bissau, and Gambia. These countries are projected to suffer losses greater than 70% of their agricultural sectors, with Zambia, Niger and Chad losing their entire farming sector. As Mendelsohn et al (2000) acknowledge, the impact revealed by the estimates may be optimistic because they are based on US climate response functions. It is also possible that the US functions are too optimistic since they rely on capital intensive agricultural systems that have significant adaptive capacity.

A study of food-insecure countries in Sub-Saharan Africa yields similar results. Using HADCM3, CSIRO and CGCM2 models, Fisher et al (2002), show the following. Sudan, Nigeria, Senegal, Mali, Burkina Faso, Somalia, Ethiopia, Zimbabwe, Chad, Sierra Leone, Angola, Mozambique, and Niger lose cereal production potential in the 2080s for the other three climate models and across all the emission scenarios. These countries currently have 87 million undernourished, equivalent to 45% of the total undernourished in sub-Saharan Africa. In contrast, Zaire, Tanzania, Kenya, Uganda, Madagascar, Cote d'Ivoire, Benin, Togo, Ghana, and Guinea all gain cereal production potential in the 2080s. These eight gaining countries currently have 73 million undernourished, equivalent to 38% of the undernourished population in sub-Saharan Africa.

Other enlightening results are in studies that rely upon Ricardian cross-sectional approach to measure the relationship between net revenue from growing crops and climate. The results, based on 11 African countries, show that African farms are sensitive to temperature changes, so that farm values decline as precipitation falls or as temperature rises. The temperature elasticity with respect to net revenue is estimated to be -1.3, and precipitation elasticity of 0.4. These elasticities imply that a ten percent increase in temperature leads to 13% decline in net revenue, while a similar increase in precipitation increases net farm revenue by 4%. Dryland farms are more sensitive with a temperature elasticity of -1.6 and a precipitation elasticity of 0.5. Irrigated farms, on the other hand, tend to be more resilient to changes in climate and may even increase in value depending on their location in temperate regions. Even though farmers have some adaptations available to them like switching to more heat tolerant crops, subject to current technology, warming will have a devastating effect on dryland farmers. But not all Africa is likely to experience the same climate change effects, with humid regions being less vulnerable than the drier ones.

The results from uniform climate scenarios further show that African agriculture is extremely vulnerable to climate change. The impact of 2.5⁰C and 5⁰C warming will lead to net revenue losses of US \$ 49.2/ha and US \$95.7/ha, respectively, for Africa as a whole. The

total net revenue is predicted with losses of US\$16 billion (2.5⁰C warming) and US\$ 31.2 (5⁰C warming). Drylands suffer damages of US \$22.6 billion (at 2.5⁰C warming) and US \$37.7 billion (at 5⁰C warming). For irrigated farms, net revenue gains are US \$ 1.4 billion 2.5⁰C warming and US\$ 3.4 billion from 5⁰C warming. Reducing precipitation (by 7% and 14%) reduces both dryland and irrigated net revenue by approximately the same amounts per hectare. The impact of climate change to individual countries varies across climate models. Such impacts, however, are not uniform across Africa, and their distribution depends on the climate scenario and location. What seems evident though is that hotter and drier regions are likely to be hurt the most.

Further results based on Ricardian analysis also show that livestock net revenues are sensitive to climate variables. The climate effects vary according to farm size. If temperature increases by 2⁰C small farms gain livestock net revenue of 25% while income in large farms is reduced by 22%. Large livestock farms will be in trouble if warming increases to 5⁰C as their income falls by 35% and yet this will be good news to small livestock farmers since their livestock net revenues increase by 58%. Both small and large farms suffer declines in livestock net revenues if precipitation increases to 14%. The overall effect is losses in billions of dollars from livestock revenues since large farmers dominate the sector. There are several explanations for these impacts. First (see Seo et al (2005), many large farms rely on cattle which are dependent on moderate temperatures, while small farmers are able to shift from cattle to goats and sheep that are temperature resilient. Unlike large farms without animal substitutes, small farmers easily adapt as the temperature changes by switching to heat tolerant animals. Second, farmers shift into crops as rainfall increases, given rainfall increases crop productivity. Third, increased precipitation reduces the quality of grazing for animals as grassland become forests, and an increase in animal diseases reduces the population of livestock.

These results show the importance of adaptation actions by governments and farmers before climate changes. Examples vary, and include (1) switching to crops or livestock suited to hot and dry conditions to help countries to adapt to current and future climate zones; (2) reducing the vulnerability of the agricultural sector by adapting to profitable irrigated agricultural systems; (3) moving the economy from agricultural dependence to reduce the climate sensitivity of the whole economy.

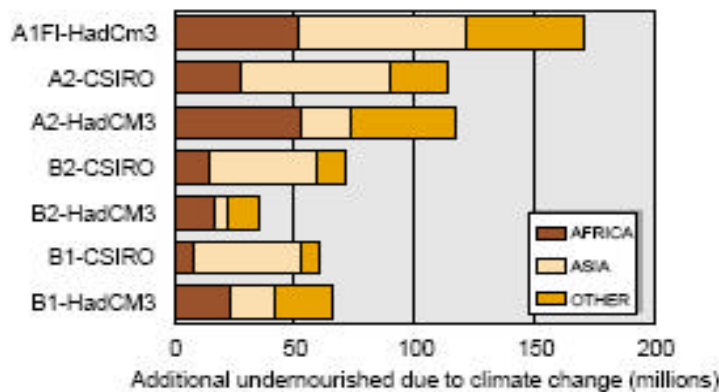
The main difference between the Ricardian and Reduced form models is that one freezes what farmers do and the other allows farmers to adapt. There is no question that farmers in Africa adapt. Farmers change whether they grow crops or livestock, they change which livestock and which crops they grow, and they change the planting dates and harvest dates all to accommodate climate. Failure to take this into account leads to reduced form model overestimating damages.

Criticism against the Ricardian model is that farmers will be slow to adjust. They certainly have been slow to adopt new technology in Africa. Mendelsohn's studies show that farmers have adapted to climate change in Africa, and the models used, as well as most models, try to address climate changes that will gradually unfold over 100 years or more. According to the models (Mendelsohn's), transition costs will be almost invisible to farmers in that farmers may not even notice they have adjusted to climate along the way.

Butt and McCarl (2005) provide additional insight to the impact of future climate change in Africa, and use the climate change projections from to Global Circulation Models – HADCM model and the CGCM model. In harmony with the other studies, their results, projected to 2030, show worsening conditions for African agriculture. Projected changes in cereal production are as follows: in Senegal yield losses range from 15 to 22%, and in Uganda,

losses range from 2 to 24%. Results for Mali show yield changes from +8 to -17% for sorghum. In Kenya, yields of maize, millet and beans increase while for sorghum and wheat yields decrease. Projected percentages of changes in cereal production as a result of climate change yield the following picture: Mali (-11.7%), Senegal (-14.5%), Kenya (+6.3%) and Uganda (-4.7%). In the case of Mali, for example, the implication is that malnourishment will increase from 30+% to over 50+%. Mali's forage yields will fall from 5 to 36%, and livestock animal weights reduced by 14 to 16%. Economic losses range from \$70 million to \$142 million. The population at risk of hunger will be expected to rise from current estimates of 34% to 72%. These results point to increased dependence of food import and weather induced price instability. Davidson et al (2003) findings also point to dire impacts of climate change, pointing out that by 2080 there could be a loss of up to 12% of the regions current cereal production, increasing the risk of food security. Figure 9 shows the total number of undernourished populations based on simulations with climate projections from the HadCM3 and the

the
differs.
show
hunger



CSIRO models. However, the regional distribution of occurrence of additional undernourished CSIRO results increased in Asian countries, HadCM3

while results show increased hunger in Africa and Latin America.

Figure 9: Additional number of undernourished due to climate change by region for SRES A2 in the 2080s (Source: Fisher et al., 2001).

Parry et al (2002) predicts the following impacts of climate change under a business as usual scenario. A 2°C increase could, by the 2050s, result in 12 million people at risk from hunger as a result of falling crop yields, and 20 million more people at risk from coastal flooding. Increases in temperature to 3.30C and 3.40C would result in an average of 60 million and 70 million, respectively at risk (Table 10). These figures show that the level of risk is highest in Africa. An increase of 4°C could result in 128 million more people at risk from hunger by the 2080s, with 108 million at risk from flooding. Coastal flooding will add to further losses as the tourism industry is adversely affected.

Table 10. Risk of Hunger - Africa

Model	2080s temperature increase above 1861 -1890 average	Impact
HADCM2	3.40C	<u>Africa</u> : 55 to 65 million more people at risk of hunger Globally: 80 million people at risk of hunger
HADCM3	3.30C	<u>Africa</u> : 70 million people at risk of hunger <u>Globally</u> : 125 million more at risk of hunger

Note: Compiled from data in Parry et al (1999)

All these studies provide evidence that African agriculture is very vulnerable to climate change and indicate the potential economic damages. The magnitudes in these studies differ because of the different assumptions made in modelling. Indicative though the studies may be, there are some problems to consider. Although there are established concerns about climate change in Africa, there is correspondingly little work that has been carried out to show how serious the problem will be. A serious problem with most African countries is paucity of quantitative information particularly on temperature and rainfall changes. The lack of data is a serious impediment to climate researchers since it limits them from using historical data and current events. Areas such as the Sahara are hardly covered, and in some countries some weather centres are known to have aged because of failure by governments to invest in both equipment and trained staff (Nature, 2005).

6.3.2 Glaciers and water supply

Projections show that the majority of the glaciers on Mount Kilimanjaro could vanish in the next 15 years if the recession of the icecap continues (an estimated 82 percent of the icecap surveyed in 1912 is now gone). Glaciers of Ruwenzori in Uganda and Mount Kenya face similar threats.

Vorosmarty et al., (2000) estimate that with a temperature increase of 1.5oC by 2025, North Africa will experience an increase in water stress. A recent global study, using SRES scenarios and different GCMs as well as a macro-scale hydrological model, indicates that by 2050s, northern and southern Africa will experience a general reduction in average annual runoff, while eastern Africa and parts of the arid sub-Saharan Africa will experience an increase (Arnell, 2004). The study further estimates that by 2025 about 370 million African people will experience increases in water stress (Table 11. In Southern Africa, the area having water shortages could increase by 29% annually by 2050 (against the current value of 9%), with Mozambique, Tanzania and South Africa being the most affected (Tyson *et al.*, 2002).

Table 11: People (millions) living in water-stressed watersheds by regions in Africa without Climate Change

Region	1995		2025			2055			2085		
	%	A1/B1	A2	B2	AI/B1	A2	B2	A1/B1	A2	B2	
Northern Africa	124.4	94	209.9	239.9	201.4	269	403.1	264.6	302.2	603.0	310.7
Western Africa	0.1	0	34.3	35.8	30.8	89.8	118.4	113.3	70.1	217.6	245.7

Central Africa	0	0	25.7	26.8	2.4	35	41.5	38.0	33.5	45.2	46.0
Eastern Africa	6.5	5	34.2	40.6	27.0	52.3	186.7	255.4	74.2	283.7	316.1
Southern Africa	3.1	2	35.6	37.6	32.9	50.3	60.8	126.7	48.2	100.5	187.6

Arnell, N.W. (2004): 'Climate change and global water resources: SRES emissions and socio-economic scenarios', *Global Environmental Change*, 14:31–52.

UNEP (2002) estimates that by 2025 nine countries mainly in eastern and southern Africa will face water scarcity (less than 1000 m³/persons/year), and twelve countries will face water stress (1000 to 1700 m³/person/year). Kigotho (2005) shows that by 2050 the monsoon winds that bring seasonal winds to Sub-Saharan Africa could be 10 to 20% drier than the 1950 – 2000 averages in southern Africa.

Assessments of the impacts of climate change on river flows and lake levels have also been conducted. In Egypt, an integrated assessment for the Nile predicts a decrease in river flow up to more than 75% by the year 2100, together with dramatic reductions in the Sudanese swamps. In these conditions, agriculture will be affected since normal irrigation practices cease when annual flow is reduced by more than 20%. The likelihood of such a situation occurring is greater than 50% by the year 2020 (Strzepek *et al.*, 2001).

6.3.3 Health

Projections indicate that climate change and small changes in temperature and precipitation will boost the population of disease-carrying mosquitoes and result in increased malaria epidemics (Lindsay and Martens, 1998). Increased flooding could facilitate the breeding of these malaria carriers in formerly arid areas (Warsame *et al.* 1995). To illustrate the adverse effect of flooding, The Sahel region, which has suffered from drought in the past 30 years, has experienced a reduction in malaria transmission following the disappearance of suitable breeding habitats. This reinforces expectation of risks of epidemics if flooding occurs (Faye *et al.*, 1995), and these problems will be exacerbated by the inability of many communities to cope with increased disease.

Studies argue that the greatest burden for malaria is borne by the African continent and that the burden of malaria remains unacceptably high for Africa. This contention is supported by the fact that over 60% and 90% of the clinical episodes and deaths from falciparum malaria occur in Africa south of the Sahara, where more than a million children mostly under the age of 5 years die from malaria each year (WHO, 2003). The economic burden of malaria is estimated at an average annual reduction in economic growth of 1.3% for those African countries with the highest burden with an estimated \$12 billion lost to the African continent's GDP annually (Sachs, 2001).

Studies have shown that in Africa climate change could be responsible for an additional 21 million – 67 million people at risk of malaria by the 2080s (Van Lieshout *et al.*, 2004). Previously unsuitable areas for malaria in Zimbabwe could become suitable for transmission with slight temperature and precipitations variations (Hartman *et al.*, 2002). Similarly, in South Africa the area suitable for malaria will double and 7.8 million people will be at risk by 2100 (Republic of South Africa, 2000). Tanser *et al.* (2003) using parasite survey data in conjunction with HAD CM3 GCM estimated a 5-7% potential increase (mainly altitudinal) in malaria distribution with little increase in the latitudinal extent of the disease by 2100.

6.3.4 Environment

6.3.4.1 Biodiversity (Ecosystem services)

The impact of predicted climate change on ecosystem services becomes clear when one examines what is already happening. Climate change has already affected the marine animals of Africa. Coral reefs in the Indian Ocean experienced massive bleaching in 1998, with over 50 percent mortality in some regions (Spalding, 2001). Damage to coral reef systems has far reaching implications for other important sectors of the economy such as fisheries, food security and tourism as well as for the overall marine biodiversity. In the Western Indian Ocean region, an average of 30% mortality of corals was recorded and losses in tourism in Mombasa and Zanzibar were estimated at about US\$ 12-18 million (Payet and Obura, 2004). Although there are a few studies that discuss how climate change will affect the terrestrial animals in Africa, available evidence points to loss or alteration of animal biodiversity especially those concentrated in the savannas and tropical forests. Also important are the consumptive and non-consumptive roles of biodiversity, and therefore the potential losses under climate change. For example, some forms of biodiversity are used as food, fibre, fuel, shelter, medicine, and wildlife trade. The tourism industry is an important nonconsumptive use of biodiversity. Many communities are, therefore, vulnerable to biodiversity loss which could result from climate change.

6.3.4.2 Bird migration (*Species lost*)

There are some unique bird species that may find other destinations as a result of climatic changes. According to Hockey (2000), about one-fifth of African bird species migrate on a seasonal basis within Africa, and that an additional one-tenth migrate annually between Africa and the rest of the world. Examples of these the waterfowl, which spend the austral summer in Southern Africa and winter in Central Africa, the Palaearctic migrants that spend the austral summer in locations such as Langebaan lagoon, near Cape Town, and the boreal summer in the wetlands of Siberia.

6.3.4.3 Large mammal migration (*Change in the size of habitat*)

East and Southern Africa have vast herds of migratory ungulates—rhinos, swine, and elephants among others. A major migratory system is located in the Serengeti area of Tanzania and the Masai-Mara region of Kenya. Reduced large-mammal migratory systems persist in the Kalahari (Botswana, South Africa, and Namibia) and Etosha (Namibia) areas of southern Africa. Typical migrations involve regular movement between dry-season and wet-season grazing areas, and are therefore sensitive to climate change. The impact of climate change on these systems is uncertain, but they could be compromised by climate change in the presence of additional land-use pressures.

6.3.4.4 Impacts on plants (*Species lost*)

Africa's biodiversity is concentrated in several unique native environments that are likely to be adversely affected by changes in rainfall. For instance, the Cape Floral Kingdom (fynbos), which is largely found at the southern tip of South Africa, has 7,300 plant species or 68 percent of the world species (Gibbs, 1987). Similarly, the adjacent Succulent Karoo biome contains an additional 4,000 species, of which 2,500 are native (Cowling et al. 1998). These two floral biodiversity hot spots occur in winter rainfall regions and face a potential threat by a shift in rainfall seasonality. A reduction in winter rainfall or an increase in summer rainfall alters the fire regime that is critical to the life cycle in the fynbos. Other important floral regions under threat include Madagascar, the mountains of Cameroon, and the island-like Afromontane habitats that stretch from Ethiopia to South Africa at altitudes above about 2,000 meters (Mace et al. 1998). Montane centres of biodiversity are particularly threatened

by increases in temperature because many contain isolated plant populations with no possibility of migration. Several thousand species of plants are potentially affected.

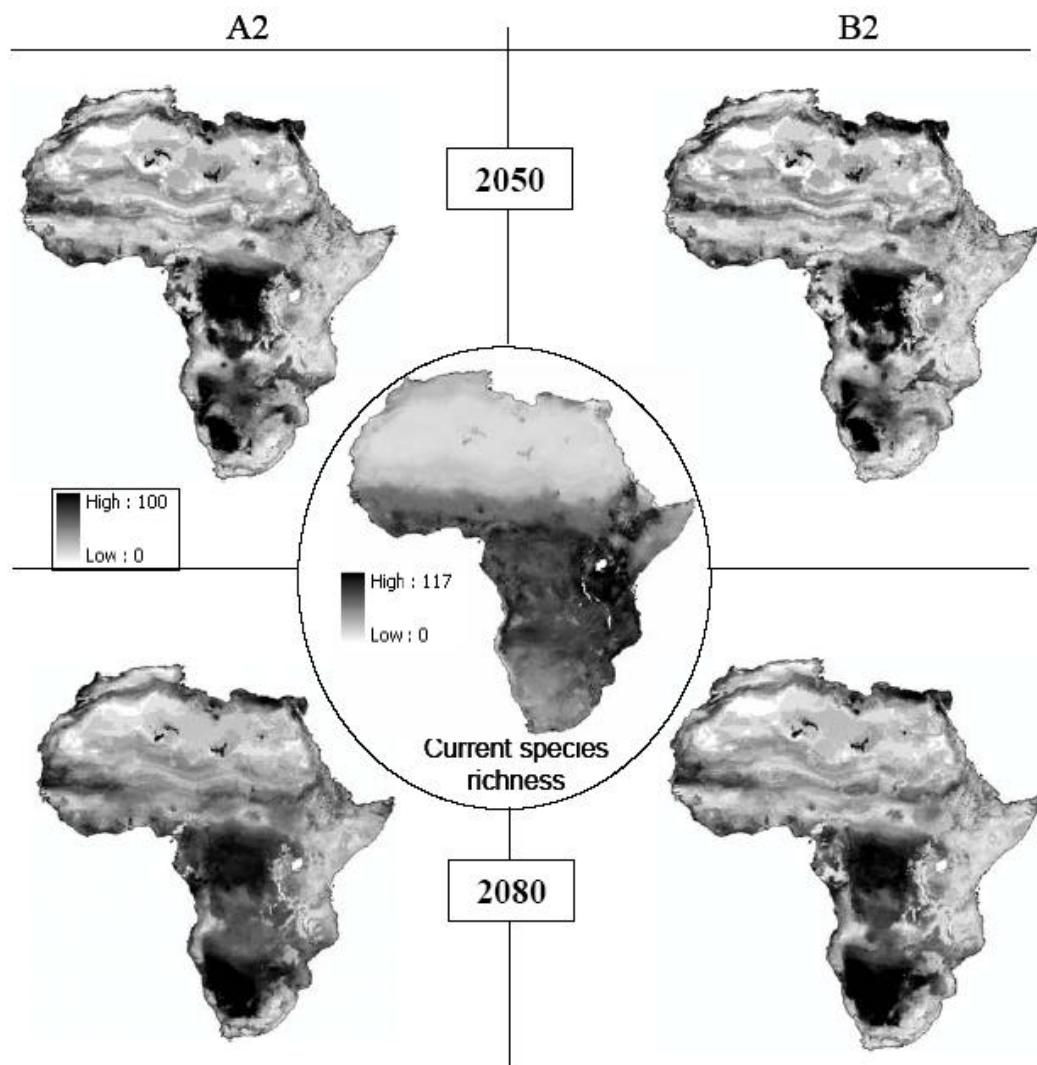


Figure 10: Percentage of species potentially lost by pixel for the two time slices (2050 and 2080) and the two story lines (A2 and B2). Current species richness is displayed at the centre of the figure. Source: Midgley and Thuiller (2006)

The species sensitivity of 141 national parks in sub-Saharan Africa were assessed using two Climate change scenarios (HADCM3, A2 and B2, for 2050 and 2080) applying a simple

IUCN Red List assessment of potential range loss (see Midgeley and Thuiller, 2005 for details). Assuming no migration of species, 10-15% of the species were projected to fall within the IUCN Critically Endangered or Extinct categories by 2050, increasing to 25-40% of species by 2080. Assuming unlimited species migration, the results were less extreme with these proportions dropping to approximately 10-20% by 2080. Spatial patterns of loss and gain showed contrasting latitudinal patterns with a westward range shift of species around the species-rich equatorial transition zone in central Africa, and an eastward shift in southern Africa, shifts which appear related mainly due to the latitudinal aridity gradients across these ecological transition zones (Figure 14).

6.3.5 Urban Impacts

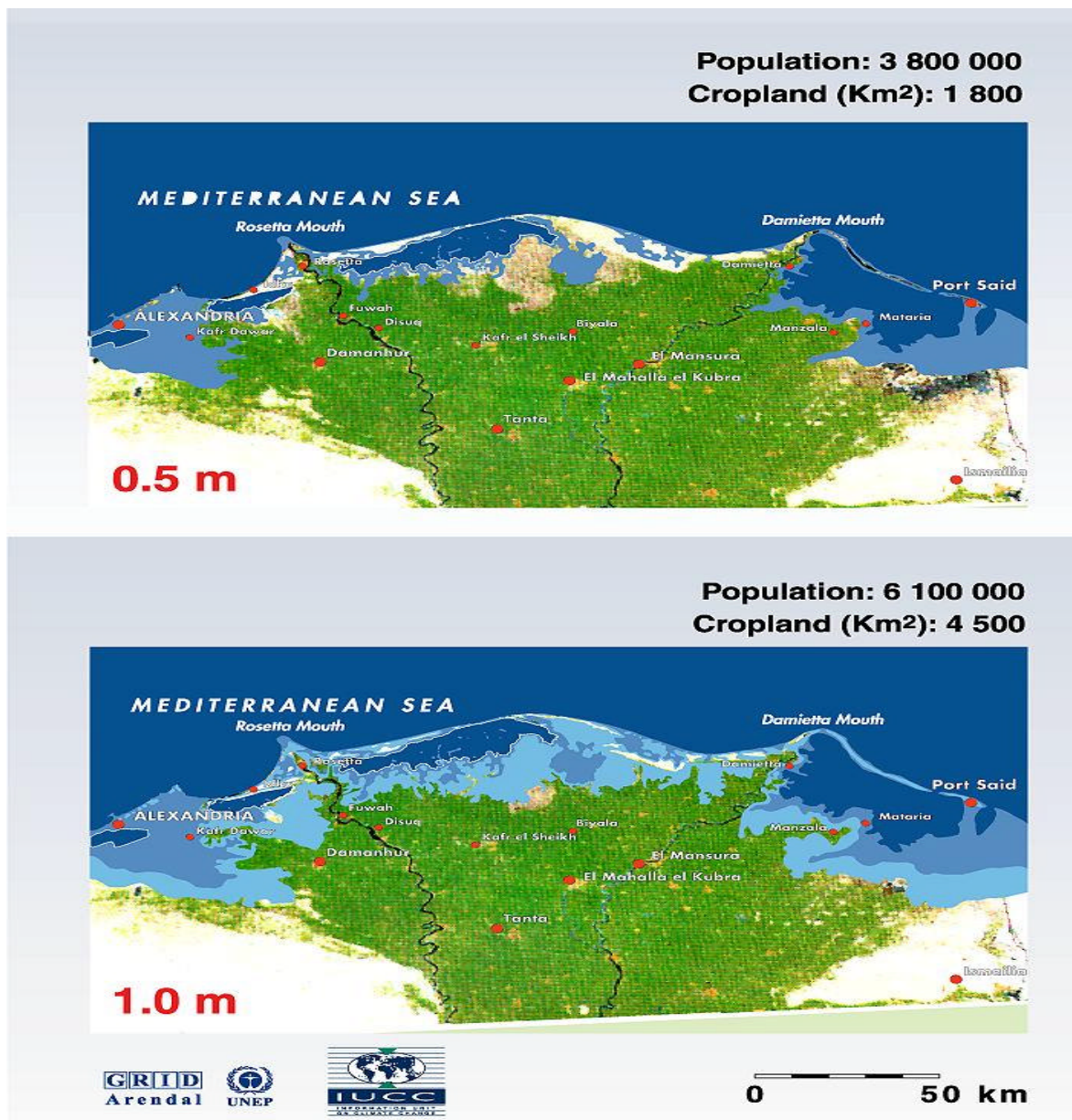
6.3.5.1 Sea Level Rise/Coastal Impacts

The potential for sea level rise as a result of global warming has been documented by several authors and country level studies. It is observed that even if global warming is kept below 2°C, sea level rise would continue into the next century. It is projected that many low-lying coastal areas will be inundated by sea level rise which could be up to 1.0 metres by 2100. Africa will not be spared the devastating impacts of this sea level rise. UNEP (2002) estimates that the number of people at risk from coastal flooding in Africa will increase from 1 million in 1990 to 70 million in 2080. Several large cities in Africa lie on or very close to the coast could suffer severe damages from sea level rise. Economic values at risk always represent a high percentage of the national GDP (between 5.8 and 542%) indicating a high socio-economic vulnerability of the African coastal states (Nicholls, 1995; Nicholls and Mimura, 1998). Population at risk represents between 0.5 and 17% of the total population of the coastal countries.

A business-as usual climate scenario estimates that a 2°C rise in temperature could place an additional 20 million people at risk from coastal flooding. An increase of 4°C could result in 108 million at risk from flooding. Egypt's coastal zone, with more than 40% of the population, will be hit the hardest. Sawahel (2005) argues that sea water will rise by 50 centimetres by 2050, forcing nearly 1.5 million people to migrate. The potential impact of sea level rise of 0.5m and 1.0 m on the Nile Delta in Egypt is presented in Figure 15. With a 0.5m sea level rise, population at risk will be almost 4 million, with almost 2,000 square km of cropland that could be lost. With a sea level rise of 1.0m, the population at risk is about 6 million with more than 4,000 square km of cropland that could be lost. The cost of a 0.5m sea level rise in Egypt without adaptation is estimated at about US\$2.5 billion (at 1992 prices), in addition to a loss of up to 14% of GNP, while the cost of protection is estimated at between 5 and 10% of GNP (van Drunen, 2005). Further estimates show that for Tanzania, a sea level rise of 0.5m would inundate over 2000km² of land, at a cost of approximately US \$ 51 million.

Sea level rise resulting from global climate change will pose a serious threat to coasts, lagoons and mangrove forests in countries such as Mozambique, Tanzania and Angola. In Benin and Côte d'Ivoire important palm oil and coconut plantations are located close to the coast (77.4 km² in Benin representing 33.6% of the inundated areas). In Ghana, the production of shallots is being threatened (Republic of Ghana, 2000) while in Kenya losses for three crops (mangoes, cashew nuts and coconuts) could reach 472.8 million US \$ for a 1.0 m sea level rise (Republic of Kenya, 2002). In Guinea, by 2050 between 132.6 and 234 km²

of rice fields (respectively 17% and 30% of the existing ones) will be lost due to permanent flooding (République de Guinée, 2002). In Nigeria, a total of 5,955 km² of agricultural lands (75% of the total agricultural area), will be threatened with a 1.0 m sea level rise (Awosika *et al.*, 1993). In the Niger delta, about 259 producing oil fields are located in the threatened areas, representing a value at risk of 10,790 million US \$ for a 1.0 m sea level rise (French *et al.*, 1995). In the Gambia, it is estimated that a 1.0m sea level rise could completely submerge its capital city, Banjul, leading to a loss of about \$217 million dollars. The cost of protection of the shorelines in Libya is 0.08% of the GDP, while it is 0.12% in Zaire.



Sources: Otto Simonett, UNEP/GRID Geneva; Prof. G. Sestini, Florence; Remote Sensing Center, Cairo; DIERCKE Weltwirtschaftsatlas.

Figure 15: Potential Impacts of Sea Level Rise on the Nile Delta

6.3.5.2 Infrastructure and Utilities

Africa has several large cities located along or in close proximity to the coast. More than a quarter of Africa's population lives within 100km of the coast, and projections suggest that the number of people at risk from coastal flooding will increase from 1 million in 1990 to 70 million in 2080. Coastal and inland flooding, related to excess rainfall, is also a risk for road, rail and air networks. This is particularly so for the several small island states in the continent such as Seychelles, Comoros island, Cape Verde, Madagascar, etc. The economies of these countries depend largely on tourism and sea level rise will substantially damage their physical infrastructure and utilities.

Low-lying roads and rails stand the risk of being flooded during heavy rainstorms and storm surges in areas close to the coast line. In Tanzania, a sea level rise of 0.5 m would inundate

over 2,000 km² of land, costing around US\$51 million (Table 5).

Table 5: Estimates (Tshs. Billions) for Structures at Risk for Various Areas in Dar es Salaam (Tanzania) for Sea Level Rise Scenarios of 0.5 metres and 1.0 metres

Area	Sea Level Rise Scenarios	
	0.5	1.0
Kunduchi/Mtongani	9.63	12.95
Mbezi Beach	14.65	26.64
Kawe	0.86	1.56
Mikocheni	0.38	0.70
Msasani	7.46	13.56
Oyster Bay	3.36	6.12
Hanna Nasif	1.73	3.14
Upanga	7.7	14.00
Kivukoni	3.54	6.43
Kigamboni	0.38	0.69
Shimo la Udongo	0.06	0.08
Kurasini	0.04	0.05
Mtoni/Mtoni Kijichi	0.04	0.05
Totals	49.83	85.97

6.3.6 Migration and Conflict

There is a high probability that climate change will be accompanied by resource degradation, such as increased droughts and desertification. Coupled to the rapidly rising population growth in Africa, this resource degradation could likely lead to increased competition for the scarce resources and heightened resource scarcity. Three types of resource scarcity can be readily identified: economic scarcity which refers to the quantity of a resource; ecological scarcity which refers to its quality, and structural scarcity which is caused by an unbalanced distribution of resources that severely affects less powerful groups in society. Resource scarcity can lead to declining agricultural production which is the mainstay of most economies of developing countries, economic hardship, migrations of people from areas of environmental stress, and tensions within and among groups (Homer-Dixon, 1994). When resource scarcity reduces the ability of states to meet the needs of their population, dissatisfaction can lead to declining state authority, which sooner or later nurtures violent collective action.

Climate change has the potential to trigger this type of situation. First, the poor will be most vulnerable to the adverse impacts of climate change and will not have the economic power to have access to scarce resources. For instance, Hare (2003) has estimated that with a temperature increase of between 1.5°C and 2.0°C, poor farmers' income declines significantly in the less developed regions. In short, climate change can exacerbate poverty, particularly in Africa. Environmental degradation and poverty breed environmental refugees as ECF (2004) has noted that a temperature rise of between 1.8°C and 2.6°C by 2050 could lead to large scale displacement of people (climate refugees from low food security, poverty and water stress).

Studies have shown a positive correlation between poverty and the propensity for conflicts as was the case in the Rwandan genocide where the conflicts broke out in the very poor areas as the poor are most likely to resort to violence than the rich and secure population (Gasana,

2002). Violence further exacerbates poverty in that besides disrupting economic activities, vital financial resources that could have been used for developmental purposes are diverted to prosecuting the war. There is loss of investors' confidence in conflict-prone economies. As a result there is a likely strong negative correlation between conflicts and direct foreign investments.

Climate change will create new environmental conflict hotspots that could lead to a significant increase in national and international conflicts over shared environmental resources, such as water and land (Levy et al., 2005).

6.4 Beneficial Impacts.

Not all changes will be negative: growing seasons may lengthen with better rains in some areas, or increasing temperature may deliver increased crop, livestock and fisheries yields. However, predicting what any of these changes are in the short-term is currently speculative, and beneficial impacts are likely to be outweighed by the adverse impacts of unpredictable change. Also, the dryness recorded in the Sahel has significantly reduced the incidences of malaria in the region.

7. SUMMARY OF IMPACTS

The range of potential impacts of climate change in Africa is highlighted in Figure 11. In harmony with IPCC (2001) findings, situations that make Africa particularly vulnerable to future climate changes include the following:

- The changing rainfall pattern affecting agriculture, and thus economic growth and development given the agricultural sectors contribution to GDP and dependence on agriculture in most African states
- Food security, at risk from declines in agricultural production and uncertain climate. Africa is already experiencing major deficits in food production in many areas. Countries that are food-insecure are therefore at greater risk about any worsening impacts of climate change. Many scenarios project decreasing grain yields and diminishing food security in small food importing countries with medium to high confidence (IPCCC WG III 2001).
- Natural resources productivity at risk and biodiversity that might be irreversibly lost. Extinction of animal and plant species is projected to have an adverse impact on rural livelihoods, tourism, and genetic resources.
- Vector- and water-borne diseases as a result of shifting temperature zones especially in areas with inadequate health infrastructure. Similarly, countries prone to droughts and flooding, particularly where there is inadequate sanitary infrastructure, will suffer most from increased water-borne diseases. This situation is worsened by inadequate funding allocated to public health in most African countries. According to IPCC WG III, the infectious diseases would adversely affect human health with medium confidence. Similarly, increases in droughts, flooding and other extreme events that add stress on water resources, human health and infrastructure are envisaged to constrain development with a high degree of confidence.
- Coastal zones vulnerable to sea-level rise, particularly roads, bridges, buildings, and other infrastructure that are exposed to flooding and other extreme events. Sea level rise and coastal erosion are bound to have an adverse impact on communities and economies especially given reliance on coastal marine fishery, and in exposing large

populations from infectious diseases related to flooding. Countries like the Gulf of Guinea, Senegal, Gambia, Egypt as well as those along the East–Southern African coast would be adversely impacted through inundation and coastal erosion with high confidence (IPCC WG III 2001).

- Exacerbation of desertification caused by changes in rainfall and intensified land use. Desertification threatens sustainable resource management, and undermines food and water security particularly in southern, North, and West Africa with medium confidence.

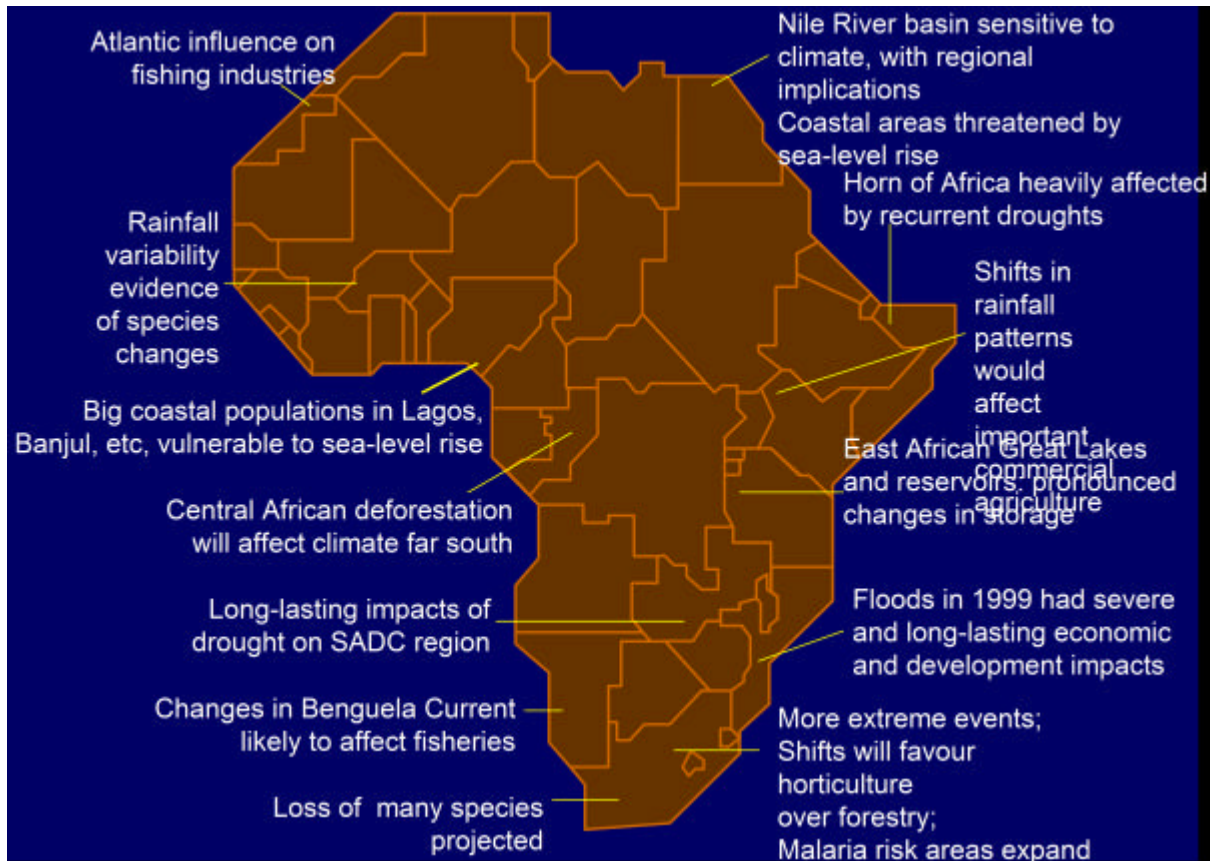


Figure 11. Key impacts of climate change in Africa

8: Adaptation

8.1 Africa's Adaptive Capacity

While adaptation presents itself as the most feasible option for dealing with climate change, the opportunity for effective adaptation is constrained by Africa's limited adaptive capacity. A number of factors can explain this low adaptive capacity of Africa. Such factors include financial constraints, pervasive poverty – where about 40% of the people in sub-Saharan Africa live below the poverty line, low technical skills, low research capacities, insufficient or lack of institutions able to deal with adaptation, and poor governance (Magadza, 2003).

8.2 Current Adaptation Strategies

Africa's adaptive capacity is generally considered low. However several factors are identified that have helped Africa cope with devastating impacts of climate variability and change. For instance, the Sahel was hit by a very devastating drought that brought the region to international attention in the early 1970s. However, in the early 1980s, the region was again hit by another major drought whose magnitude was worse than that of the 1970s, but the losses were minimal in comparison. Several factors can account for the resilience of the people. First, local populations are increasingly relying on local networks and groups to cope and adapt to times of climate and other stresses in Africa. Local savings schemes, many of them based on regular membership fees are useful financial 'stores' that are often drawn down during times of stress (e.g. Ellis and Bahigwa, 2003). Second, the role of the state and future governance in places such as the Sahel, for example, is changing rapidly as well as the region's linkages between countries and to global aid systems since the 1970s. Regional co-operation, such as the CILSS grouping (the Permanent Interstate Committee for the Fight against Drought in Sahelian countries founded in 1973 in the aftermath of the 1970s drought) does offer regional assistance during times of need, including the sharing of knowledge and best practice amongst a range of other possible advantages (e.g. eco-regional initiatives) (Batterbury and Warren, 2001). However, with the increase in the frequency and intensity of droughts brought about by global warming, it is likely that the adaptive capacity of Africans may be progressively weakened. The resources they draw upon to build their resilience will be eroded and the impacts of climate change may be progressively damaging in the near future.

Specific adaptation strategies that are being employed to reduce the adverse impacts of climate change are listed below.

8.2.1 Agriculture

In agriculture, for instance, the following adaptation strategies are implemented across Africa.

- *Seasonal changes and growing dates:* Some farmers have started adjusting to the changes in the onset and cessation of rainfall by changing their planting dates to coincide with the new rainfall regime.
- *Cultivation of different crop varieties and species:* Some drought tolerant and early maturing crop varieties are being cultivated across Africa.
- *Water supply and irrigation schemes:* Several indigenous small-scale rainwater harvesting schemes are being implemented across the region. This is augmented by dry season agriculture on fadama plains. The use of drop irrigation systems is also spreading in Senegal.
- *Other inputs and management adjustments.* The use of fertilizers is also being encouraged in several parts of the region. Also, several grain storage facilities are being developed and provided in the region as a significant proportion of the cereals produced are often lost due to poor storage. Multiple and flexible agricultural management tools and systems are also showing some positive results in enhancing agricultural yields. A simulation study examined wheat grain yield cultivated under current and future climate conditions (+1.5 °C and +3.6 °C) in Egypt, to elaborate a number of adaptation measures under irrigated agriculture system (Abou Hadid, forthcoming). By changing wheat cultivars, irrigation amount and sowing date, the reduction in the grain yield could be minimized from -28% to be -4% under climate change conditions of +1.5 OC, and from -37% to be -18% for +3.6°C. The increase

in crop water consumption could be minimized from 8% to 1% under climate change conditions of +1.5 OC, and from 42% to be 4% for +3.6⁰C.

- *Tillage.* Minimum and reduced tillage technologies in combination with planting of cover crops and green manure crops are being implemented by some farmers and are aimed at reversing existing soil organic matter, soil erosion, and nutrient loss and to combat potential further losses due to climate change. Reduced and minimum tillage techniques have spread widely in some countries in the region.
- *Improved short-term climate prediction.* Several agencies now provide seasonal climate predictions to help farmers take informed management decisions to reduce climatic uncertainties in their daily operations.
- *Livelihood diversification:* Several farmers are diversifying their livelihoods by engaging in more non-agricultural income generating activities, thereby reducing their exposure to climate risks.

8.2.2 Water Resources

Several mechanisms are currently being implemented to manage Africa's water resources in the face of climate variability and change. These include the construction of large dams to provide sufficient water for irrigation and urban consumption, formulation of good policy instruments, such as the development of regional institutions to manage shared river basins, and appropriate pricing mechanisms and reduction in water services losses to effectively manage water demand, particularly in the urban centres. Managers of the Seven Foks Dam on the Tana River in Kenya currently use climate information to assist decisions in water allocation. Assessments and lead-time analyses are made for the coming season with respect to setting up contingency planning for optimal allocation to water-reliant sectors (IRI, 2005).

8.2.3 Coastal Structures

Several strategies to prevent coastal damages are being put in place in several African countries such as in Nigeria and in Mozambique. The cost of building these coastal protection measures are however very prohibitive and beyond the budget of several poor African countries. However, small island states such as Seychelles are experimenting with the use of tree stumps to prevent beach erosion and damage to hospitality infrastructure along the coastlines. This strategy is being done in a participatory manner with local inhabitants and the hotel managers.

8.2.4 Health

Several measures are currently being implemented to reduce the burden of disease in Africa. Malaria is the frontline disease associated with climate change in Africa. Africa is currently implementing the "Roll Back Malaria" programme through the use of insecticide treated mosquito nets. Preliminary assessment of this programme is shown to significantly reduce malaria incidences in Kenya (Wandiga et al., 2005).

Conclusion

Africa is dominated by tropical weather patterns which make for highly variable climate under current climatic conditions. This increased climate variability, coupled with the high

dependence of African economies on agriculture and the direct consumption of natural resources, creates the potential for dramatic negative consequences of global climate change. Warmer temperatures have a potential of facilitating the increased breeding of vector-borne disease such as malaria, and hygiene-related illnesses such as cholera, etc. Climate change will also impose other costs to the economy, human development and the environment. The transport system could suffer because of destroyed roads and bridges, railway lines, waterways, affected harbors due to sea level rise, and disrupted air transport due to increased precipitation or bad weather. The adverse impacts in some parts of the continent are likely to trigger spontaneous migration as an adaptive option. While the region is making concerted efforts towards reducing the impacts of climate change through adaptation, it is imperative that the developing countries who contribute the bulk of the greenhouse gas that is responsible for global warming, should drastically cut their emissions. In addition, they should help Africa facilitate adaptation by providing the required resources (financial and technical) to enable Africa adapt to climate change.

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Appendix 1: CLIMATE CHANGE INDUCED DISASTERS IN AFRICA (DROUGHT)

COUNTRY	LOCATION	DATE	NUMBER OF PEOPLE		DAMAGE COSTS US \$
			Affected	Killed	
BURUNDI	Busoni, Bugabira, Ntega, Kirundo communes (Kirundo province), Muyinga province	January-2005	2,150,000	120	
	Muyinga, Kirundo provinces	January-2001	224,710		
	Bugabira, Busoni, Kirundo, Ntega (Kirundo province), Muyinga province, Cankuzo province, Moso and Imbo regions	July-2000	700,000	6	
	Kirundo, Gitega, Ruyigi, Cankuzo, Karuzi, Muyinga, Rutana, Makamba, Bugabira Provinces	October-1999	187,600		
DJIBOUTI	Ali Sabieh, Dikhil, Tadjourah, Obock, Djibouti	April-2005	150,000		
		August-2001	95,000		
		January-2000	150,000		
		August-1999	100,000		
	Gouvetto, Kabah-Kabah, Assamo, Guestir, Ali-Addeh, Ho-Hol (Ali-Sabieh dist.), Yokobi, Asseyla (Dikhil dist.), Makrassoul, Dorba, Assa-Guela, Dabnou, Adgueno, Assal, Neima, Debne-Auri, Bahlo (Tadjourah dist.), Adguenou (Obock dist.), Damerjob, Artawea	July-1996	100,000		
	Countrywide, especially Tadjourah	July-1988	30,000		
		April-1981	80,000		
July-1980		145,000			
ERITREA	Debut, Gash Barka, Anseba regions	2003-2004	2,300,000		
	Northern, Southern Red Sea regions	January-2002	900,000		
	Highlands and Red Sea regions	May-2001	738,000		
	Anseba, Northern Red Sea, Southern Red Sea regions	March-2000	335,000		
ETHIOPIA	Tigray, Oromiya, Amhara, Somali, Afar regions	2002	13,200,000		
	Afar region, East, North and South	2002	2,000,000		
	Amhara, Oromiya, Tigray, Somali, SNNPR, Afar	January-2002	14,300,000		
	Liben, Afder, Gode, Warder, Degah Bur, Siq (Somalia state)	March-2001	1,000,000		
	Ambassel, Kutaber (South Wollo), North Borena, East Haraghe, South Tigre, Welayita, Konso, Ogaden, Somali, Amhara, Oromiya, Tigray regions	March-2000	10,500,000		
	South Tigray, Wag Hamra, North and South Wello, North Shewa, East Harerge, Konso Special, VWereda, Welayita	April-1999	610,000		
		1998			156,000,000
	Somali state + Borena, Bale (Oromiya state) +South Ome zone	April-1997	986,000		
	Eastern and Southern	1992	500,000		
	Togray, Wello, Gondar, Ogaden, Harerghe	October-1991	6,160,000		

	Eritrea, Tigray, Harerge	October-1990	6,500,000		
	Northern Ethiopia, Eritrea, Tigray, Wollo, Gondar, Harerge	1989	3,800,000		
	Eritrea, Tigray, Wello, Shewa, Gama, Gofa, Sidamo, Gondar, Bale	1987	7,000,000		
	Eritrea, Tigray, Wello, Shewa, Gama, Gofa, Sidamo, Gondar, Bale	1987	330,000	367	
	Wollo, Tigray, Eritrea, Shoa, Gonder, Harerge, Sidamo	October-1984	7,750,000	300,000	
	Wollo, Gondar, Goe, Eritrea, Tigrai	May-1983	7,000,000		
	Wollo, Tigre provinces	1978	1,400,000		
	Wollo, Tigre provinces	1977	300,000		
	Kangra	1975			76,000,000
	Wollo, Tigray, Kangra provinces	Apr/1974		200,000	
	Tigre, Wollo, North Shoa	1973	3,000,000	100,000	
	Hamasion division	1969	1,700,000		1,000,000
	Nationwide	Jul/1965	1,500,000	2,000	
KENYA	Makueni, Kitui, Malindi, Kwale, Kilifi, Taita Taveta, Mandera, Wajir, Marsabit, Kajiado, Garissa, Myale districts (North East, East and coastal regions)	Dec/2005	2,500,000	27	
	Kitui, Mbeere, Mwingi districts (Eastern province), Turkana, Marsabit, Mijara, Mandera, Kajiado, Wajir, Garissa, Narok, Tana river districts (North Eastern province), Kilifi, Kwale Taita Taveta districts (Coastal provinces),	June-2004 July-2004	2,300,000		
	Pokot district	Aug/2002	150,000		
	Turkana, Marasabit, Isiolo, lowlands of Samburu, Tana river, and several other areas	Apr/2001	4,400,000		
	Baringo, Garissa, Isiolo, Kajiado, Kitui, Machakos, Makueni, Mandera, Mbeere, Moyale, Mwingi, Samburu, Tana River, Tharaka, Turkana, Wajir, West Pokot, Marsabit, Laikipia, Marakwet, Keiyo, Nyeri, Taita Taveta, Kwale, Lamu, Kilifi, Trans Mara, Nyandarua, Maragua, Ijara, Koibatek, Narok	Jan/2000	4,212,600	85	
	Garissa, Isiolo, Wajir, Mandera, Turkana, Baringo, Kifili, Meru, Makueni, Marsabit/moyale, Tana river, Kitui, Mwingi, Mbere, Tharaka Nithi, Nyambene, Machakos, Taita Taveta, Muranga/Makuyu/Maragwa, Kajiado, Kilifi districts	28/Feb/1997	1,600,000		
		Jan/1995	1,200,000		
	Niortheastern regions	1992	2,700,000		
		1984	600,000		
	Turkana district	1980	40,000		

	Countrywide	1971	150,000		1,500,000
		1965	260,000		
MADAGASCAR	Vangaindrano district	Nov/2005	14,000		
	South	2003	600,000		
	Ambovombe, Amboasary, Bekily, Ampanihy, Beloha, Tsihombe, Ambatondraza, Amparafaravola, Andilamena, Vatomandry, Manahoro, Marolambo, Antanambao, Manamposty, Antsirabe, Faratsiho, Antanifotsy, Betafo	Jun/2000	231,290		
	South	May/1992	950,000		
	South	Dec/1990	250,000		
	South	Apr/1988	116,500		
	Toliary, Tolagnaro	1981	1,000,000		
MALAWI	Southern and central regions	Oct/2005	4,500,000		
	Balaka, Nlentyre, Chikwawa, Machinga, Mangochi, Mulanje Nsanje, Phalombe, Thyolo, Zomba	Feb/2002	2,829,435	500	
	Dedza, Dowa, Mzimba, Nkhotakota, Ntcheu, Salima districts	1995			
	Dedza, Dowa, Mzimba, Nkhotakota, Ntcheu, Salima districts	Feb/1994	3,000,000		
		Apr/1992	7,000,000		
		1990	2,800,000		
MAURITIUS		Nov/1999			175,000,000
MOZAMBIQUE	Maputo, Gaza, Inhambane, Manica, Sofala, Zambezia, Tete regions	May/2005	1,400,000		
	Magoé, Zumbo, Cahora Bassa, Changara, Moatize, Chiuta, Mutarara districts (Tete province)	Jan/2003	175,000	9	
	Chibabava district (Sofala province)	Apr/2002	300,000		
	Maputo, Gaza, Inhambane provinces (South), Sofala, Tete, Zambezia provinces (Center)	Mar/2002	600,000	9	
	Inhambane region	Jan/2001	100,000		

	Maputo, Gaza, Inhame	Feb/1999	3,300,000		
	Inhambane province	Sep/1987	8,000	50	
	Maputo, Gaza, Inhambane, Manica, Sofala, Zambezi	1985	2,466,000	100,000	
	Maputo, Gaza, Inhambane, Manica, Sofala, Zambezi	Feb/1983	4,750,000		
	Cabo Delgado, Nampula, Tete, Manica provinces	1982			
	South, Central	1981	4,000,000		
		1980	6,000,000		
RWANDA	Gashora, Bugesera districts	2003	35,000		
	Kibungo, Kigali rural, Umutara, Butare, Gitarama prefectures - Muyinga, Kirundo provinces	Jun/2000	270,000		
	Umutura, Kibungo, Kigali Rural, Gitamara, Butare, Gikongoro	Nov/1999	894,545		
	Widespread	Feb/1977	1,700,000		
SOMALIA	Gedo, Bakol, Bay, Hiran, Middle and Lower Juba regions	2005	200,000	2	
	Sool Plateau, Sanag, Togdheer, Nudal valley, Mudug	2004			
	Garbaharey, Burbudo districts (south), Gedo, Bay, Baakool regions	Dec/2001	500,000		
	Bay, Bakool regions	Jun/2001	1,100,000		
	Rabdure, Elberde, Tiyaglow, Hudur districts (Bakol Province), Gedo, Bay, Hiran regions	Jan/2000	650,000	21	
	Awdal, Gedo regions	1988	53,500		
	Togdheer, Sol, Sannag, Bari, Nugall, Mudug, Galguduud, Hiraan, Bakool, Shabeellaha hoose, Gedo	1987	500,000	600	
	North West to Central areas	1974	230,000	19,000	
	East Burao, North Mudugh	1969	30,000		500,000
	Nationwide, Galcaio	Dec/1964	700,000	50	
UGANDA	Kalapata, Nyakwae (Kotido district), Rupa, Nadunget (Moroto district), Karamoja region	Mar/2005	600,000		
	Moroto, Kotido, Nakapiripirit (Karamoja region)	2000-2005	586,326		
	Moroto, Kotido (Karamoja Region)	Jan/2000	190,000	115	
	Northern Karamoja District	1999	700,000		

		1998	126,000		1,600,000
	Northwestern	1988	600,000		
	Karamoja	1987	331,000		
	Karamoja	1980	500,000		
	Karamoja	1967	25,000		200,000
ZAMBIA		2005	1,200,000		
	Southern, Western, Eastern provinces	2002-2005	3,162,000	12	
	Itezhi-Tezhi, Kalomo, Kazungula, Mazabuka, Namwala, Siavonga, Sinazongwe districts (Southern), Kalabo, Koama, Lukulu, Mongu, Senanga, Sesheke, Shangombo districts (Western)	Mar/2001	830,630		
	Southern, Western, Central & Eastern Lusaka Provinces	Aug/1995	1,273,204		
		Feb/1992	1,700,000		
	Chipinge, Gwanda, Umzingwane, Chiredzi, Hwange, Kariba, Guruve, Mberengwa, Chivi, Matobo, Tsholotsho, Masvingo	Mar/2002	6,000,000		
	Kwekwe, Gokwe South, Zvishavane, Shurugwi, Gweru, Mvuma, Mberengwa, Gokwe North (Midlands province)	Feb/2001	700,000		
	Southern (Matabeleland)	Aug/1998	55,000		
		1995	5,000,000		97,000,000
		1994	5,000,000		
		Apr/1992	4,600,000		
		1984			1,000,000
1982		700,000		2,500,000,000	

Source "EM-DAT: The OFDA/CRED International Disaster Database
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