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Fighting climate change: Human solidarity in a divided world

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Climate Change and Human Development in Africa: Assessing the Risks and Vulnerability of Climate Change in Kenya, Malawi and Ethiopia

Intergovernmental Authority on Development (IGAD)
Climate Prediction and Applications Centre (ICPAC)

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Climate Change and Human Development in Africa:
Assessing the Risks and Vulnerability of climate Change in Kenya, Malawi and Ethiopia

DRAFT REPORT

By

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1. Introduction

Human induced climate change emanating largely from increase in the concentration greenhouse gases in the atmosphere and sustainable development are two closely related challenges facing human kind in the 21st century (Figure1.1). The challenges associated with the devastating effects of climate change (Table 1) has been addressed by the United Nations Framework Convention on Climate Change (UNFCCC) which calls for stabilization of the Greenhouse gases (GHGs) emissions in the atmosphere at a level that would prevent 'dangerous anthropogenic interference' with climate system, with a time frame sufficient to allow ecosystems and the environment as a whole to adapt naturally to climate change, to ensure that food production is not threatened, and enable economic development to proceed in sustainable manner.

Table 1.1: Impact of climate change on poverty and the Millennium Development Goals (*Source: DFID, 2004*)

Impact of Climate Change on Poverty and the Millennium Development Goals		
Changes in mean climate, extreme events, variability and sea level rise ⇨	Impact on poverty ⇨	Impacts on Millennium Development Goals
Increased temperature and changes in precipitation reduces **agricultural & natural resources**	Lowered industrial output and labor productivity, high inequality, impacts on trade and fiscal and macroeconomic burdens lead to **reduced economic growth**, and its poverty reducing effects	**Goal 1:** Eradicate poverty and extreme hunger **Goal 2:** Achieve universal primary education
Change in precipitation, run-off and variability leads to greater **water stress**		**Goal 3:** Promote gender equality and empower women
	Reduced productivity and security of **poor people's livelihood and assets,** and reduced access for the poor to their livelihood assets	**Goal 4:** Reduce child mortality **Goal 5:** Improve maternal health **Goal 6:** Combat HIV/AIDS, malaria and other diseases
Temperature, water and vegetation changes contribute to **increased prevalence of disease**		**Goal 7:** Ensure environmental sustainability
	Less effective coping strategies among the poor, and increased **vulnerability** of poor people	**Goal 8:** Promote global partnerships

Africa is very vulnerable to the current climate variability including the recurrent droughts and floods. Today recurrent extreme climate events such as floods, cyclones, and droughts are devastating most economic, social and environment systems in Africa. The combined impact of HIV/AIDS, declining commodity prices and, in certain areas, conflict, has significantly reduced the capacity of poor households in Africa to cope with shocks of extreme climate events. The impacts of future climate changes on economies and livelihood assets in Africa will be very devastating. Climate change and existing climatic variability are likely to impact negatively on sustainable development plans of many African nations, and will almost certainly make the process of international, regional and national poverty reduction efforts to be only dreams due to the:

- Likely negative effect on economic growth – the rate and pattern of which is critical to eradicating poverty;
- Direct effect on poor people's livelihoods and the assets upon which they depend; and
- Increasing level of risk to which countries and people already extremely vulnerable to shocks are likely to be exposed.

There is urgent need for realistic adaptation options to reduce the vulnerability of environment, strengthen society livelihoods and economic systems, and cope with the consequences of current extreme climate variability and future climate change in Africa. Adapting to future climate changes would require developing systems capable of absorbing the current climate shocks and at the same time integrate future climate change risks.

This report reviews climate change and human development in Africa with special reference to assessing the risks and vulnerability of climate Change in Kenya, Malawi and Ethiopia. The report presents the current state of global and regional climate change and projections for 2030 and 2050.

1.1 Global climate change issues

IPCC (2001) noted that averting 'dangerous anthropogenic interference' with climate system will require dramatic shift in energy policy at the national and international levels to prevent, for example, Carbon dioxide (CO_2) emissions exceeding 400-450 ppmv. According to the latest assessment (IPCC, 2007), the concentrations of most of the GHGs are increasing at rates larger than reported in the Third Assessment Report (TAR). However, the concentrations of some of the Montreal Protocol gases, for example methane, are declining.

Subsistence rain-fed agriculture is the mainstay of most African economies contributing GDPs that range from 10% to 70% , while African agriculture has the slowest record of productivity increase in the world (Mendelsohn et al, 2000) and is the only major region with a decline in food production per capita during 1980–2000 (Sachs et al., 2004). 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 poorest inhabited continent in the world and, on average many of the countries in it are poorer than they were 25 years ago. Although some African countries recorded some modest growth during the 1990s, this growth only recovered ground lost during the 1980s in most cases. The continent remains mired in poverty and a strangling debt portfolio. The number of people living below the poverty line has increased by 50% over the last 14 years (Amoakoh, 2004 quoted in Nkomo, *et al.*, 2006). 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 1.1). There is also considerable internal variation in economic development within countries. Urban areas, especially capital cities, are generally wealthier than rural zones.

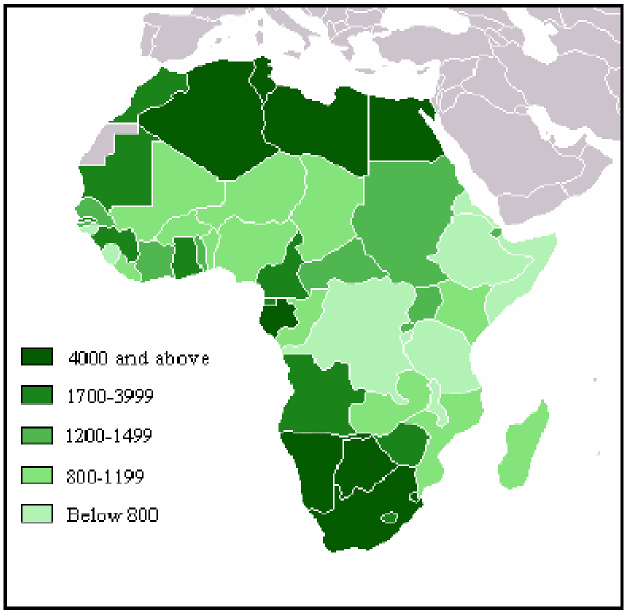


Figure 1.1: African States by GDP per Capita in US Dollars (2002): *Source: Wikipedia*

Sachs et al (2004) noted that, apart from climate stress, some of the constraints to Africa's economic development include very high transport costs, small market size, low-productivity agriculture, a very high disease burden, adverse geopolitics and a very slow diffusion of technology from abroad, among others.

The UNDP's *Human Development Report* (2007) is intended to explore the linkages between climate change and human development, focusing on the twin themes of risk and vulnerability as key determinants of well-being of areas affected by climate change. The *report* is expected to include four broad clusters namely:

- Climate change impacts and adaptation – implications for human development
- Living within a carbon budget – the agenda for mitigation
- The Kyoto Protocol and beyond – the world after 2012
- Statistics and measurement

This ***Thematic paper*** is part of the first cluster which is devoted to *Climate change impacts and adaptation: implications for human development* that is expected to provide state-of-the-art climatic modeling systems to generate map-based projections of climate change at regional, national and sub-national scales of analysis, to identify and assess key geographic locations where climate change impacts such as drought and flood are projected to be particularly severe in terms of frequency and intensity, and examine the livelihood and broader economic impacts of these locally-specific projections.

The focus of this ***thematic paper*** includes:

- A review of evidences of climate variability and change in Africa, and the assessments of vulnerabilities to current climate extremes
- A regional overview identifying increased risk of drought or flood to 2030 and 2050
- Discussion of map-based projections detailing how the model anticipates climate change to 2030 and 2050, both regionally, and for specific countries and sub-national areas with specific reference to Ethiopia, Kenya and Malawi
- Assessment of the development and application of African climate models in early warning and forecasting systems with special reference to establishing needs for users, dissemination of information, key gaps, failings and recommendations

2. Impacts and vulnerability to Climate variability and change in Africa

Africa's environment and socio-economic systems are highly vulnerable to the impacts of climate extremes such as droughts and floods (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). These conditions have persisted to the present day, with signs of increasing wetness, especially during the La Niña years of the 1990s as can be seen in Figure 2.1 (Ogallo 1989,1993). During the mid-1980s drought's economic losses in Africa totaled several hundred million US$ (Tarhule and Lamb, 2003).

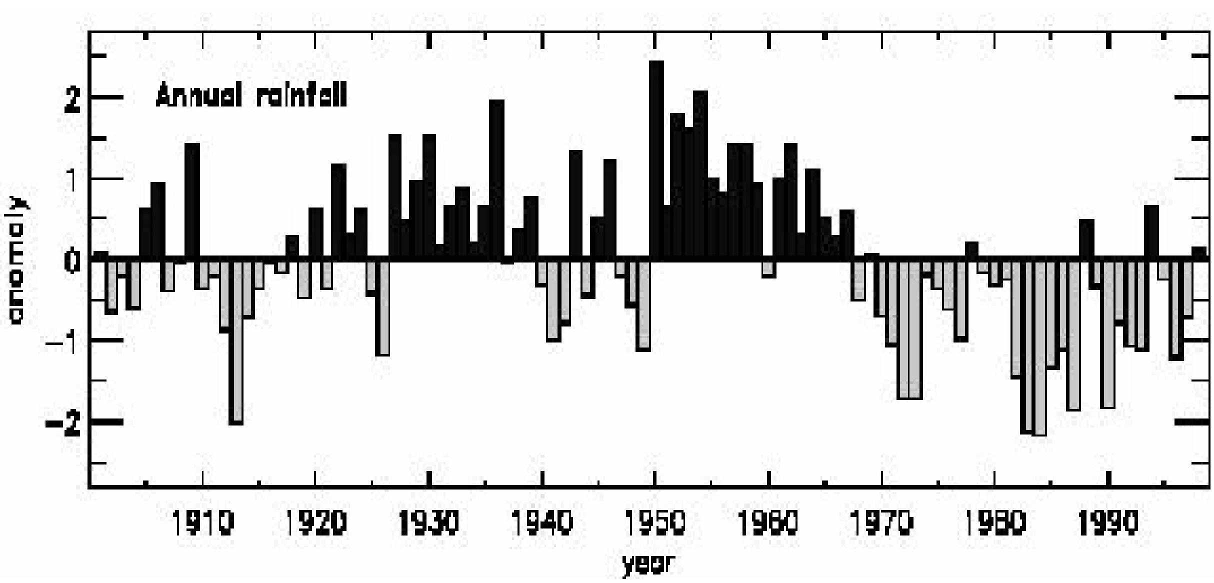


Figure 2.1: Spatially aggregated annual rainfall anomalies (in standard deviations) for the Sahel. Anomalies are calculated with respect to the mean for the entire series (1901-1998) (*Source: Adger and Brookes, 2001)*

The gradual yet dramatic disappearance of tropical mountain glaciers such as on Mount Kilimanjaro has been attributed partly to global warming (IPCC, 2001). An estimated 82 percent of the icecap that crowned Mount Kilimanjaro when it was first thoroughly surveyed in 1912 is now gone. According to recent projections, if recession continues at the present rate, the majority of the glaciers on the mountain could vanish in 15 years. Glaciers on the other African mountains are also retreating very fast. The snow and glaciers act as a water tower, and several rivers are drying out in the warm season due to the loss of this frozen reservoir. Figure 2.2 shows the instrumental record trend of mean annual temperature in Africa. Significant temperature increase in the recent years is very evident.

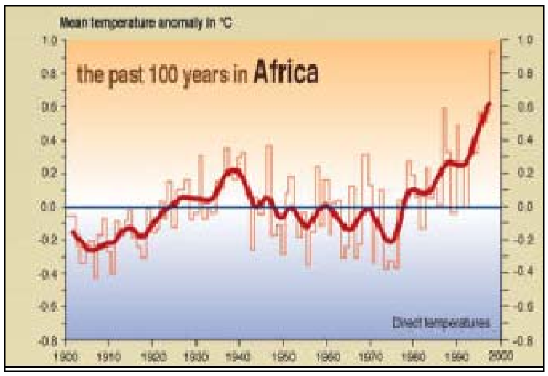


Figure 2.2: Mean annual temperature trend in Africa (*Source: IPCC, 2001*)

Most 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 runoff associated with variations in rainfall which ultimately affect river flows have been observed in Africa.

Many diseases in Africa such as malaria are known to be sensitive to climate factors. A study in Ghana by Agyemang-Yeboah (2005) (quoted in quoted in Nkomo, *et al.*, 2006) confirms a positive correlation between malaria, cholera and meningitis, and climatic elements (Figures 2.3a-b). The strong correlation between malaria epidemics and anomalously high rainfall has also been observed in both the east African highlands (Githeko and Ndegwa, 2001) and in semi-arid areas of Africa (Thomson et al., 2006, IRI, 2005). 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 (2002) have noted a five-fold difference in GDP between malarious and nonmalarious countries.

Other climate sensitive diseases are also common in Africa. For instance, vector-borne diseases such as Rift Valley Fever (RVF) increase dramatically during periods of above normal temperature and rainfall. Cholera, a water and food-borne disease is common in Africa during the periods of too heavy rainfall and floods such as during periods of strong El Niño years at some locations. Figure 2.4 highlights some of the impacts of disasters that are associated to climate extremes in Africa between 1971 and 2000.

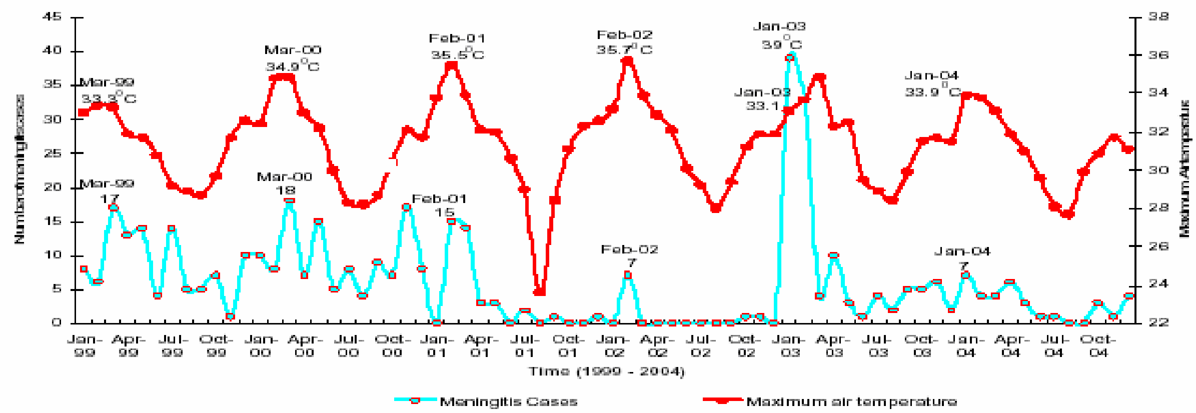


Figure 2.3a: Distribution of meningitis cases

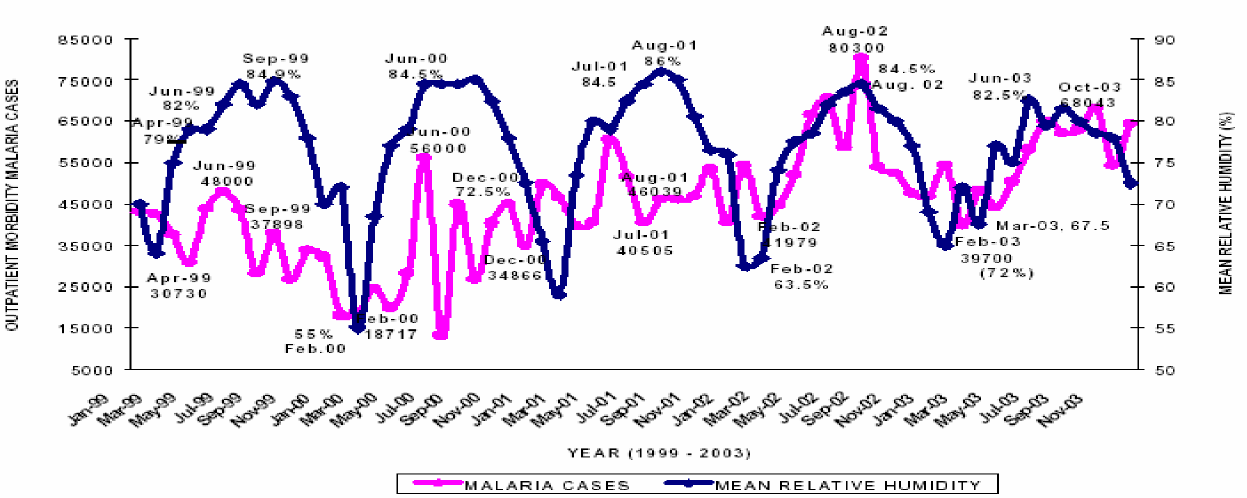
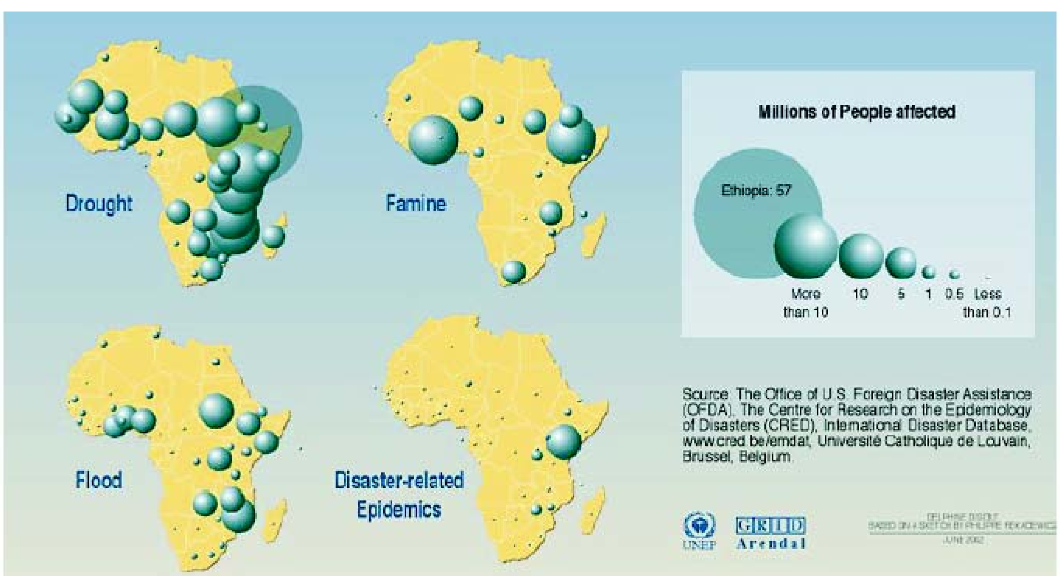


Figure 2.3b: Distribution of malaria cases and Relative Humidity *(Source: WHO, 2003)*



Source: UNEP – Vital Water Graphics, 2005

Figure 2.4: People affected by natural disasters in the period 1971-2000

This report reviews climate change and human development in Africa with special reference to assessing the risks and vulnerability of Climate Change in Kenya, Malawi and Ethiopia whose locations are shown in Figure 2.5, and the adaptation options.

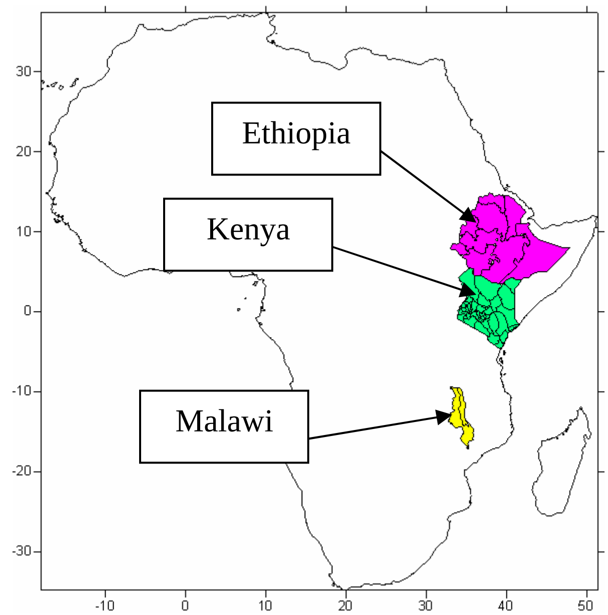


Figure 2.5: Map of Africa showing the position the case study countries of Malawi, Ethiopia and Kenya

3. Climate Variability and Change in Kenya, Ethiopia and Malawi

This section is devoted to climate change issues in the three case study countries. The extent and pattern of economic growth in any country is the outcome of the interaction of the country's initial conditions, institutions, policy choices, and the external shocks or stimuli they receive and lack. Climate variability and change add to this complex picture through their impact on key sectors of the economy, or important drivers of growth, including agriculture and natural resources, water, health and infrastructure.

3.1 Kenya

Kenya lies between latitudes 5° North and 5° South and between longitudes 34° and 42° East on the eastern side of the African continent. Rain-fed agriculture is one of the main sectors of the economy. Additionally, livestock production is central to livelihoods and food security in the arid and semi-arid lands (ASALs). Weather-related hazards therefore present a serious threat to the socio-economic development of the country.

Traditionally, the ASALS have been more prone to droughts. These have been exacerbated by refugees resulting from armed conflicts in neighboring countries, and localized conflicts over limited resources by communities living in these areas. Increased population, sedentary lifestyles and introduction of some rain dependent crop farming have sometimes restricted the migration of the pastoralists making the society more vulnerable to climate variability and change.

In recent years some droughts have persisted for quite a long period, as can be seen in Figure 3.1. Some of the long droughts have been followed or preceded by floods, especially those associated with El Niño / La Niña (Ogallo, 1988, 1989, 1993). It has been noted that, when weighted by GDP impact, droughts pose a substantially higher risk than floods throughout the country. Table 3.1 shows the trend in the number of people affected by droughts in Kenya.

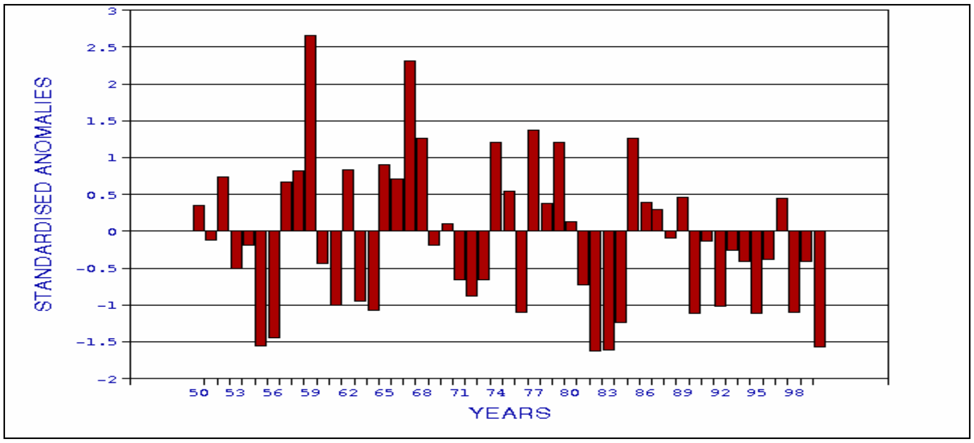


Figure 3.1 Temporal variations of the March-May rainfall season in North West Kenya

Table 3.1: Numbers affected by drought in Kenya, 1975–2006

Year	**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
2004-6	2.5 million initially to 3.5 million currently estimated

Source: National Disaster Management Policy, Republic of Kenya, 2004; and rapid food security assessments by the Kenya Food Security Steering Group

3.1.1 Current Climate and Evidence of Climate Change

Over two-thirds of the country receives less than 500 mm of rainfall per year and 79% has less than 700 mm per year (Figures 3.2a). The degree of variability is highest in the Arid and semi arid areas (Fig 3.2b). Most of the country experiences a bimodal rainfall seasonal pattern, with two rainy periods, namely the short rainfall season concentrated within October to December and long rainfall season in March to May. The hot dry season is concentrated within mid-December to mid-March; while June to August is generally a cool and dry season with parts of western Kenya having a third rainfall season during this period. Substantial rainfall is received near some large water bodies, especially Lake Victoria, throughout the year.

Both instrumental and proxy records have shown significant variations in the space-time patterns of climate in Kenya. Such records include indices derived from temperature (Figure 3.3), rainfall (Figures 3.1 & 3.4), and changes in lake levels and associated impacts (Figure 3.5a&b). Details of these can be obtained from Birkett *et al*., 1999 and Ogallo, 2002. Increase in extreme rainfall events in the recent years is evident in Figure 3.4.

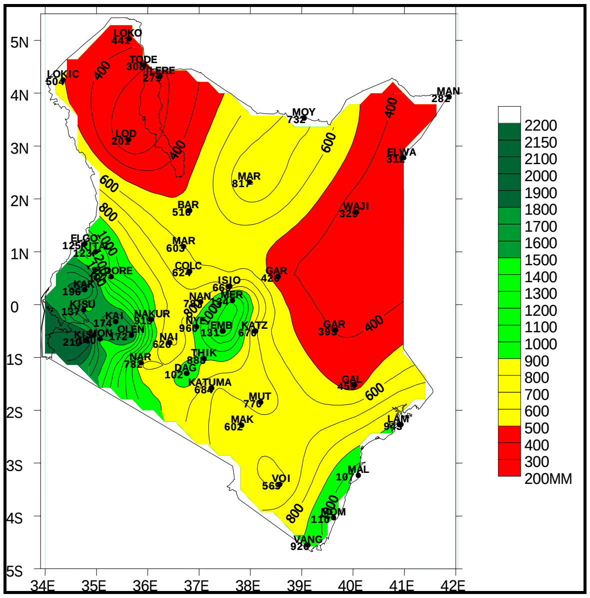


Fig. 3.2a: Distribution of mean annual rainfall (showing wetter areas bordering Lake Victoria and central highlands of the Rift Valley)

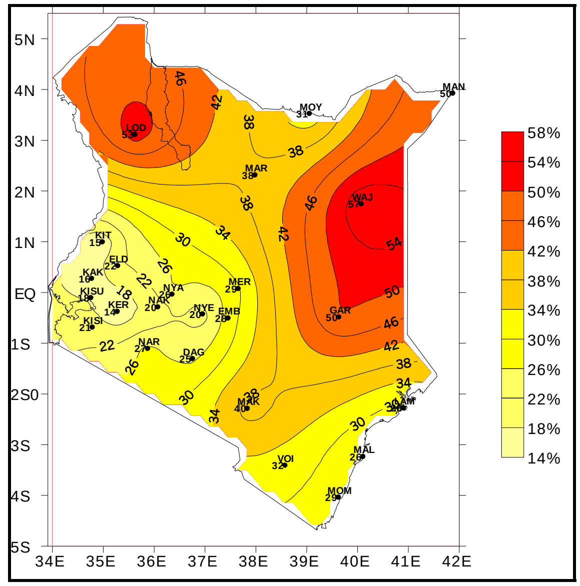


Fig. 3.2b: The coefficient of variation of annual rainfall in Kenya (higher values in areas with large intra-annual variability)

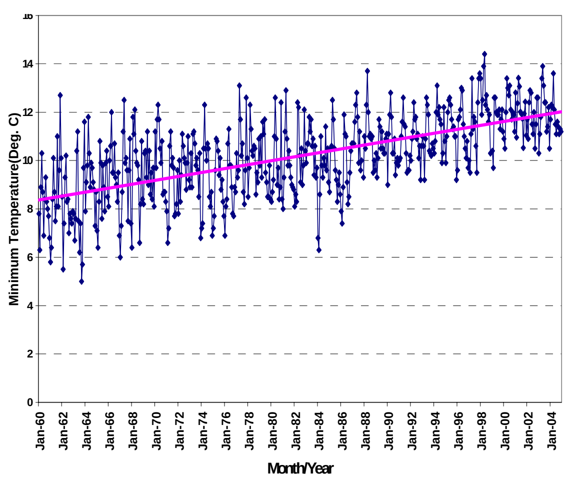


Fig 3.3: Minimum temperature for Kericho

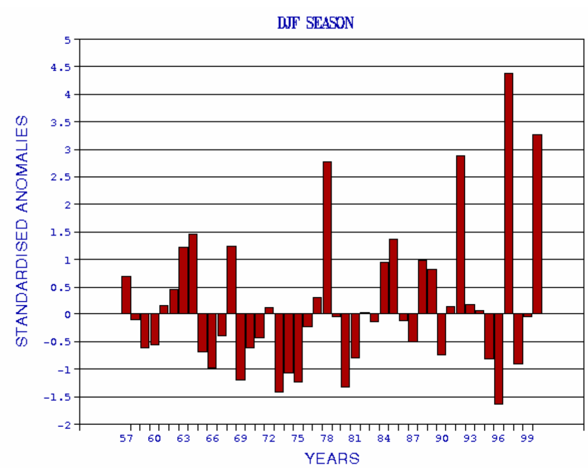


Fig 3.4 Recent increasing trend of December – February seasonal rainfall in coastal Kenya

Figure 3.5a: Fluctuations in the levels of Lake Turkana, 1888-1990 *(Source: World Lakes Database 2002)*

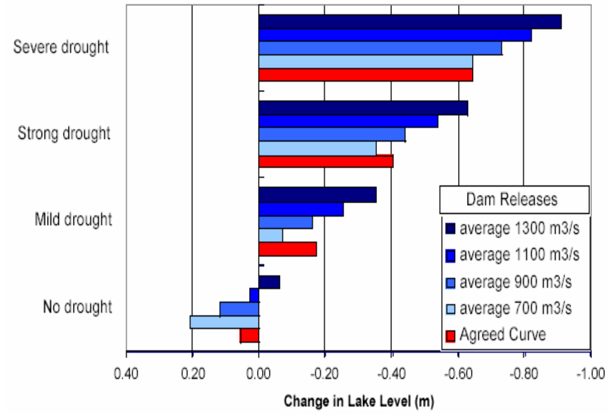


Figure 3.5b: Impact of droughts and dam operations on L. Victoria levels, *USDA (2005)*

Natural disasters related emergency relief seems to be an integral part of Kenyan ASALS livelihood systems, although there is significant variability from year to year. Table 3.3 lists the number of people needing emergency relief in Kenya since 1965 due to drought and flood disasters. The most severe events in this period were those of 1992/3, 2000/1 and 2005/6.

Table 3.2: Number of people in Kenya requiring relief in flood and drought disasters since 1965

Year	Number of People Needing Relief	Type of Disaster	Year	Number of People Needing Relief	Type of Disaster
1965	260,000	Drought	2000	125,000	Floods
1971	130,000	Drought	2000	2,740,000	Drought
1979	40,000	Drought	2001	3,400,000	Drought
1984	600,000	Drought	2002	60,000	Floods
1992	2,700,000	Drought	2003	45,000	Floods
1993	1,200,000	Drought	2005	3,500,000	Drought
1997	212,000	Floods	2006	Records not yet available	Drought January-August 2006
1998	539,000	Floods	2006	Records not yet available	Floods September-December 2006

(*Sources: UN-ISDR, UN socio-economic database, Government of Kenya) ;(According to UN 2007 Statistics, Kenya Population varied from millions 9.5 in 1965; 11 in 1970; 13.5 in 1975; 16.2 in 1980; 19.6 in 1985, 23.4 in 1990; 7.4 in 1995; 31.3 in 2000, 32 in 2004, and 34.7 in Mid 2006. Current growth rate is about 2.4%)).*

The population census is carried out in Kenya every ten years. The current population is about 34 million based on projections from 1999 census which was 28.7 million. Past censuses indicate that the population was 23.2 million in 1989, 16.2 million in 1979 and 10.9 million in 1969.

Environment and Socio-Economic Resources of Kenya and Vulnerability to Climate variability/Change

Most of the socio-economic activities in Kenya are rain dependent, and are often devastated by extreme events such as floods and droughts. This section looks at the vulnerability associated with current climate variability on some key sectors.

3.1.2.1 *Energy Resources*

The provision of energy services is essential for industrialization, social development and improved quality of life. Future energy options are also key to the national adaptation strategies to future climate changes. The environment provides natural resources that are raw materials for the energy industry. In Kenya energy sources include wood fuels 75%, fossil fuels 18 %, hydro and geothermal powers 1.4% and others (wind, etc) (NEMA, 2003). On the other hand, the environment is the recipient of the residues of thermal energy and solids, liquids and airborne wastes produced by some energy systems. Kenya has no known deposits of fossil fuels although petroleum based fuels are the primary movers of the domestic economy. Currently, consumption averages 2.3 million tonnes per annum (NEMA, 2003). This is expected to increase with the fast increasing population and the national demand for various uses.

The major source of energy for industrial and urban uses is hydropower. Reservoir storage has marked sensitivity to variations in runoff and periods of drought. During the year La Niña related drought of 2000/01 blackouts and power rationing were the order of the days, and a US$72 million loan was taken from the World Bank to provide emergency independent fuel power supply (Republic of Kenya, 2000). Water rationing was imposed on Nairobi city residents during February 2006 because water in supply reservoirs had fallen to unsustainable levels. Climate change, affecting availability of hydropower, will have significant impacts on future development of Kenya, and reduction of poverty in Kenya, calling for an urgent need to assess the national potential of other clean energy resources such as solar and wind.

3.1.2.2 *Water Resources*

Water has been recognized as an entry point to sustainable development. According to NEMA (2003), it is estimated that Kenya has 19,500 million m^3 of renewable surface water converting to 650 m^3 per capita. This is expected to drop to 250m^3 per capita in 2025 when the population is projected to grow to 60 million. This is against a global recommendation of 1,000m^3, per capita and puts the country in the category of chronically water scarce countries. This is a serious challenge, especially in the low potential areas which make up over 80 % of the country's area, commonly called ASALs, and may be drastically made worse by climate change since climate factors, especially rainfall, temperature and evaporation, have significant impacts on availability and quality of water resources of the region. While floods cause landslides, soil erosion, and water contamination, they also damage water and power infrastructure inland. There are already serious conflicts over limited water and grazing resources in the ASALs during the periods of droughts.

3.1.2.3 *Agriculture, Livestock and Food Security*

Demand for agricultural land has forced many people to migrate to arid and semi-arid lands where rainfall variability is highest taking with them farming practices that often accelerate land degradation. The vulnerability of the agricultural sector is associated with poverty among the small-scale subsistence farmers, farming in the marginal rainfall areas, over-cultivation and land degradation, lack of economic diversification and lack or little knowledge on the use of climate information to maximize agricultural production. Figure 3.6 gives an example on the relationship between major food crop maize yield and seasonal rainfall variability. The figure reflects the potential impacts of any changes in rainfall patterns of agricultural production, food security and national GDP.

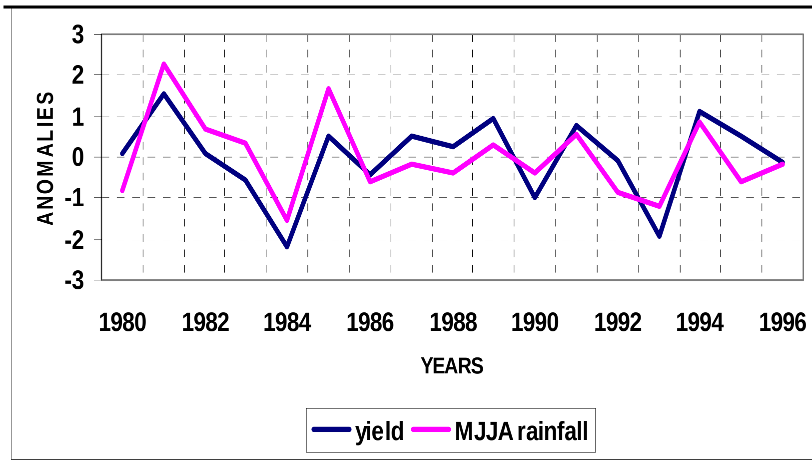


Fig. 3.6: Relationship between maize yield and seasonal rainfall in Trans Nzoia, (ICPAC 2006)

Food insecurity is a major problem, with malnutrition rates highest in the ASAL where there are acute malnutrition rates of over 15 percent in children under five (ALRMP, 2003), and up to 2-5 million can quickly become dependent on relief aid during major droughts. During prolonged drought seasons, traditional local coping strategies by pastoralists may no longer be sufficient (Campbell, 1999; Oba, 2001) hence increasing vulnerability. The droughts of 2000/2001 were the worst Kenya had experienced in 60 years (USAID, 2002). The below-normal 'long' season rainfall of 2000 was followed by a relatively dry 'short' rain season, and then another poor 'long' season in 2001. The increasing distances between water and pasture caused problems to the health of cattle, and created local conflicts over resources (USAID, 2002). Weakening of the market for livestock, scarcity of currency and the depletion of local food stores left a large proportion of the population dependent on food assistance (USAID, 2002).

Over the last three decades the frequency of droughts and floods has increased, resulting in loss of livestock. The country suffered another serious drought during most of 2005 up to mid 2006, particularly in Northern and Eastern Provinces. The severity was caused by three years of rainfall deficits (KMD, 2006), and the resulting crop failures and famine left an estimated 3.5 million people, in 37 districts across Kenya, seriously in need of food relief (World Vision, 2006). The latest floods in Kenya during the 2006 September-December rainfall season, that extended into the usually dry season of January-February, led to one of the highest loss of livestock and human deaths, some of which were due to floods related rift valley fever disease.

3.1.2.4 *Health*

A variety of tropical diseases common in Kenya are also sensitive to changes in meteorological parameters such as rainfall, temperature, and humidity. These include malaria, cholera, Rift Valley Fever (RVF), and meningitis among others. In recent times, significant variations in climate extremes have been observed over parts of the country that may have effects on these diseases. It has, for example, been observed that some areas that were once classified as cold and malaria free zones are now becoming warmer and good breeding sites for mosquitoes and hence experiencing frequent malaria epidemics (Githeko and Ndegwa, 2004). Altered temperature and rainfall patterns also could increase the incidence of yellow fever and trypanosomiasis.

Serious disease outbreaks have been associated with very wet periods with, for example, cholera and RVF epidemics occurring across East Africa after heavy rainfall and flooding in 1997/98 (NOAA, 1998). Over 3 million families were affected and health resources stretched well beyond manageable levels (Karanja, 2001). According to WHO (1998), bovine disease killed over 80 percent of livestock in northern Kenya, which resulted in a long-term impact on livelihood capacity to cope with poverty, overloaded veterinary support and aid relief. The September 2006 to February 2007 floods in Kenya were also accompanied by Malaria and RVF outbreaks. The current RVF outbreak may result in some of the highest number of deaths. By the time of this assessment human death toll of over 100 had been reported with almost total collapse of the livestock industry.

3.1.2.5 *Coastal zone and Marine Resources*

The coastal zone of Kenya is a point of entry of imports and exit for exports for Kenya and several neighboring land locked countries. It is one of the most important economic engines for Kenya, including tourism and hotel industries, fishing, and many coastal and marine activities. There is heavy migration from rural to the coastal urban cities in search for jobs and livelihood. The destruction of mangroves and other coastal ecosystems is quite alarming. Extreme climate events such as tropical cyclones, sea level rise, storm surges, tsunamis, floods and droughts often have far reaching consequences to the marine and coastal zone activities. Climate change including sea-level rise will affect many coastal livelihood activities.

3.1.2.6 *Environment and Biodiversity*

Local environment resources are fundamental to most economic and society livelihood activities. Increased pressure on natural resources by human activities raises critical environmental issues related to biodiversity, deforestation, desertification, drought, floods, and water and air pollution. Forest resources and land cover are being depleted due to the rapid increase in population and the demand for human settlements and agricultural land, grazing, sources of construction materials, food, fuel wood, essential oils and herbal medicines. These factors increase the vulnerability of Kenyan environment resources to floods, droughts, and other climate extremes that may be induced by climate change. According to the Initial National Communication of Kenya (2002), the most vulnerable areas to climate change in Kenya are expected to be the arid and semi-arid lands (ASALs), where frequency and severity of both droughts and floods is expected to increase.

3.1.2.7 *Human settlements*

Many settlements in Kenya are located in flood prone lowlands. Even in the urban areas many slums (Fig. 3.7) are concentrated within the flood channels. The floods impact negatively by destroying houses, infrastructure, and displacement of people making them environment refugees. For example, in May 2003, most parts of the country reported flooding, massive landslides, loss of lives, destruction of crops and property, and the displacement of at least one million people in Western and Nyanza Provinces, where displacements by floods are perennial during most of the rainfall seasons. The worst cases in history were recorded in 1961/62, 1997/98, and during many of the El Niño years. People living on the banks of the Tana River in Coast Province had to leave their homes after the river burst its banks, destroying 200 acres of crops, and thousands of refugees became homeless at Dadaab camp in Garissa following flooding. Despite the continuing drought, heavy rain in April 2005 displaced 25,000 people (UNEP, 2006) and by 2006, Oxfam predicted that it may take Kenya 15 years to recover from the consequences. When late 2006 rains arrived, they brought flash floods, hitting the northeastern particularly badly, and forcing villagers around Lake Victoria in the east to move to higher ground. Settlement needs will increase years by year due to population rise. Climate change will therefore threaten many people if the settlements are not well planned.

Figure 3.7 Slum settlements in Nairobi, Kenya (Source: ICPAC)

3.2 Malawi

Malawi is a landlocked country in southeastern Africa situated in a geographical position of latitudes 9º to 18º south and longitudes 32º to 36º east. The country has a wide range of relief and varies in altitude from sea level to well over 2000 meters above sea level with slightly over one fifth covered by water bodies, largely dominated by Lake Malawi. It has a tropical climate, which is relatively dry and strongly seasonal with one distinct rainy season that spans from November to April and a dry (cool/warm) season stretching from May to October. Annual average rainfall varies from around 700mm in low lying areas such as Shire Valley in southern Malawi to over 2000mm over highlands and lake shore areas **(**Figure 3.8). In addition, frost may occur in isolated areas in June and July.

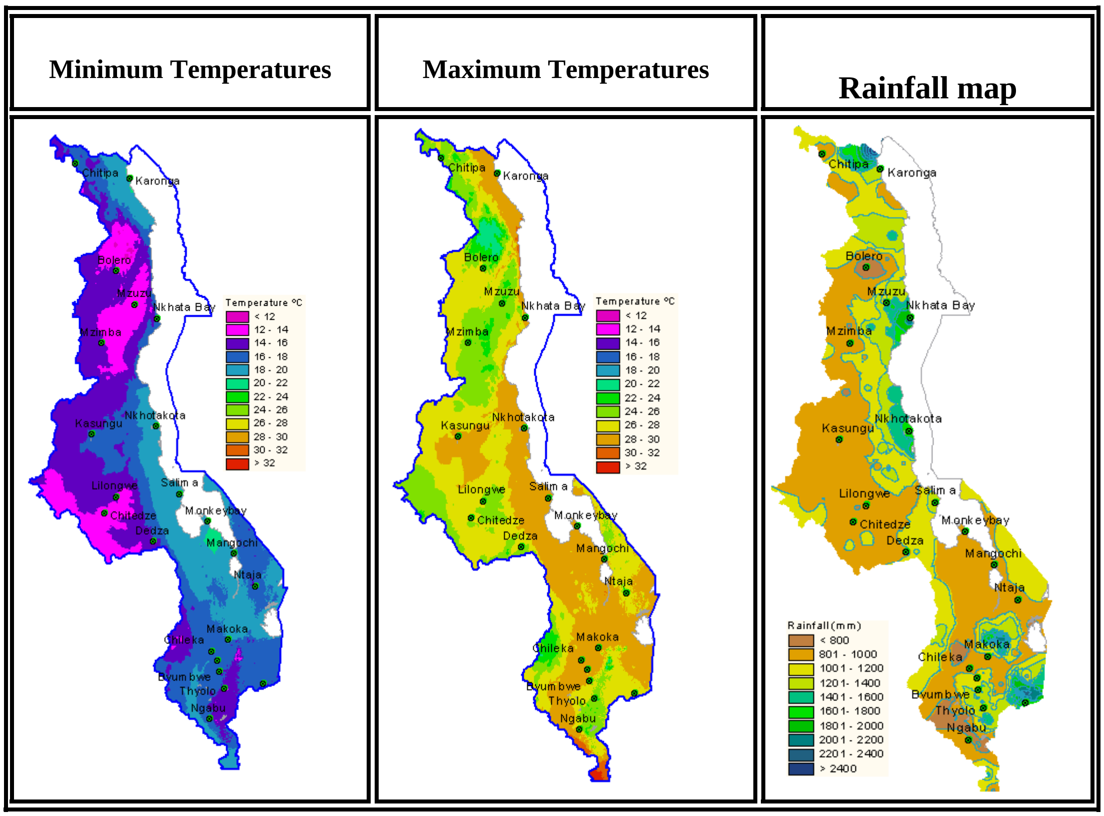


Figure 3.8: Climatology of Malawi

The country is affected by extreme climate events such as droughts, floods, strong winds, and land slides every rainy season. These events adversely affect food production systems resulting in famine, deaths, damaged infrastructures, and migration of the indigenous population. The low-lying areas such as Lower Shire Valley and some localities in Salima and Karonga are more vulnerable to floods than higher grounds.

3.2.1 Current Climate and Evidence of Climate Change

The evidences of climate change and variability in Malawi are manifested in significant variations in Lake Malawi (Figure 3.9) and river levels, significant trends in seasonal rainfall (Figure 3.10a&b), and surface temperatures (Figure 3.11) among others. The severe droughts of 1993/1994; 1994/1995 and 1999/2000 may have contributed significantly to the lowering of the lake levels. The resulting and continued lack of outflow from the lakes was blamed on channel blockage. The vegetation overgrowth and piling of sedimentation from small tributaries near the lake blocked water flow (Calder *et al*., 1995). The water balance of the lakes has demonstrated that the lake levels are very sensitive to climate.

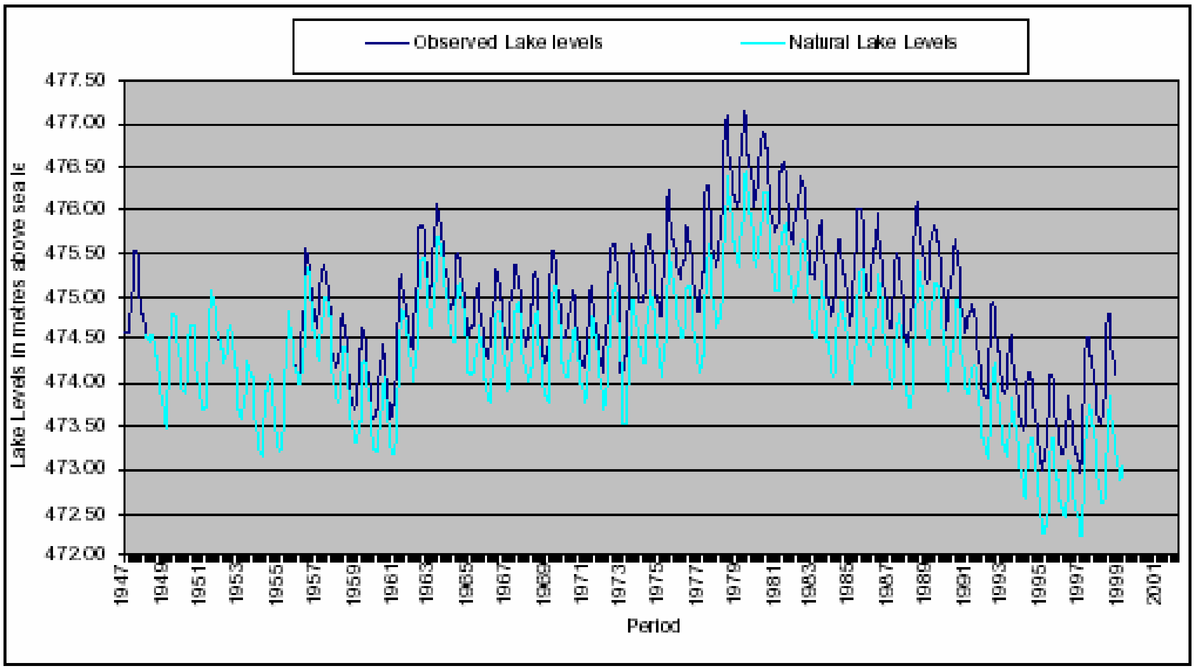


Figure 3.9: Hydrographs of Naturalized and Observed Levels of Lake Malawi (*Source: Osborne, 2000)*

Some key climatic elements such as rainfall and temperature (both minimum and maximum) have shown significant decreasing and increasing trends respectively in their recent instrumental records (Figures 3.10 and 3.11).

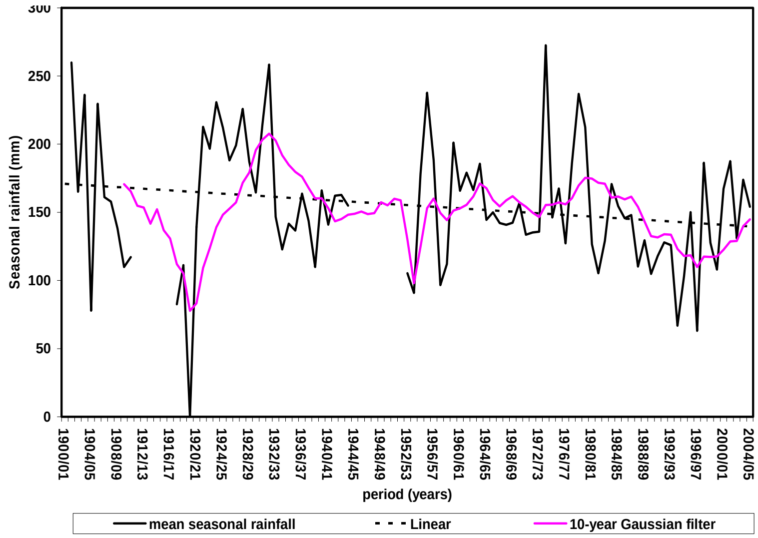


Figure 3.10: Evidence of decadal rainfall variability and decreasing trend in mean seasonal rainfall for Karonga, 1900–2005

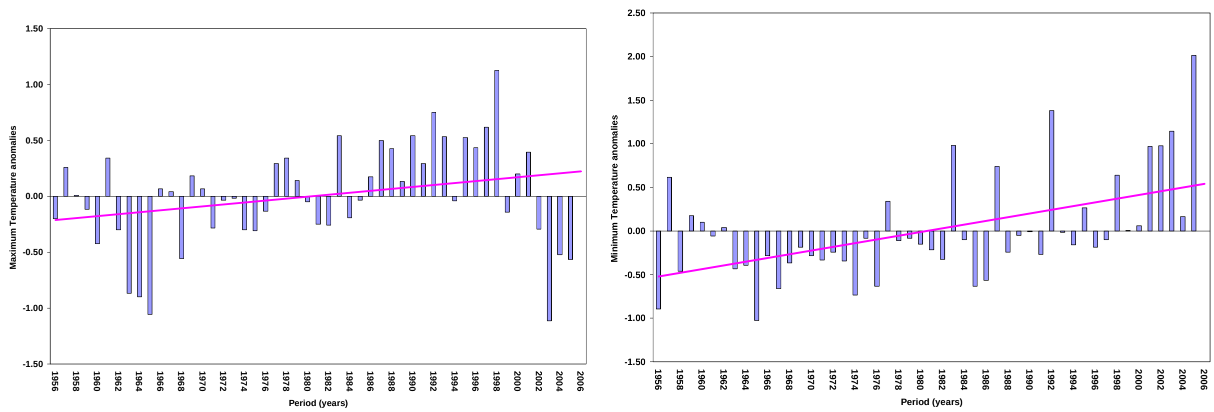


Figure 3.11: Increasing trend in Maximum (left) and Minimum (right) Temperature over Malawi as represented by Bvumbwe (1960 – 2006)

3.2.2 Environment and Socio-Economic Resources of Malawi and Vulnerability to Climate Variability/Change

Droughts and floods (Fig 3.12 and table 3.4), have increased in frequency, intensity and magnitude over the recent decades and have adversely impacted on food and water security, water quality, energy and the sustainable livelihoods of rural communities. For example, in 1989, more than 400 people died in Lower Shire and, in 1991, over 1000 in Phalombe flash floods (UNDP, 2000), and the Makhanga-Bangula road and rail are unserviceable since 1989 due to flood damages. From 1970 to 2006, Malawi experienced 40 weather-related disasters, but 16 of these occurred after 1990 (Fig 3.12). Table 3.4 gives examples of the extent of impacts of weather-related disasters in Malawi from 1975-2006.

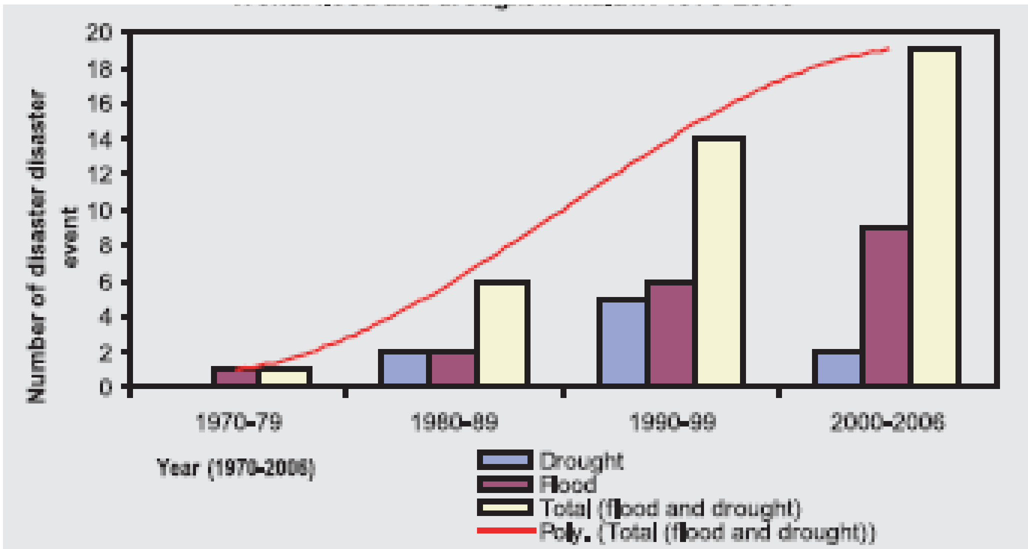


Figure 3.12: Evidence on the increasing frequency of drought and floods (1970 -2006) *(Adopted from a report by ActionAid October 2006)*

Table 3.4: Evidence of impacts of climate disasters in Malawi 1975-2006

Year	**Type of disaster**	**Area/Sector**	**Extent of damage/Impacts**
1975	Floods	Parts of Karonga, Mangochi, Machinga, Mulanje and Nsanje Districts.	Over 10.000 households affected.
1979	Floods	Part of lake shore areas of Rumphi district.	Several crops and houses destroyed.
1991	floods	Some areas in Salima, Mangochi and Lilongwe districts.	Over 563 households affected, more than 40 houses destroyed and several maize fields and crops damaged
1992	Drought	Several parts of the country affected.	General crop failures, water scarcity, drying of water reservoirs (dams, fish ponds, lake levels, rivers), famine, loss of human and animal lives
1999	Floods	Parts of Chikwawa, Machinga, Zomba, Nsanje, Mulanje, Nkhotakota, Nkhata Bay and Karonga districts.	Over 60,000 households had their houses, gardens and crops damaged.
2000,2003 & 2004	Strong winds	Areas in Nkata bay, Zomba , Ntcheu, Mzuzu Mchinji, Lilongwe, Mulanje, Blantyre, Kasungu, and Mchinji districts.	Over 88 households affected and over 208 houses destroyed including crops.
2005	Army worm	Occurrence of army worm in Chitipa and Karonga districts.	Army worm infested over 2687 hectares of maize and rice and also affected over 10,164 farm families in both districts.
2006	Hailstorm	Some parts of Neno and Lilongwe districts.	70 houses destroyed and over 130 households affected.
	Floods	Some parts of Chikwawa, Phalombe, Mulanje and Salima districts.	Over 2918 households affected.

(*Extracted from National Profile of Disasters in Malawi Ministry of Poverty and Disaster Management, 2005)*

Some of the most important sectors of economic growth that have been frequently impacted include energy; agriculture and livestock; fisheries; gender; human health; land use, Land Use Change and Forestry; Water; Wildlife among others. These are the subject of discussion in the next sub-section.

3.2.2.1 *Energy sector*

The energy for industrial and urban uses in Malawi is primarily driven by rain-dependent hydro electric power from the Shire River. The power generation has been negatively affected by the droughts and floods. Floods disrupt electricity production due to siltation caused by poor and unsustainable agricultural practices, deforestation, and noxious weeds, such as water hyacinth that choke and block the in-take points.

3.2.2.2 *Water Sector*

Water is a critical resource for human and industrial use, and for the maintenance of ecosystems. Although Malawi may be considered to be generally rich in water resources the distribution is not even. The surface water resources consist of a network of river systems comprising the Shire, Ruo, Bua, South Rukuru, Songwe and other smaller rivers together with Lakes Malawi, Chilwa, Malombe, and Chiuta. The quantity of surface water resources, especially in river systems, is highly dependent on runoff from rainfall and thus water resources are usually more abundant during the rainy season than the dry season.

Ground water resources are found in two main aquifers, the relatively low yielding Precambrian weathered basement complex 20% aquifer, which forms 85% of the country’s geology, and the high yielding quaternary alluvial deposits exclusively covering the shore of Lake Malawi and the Lower Shire Valley. The annual groundwater recharge is estimated to be 15-100 mm per year, but in some parts of the country, recharge rates greater than 200 mm per annum have been recorded.

Matching the demand by various sectors to the available water resources, it has been shown that the amount of water available is higher than the amount demanded by domestic consumption and irrigated agriculture.

3.2.2.3 *Agriculture Sector*

Although over 21% of the land area of Malawi is covered by rivers, lakes, and marshes, crop and livestock production are mostly dependent on rainfall with less than 5% of arable land under irrigation. In the last three decades, the country experienced variability and unpredictability of seasonal rainfall. There have been six significant droughts (1978/79, 1981/82, 1991/92, 1993/1994, 2001/02 2004/05), which resulted in frequent and increasingly long dry spells, and erratic onset and cessation of rainfall that rendered the growth in agricultural GDP negative (Fig. 3.13). The high frequency of droughts has impacted severely on agriculture, especially the smallholder sector, which accounts for the greater part of maize production, the main staple food (Clay, *et al.*, 2002). On the other hand, the high sensitivity and resilience of this sector is well demonstrated by the bumper yields realized in the years of high and well-distributed rainfall. For example, there was a maize crop failure during the 1991/92 when the maize production declined by 60%. This was followed by a bumper harvest during 1992/93 (Fig. 3.13b).

Flooding has also severely disrupted food production in several districts of the country. The most vulnerable groups are rural communities, especially women, children, female-headed households and the elderly.

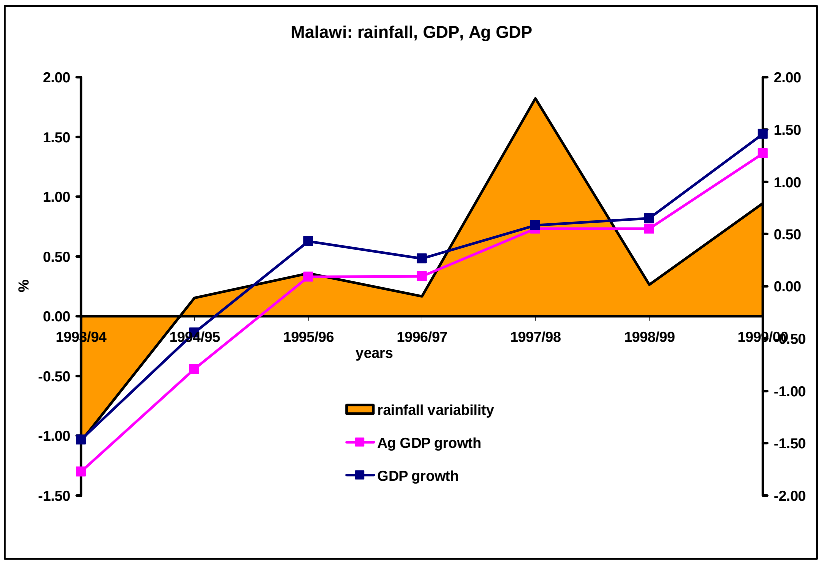


Figure 3.13a: Relationship between annual seasonal rainfall and Gross Domestic Products (GDP) growth over Malawi

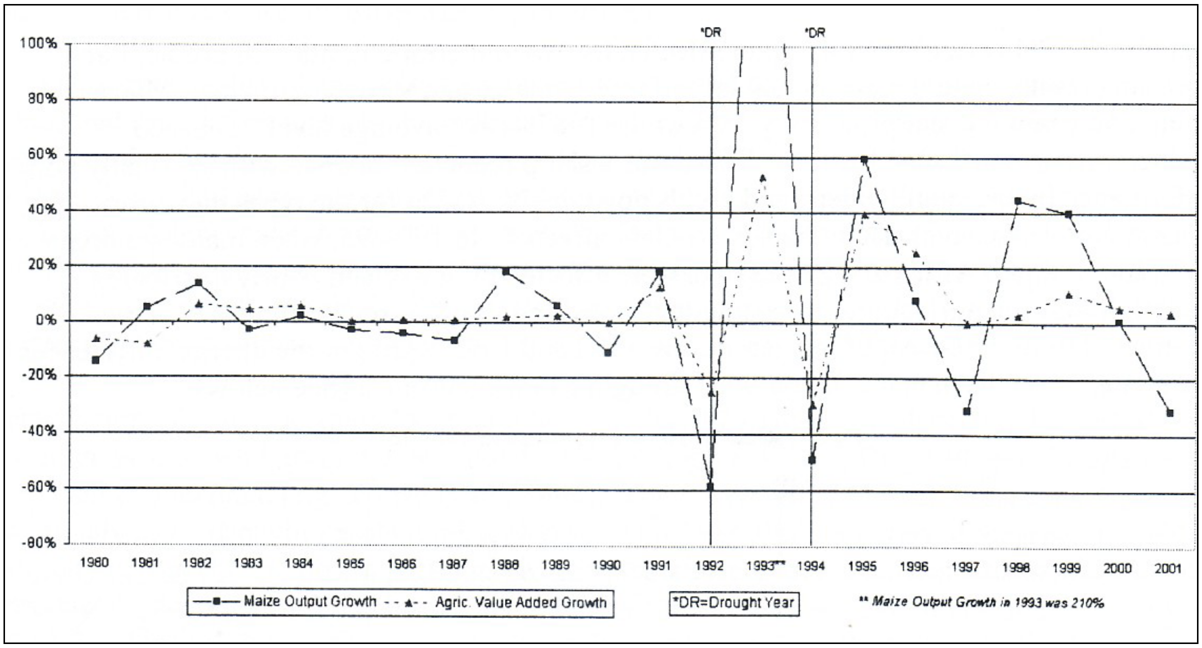


Figure 3.13b: Malawi Agricultural Sector Growth Rates, 1980 – 2001 (% per annum): *Source: Clay et al., 2002*

3.2.2.4 *Human Health sector*

The human health sector is directly and indirectly affected by climate factors. For instance, infant malnutrition and chronic ailments associated with malaria, cholera and diarrhea have been linked to droughts and floods. There has been a noticeable increase in diseases such as malaria, cholera and dysentery associated with changes in rainfall patterns, and this has created health challenges that are particularly affecting women. For example, malaria is expected to increase and spread to previously cool zones as temperatures increase due to global warming.

3.2.2.5 *Fisheries sector*

Fisheries provide vital livelihoods for lake and river basin-dwelling communities in Malawi. Five major water bodies are important for fish production, including Lake Malawi, Lake Chilwa, Lake Chiuta and sections of the Shire River. Lake Malawi is the major water body for fish production in the country where fisheries constitute 4% of national Gross Domestic Product (GDP) and provide livelihoods for over 400,000 people.

Droughts and floods are major climatic hazards affecting fisheries sector resulting in low fish production and loss of biodiversity. Drought affects fish production adversely both in natural water bodies and aquaculture through non-availability of water and also greatly reduced water levels vital to fish production. For example, droughts of 1914-1915, 1966-1967 and 1993-1994 caused Lake Chilwa to dry out completely resulting into total loss of fish stocks.

Floods have been responsible for the destruction of fish ponds, such as in 2000/01. Fisher folks around Lake Chilwa, migrate southwards from the northern marshes as the water level decreases on a seasonal basis. During periods of recession when the drought persists for more than three years, they migrate to other water bodies such as Lakes Chiuta and Malombe.

3.2.2.6 *Wildlife sector*

Malawi has a wide variety of wildlife that is ecologically and socio-economically important. The majority of the wildlife is in protected areas (about 22% of the total land area covering over 94000 km^2), which also help to conserve catchments. Socio-economically, communities neighboring protected areas are permitted to harvest resources such as firewood, medicinal plants and thatch grass from the protected areas as the cases are in Kasungu National Park and Vwaza Marsh Wildlife Reserve.

The major climatic hazard that affects the wildlife sector is drought. Severe drought incidents that have so far afflicted wildlife in Malawi have illustrated that impacts of increases in temperatures and deficits in precipitation can be variable but certainly harmful. For instance during the severe droughts of 1979/80 and 1991/92 rainy seasons, high mortality of Nyala (*Tragelaphus angasi G*), which is the key species in Lengwe National Park, was one of the observed impacts besides overcrowding at water holes, poor regeneration of vegetation and over-browsing. Nyala is a vulnerable species that may not adapt easily to climate-induced habitat changes.

3.2.2.7 *Environmental sector*

Malawi experiences a variety of extreme weather events that have recently increased in frequency of occurrence and intensity. The 1991/92 drought caused many river catchments to dry up and the Shire River water levels became precariously low threatening hydro-power generation downstream. Droughts also lead to land degradation and loss of soil fertility, as well as forest fires. For example, during the drought of 1995, some 5,550 ha (or 36%) of Chongoni forest were destroyed by forest fires caused by human activities such as hunting resulting in smoke haze, pollution, loss of seedlings and biodiversity.

Landslides occur during prolonged torrential rains mainly in the southern parts of the country. In the 1992/1993 rainy season, landslides caused a loss of over 500 lives and severe damage to socio-economic structures in Mulanje - Phalombe areas (Figure 3.14). Tornado-type wind systems have increased in frequency during the rainy season. This has resulted in loss of life and damage to building structures especially in rural communities where building standards are very low. Particular weather systems cause outbreaks of pests such as armyworm and diseases like cholera and malaria leading to illness, loss of life and reduced agricultural productivity.

Figure 3.14: Landslide Gully Erosion during torrential rains causing severe damage to socio-economic structures in Mulanje - Phalombe areas

Increasing demand, over utilization, deforestation and land misuse activities are threatening the local environment resources making them very vulnerable to future climate change.

3.3 Ethiopia

Ethiopia lies between 3.5° - 15°N latitude and 33° - 48°E longitude (Figure 2.5) in Northeastern Africa with an area of about 1.1 million square kilometers. Its population as at 1996 was estimated at 54.9 million, with the growth rate of about 3% per annum. Most of its population (>80%) live in rural areas. About one third of the land area is comprised of hilly and mountainous plateau between 1500 and 3500 meters Above Sea Level (ASL). The highland is surrounded by arid and semi-arid lowland plains (<1500 meters ASL). The highland is also divided by the Southwest-Northeast oriented Rift valley (extension of the Great African Rift Valley).

The climate of Ethiopia is mainly controlled by the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) and the associated atmospheric circulation as well as by its complex topography. It has a diversified climate ranging from semi-arid desert type in the lowlands to humid and warm (temperate) type in the southwest. Mean annual rainfall distribution has maxima (>2000 mm) over the Southwestern highlands and minima (<300 mm) over the Southeastern and Northeastern lowlands. Mean annual temperature ranges from < 15°C over the highlands to > 25°C in the lowlands. Although season length varies across the country, one can generally identify three seasons, Bega (a dry season from October to January), Belg (a short rainy season between February and May), and Kiremt (the long rainy season from June to September).

Agriculture (including livestock) is the most important sector of the national economy and the main source of livelihood for 85% of the population. It is the source of 90% of the export earnings and 40 to 50% of the Gross Domestic Product (GDP). Food crops, industrial crops, export crops (e.g. coffee), livestock and livestock products are the main components of Ethiopian agriculture.

3.3.1 Current climate and Evidence of Climate Change over Ethiopia

Key climatic elements used in this assessment are rainfall and temperature (both minimum and maximum). Some examples of the recent trends of Ethiopian rainfall are shown in Figure 3.15 that indicates a decreasing tendency in the annual rainfall in some areas. The same trend has also been noted in seasonal rainfall. Easterling *et al.* (2000) noted a significant decrease in the number of days with precipitation exceeding 25.4mm over Ethiopia and Eritrea during the main rainfall season (June to September).

Figure 3.16 shows the annual time series of minimum and maximum temperature for 40 stations averaged over Ethiopia. The figure reveals a warming trend in temperature and it is evident that the average annual minimum temperature is increasing much faster than the average annual maximum temperature. This confirms results from some recent studies (Easterling *et al.,* 2000; Nicholls, 1993; ICPAC, 2006).

Droughts and floods are also very common occurrences in Ethiopia. Some of these have been associated with ENSO events. According to Nicholls (1993), and Webb and Braun (1994), 1888 was a major ENSO year that led to serious drought in Ethiopia which killed about one-third of the population through famine, and 90% of the animals perished due to rinderpest infestation. The 1972/73 ENSO related drought also led to the Wollo famine, during which about 200,000 people died. The other major drought was during 1983/84 that took the lives of an estimated one million people, destroyed crops, and contributed to the death of many animals. However, the impacts of drought seem to be reducing in the recent years due to improved early warning and new drought management policies.

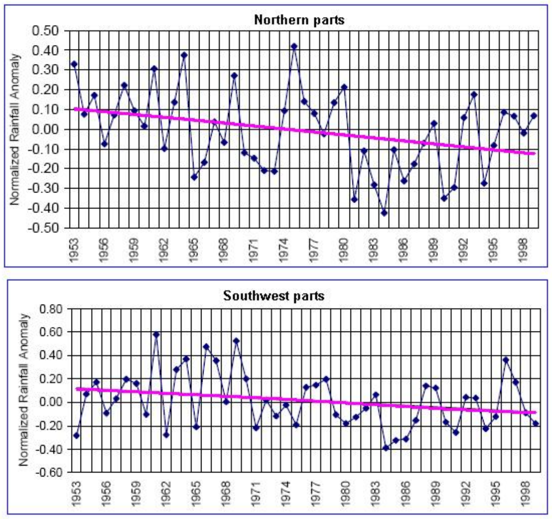


Figure 3.15: Normalized annual time series of rainfall and a fitted trend line over Northern (above) and southwest (below) parts of Ethiopia (NMSA, 2001)

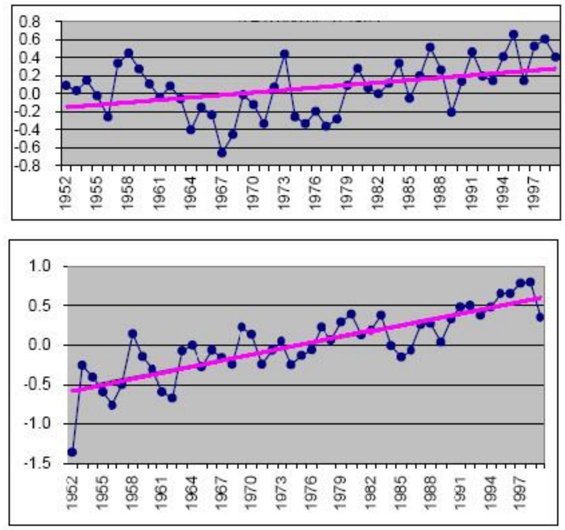


Figure 3.16: Normalized annual time series and a fitted trend line of maximum (above) and minimum (below) temperatures over Ethiopia (NMSA, 2001)

Major floods occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 leading to loss of life and property. The recent flood of 2006 led to the following (NMSA, 2006):

- More than 250 people dead; about 250 people unaccounted for; 10,000 people displaced in Dire Dawa. Figure 3.17 shows destruction of infrastructure by the floods in Dire dawa
- More than 364 people dead and more than 8,300 people displaced in Southern Omo; over 2,700 head of livestock drowned and washed away; 760 traditional silos washed away
- More than 16,000 people displaced in West Shewa
- Similar situations experienced over Afar, Western Tigray, Gambella, Zuria and over the low lying areas of Lake Tana
- Spread of Acute Water Borne Diarrhea (AWD); Malaria outbreaks with 129 people dead and 16,803 reported cases (Report from the Ministry of Health)
- Inundation of crop fields Near river banks and water bodies (For example, 500 ha of crop damage over Chefa)
- Flooding of crop fields on sloppy farm lands
- Water logging on clay type of soils on valley farm lands.

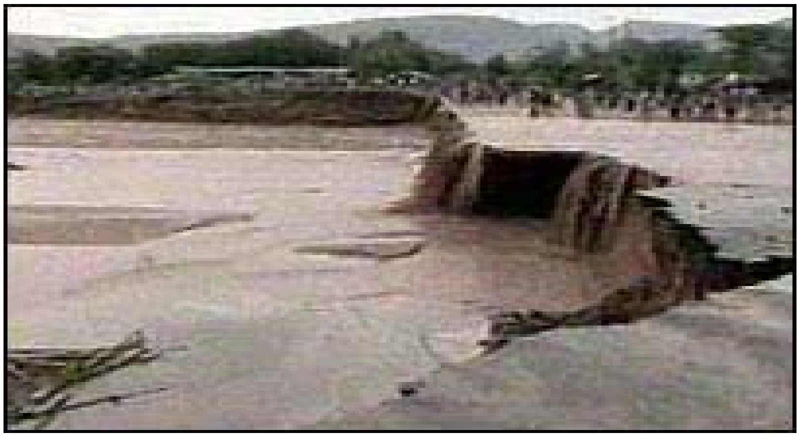


Figure 3.17: Flood in Dire Dawa in August 2006 due to the overflow of the Dechatu River

3.3.2 Environmental and Socio-economic sectors of Ethiopia and their vulnerability to Climate Variability / Change

The main natural resources of Ethiopia are water, forest, biodiversity and agricultural land and energy. It is evident that these resources are very sensitive to climate variations. Activities such as agriculture, human health, energy and water supply that depend on these natural resources are, therefore, also sensitive to climate variations. Major environmental problems associated with occurrence of extreme climate variations as well as climate change including soil erosion, deforestation, drought, over-grazing, desertification, loss of biodiversity and pollution of water are also quite common over Ethiopia. The impacts of the climate variability/change on the various socio-economic resources are discussed next

3.3.2.1 *Agriculture, Food Security and Livestock*

About 73.6 million hectares (66%) of the country's land area is estimated to be potentially suitable for agricultural production (MEDaC, 1999). Unfortunately, Ethiopia is prone to drought that often leads to famine and deaths of both humans and animals. Some of the droughts that have occurred are shown in Table 3.5. The east and north of the country are the most vulnerable and have the highest food insecurity. The number of people vulnerable to acute and chronic food insecurity is always increasing as a result of dependence on rain-fed agriculture and the high population. In North-Eastern Ethiopia for example, drought induced losses in crop and livestock between 1998 and 2000 were estimated at $266 per household – greater than the annual average cash income for more than 75% of households in the region (Carter et al., 2004).

Table 3.5: Chronology of El Niño and Drought/Famine in Ethiopia

El Niño Years	Drought/Famine	Regions
1539-41	1543-1562	Hararghe
1618-19	1618	Northern Ethiopia
1828	1828-29	Shewa
1864	1864-66	Tigray and Gondar
1874	1876-78	Tigray and Afar
1880	1880	Tigray and Gondar
1887-89	1888-1892	Most of Ethiopia
1899-1900	1899-1900	Most of Ethiopia
1911-1912	1913-1914	Northern Ethiopia
1918-19	1920-1922	Most of Ethiopia
1930-32	1932-1934	Most of Ethiopia
1953	1953	Tigray and Wollo
1957-1958	1957-1958	Tigray and Wollo
1965	1964-1966	Tigray and Wollo
1972-1973	1973-1974	Tigray and Wollo (About 200,000 people dead)
1982-1983	1983-1984	Most of Ethiopia
1986-87	1987-1988	Most of Ethiopia
1991-92	1990-1992	Most of Ethiopia
1993	1993-94	Tigray, Wollo and Addis
	2002/2003	Most of Ethiopia (15 million people in need of food assistance)

Sources: *Quinn and Neal (1987); Degefu (1987); Nicholls (1993); Webb and Braun (1994)*

3.3.2.2 *Water Resource availability*

Ethiopia has abundant water resources, although not evenly distributed in all parts of the country. It is known as the "water tower" of Northeast Africa with 12 major rivers, many of which are trans-boundary, with the total annual runoff estimated at about 111 billion cubic meters. A good example is River Nile that runs through into Sudan and Egypt, and is key to most livelihoods in Egypt. It also has eleven major lakes. Although the water resource is enormous, very little has been developed for agriculture, hydropower, industry, water supply and other purposes. Population growth, coupled with extreme climatic events, has made the water resources more vulnerable and water stress is already being experienced, for example, in Awash and Abay River basins.

Studies have shown that the water resources of the Lakes Tana and Ziway are highly vulnerable to climate variability, especially in the distribution of runoff throughout the year. With climate change, the runoff may become much more seasonal and as a result small streams may dry up completely for part of the year (Zeray et. al., 2006).

3.3.2.3 *Human Health*

Several studies of long-term trends in malaria incidence and climate in Africa, have not found a link to temperature trends, but instead emphasizes the importance of including other key determinants of malaria risk such as drug resistance, human migration and immune status, inconsistent vector or disease-control programmes, and local land-use changes, (Patz *et al.*, 2005). However, over the highland Debre Zeit sector of central Ethiopia, an association has been documented between increasing malaria prevalence and incidence with concomitant warming trends from 1968 to 1993 (Tulu, 1996). By controlling the confounding factors, the association could not be explained by drug resistance, population migration, or level of vector-control efforts.

Climate change is expected to exacerbate the occurrence and intensity of future disease outbreaks and perhaps increase the spread of diseases in some areas. It is known that climate variability and extreme weather events, such as high temperatures and intense rainfall events, are critical factors in initiating malaria epidemics especially in highlands of western Kenya, Uganda, Ethiopia, Tanzania, Rwanda and Madagascar (Zhou *et al*., 2004).

3.3.2.4 *Energy Resource*

Ethiopia is endowed with various energy resources. The gross hydro-energy potential of the country is about 650 terawatt-hours (TWh) per year (CESEN, 1986). The current energy consumption is mainly biomass at 95%, petroleum 4% and hydro 1%. Dependence on the biomass has led to massive deforestation. Natural forests are believed to have once covered 40% of the country’s land area. The loss of natural forest cover is estimated to be in the range of 150,000 to 200,000 hectares per year. Deforestation will interfere with the catchment areas of the hydropower generation plants thereby creating an energy crisis. The hydropower generation is also highly vulnerability to the climate variability/change since the runoff of the main rivers supplying the dams will be reduced while some of the major rivers become seasonal.

3.3.2.5 *Economic Growth and Development*

Occurrence of a single climate disaster such as drought or flood is capable of stagnating or even reversing the economic growth achieved over a decade or so. This is especially so if the main source of economic growth are climate-related such as rain-fed agriculture. Figure 3.18 shows the relationship that exists between annual rainfall, country gross domestic products (GDP) and the gross domestic products from the agriculture sector over Ethiopia. This figure clearly indicates that Ethiopia's GDP faithfully follow its annual rainfall.

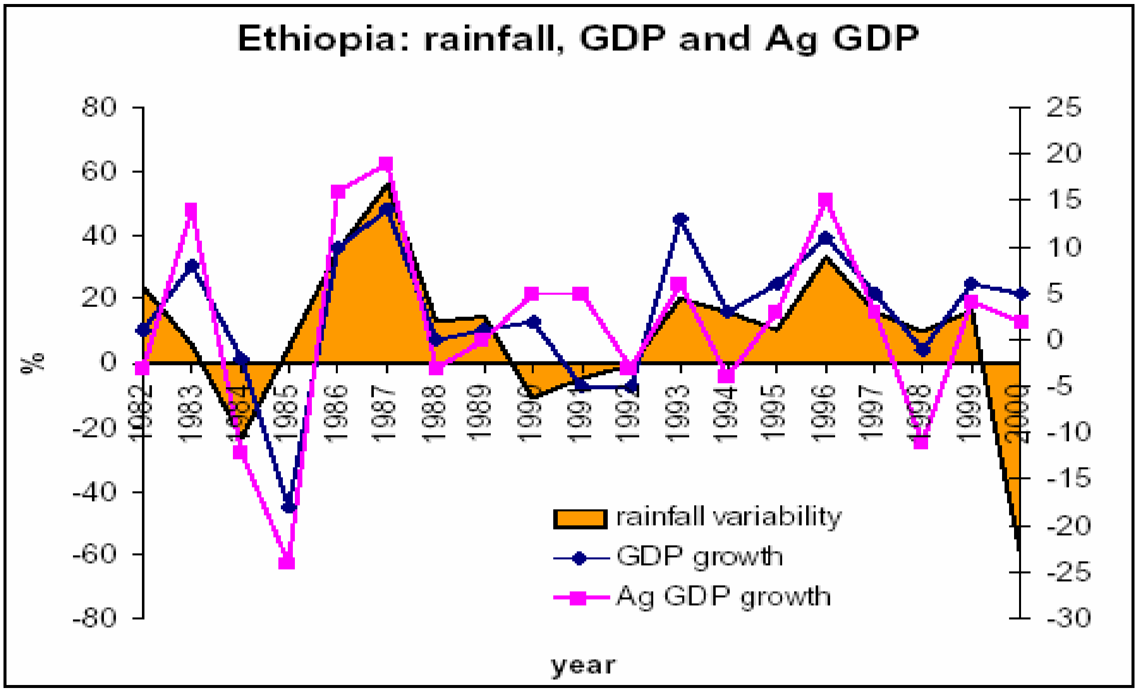


Figure 3.18: Relationship between annual rainfall and Gross Domestic Products (GDP) growth over Ethiopia. *From de Jong (2005), cited in World Bank (2005)*

4. Climate Change Scenario Projections for 2030 and 2050

It was highlighted in the previous sections that human socio-economic development activities including forces related to population, economy, technology, and governance have caused serious environmental degradation through the pollution of land, water, air and the biosphere with far reaching implications. Future climate change expectation cannot therefore be adequately addressed without a sound understanding of the future expectation of the emission and concentration of GHGs in the atmosphere, which will depend on socio-economic trends including population and economic growth, technological changes, energy demand, and fuel mix among others.

There are a number of approaches for developing future climate change scenarios (Cubasch *et al*. 2001; Chaponniere and Smakhtin, 2006; UK MET OFFICE, 2004) including incremental (arbitrary) scenarios, and General Circulation Models (GMCs). The GCMs use the expected future state of emissions as inputs to develop scenarios for the future periods. IPCC (2001) have developed a set of six global emission scenarios that can be used in climate change studies. These are known as SRES scenarios A1FI, A1T, A1B, A2, B1 and B2.

The “A” scenarios have more of an emphasis on economic growth while the “B” scenarios emphasizes on environmental protection. The “1” scenarios assume more globalization while the “2” scenarios assume more regionalization. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

It should be noted that most climate change studies include all scenarios in the projection of the potential future climate changes. These options were available in this study but only the report for A1B scenarios are presented since all the countries under study have limited technological advances as well as currently lacking fossil fuel reserves.

Challenges related to the development of realistic regional climate change scenarios for vulnerability and adaptation studies are addressed in the next section.

4.1 Methodology used for the downscaling of regional climate change scenarios

Realistic regional and local scale climate change scenarios are critical for an assessment of the impacts, and vulnerability for the specific socio-economic sectors and hence the development of appropriate adaptation strategies. In order to generate regional climate change scenarios high resolution Regional Climate Models (RCMs) are usually “nested” within GCMs to be able to represent the unique effects of smaller scale factors such as mountains, lakes, and land use among others (IPCC, 2001).

Several computer application software packages are now available for down scaling regional climate change scenarios based on these IPCC SRES scenarios. These include UK MET Office Providing Regional Climates for Impacts Studies (PRECIS), COSMIC and MAGICC/SCENGEN among many others (Raper *et al*. 1996, Harvey *et al*. 1997). The Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) module consists of a suite of coupled gas-cycle, climate and ice-melt models integrated into a single software package that determines changes in greenhouse-gas concentrations, global-mean surface air temperature and sea-level resulting from anthropogenic emissions of greenhouse gases and aerosols. The SCENario GENerator (SCENGEN) uses the output from MAGICC to produce maps showing the regional details of future climate. MAGICC/SCENGEN has been used in this report due to its simplicity, and its availability for free download and use. An overview of MAGICC/SCENGEN is given in Raper *et al*. (1996).

Although about 17 models are available for use in MAGICC/SCENGEN, an ensemble of only six GCMs were used in this study based on some previous studies carried out over the region. These included CSM_98, ECH395, ECH498, GFDL90, HAD295, and HAD300.

General Circulation Models (GMCs) are mathematical models of the global climate processes. The representations of the processes (parameterization) and other complex processes that drive climate variability and change often vary from model to model. The most common approach in many studies is to run as many models as possible and then find some ways of using the products from all models through some averaging or composites of products from various models. Such products are sometimes referred to as ensemble products. The advantage of using such ensemble averages is that they provide better results by reducing the uncertainty associated with individual model (Raper et al. 1996, Harvey et al. 1997, UK MET OFFICE 2004, IPCC 2007). Projections of temperature and precipitation are provided for both 2030 and 2050 scenarios.

4.2 Climate Change Scenario Projections for Kenya, Ethiopia and Malawi for 2030 and 2050

The climate change scenarios for the specific countries are highlighted in the next sections, while some of the limitations of the generated scenarios were highlighted in the previous sections. The scenarios were based on annual and seasonal time scales. It should be noted here that the socio-economic activities in the three countries are closely linked to the major rainfall seasons, December- February (DJF), March-May (MAM), June-August (JJA) and September-November (SON). Rainfall is key to many economic activities in the different countries as was discussed in earlier sections. The signal to noise ratios results showed higher skills for temperature than precipitation.

4.2.1 Ethiopia

The results of the IPCC mid-range emission scenario (A1B) show that compared to the 1961-1990 average, the mean annual temperature across the country will increase by between 0.9 and 1.1 °C by the year 2030 and from 1.7 to 2.1 °C by the year 2050. The corresponding results for annual precipitation show a change of between 0.6 and 4.9 % and 1.1 to 18.2% for 2030 and 2050 respectively (see Figures 4.1 and 4.2).

Most of the livelihood activities such as agricultural seasons are dependent on seasonal temperature and water availability from rainfall. It is therefore very important to not only have good knowledge of seasonal variability of climate change, but also changes in the patterns of daily weather events including extreme events such as the dry/wet spells, hot/cold spells, droughts and floods among others. There were significant variations in the seasonality patterns, but magnitude projected in mean seasonal temperature changes among the four seasons December- February (DJF), March-May (MAM), June-August (JJA) and September-November (SON) was more or less similar to the annual changes indicated above. The percentage change in seasonal rainfall is expected to be up to about 12.5% over most parts of the country. The largest change of about 22.1% was observed in 2050 DJF season, while decreases were observed over parts of the northern sectors. (See seasonal maps in annex 9.1 and Table 4.1).

4.2.2 Kenya

Results for Kenya show that, compared to the 1961-1990 average, the mean annual temperature will increase by between 0.8 - 0.9 °C across the country by the year 2030 and from 1.5 to 1.6 °C by the year 2050 for the IPCC mid-range emission scenario (A1B) while annual precipitation will change from 7.0 - 9.7 % and 13.3 - 18.8 % for 2030 and 2050 respectively (see Figures 4.1 and 4.2). The order of magnitude projected in mean seasonal temperature changes among the four seasons (DJF, MAM, JJA and SON) is more or less similar to the annual changes (see seasonal maps in annex 9.1 and Table 4.1). It should be noted that higher temperatures would lead to higher rates of evapotranspiration and decreased surface water availability. Areas that are projected to have increased rainfall (most parts of Kenya and Ethiopia except the north) may not necessarily have surplus water as evapotranspiration rates and water conservation practices will be significant factors in the water balance of those areas and hence determine water availability. However, a reduction in rainfall, as observed in most parts of Malawi, coupled with increased temperature will certainly lead to water deficit.

4.2.3 Malawi

Compared to the 1961-1990 normal the mean annual temperature will increase by between 0.9-1.0 °C in 2030 and from 1.6 to 2.0 °C in 2050 over Malawi for the IPCC mid-range emission scenario (A1B) while annual precipitation will change from -1.4 to 3.3 % by 2030 and from -2.6-6.2 % by 2050 (see Figures 4.1 and 4.2). Most parts of Malawi may expect a slight increase in precipitation while the southern tip is expected to have a slight decrease.

The order of magnitude projected in mean seasonal temperature changes among the four seasons (DJF, MAM, JJA and SON) is more or less similar to the annual changes indicated above. A decrease (by 16.7%) in seasonal rainfall is expected in JJA and SON while the other two seasons will remain the same (see seasonal maps in annex 9.1 and Table 4.1).

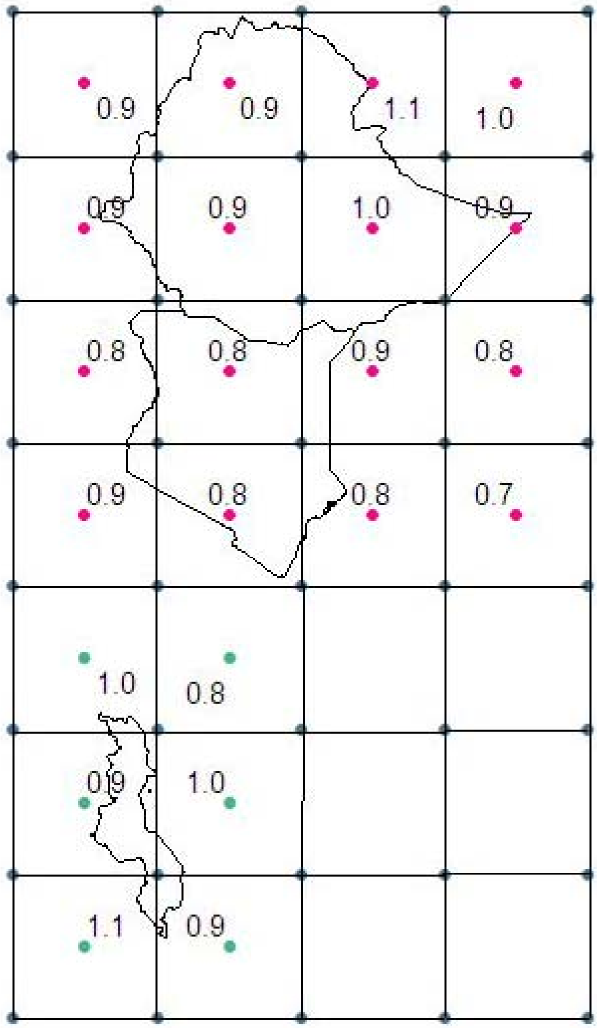


Figure 4.1a: Composite change in Mean Annual Temperature by 2030 using six GCMs (^{0}C)

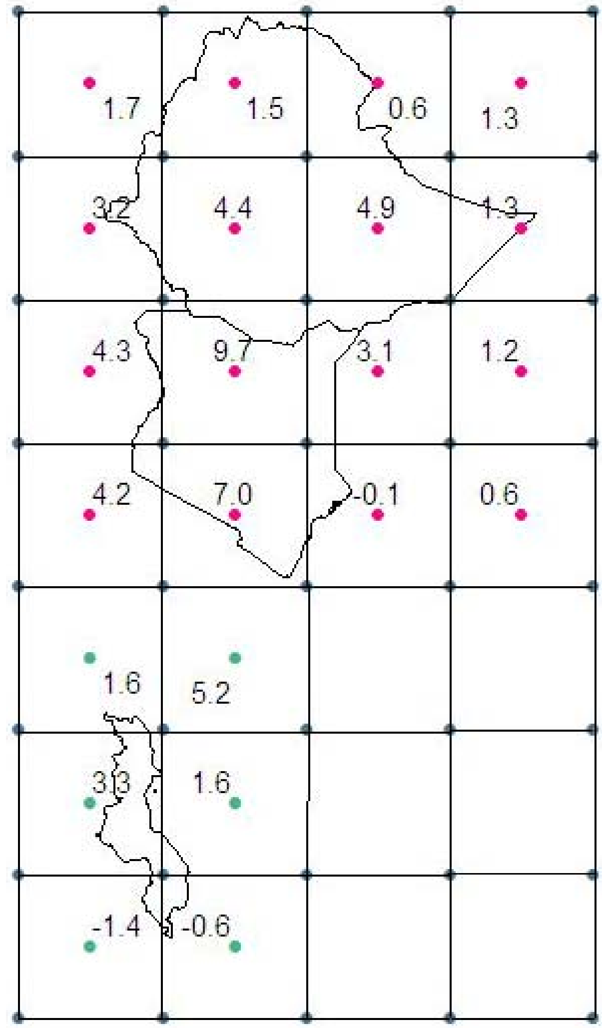


Figure 4.1b: Composite change in percent Mean Annual Precipitation by 2030 using six GCMs

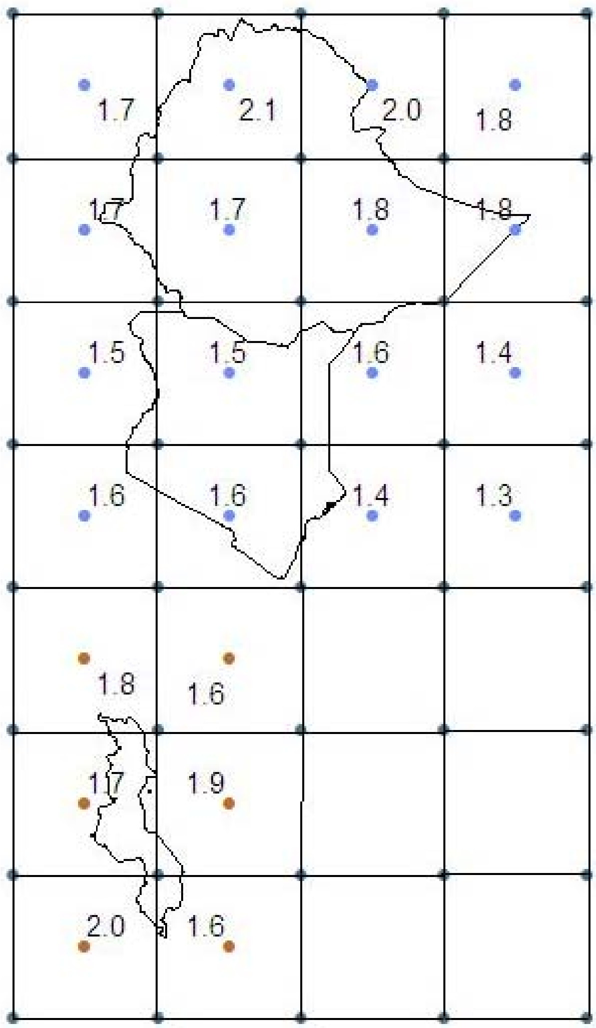


Figure 4.2a: Composite change in Mean Annual Temperature by 2050 using six GCMs (^{0}C)

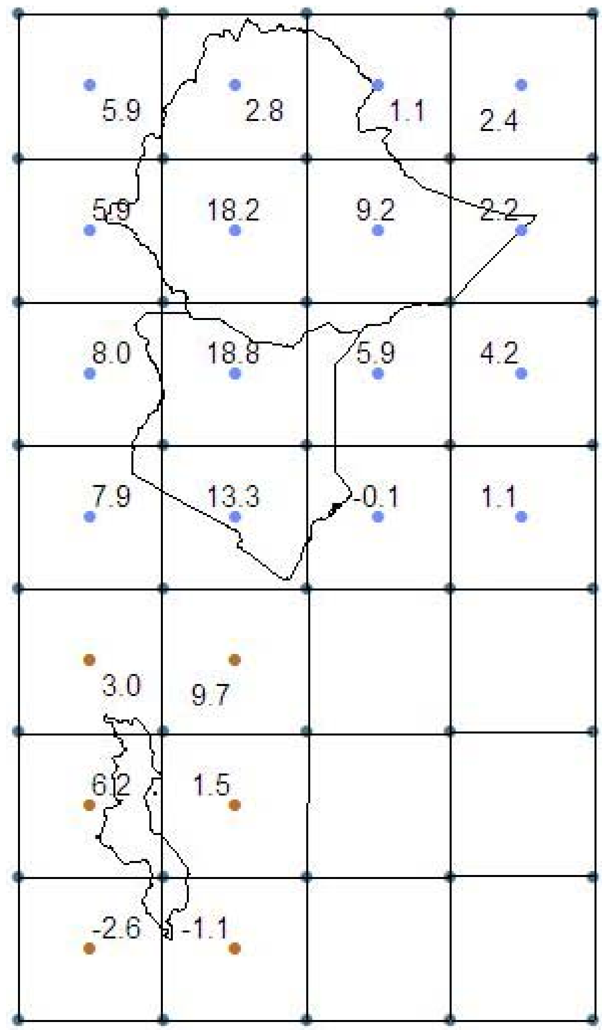


Figure 4.2b: Composite change in percent Mean Annual Precipitation by 2050 using six GCMs

4.3 Floods and Drought Projections

It should be noted that although the physical reality of most of the projections have not been vigorously tested in this study due to various limitations, the results showed changes in mean annual, and seasonal rainfall and temperatures that would have far reaching implication on the frequency or severity of extreme weather events such as extreme temperatures, heat waves, extreme rainfall events and more intense and prolonged droughts and floods. The results for the projections for example indicated increases of mean annual rainfall of up to 5% in central parts of Ethiopia and 10% in northern parts of Kenya for 2030 scenario. The corresponding values for 2050 are 18% in northern Kenya and central parts of Ethiopia.

Most parts of Malawi may expect a slight increase in precipitation during MAM, and DJF, with some decrease during JJA and SON seasons. Annual precipitation for Malawi is however projected to change between from -1.4 to 3.3 % by 2030 and -2.6-6.2 % by 2050 respectively. Although the increases / decreases may not be significant, some of these regions are generally arid and semi-arid such that the percentage projected increase in rainfall may not result into significant amounts. In general however, such changes could have far reaching implication on the frequency or severity of floods and droughts.

Some details of the projections are given in Table 4.1. In general, the rainfall projections indicate an increase in precipitation across the equatorial and parts of the northern parts of the study region, and a slight decrease to the south in all the seasons.

Table 4.1: Rainfall projections over the case study countries

			Projections	
Country	Region	Seasons	2030	2050
ETHIOPIA	Central & South	MAM	1 – 7% increase	2 – 13% increase
	North		1 – 3% decrease	2 – 6% decrease
	Whole of Ethiopia	JJA	4 – 6 % increase	7 – 12% increase
		SON	3 – 6% increase	6 – 11% increase
	Central/West/South	DJF	4 – 11% increase	2 – 22% increase
	Northeast		2% decrease	4% decrease
KENYA	Whole of Kenya	MAM	2 – 12 % increase	4 – 22% increase
	North/Western	JJA	5% increase	9% increase
	Eastern/Southern		4 – 11% decrease	8 – 21% decrease
	Whole of Kenya	SON	1 – 6% increase	0.5 – 11% increase
	Whole of Kenya	DJF	6 – 21% increase	11 – 40% increase
MALAWI	North	MAM	1% increase	2% increase
	South		1% decrease	2% decrease
	Whole of Malawi	JJA	5 – 9% decrease	9 – 17% decrease
	Whole of Malawi	SON	2 – 6% decrease	4 – 10% decrease
	Whole of Malawi	DJF	0 – 2% increase	0 – 5% increase

4.4 Assessment of the Vulnerability and Adaptation Options, and Mainstreaming climate information in sustainable development

The livelihoods of many millions of people in Africa are critically dependent on climate. The variability and extremes of climate is therefore holding back the alleviation of poverty, which is a serious problem especially in the least developed countries in Africa, and national development in most countries of the region. Achievement of the Millennium Development Goals (MDGs) will be possible only if the countries of Africa successfully adapt and cope with both natural climate variability and human-induced climate change.

IPCC (2007) has noted that climate change is now inevitable with potentials of unprecedented reversals in human development in vulnerable countries and communities. This calls for urgent priority for adaptation through enhanced resilience. Adaptation is successful if it reduces the vulnerability of vulnerable poor countries and poor people to existing climate variability, while also nurturing the potential to anticipate and react to further changes in climate in the future. The evidence from past experience suggests that this is best achieved through mainstreaming and integrating climate responses into development and poverty eradication processes.

According to UNDP (2003), mainstreaming of climate information is used to describe the consideration of climate issues in decision making processes such as planning and budgeting. Integration is used when specific adaptation measures are added to design and implementation strategies. Thus, integration occurs in instances where adaptation is deemed to be a priority in order to effectively achieve development goals. The rationale for integrating adaptation in development strategies and practices is underlined by the fact that many of the interventions required to increase resilience to climatic changes generally benefit development objectives. Adaptation requires the development of human capital, strengthening of institutional systems, and sound management of public finances and natural resources (Adger et al 2003). Such processes build the resilience of countries, communities, and households to all shocks and stresses, including climate variability and change, and are good development practices in themselves.

IPCC regional review of the impacts of climate change identified three vulnerable sectors in Africa as water resources, Agriculture/food security and health (IPCC, 2001). Analyses of vulnerability are limited due to poor data and many other related issues. Energy is however very key and is cross cutting in addressing adaptation strategies for all sectors. Water resources are a key vulnerability sector in the study region because of the rapid population growth and the resultant land use practices that threaten natural water recycling by the natural hydrological processes. Although there is a projected increase in precipitation during some seasons over parts of Kenya, Ethiopia, and Malawi, the infrastructure to store and serve water is mostly overstretched in capacity, and extreme events such as floods that cause physical damage will add to the problem. Environmental degradation is increasing unabated in the three countries by various land misuse activities, giving serous implications on environmental erosion and general degradation for increased rainfall scenarios.

Sea-level rise, coastal erosion, saltwater intrusion, and flooding will have significant impacts for coastal communities in Kenya. Kenya’s second largest city Mombassa is situated along the coast and is highly vulnerable to extreme events, sea-level rise, and coastal erosion as a result of inadequate physical planning and escalating urban drift. Rapid unplanned expansion is likely to predispose large populations to infectious diseases from climate-related factors such as flooding.

Increase in floods/droughts will also provide new challenges to national disaster risk reduction strategies. UN Kyogo Framework for action 2005-2015 calls for building the resilience of Nations and communities to disasters. Need for integrated policy for sustainable water resources management is required including for the shared water basins. There are also urgent needs for building capacity for assessment of available water potentials, monitoring changes, prediction and early warning of the hydrological droughts/floods of the specific basins.

There is wide consensus that climate change will worsen food security, mainly through increased extremes and temporal/spatial shifts. The GHA region already experiences a major deficit in food production in many areas, and potential declines in soil moisture will be an added burden. Agriculture, which is the main stay of food security in the region, is rainfall dependent. Recurrent droughts interspersed with floods have worsened the food situation in the region and put it at greater risk of adverse impacts of climate change. Complicating the picture for these two sectors, water resources and food security, is desertification. Desertification is a critical threat to sustainable resource management in arid, semi-arid, and dry sub-humid regions of Africa, undermining food and water security. Adaptation of the regional agricultural systems to climate change would require building capacity to reduce vulnerability and timely identify climate change risks on specific agro systems. The strategies would also include mainstreaming climate information in all agriculture and food security planning. It will also require ability for developing impact scenarios.

Changes in temperature and rainfall will have many negative impacts on human health. Changes in disease vector habitats will expose new populations to diseases such as malaria. The prevailing climate over the study region is favorable to most major vector-borne diseases, including malaria, schistosomiasis, onchocerciasis, trypanosomiasis, filariasis, leishmaniasis, plague, RVF, yellow fever and tick-borne hemorrhagic fevers. Extreme weather events can exacerbate these diseases and often trigger epidemics. Increased rainfall followed by warm temperatures could lead to more frequent outbreaks of RVF. This is already evident in Kenya with the outbreak of the disease in 1998 and more recently in 2006. There need to mainstream climate information and the health impacts scenarios in all health planning.

In general, Africa must start planning now to adapt to climate change. Current technologies and approaches are unlikely to be adequate to meet projected demands, and increased climate variability will be an additional stress. It was the view of the IPCC regional review report (IPCC, 2001a) that it is unlikely that African countries on their own will have sufficient resources to respond effectively. This view is still holds true for the study region.

In general, technology and technology transfer will play pivotal role in adaptation, alongside public policies that restructure the incentives and regulatory systems that govern energy generation and consumption. Technology options involves application of technology that would reduce emission of greenhouse gases; increase efficiency of the energy systems, etc. This could include improving the efficiency the commonly used charcoal stoves; replacement fossil fuel with renewable energy sources particularly solar energy and wind energy; and increased use of geothermal energy. How to integrate indigenous technology that the society in Africa has used to adapt to the past climate shocks must also be addressed.

A diversity of constraints facing many nations limits overall adaptive capacity for the region. External funding drives programs in many African countries, so agendas usually align closely with donor agency interests. The countries are usually at the mercy of donor agencies that often regard immediate problems of poverty, erosion, health, and empowerment as the only priority issues for Africa. Longer term planning, for example, land-use planning in areas that are susceptible to flooding under infrequent cyclonic events, never receives the attention it deserves. Most African countries are unlikely to motivate internal funding for climate change; therefore, it is critical that funding agencies award high visibility to issues of climate change. Climate change must however be mainstreamed in all environment, society and economic development plans to reduce climate related risks in support of international, regional and national sustainable development goals.

There is serious limitation in the capacity in most African countries to address the multidisciplinary climate change challenges. Capacity building is the highest priority in the three countries, including the need to train and retain the built capacity together with strengthening scientific and technical capacity. There are also limitations in hardware/software, data, monitoring and observation capacity. There is also need for multidisciplinary research to improve our understanding of adaptation, and identification of vulnerable systems and assessments of vulnerability/impacts including issues related to environment. The region has serious limitations in modeling capacity yet regional scenarios are critical in all climate change adaptation studies.

Specialized institutions in Africa such as ICPAC, ACMAD and DMCH could be mandated to play a central role in the implementation of regional adaptation capacity building program including verification/calibration of models to local conditions and building capacity for regional/local climate change scenarios. Other critical issues needed to address adaptation challenges of the region include education and public awareness, intuitional arrangements and networking. There is also need for formulation of realistic adaptation strategies and their dissemination at global, regional and national levels that could support adaptation initiatives by vulnerable countries and communities. Resources are critical for adaptation since some of the adaptation systems are quite expensive and hence resource mobilization strategies must be integral part of any adaptation strategy. Some of these requite cross-cutting adaptation planning, strategic partnerships and alliances; demonstration projects and as well as mainstreaming of climate change activities into all development planning activities.

5. Application of African Climate Models in Early Warning and Forecasting Systems

Specially tailored climate services enhance decision-making in many socio-economic sectors. It is expected that if the society can use such climate information to cope with the current climate variability shocks then it has high probability of coping with the impacts of future climate change. In this regard the factoring of climate forecasts and early warning products in all socio-economic sectors is critical for sustainable development of Africa. This section reviews the application of some of the African climate models in prediction, early warning systems, and various climate risk reduction activities.

Some attempts are now being made to factor climate information in the planning of some of the sector specific activities in the Greater Horn of Africa through support of the Climate Prediction and Applications Centre (ICPAC) and National Meteorological and Hydrological Services (NMHSs). Similar efforts are also being done by the other two climate Prediction and Application Centres in Africa namely African Centre for Meteorological Applications for Development (ACMAD) located in Niamey (Niger); and Drought Monitoring Centre-Harare (DMCH) located in Harare. Low human, technical and institutional capacities have however been key handicaps to optimum use of the climate information from the African climate centres and the NMHSs.

Climate products required for adaptation and other applications can be grouped into three large categories namely past, present and future climate information. Past climate records provide history of past climates and past impacts/vulnerabilities, while current products provide the current level of climate stress together with the associated drivers of climate stress. The time scales of future climate expectations range form short, medium, to long range categories. Short range extends to the order of few days, while medium range extends to about two weeks. The longer time scales (long range) extend beyond two weeks, months, seasons, years, decades, centuries, and other climate change time scales. The skill of prediction reduces as the range increases from short to medium and beyond. The recent discovery of the roles of El Niño and southern oscillation (ENSO), Indian Ocean Dipole; Julian Madden Osculation, among many other recurrent climate controlling systems have lead to great improvement of climate prediction beyond two weeks, and seasons over some regions of the world (Ogallo 1989).

The spatial scales for climate forecasting can on the other hand be grouped largely into global, regional and national/local scales. The skill of climate forecasting is higher at global scale and lowest at national/local levels for all time scales due to the complexity of the systems at national/local levels. It should be noted that future climate information required for adaptation is largely for addressing national/local adaptation challenges where most livelihood systems are concentrated.

For climate change adaptation, it was noted in section 4.3, that scenarios of the future climate change expectations are derived from different forcings of higher GHG concentrations (IPCC 2001). It was further noted in the previous section that specially tailored climate services are required to reduce climate risks in all socio-economic sectors. Some attempts are now being made to factor climate information in the planning of some of the sector specific activities in the Greater Horn of Africa through support of the Climate Prediction and Applications Centre (ICPAC) and National Meteorological and Hydrological Services (NMHSs). Similar efforts are also being done by the other two Climate Prediction and Application Centres in Africa, namely African Centre for Meteorological Applications for Development (ACMAD) located in Niamey (Niger); and Drought Monitoring Centre-Harare (DMCH) located in Harare. AGRHYMET which is located in Niamey and is devoted to agriculture and food security applications especially for the Sahel region of Africa. Low human, technical and institutional capacities to have been key challenges to optimum use of available climate information. The capacity of the society to cope with the current climate variability shocks is also critical for adaptation to the negative impacts of future climate change. These centres were established in order to contribute to monitoring, prediction, early warning and applications for the mitigation of adverse impacts of extreme climate events on various socio-economic sectors in Africa.

The African climate centres and NMHSs produce several climate products for addressing past, present and future climate risks. These include among others daily, 10-days, monthly and seasonal rainfall outlooks. Most of the long range climate products in Africa are derived from empirical methods that rely largely on sea surface temperatures, El Niño/Southern Oscillation (ENSO) and related variables. Products from General Circulation Models (GCMs) and high resolution Regional climate models are also used in the three African climate centres, but most of these products are based on model runs from collaborating advanced climate centres of the developed countries. Figure 5.1 and 5.2 shows some examples of prediction and early warning products that are operationally being used at ICPAC. The skills of the models have been very high especially for the months of June-December, and especially when there are persisting large scale sea surface anomalies like during ENSO, and the Indian Dipole periods.

The three African centres namely ICPAC, ACMAD and DMCH in collaboration with the NMHSs regularly release seasonal climate prediction products that have played important and useful roles in providing the region with climate advisories and timely early warnings for disaster risk reduction and support to regional sustainable development efforts. Attempts are now being made to down-scale and integrate such products to provide tools to risk management in agriculture and food security, hydrology and water resources; hydropower/hydrodam management, health (especially malaria and Rift Valley Fever (RVF) diseases); forage outlook;

resource based conflict early warning, etc). Some of the examples of applications of seasonal climate outlook in sector specific risk management are shown in figures 5.3 to 5.6, while example of the seasonal climate outlook products that are being provided by the African climate centers are shown in figures 5.1 and 5.2.

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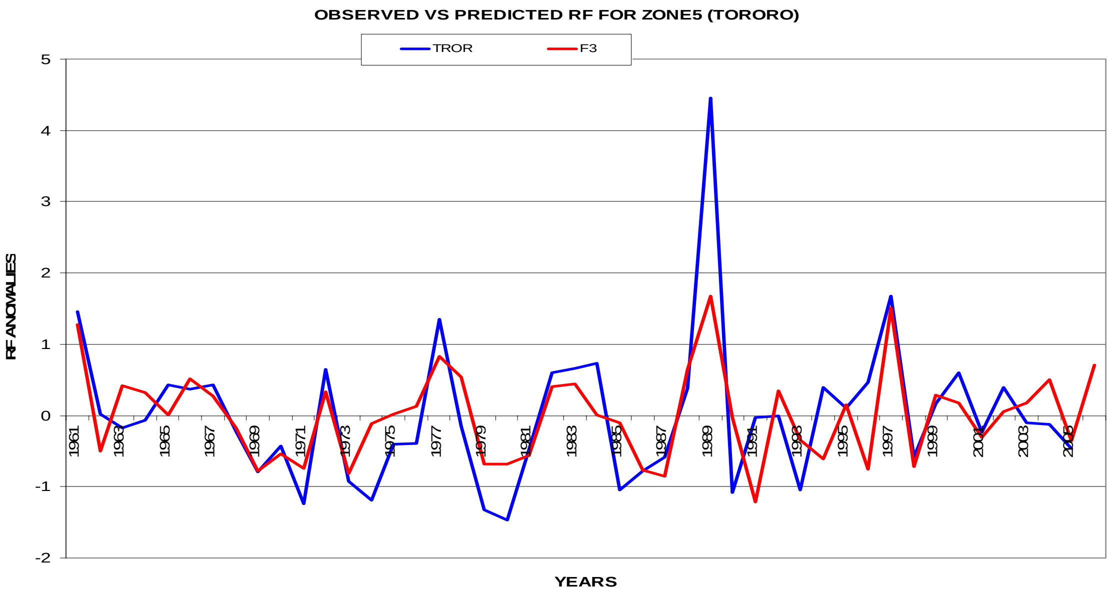


Figure 5.1a: ICPAC statistical climate prediction model for a selected zone in Uganda

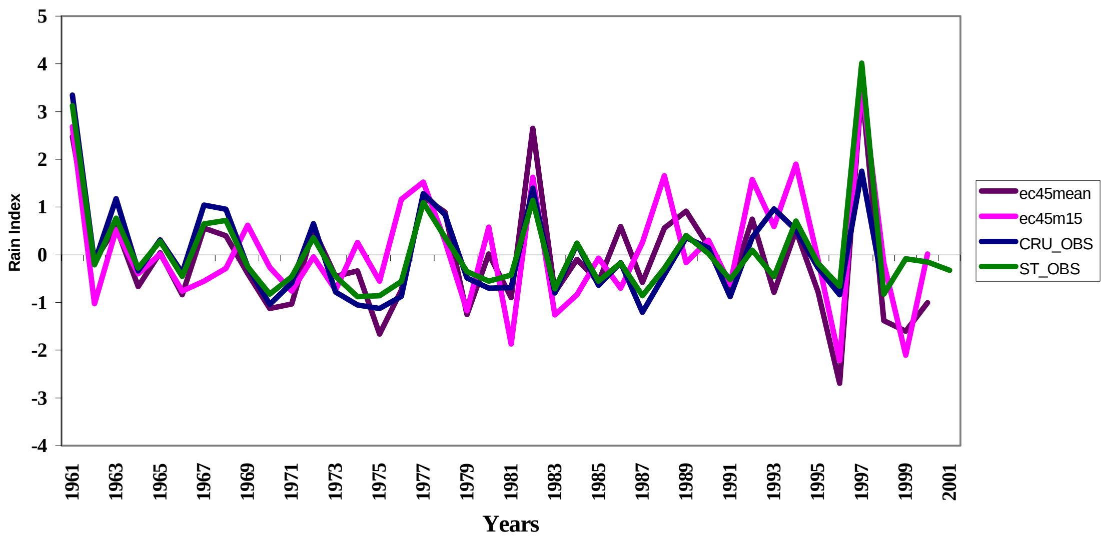


Figure 5.1b: ICPAC dynamical model simulation of inter-annual variability during the October to December season over the Greater Horn of Africa

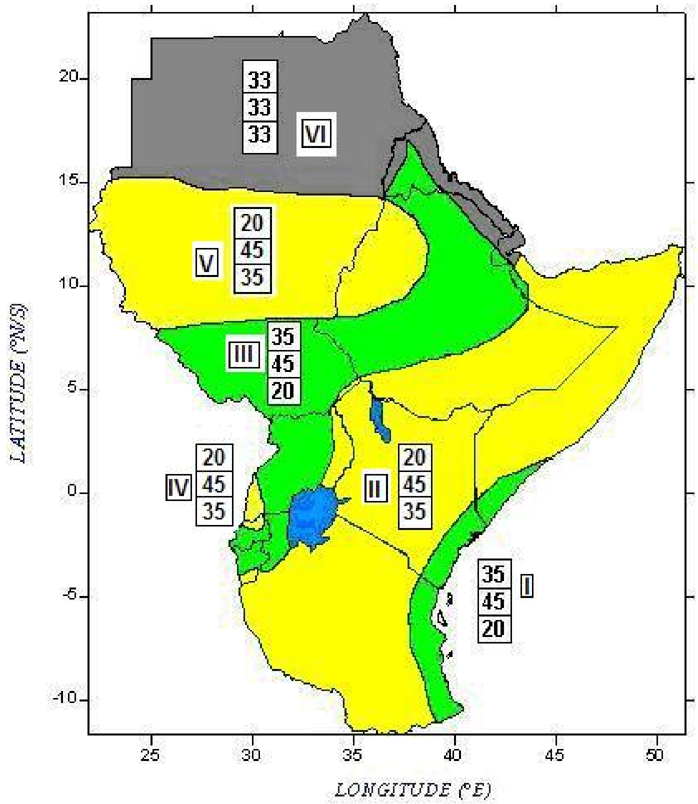


Figure 5.2: ICPAC Climate Outlook for March – May 2007

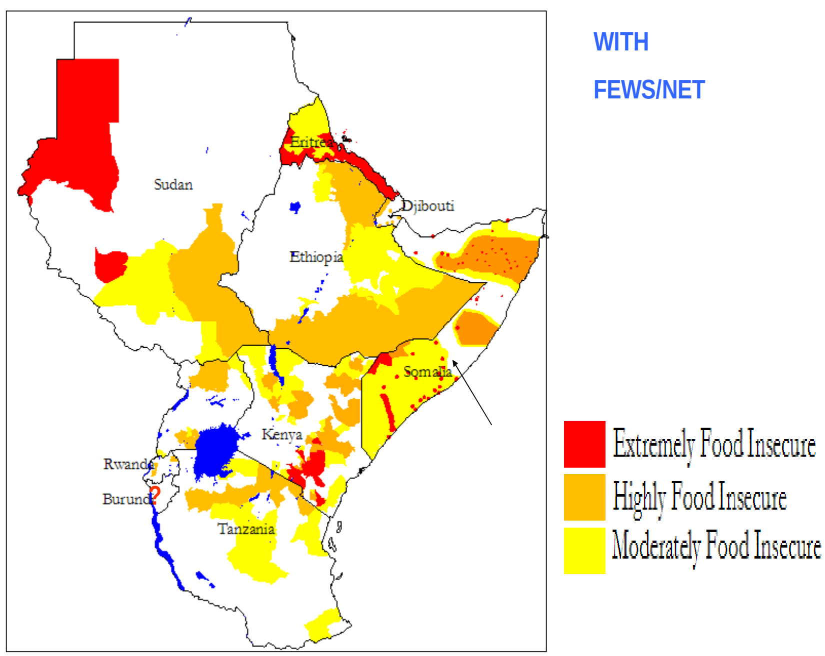


Figure 5.3: Food Security Outlook products based on Seasonal Climate Outlook, e.g. Fig. 5.2

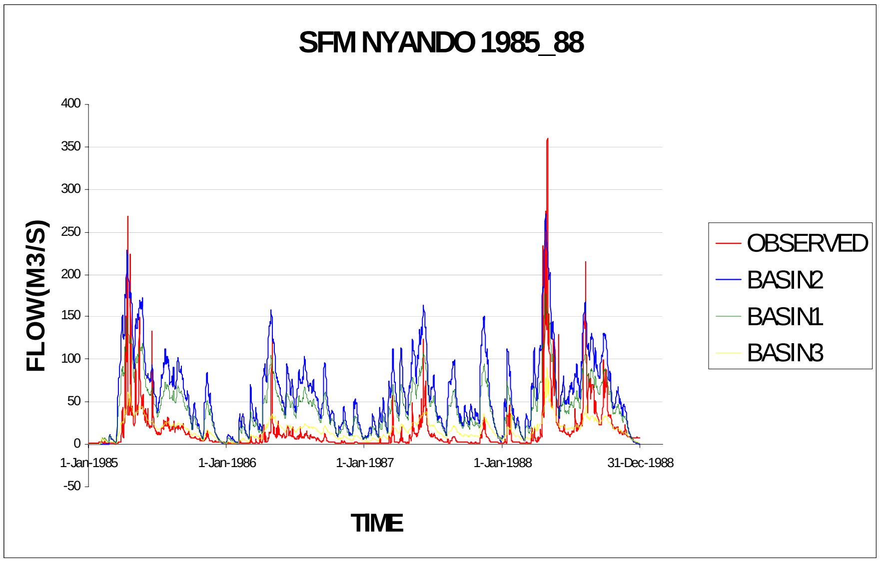
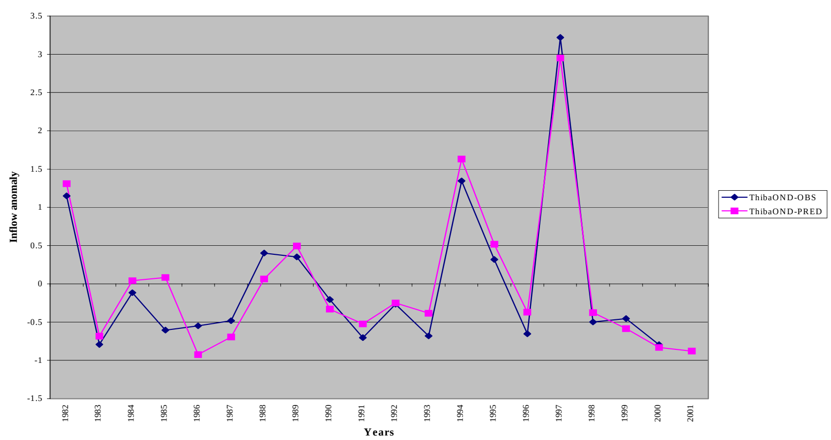


Figure 5.4: Flood Forecasting in partnership with WMO, USGS, NOAA/CPO developed in parallel with Fig. 5.2



Comparison between Observed and Predicted OND Thiba Inflow anomaly into Kamburu Dam between 1982 – 2001-Kenya

Figure 5.5: Hydropower/Hydrodam management based on Seasonal Rainfall Outlook such as Fig. 5.2

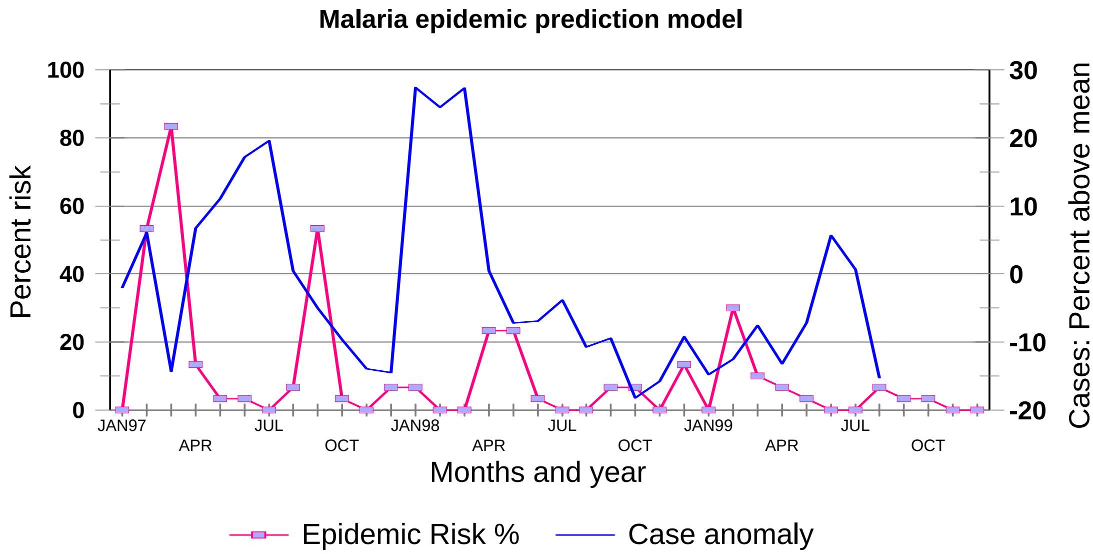


Figure 5.6: Malaria early warning model by Githeko et al (2001) based on seasonal Climate Outlook products

6. Need for Users, Dissemination and Gaps

The needs for the users vary from one sector to another. Agricultural sector users may for example require threshhold climate information specific for various development stages, while domestic water users may be interested only on water availability at the water supply source (river, lake, roof harvesting, etc). For construction and infrastructure development, long term average and variability including those of extreme events may be of higher priority, while priorities for the air, sea and road transport sectors may be current and short range weather information, etc. Thus, any efforts to enhance the use of climate information in climate risk reduction including climate change adaptation strategies must be cognisant of the diversity of the user needs. Such diversity products are not readily available at the moment in most climate centers.

One of the key challenges to optimum use of the climate prediction and early warning products world wide is the difficulty in the use of the probability based products that are being released by the climate centres and the NMHSs. The other challenges include variation in users needs; Quality / accuracy/ credibility of the provided products; clarity / user friendly of the information, low knowledge of the linkages between climate and users requiring multidisplinary research; lack of archive data for computing baselines / past scenarios; low technology level for optimizing the use of available information, resources constrains; among others.

Sharing capacity for climate information to vulnerable rural community is very weak in Africa. Most of the providers and users of climate information prefer to guard and hoard the information that they have with ownership jealousy. The climate dissemination systems to local communities are also very weak or nonexistence, and the information often been reach the users too late to have significant impacts in reducing local climate risks. One of the innovative systems that has been introduced by the three centres in Africa to address these challenges has been the use of regional climate outlook forums (RCOs) that include education and awareness of the users; interactions between various stakeholders; development of the consensus regions climate outlooks; formulation of mitigation strategies and dissemination of climate early warning information. The media experts are part of the COFs and they have been able to release timely early warning information and to raise the RCOF profiles at national levels including the users' understanding and appreciation of climate information in decision making at all levels. Users of climate information in sectors as diverse as agriculture, health, energy, water resources management, and natural disaster prevention have been able to forge some interactions and begin to work closely with the service providers to ensure that, together, providers and users of climate information can substantially improve development decision making. The climate experts and users have undertaken few pilot projects at individual locations and countries to demonstrate the benefits of integrating climate information in sector specific risk management activities. The need to up scale such information to cover the whole country/region, especially at community levels is critical for reducing climate risk reduction including adaptation to future climate changes in GHA.

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According to ICPAC's recent survey, and the recent GCOS (2006) report key gaps in applications of early warning climate products include gaps in communication between users and climate communities; lack of understanding by many policymakers of how climate variability and change might impact on development Goals; policy constraints; gaps in technical, scientific and human capacity; gaps in providing sector specific climate services, gaps in modeling , prediction and early warning capacity, gaps in vulnerability/impacts assessments, climate observations, monitoring and data management issues, gaps in integrating climate risk management into development practice among many others. Most of the users in the regions are illiterate and their awareness on the usefulness of climate information is very low. The users' perceptions are also very low. Many of them still prefer to use traditional/indigenous technology including traditional early warning inherited from ancestors. Relevant policies for climate risk management and climate change adaptation are also lacking.

In order to initiate the routine integration of climate information into development activities, a critical first step is effective and compelling presentation of data, analyses, and policy options to those who set priorities and allocate resources. Given the need for accurate and adequate data on climate and development outcomes including the development and validation of climate models, and generation of risk scenarios the need for adequate observation network, monitoring systems, multidisciplinary data bases, analysis / computing capacity , dissemination / feedback systems, and effective policies are critical. The policymakers will also need the capacity to make climate risk informed decisions.

One key element in integrating climate risk management into development practice is reaching community-level stakeholders. Rural communities that depend on farming and other primary production activities are the ultimate stewards of much of the natural resource base and the segment of society that is most affected by climate. The communities need timely and accurate user friendly climate/weather information, including risk maps. The users also need the ability to maximize the use of such weather/climate information and hence their capacities to understand the information should be enhanced.

Integrating climate information into the risk management strategies of communities with climate-sensitive livelihoods depends on effective use of communication infrastructure and networks to support dialogue with users, to facilitate awareness and education campaigns, and to receive feedback so that users can influence the services they receive. It is recommended that there is need to identify, learn from, and replicate successful climate risk management activities such as those that have been demonstrated from some sector specific pilot projects including agriculture, livestock, hydropower, health, water resources, and disaster management, among others. In this regard, African centres have been organizing regular RCOFs and capacity building workshops for the users at the beginning of the major rainfall seasons to develop consensus regional climate outlooks and to formulate mitigation strategies since 1997.

RCOFs have facilitated the production of downscaled climate prediction products tailored for applications in specific sectors such as agriculture, livestock, hydropower, health, water resources, tourism, and disaster management among others. Many of these pilot application cases have been limited to particular locations and countries. These efforts should be up scaled to all parts of the country and region.

Several issues contribute to gaps in providing climate services. These include issues of data policy, the role of the NMSs as service providers, regional and sub-regional integration, building capacity for climate services, and utilizing climate information for development.

Of immediate concern to this thematic paper is capacity building for application climate services, especially in regards to vulnerability/climate risks assessment, climate change modeling, and development of regional climate change scenarios for adaptation studies. The African centres such ACMAD, ICPAC and DMCH could be used to for the development regional capacity for climate adaptation including climate modeling / climate change scenario development; impacts/ vulnerability/ risk assessment methods; together with issues related to adaptation and mitigation. ICPAC’s past and present experiences have shown that it is cheaper to train within Africa. It has been possible to use resources for training one expert in the north to train ten experts at one of the three climate centres in Africa. The lessons/ experiences for the training undertaken within the African centres are also very relevant to the trainers when they go back home. It has also been easy to bring diversity of experienced experts from various parts of the world, including within the UN system, to the African centres at different times of the training to interact with the trainers on short duration. The contribution by the world class experts to such training do give the national trainers confidence and professional networks when they go back home. The use of the Africa centres for climate risk capacity building including adaptation issues will require strengthening of human and equipment capacity of the Centres enable it effectively provide these required multidisplinary challenges.

It is important to once again note that basic observations and data base development are an essential prerequisite for meeting all the other needs identified above, and, if the gaps in the use of climate information for policy, risk management, and climate services provision are to be filled, it would be essential also to fill the major current gaps in observations and data management. The observational networks should, therefore, be strengthened and capacity for data storage and archiving enhanced

7. Conclusion and Recommendations

The impacts of the extreme events have the potential to destabilize development activities in the region if their frequencies increase. It is expected that if the society can cope with the current climate variability shocks then it has high probability of adapting to the impacts of future climate change. In this regard the factoring of climate forecasts and early warning products in all socio-economic sectors is critical for sustainable development of Africa. There is need to integrate climate variability/change concerns into the national planning and development processes. This would require wide ranging changes in government policies. For example, policy makers and planners will have to re-think conventional approaches. Environmental issues will increasingly assume a higher priority ranking, while economic and institutional measures and arrangements would have to be sufficiently flexible in order to adapt relatively fast to emerging trends or events. Enhancing the adaptive capability requires significant increased capacity in science and technology and formulation of policies that are sufficiently flexible and receptive to constant change.

There is great potential in investing in seasonal forecasting and development of tools for sector specific applications such as crop models that can be used to make adjustments in management. Although these models are still experimental, they offer a realistic response to extreme climate variability that provide coping lessons for climate change adaptation. Data must be collected to calibrate and validate these models. In the longer term, governments will need to develop win win strategic plans that are based on solid foundations. This is an area that is underdeveloped in almost all of Africa.

The threats posed by climate change increase the urgency of promoting growth and development today. This is fundamental to reducing the vulnerability of developing countries to inevitable impacts of climate change, and enabling them to better manage these impacts. If unchecked, climate change can alter the prospects for growth and development in some of the poorest countries. This underlines the urgency of strong and early action to stabilize greenhouse gases (GHGs) emissions. Recent IPCC assessment reports have however noted that even if the GHGs emissions are stabilized, climate change is still invertible due to the long resident period of some of the GHGs in the atmosphere.

For the development of realistic adaptation strategies, there is need for relatively accurate future regional climate scenarios. Research and pilot application projects for the development and implementation of adaptation strategies that can be scaled up to national level/ regional levels; and availability of realistic regional and local scale scenarios are currently some of the major challenges of adaptation studies in Africa. Other critical issues needed to address adaptation challenges of the region include education and public awareness, institutional arrangements and networking. There is need for formulation of realistic adaptation strategies that could support adaptation initiatives by vulnerable countries and communities. Resource mobilization strategies are critical in any adaptation strategy. Many of the adaptation needs are cross-cutting and may require demonstration projects and strategic partnerships / alliances amongst various sectors at national, regional and international levels.

In general, technology and technology transfer will play pivotal role in adaptation, alongside public policies that restructure the incentives and regulatory systems that govern energy generation and consumption. How to integrate indigenous technology that the society in Africa has used to adapt to the past climate shocks must also be addressed.

In most parts of Africa, capacity building is critical in all areas including ability to identify climate change risks and vulnerability as key determinants of well being of the vulnerable communities; monitor impacts on regional climate; verification of models; downscaling global climate models to regional/local conditions; developing impact scenarios; reduce vulnerability to climate change; effectively access and utilize resources and technology required to minimize the costs of climate change; education, public awareness and outreach, together with addressing regional technological needs and challenges, including issues related to the integration of indigenous technology.

This study recommends the use of specialized institutions in Africa such as ICPAC in collaboration with partners to play central roles in the implementation of capacity building programme.

Many of the African countries are classified within the Least Developed Countries (LDCs) that are characterized by extreme poverty as well as inadequate human and institutional capacities. In the GHA for example, nine of the ten countries are classified within the LDCs. Resources are therefore very limited. Resources are required for not only providing multidisciplinary human resources; technical capacity, institutional development, but also for education, awareness, policy development and various gaps and needs that have been highlighted in the report.

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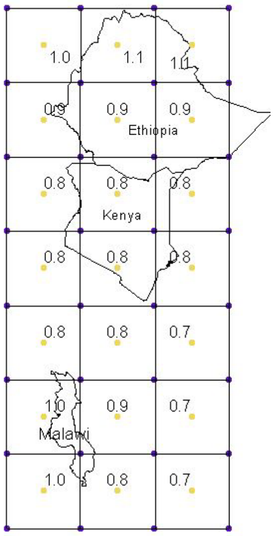
9. Annexes

9.1 Annex 1: Seasonal Temperature and Rainfall Projections



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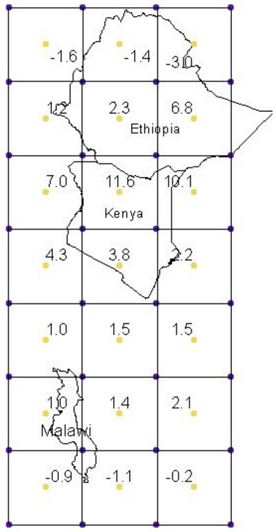

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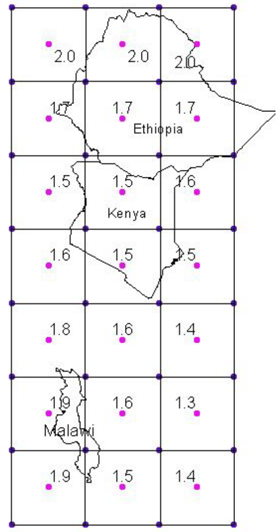

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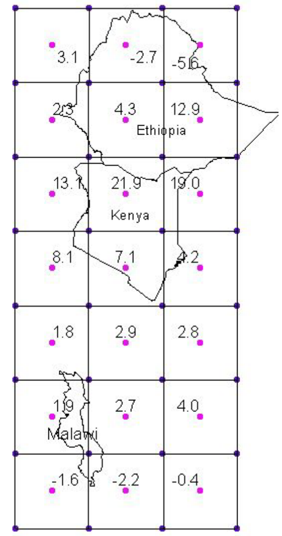

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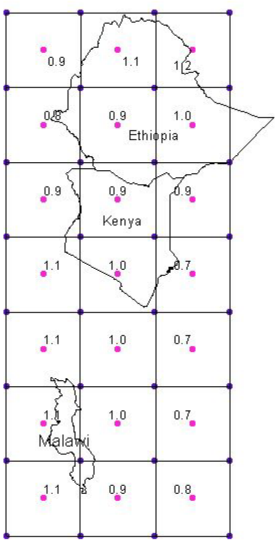

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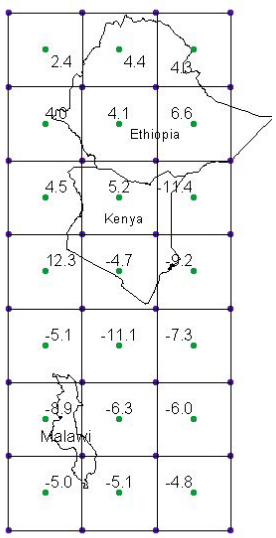

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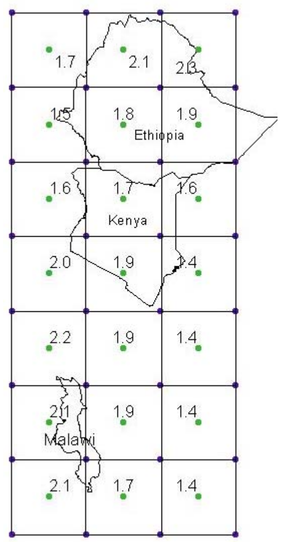

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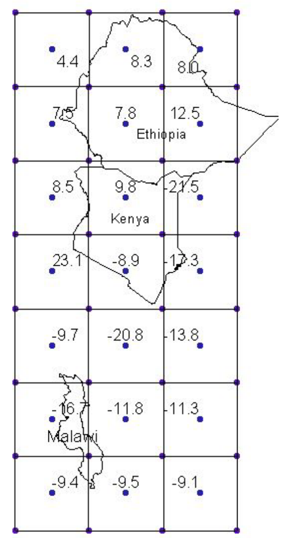

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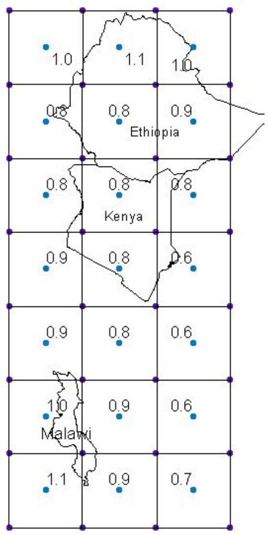

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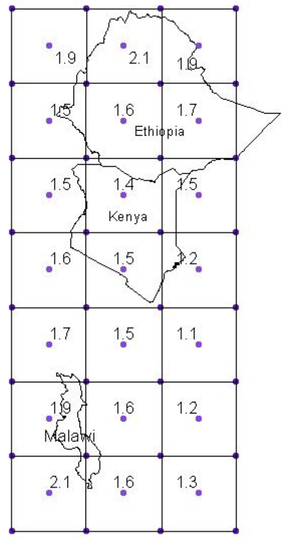

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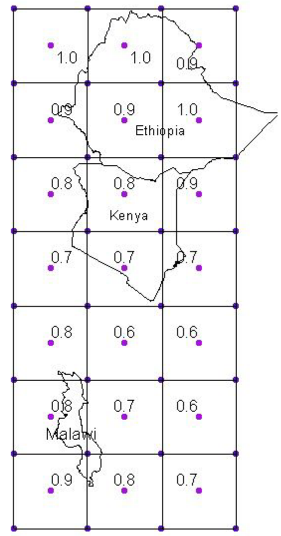

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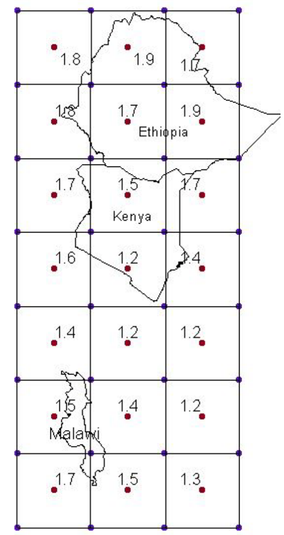

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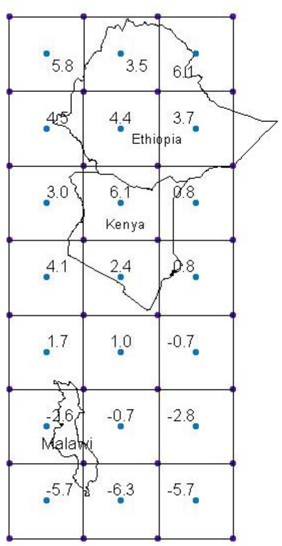

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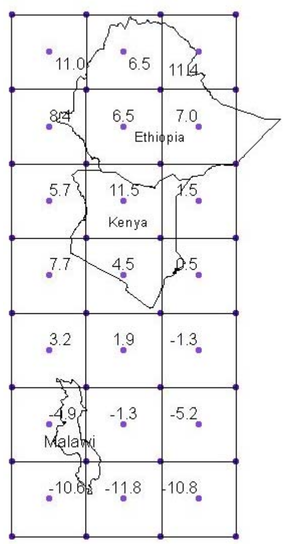

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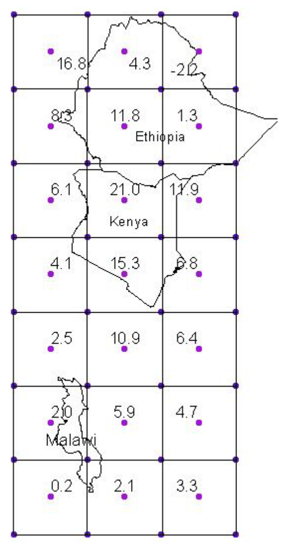

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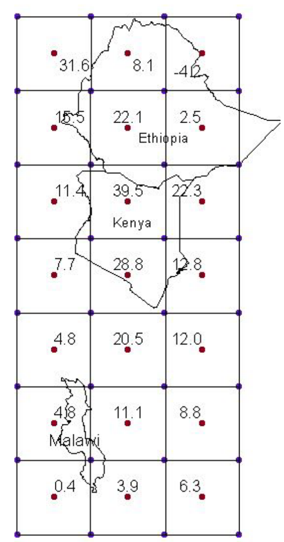

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