Climate Change, Climate Variability and Adaptation in Ethiopia

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Abstract

This paper attempts to identify climate change and variability indicators and consequences in Ethiopia and to pin-point current climate risk adaptation measures and to suggest further areas of intervention. Climate influences natural systems (ecosystem) resources, industries, communities, productivity and reliability of supplies, regions and nations. Climate generally affects our everyday life, and hence its slight deviation from 'normal' has various consequences. The incidence and magnitude of climatic disasters today is widely recognized as posing a serious threat to the survival, dignity and livelihood of countless individuals, particularly the poor. It is now understood that climate or environmental crises have a compelling influence over social structures and political stability in vulnerable traditional societies such as Ethiopia. Ethiopia's climate is influenced by general atmospheric and oceanic factors that affect the weather system and the time of inception and intensity of the rains which are received during the Ethiopian spring, autumn and summer seasons either in a uni- or bi-modal pattern. The summer rainfall (June-September-"Belg") contributes about 74% of the annual rainfall in the country as compared to the spring (February-May-"Meher") and autumn (September-November) rainfalls. A weakness or failure of the rainfall in one or more of the rainy seasons has disastrous consequences in the country. Although Ethiopia receives rainfall during the spring and autumn seasons depending on location, the summer rainfall contributes about 74% of the annual rainfall in the country. A weakness or failure of the rainfall in one or more of the rainy seasons has disastrous consequences in the country. During the last century, Ethiopia's climate variability and the consequent agricultural as well as socio-economic crises attracted continuous global attention. It was reported that shortage of precipitation and its variability in space and time had led to recurrent and substantial shortfalls in agricultural production, which claimed tens of thousands of human and animal lives. During these years, the country suffered significant production deficit of about 20% in the agricultural sector resulting in a decrease of total annual production by about one million tons. Several simulation studies indicated the likely impacts of climate change on Ethiopia. An increase of temperature by 10 °C and decrease of rainfall by up to 2% are projected for the year 2030. The climate in Ethiopia is expected to be more variable with climate change; increasing the chance of extreme events such as drought and floods. Several reports have indicated the likely negative effects of climate change on Ethiopia on water resources (drying or a decrease in water level of lakes), ecosystems (ecosystem transformation and biodiversity loss), health (epidemics of malaria, Rift Valley Fever, cholera), food security, and on efforts being made in achieving the Millennium Development Goals. It is concluded that the effective reduction of vulnerabilities to current climate variability and change requires coordination across different levels of governance and the involvement of various stakeholders.

Keywords: Climate Change, Climate Variability, Adaptation

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Introduction

Rainfall is the most variable and unpredictable climatic factor in Ethiopia having the highest (up to 89%) coefficient of variation. Although a decreasing annual rainfall trend is observed nationally, there were location differences in such a way that there was an increasing trend in some places (e.g., Addis Ababa) and a decreasing trend in others (e.g., Jijiga and Mekele). However, contradictory rainfall trend analyses were reported in the literature, which could be due to variations in the duration of time considered. The amount and distribution of the rainfall during the crop growing seasons are more critical and detrimental than the annual total rainfall. The start and end of the rains and their distribution and the length, frequency and probability of dry spells in the growing season are key elements that determine the planning, performance, and management of Ethiopian agriculture. Unusual rainfall amounts and distributions usually lead to poor harvest and/or complete crop failure, and shortage of pasture and animal feeds. Such unusual and extreme conditions finally result in drought with a resultant depletion of assets, societal vulnerability, mass migration, and loss of life.

Drought, followed by flood and unexpected frost, is the major climatic disaster in Ethiopia. The intensity, frequency and the effects of droughts in Ethiopia, and the number of people in need of food aid have increased since the mid 1970s. Reports suggested that such dramatic increase in the intensity and frequency of drought could be due to global climate change. However, the intensity and frequency of drought in Ethiopia varies with season and geographical location. The northern, northeastern, eastern and southeastern parts of the country are more drought-prone than the other parts of the country; and the Belg production season is more drought sensitive than the Kiremt production season.

Rainfall variability has direct impacts on natural resources, agricultural output, road and transport services, water intensive-industries, electric power production, and on human health in Ethiopia. These impacts are generally unmitigated because there is little- knowledge, hydraulic infrastructure, coordination and financial resource to store and manage water (McBeill, 2000).

The Ethiopian economy is based on agriculture, which contributes 47% to GDP, 80% to total export and 85% to employment. This makes the Ethiopian economy strongly linked and highly vulnerable to hydrological variability. Rainfall variability currently costs the Ethiopian economy over one-third of its growth potential, and it is expected to reduce the rate of economic growth by 38% per year and to increase poverty by 25% over a twelve-year period.

Rainfall Variability in Ethiopia

In Ethiopia, rainfall is better studied than any other climatic parameter because of its intra- and inter- season variability both in space and time. Analysis of rainfall from 1898-1997 in the central highlands of Ethiopia (Addis Ababa, Debre Markos, Debre Zeit, Ejaji, Fiche, Kombolcha, Majete, Sheno, Shola, Tulu Bolo and Wonji) showed a decreasing trend and extreme variability of rainfall (Osman and Sauerborn, 2002; Figure 1). These authors observed positive rainfall deviations from the long-term mean in the first and negative deviations in the second half of the 20th century. They also indicated that agro-ecological crises were coincided with precipitation lows.

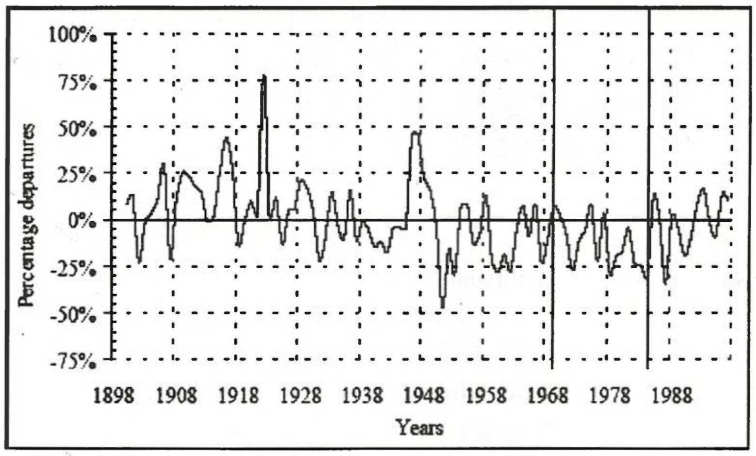


Figure 1. Departure of long-term summer rainfall from its long-term average in the central Ethiopian highlands. (From Osman and Sauerborn (2002).

The positive departures observed in the first half of the 20th century are highly pronounced in the first three decades (Figure 1). Osman and Sauerborn (2002) noted that the second half of the 20th century suffered predominantly negative rainfall deviations, with summer values frequently lower than the long-term average. Similar findings were reported by Seleshi and Demaree (1995) for northern Ethiopia including Eritrean highlands. Seleshi and Demaree (1995) indicated high concentration of meteorological drought in Addis Ababa in the period from 1948-1973. They also reported meteorological, hydrological and agricultural drought in Ethiopia in the second half of the 20th century.

These rainfall variations in the central highlands of Ethiopia had considerably influenced the surface flow regimes of major rivers and springs originating from and flowing through the central highlands of Ethiopia, as well as the land use patterns in the area (Osman and Sauerborn, 2002b).

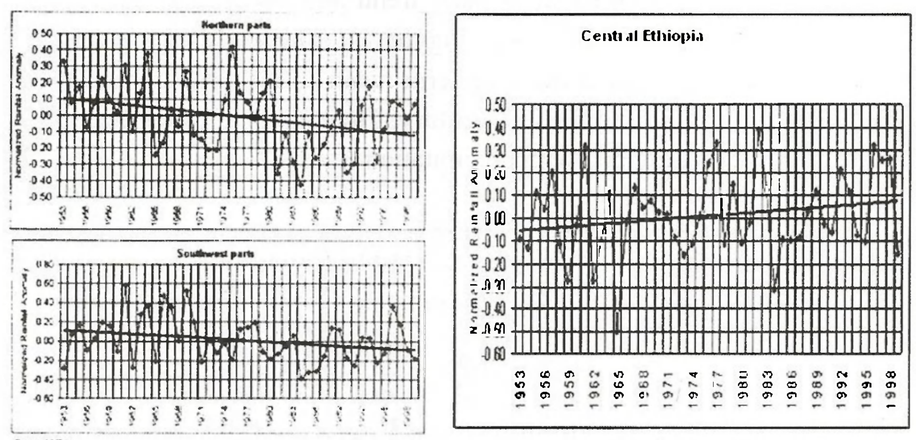


Figure 2. Annual rainfall variability and trend in Ethiopia.

Examination of the long-term rainfall data of 93 meteorological stations in Ethiopia indicated a coefficient of variation ranging from 25-89% (Tesfaye, 2009). From the 93 stations considered, 15 had above 50% coefficient of variation indicating the extreme variability of rainfall in the country.

Pooled rainfall data over 42 meteorological stations for the period 1953-2002 showed a relatively constant trend in the country (Tesfaye, 2009). However, examination of regional data indicated a slight decline in rainfall trend in the northern and southeastern parts of the country while there was a slight increasing trend in the central part of the country (Figure 2). Moreover, analysis of data for each individual weather station showed either increasing (Addis Ababa) or decreasing (Jijiga) rainfall trend (Figure 3).

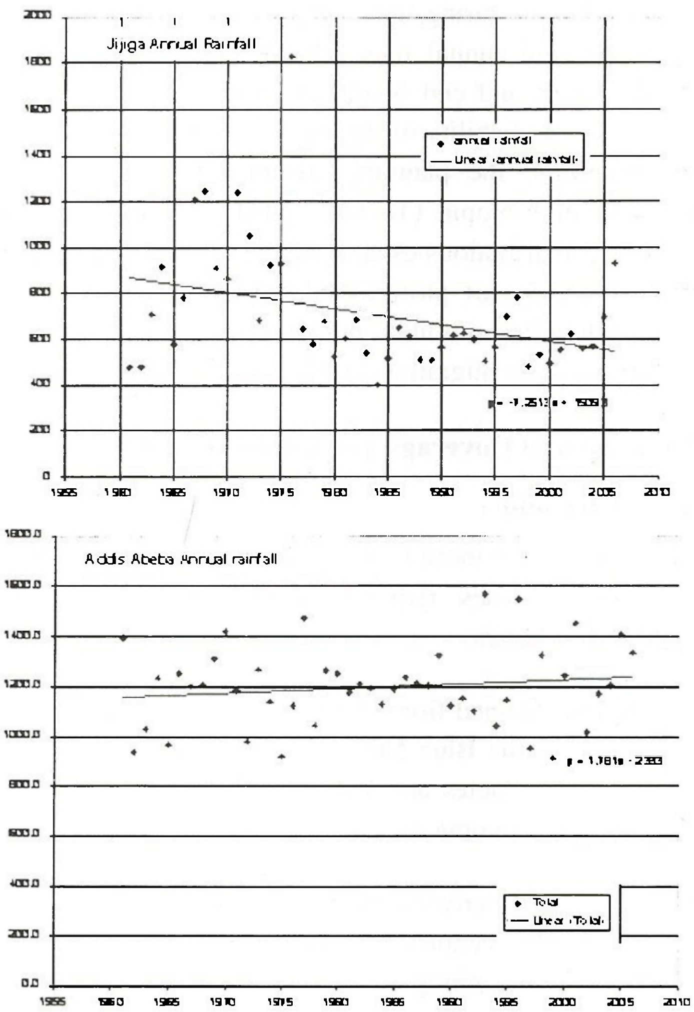


Figure 3. Annual rainfall trends at Jijiga and Addis Ababa weather stations.

A vulnerability assessment showed that a decrease in rainfall over the northern parts of Ethiopia was expected (Board and Agrawala, 2000). An investigation with three global climate models also indicated a risk of more frequent droughts under climate change (Board and Agrawala, 2000).

For the highly rainfall dependent Ethiopian agriculture, the amount and distribution of the rainfall during the crop growing seasons are more critical and detrimental than the annual total rainfall (Tesfaye, 2004; Simane and Struck, 1993). The start and end of the rains and their distribution and the length, frequency and probability of dry spells in the growing season are key elements that determine the planning, performance, and management of dryland agriculture in Ethiopia (Tesfaye, 2004)). This is because unusual rainfall amounts and distributions usually lead to poor harvest and/or complete crop failure, and shortage of pasture and animal feeds. Such unusual and extreme conditions finally result in drought with a resultant depletion of assets, societal vulnerability, mass migration, and loss of life.

The Frequency, Spatial Coverage and Cause of Drought in Ethiopia

The frequency of drought

Ethiopia is currently known more by its frequent and disastrous droughts than its beautiful historical places, rich natural resources, attractive parks, and unique archeological findings.

Based on information obtained from chronicles, archived data, historical texts, recodes of the levels of the Blue Nile in Egypt, travelers' and missionary's' dairies, European settlers notes and folk songs, NMSA (1987) complied the frequency of drought in Ethiopia as shown in Table 1.

The frequency of drought increased from one in 100 years in the 1st century to one in six years in the 20th century and also once in 3 years around the end of the 20th century and the beginning of the 21st century (Table 1). In general, the intensity, frequency and the effects of droughts have increased since the mid 1970s (USAID, 2003; ECBP, 2007). Besides climate variability, the dramatic increase in the frequency of drought in the past three decades could be due to global climate change.

Table 1. Frequency of occurrences of drought events in Ethiopia

Year interval	Number of disasters	Average recurrence
253BC-42 BC	5	Once in 40 years
12AD-787AD	6	Roughly once in 100 years
832-968	3	Roughly once in 45 years
1006-1200	4	Roughly once in 48 years
1252-1340	5	Roughly once in 18 years
1400-1789	26	Roughly once in 15 years
1800-1900	10	Roughly once in 10 years
1900-1987	14	Roughly once in 6 years
1988-2002	5	Roughly once in 3 years

The drought prone areas of Ethiopia

Almost all parts of the country experienced some degree of drought in the past three thousand years although the frequency, intensity and duration of the drought vary from one region to another. The most drought prone areas of Ethiopia are the northern and northeastern regions (Tigray, parts of Wollo and Gondar, Afar), the eastern (Somali Regional State, Hararghe) and southeastern (parts of Bale) and the southern (Borena) parts of the country (Comenetez and Caviedes, 2002; Wolde-Gergis *et al.*, 2001; Wolde-Mariam, 1986). The areas that are less affected by severe droughts and ensuing famines are the regions located in the central highlands and in the uplands descending to Sudan (Comenetez and Caviedes, 2002).

A pattern of drought progression has been indicated by Wolde-Mariam (1986) that drought and famines begin to be felt in the northeast part of the country and then propagate southward along the Awash Valley into the southern regions of Hararghe and Bale. As the seriousness of drought mounts, the central highland regions of Wollo, Shewa, Arssi, Keffa, and Wollega become involved. The last regions to fall under the influence of dryness, livestock mortality and increased lack of staple crops are the western regions of Gojam, Gondar, Wollega, and Illubabor (Wolde-Mariam, 1986).

The intensity and frequency of drought also varies depending on the season type. For example, in 1971, 1973, 1975, 1977 and 1984, more than half of the administrative regions of the country were affected by drought because of lack of the *Belg* rains. The 1975 drought was the most severe and affected 11 of the 13 administrative regions. The year 1987 was the period when there was lack or shortage of the *Kiremt* rainfall and as a result more than 50% of the regions comprising 70% of the total area of the country were under drought. Droughts as a result of lack or shortage of *Kiremt* rainfall were also recorded from 1969-72 and from 1984-87 (Wolde-Giorgis, 1997). Records of drought events and their intensities and historical rainfall analyses indicated that *Kiremt* rainfall is more consistent, with the occurrence of few and mild droughts, than the *Belg* rainfall (Tesfaye and Walker, 2004).

Climate Change and its Likely Effects in Ethiopia

Ethiopia is facing serious climate variability throughout its history. However, the intensity and frequency of variability has dramatically increased in the last three decades probably due to the effect of climate change.

According to IPCC (2001a), climate change refers to any change in climate over time whether due to natural variability or as a result of human activity. According to UNFCCC (2001), climate change refers to a change in climate that is attributable directly or indirectly to human activity that alters atmospheric composition. In general, climate change refers to changes in long-term trends in the average climate, such as changes in average temperatures and rainfall. On the other hand, climate variability refers to changes in patterns, such as rainfall, weather and climate.

It is now believed that climate change is caused by excess emission of greenhouse gasses. The developed industrialized countries and the fast growing ones like China and India emit more than 95% of the greenhouse gasses (CO_2, CO, CH4, N_2O, SO_2). However, the least developed countries emit small quantity of these greenhouse gases. For example, Ethiopia's emission of CO_2 in 1998 was negligible compared to 2.1% in Africa and 8% in the world (UNFCCC, 2001; 2002). Ironically, the country is becoming a victim of the looming disaster of climate change.

Studies showed that Africa had already warmed by 0.7 °C over the 20th century (IPCC, 2001a). Scenario investigations with general circulation models (GCMs) showed that the continent could be warmed by a temperature ranging from 0.2 °C per decade (low scenario) to more than 0.5 °C per decade (high scenario) (Hulme *et al.*, 2001; IPCC, 2001a).

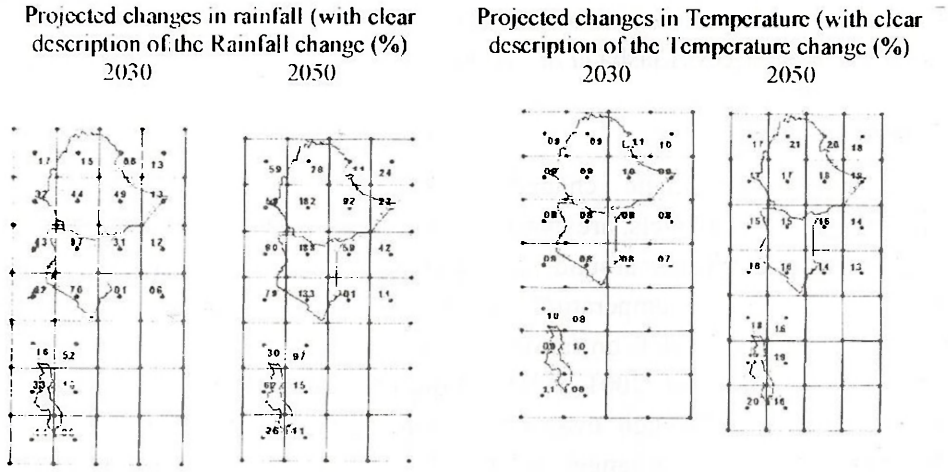


Figure 4. Projected changes in temperature and rainfall of Ethiopia for the years 2030 and 2050

Simulation of future climate for 2030 and 2050 using different simulation models (Canadian Climate Center Model, CCCM; Geophysical Fluid Dynamics Laboratory Model, GFDL, the United Kingdom Meteorological Office-1989 model, UKMO-89; and GFDL-Transient Models) indicated an increase in temperature and a decrease in rainfall over Ethiopia (NMSA, 2001). According to this simulation study, there will be an increase of temperature by 10 and 20 °C and a decrease of rainfall by about 1 and 2% in 2030 and 2050, respectively (Figure 4). These changes are expected to decrease revenue per hectare (Deressa and Hassan).

Extreme events

Global circulation models suggest that, in general terms, the climate in Africa will become more variable with climate change. Although the exact nature of the changes in temperature or precipitation, and extreme events are not known and still debatable, there is general consensus that extreme events will increase and may get worse (Elasha *et al.*, 2006). The IPCC (2001a) reports changes in some extreme climate phenomena indicating that extreme events, including floods and droughts, are becoming increasingly frequent and severe in Africa, particularly in the Horn of Africa. Flooding and droughts are now common across Ethiopia. It is likely that the increased frequency of recorded disasters results from a combination of climatic change and socio-economic and demographic changes (Elasha *et al.*, 2006).

Water resources

The impacts of climate change, including, changes in temperature, precipitation and sea levels, are expected to have varying consequences for the availability of freshwater around the world. Within the Nile basin, there is a high confidence that temperature will rise (Conway, 2005) but there are disparities between models on rainfall predictions over both the Blue Nile and White Nile (Hume *et al*, 2001; 2003). However, temperature rise will lead to greater water loss through evaporation placing additional stress on water resources regardless of changes in rainfall (Hume *et al*, 2000). Nine recent climate scenarios showed decreases in Nile flows from zero to approximately 40% by 2025 (Strzepek *et al*, 2001). Dramatic decreases in water level (e.g. Rift Valley Lakes) or disappearance (e.g., lake Haramaya) of lakes is now becoming a recent phenomenon in Ethiopia. Decreases in both surface and ground water levels in Ethiopia will affect water supply in quality and quantity for human, animal, agricultural and industrial consumption as indicated by Elasha *et al.*, (2006) for the whole African continent.

Human Health

The health effects of a rapidly changing climate are likely to be overwhelmingly negative (IPCC, 2001b). The outbreak of Rift Valley Fever, cholera and malaria are expected to increase with climate change (e.g., Mesfin and Tarekegn, 2000; Elasha *et al.*, 2006). Christopher (2004) showed highly suitable conditions for malaria transmission by the 2080s in previously malaria-free highland areas in Ethiopia, Kenya, Rwanda and Burundi.

Agriculture and food security

Agriculture is the most important sector in the economy of Ethiopia representing 47% of the country's GDP, contributing about 80% of the total export value and employing 85% of the population (USDS, 2007). Agriculture is mostly subsistence in nature with a high dependence on rainfall (over 95%). As a result, agriculture in Africa and particularly in Ethiopia is highly vulnerable to changes in climate variability, seasonal shifts, and precipitation patterns (WRI, 1996).

According to FAO (1999), the general impacts of climate change on agriculture include reduction in soil fertility; increasing variability in growing season conditions (shifts in start of rainy seasons, length and quality of rains, etc); decreased livestock productivity directly (through higher temperatures) and indirectly (through changes in the availability of feed and fodder); increased incidence of pest attacks resulting from high temperature; manifestation of vector and vector born diseases; and negative impacts on human health affecting human resource availability. The impact of these changes on agriculture is exacerbated by the lack of adaptation strategies, which are increasingly limited due to the lack of institutional, economic and financial capacity to support such actions (FAO, 1999). As a result, the food security threat posed by climate change is great for Africa, where agricultural yields and per capita food production have been steadily declining, and where population growth will double the demand for food, water and forage in the next 30 years (Davidson *et al*, 2003; Elasha *et al*., 2006).

Ecosystem and Biodiversity

Ethiopia is endowed with a highly diverse fauna and flora. Biodiversity in Africa in general and in Ethiopia in particular is already under threat from a number of natural as well as human induced pressures. Climate change is now an additional stress factor (Desanker, 2002). Changing rainfall patterns could lead to soil erosion, the siltation of rivers and the deterioration of watershed leading to ecosystem transformations. Increasing frequency of droughts and floods associated with climate variability and change could have a negative impact on the ecosystems of Ethiopia. Projection of climate change based on GFDL model has shown ecosystem transformation in Ethiopia (NMSA, 2001). For example, the lower Montane Moist forest ecosystem will be transformed into subtropical moist forest and sub tropical dry forest will be converted to tropical dry forest in the northwestern part of the country. In the southeastern part of the country, the topical desert will dominate the other ecosystems (NMSA, 2001).

Climate change will trigger species migration and lead to habitat reduction. One study examining over 5,000 African plant species predicts that 81-97% of the plant species' suitable habitats will decrease in size or shift due to climate change (McClean, 2005). Moreover, the same study noted that by 2085 between 25 and 42% of the species' habitats are expected to be lost altogether. Moreover, ecosystem services that rely on sub-Saharan African plant diversity, including indigenous foods, as well as both locally used and potential exotic plant-based medicines are likely to be adversely impacted by climate change (WRI, 2005).

Millennium Development Goals

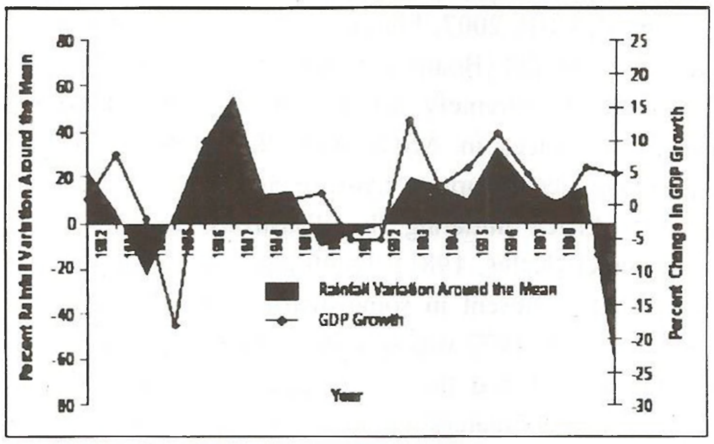
Climate change has the potential to undermine economic development, increasing poverty and delaying or preventing the realization of the Millennium Development Goals (MDGs) (Elasha *et al.*, 2006). According to Elasha *et al.* (2006), the lack of effective adaptation to the adverse effects of climate change can jeopardize the achievement of MDG goal 1 (eradicating extreme poverty and hunger), goal 6 (combating HIV/AIDS, malaria and other diseases) and goal 7 (ensuring environmental sustainability. This indicates a direct link between climate change and development, where the impacts of climate change could largely impede economic development.

The Effects of Climate Variability in Ethiopia

National Economy

Ethiopia has highly variable rainfall both in space and time and experiences several drought incidences. Such unmitigated hydrological variability now costs the Ethiopian economy over one-third of its growth potential (Sadoff, 2006). Currently, the extremely low level of hydraulic infrastructure and limited water resource management capacity in the country undermine attempts to manage rainfall variability. These conditions leave Ethiopia's economic performance virtually hostage to its hydrology (Sadoff, 2006).

The very structure of the Ethiopian economy, with its heavy reliance on rainfed subsistence agriculture, makes it particularly vulnerable to hydrological variability (Sadoff, 2006). According to a World Bank study (Sadoff, 2006), water variability reduced projected rates of economic growth by 38% per year and increased projected poverty by 25% over a twelve year period.



Source: World Bank 2006

Figure 5. Rainfall variation around the mean and GDP growth in Ethiopia.

The vast majority (80%) of Ethiopia's population subsists on rainfed agriculture, thus their welfare and economic productivity are linked to the variable rains (Grey and Sadoff, 2005; Sadoff, 2006). The correlation between rainfall and overall GDP is found to be strong (Figure 5). According to Sadoff (2006), the impact of rainfall variability is felt not only on agricultural outputs but also on other sectors (environment, electric supply, manufactured goods, income, consumption and prices). Such effects of rainfall variability are severe mainly because they are unchecked either by good physical infrastructure or good management practices (Sadoff, 2006).

Recent frequent floods disrupted the economy by destroying roads, electric power lines and installations, buildings, crop fields, animals and the working force. For example, the 2006 flood damage in Dire Dawa city was estimated at Ethiopian Birr 70 million (ECBP, 2007). A single day heavy frost in the highland areas of east Hararghe caused an estimated damage of Ethiopian Birr 48.1 million (HU, 2005).

Effects on Human Lives and Food Security

Drought

Hydro-meteorological hazards, particularly drought, are the leading cause of disaster and human suffering in terms of frequency, area coverage and number of people affected (ECBP, 2007; Figure 5). Famine has long been associated with fluctuations in rainfall (Board and Agrawala, 2000). Although the 1972-73 El Niño was not extremely severe when compared with subsequent episodes, its consequences in Africa were the most calamitous of recent decades. This event deeply upsets hydro-meteorological regimes of eastern and sub-Saharan Africa initiating the disastrous drought and subsequent famines of the Sahel (Kates, 1981). In Ethiopia, the precipitation of *Kiremt* rains were so scant or absent in some districts that the subsequent harvest season of the autumn of 1972 was seriously reduced, particularly in northern Wollo. As 1973 arrived and the ENSO episode became more severe, the failure of the *Kiremt* to materialize extended the drought further into the northern highlands. Agricultural dryness also expanded into the eastern and southern regions of the country to encompass 55% of all the 102 provinces into which the country was divided before the administrative restructuring in 1983. By mid-1974, the continued drought and failed summer harvest grew to comprise 60% of the provinces as the specter of famine covered most of the country with the exception of the western regions (Wolde-Mariam, 1986).

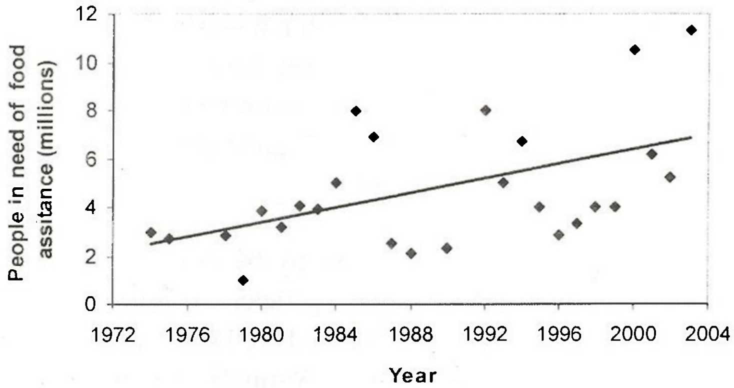


Figure 6. Number of people in need of food assistance in Ethiopia for the period 1974-2003. (Data source: Abate (2003).

The 1982-83 drought affected around 6.7 million people (Wolde-Georgis *et al.*, 2001) and consequent famine claimed the lives of 500, 000 to 1,000,000 people (Dejene, 1990; Ezra, 2001).

Continued droughts in 1991-92 and 1993-94 caused as much distress as during the 1980s. Moreover, in 1997-98, a drought induced by another El Niño cost nearly $28 million in damages (Comenetez and Caviedes, 2002). This drought was followed by catastrophic flooding in 1998 that compounded the shortage of food, which resulted in rural exodus and city in-migration (Wolde-Georgis *et al.*, 2001). The failure of the 2000 *Belg* rains was more critical than the case in 1984 as it followed consecutive years of drought in 1998 and 1999, which had killed livestock and over-stretched the coping capacities of local communities (Board and Agrawala, 2000).

Like that of farmers who suffer from periodic crop failures, pastoralists also suffer from loss of livestock when seasonal rainfall fails or when unusually heavy storms cause widespread flooding. Pastoralists, who move seasonally in search of water and grazing, often are trapped when drought inhibits rejuvenation of the denuded grasslands. During such times, a family's emergency food supplies diminish rapidly, and hunger and starvation become commonplace until weather conditions improve and livestock herds are subsequently rejuvenated. The 1973 famine had threatened the lives of hundreds of thousands of Ethiopian pastoralists, who had to leave their home grounds and migrate into neighboring countries in search of food and relief from starvation.

The effects of drought are often combined with other hazards such as migratory pest infestation (locust), prevalence of some crop diseases and pests (ECBP, 2007), malaria outbreak (Mesfin and Tarrkegn, 2000) and livestock diseases. Because of such compounded effects, the number of people in need of food in Ethiopia sharply increased from 1974 to 2003 (Figure 6). Generally, recurrent drought depletes different economic assets of the majority of the Ethiopian population and creates weak resilience (high vulnerability) against disaster impacts year after year (Abate, 2003). Depletion of assets due to recurrent droughts increased the vulnerability of households and decreased their ability to cope with climatic risks and other natural hazards.

Flood

Flooding caused by heavy rainfall and river overflowing has regularly affected people and their property, especially those in the low lying areas of Somali, Afar, Gambella, Oromiya, Amhara and the Southern regional states. The devastating flood incidences in Dire Dawa city, Gode in the Somali Regional State and South Omo in the South Nations and Nationalities and Peoples Regional State (SNNPRS) in 2006 are recent examples. Flash floods affect all regions depending on the intensity of rainfall. Some floods such as those in the 1996 and 2006, triggered disasters which claimed the lives of hundreds of people, displaced hundreds of thousands and destroyed physical, natural and economic assets (ECBP, 2007). It is also observed that a series of flooding had inflicted environmental as well as socio-economic damage to the central highlands of Ethiopia (UNDHA, 1995; Osman and Sauerborn, 2002).

Ethiopia is mountainous with rugged topography and steep slopes. The highlands are extensively deforested; rains are sometimes heavy and torrential; water converges in river basins and causes swelling of rivers. The watersheds of the major rivers are highly degraded with negligible vegetation cover, reducing infiltration into the ground and increasing runoff (ECBP, 2007).

Floods are recurrent in some countries of Africa; even communities located in dry areas have been affected by floods. The floods had a devastating effect on livelihoods, destroying agricultural crops, disrupting electricity supplies and demolishing basic infrastructure such as roads, homes and bridges (UNEP-Atlas, 2005). It is also not uncommon for some countries to experience both droughts and floods in the same year; the flooding experienced in East Africa followed periods of extended drought.

According to ECBP (2007), the most drought prone areas of Ethiopia are: central and western Tigray; north Gondar, north and south Wollo and Oromia zones of Amhara Region; east, north and west Showa zones and Hararaghe areas of Oromia region; South Omo, Gurage, Sidama and Hadiya zones of SNNPR, and Dire Dawa city.

Frost

Extremely cold temperatures are becoming common in the highland areas of the country exasperating the existing food insecurity. For example, the incidence of frost damage to field and vegetable crops as well as some ornamental plants grown in the valley bottoms and lower landscape positions particularly in the surroundings of sinkhole lakes and the lower positions of the sub-catchments in the highlands of East Hararghe is often taken for granted with varying degrees of severity from year to year. However, unlike other years, frost incidence occurred twice at the end of 2004 cropping season in these areas. The first incidence occurred between late October and mid to late

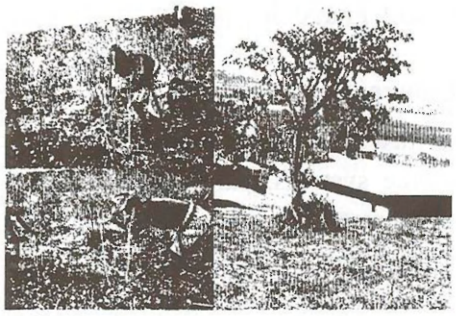


Figure 7. Clearing of a frost killed *khat* plantation (left) and a frost attached tree (right) in January 2005 at Haramaya, Ethiopia.

November with some deviations depending on localities, and caused severe damage on field crops (mainly sorghum and late planted beans) and some vegetable crops. The second frost incidence that was abnormal and almost unknown to the farmers in east Hararghe Zone of eastern Oromia and Harari Regional States occurred between January 1 and 5, 2005. For example, the temperature that was recorded at the Haramaya University (HU) campus meteorological station on 1 January 2005 was -7.5 °C (AU, 2005). Such low temperature is uncommon in the tropical climates. Besides its unexpected occurrence, the damage caused by the second frost incidence was extensive and very severe and affected plants on vast areas that are not even known to be affected in the past by the normal frost incidence. The frost severely affected field crops, vegetables, perennial cash crops of the farmers (*khat* and coffee) and fruit and forest trees (AU, 2005; Figure 7). The unusual frost affected crops and vegetation on an area of 3,137 ha affecting 51,257 households with an estimated monetary loss of Ethiopian Birr 48.1 million (AU, 2005). Although not extensively reported, many farmers in the highland areas of the country are feeling such unusual temperatures and their devastating effects.

Effect on Crop Yields

Crop yield is strongly correlated with rainfall variability in Ethiopia (Lemi, 2005). Complete dependence on natural rainfall and low-input farming methods are typical features of Ethiopian agriculture. Thus, the amount and temporal distribution of rainfall is the most important factor in determining national crop production levels. On top of climate variability, changes caused by climate change represent a huge threat.

Effect on Natural Resources

Rainfall fluctuations in East Africa have had significant short- and long-term effects on natural resource systems, particularly lakes, wetlands, and rivers (Conway *et al.*, 2005). Climate variability represents a significant challenge for water resources management. Further changes in rainfall and river flows, caused by human-induced climate change, undermine traditional methods of water resource management. They increase the severity and frequency of floods and droughts, and increase water scarcity. Rainfall in central Ethiopia provides over 50 % of the main Nile flows to Egypt. During the 1970s and 1980s, rainfall across much of the Ethiopian highlands declined. This contributed to the major famine of 1984-5 in Ethiopia. Low rainfall also meant that Egypt suffered a succession of low Nile flows. By 1988, Egypt was very close to a major water shortage. Recurrent drought also caused genetic erosion and biodiversity degradation in Ethiopia (e.g., ECBP, 2007).

Adaptations to Climate Variability and Climate Change

Vulnerability is defined by the IPCC as the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes. In this respect, vulnerability is seen as the function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2001b).

Because of high climatic variability, communities residing in marginal environments such as those in Ethiopia have developed strategies to cope with drought. The high vulnerability of people in Africa to climate variability is attributed to a large extent to their low adaptive capacity which results from a deteriorating ecological base, widespread poverty, inequitable land distribution, a high dependence on the natural resource base and the ravages of HIV/AIDS (Hulme, 1996; Magadza, 2003; Ikeme, 2003). Improving adaptive capacity is important in order to reduce vulnerability to climate change (Elasha *et al.*, 2006).

Despite the low adaptive capacity of Africa in general and Ethiopia in particular, people have developed traditional adaptation strategies to face the great climate interannual variability and extreme events. Those communities, who have faced harsh environmental conditions over prolonged periods, have consequently been trying, testing and adopting different types of coping strategies (Elasha *et al.*, 2006). An unusually persistent drought may increase people's vulnerability in the short term, but it may encourage adaptation in the medium to long term (Mortimore, 2001). This reinforces the observation that local people have perceived, interacted with, and made use of their environment with its meager natural resources and changing climatic conditions. This practical coping mechanism is particularly true for the drought prone areas in Ethiopia and in the African Sahel region, which is susceptible to frequent climatic hazards (Elasha *et al.*, 2006).
According to different sources (e.g., ECBP, 2007; Elasha *et al.*, 2006; Admassie, 2007; Hellmuth *et al.*, 2007,), the currently practiced climate variability and climate change adaptation strategies in Ethiopia are diversification of herds and incomes, growing of drought and heat resistant and early maturing crop varieties, use of small-scale irrigation, water harvesting and storage, and improved water exploitation methods, labor migration, response farming (season-customized farm management practices), increased agro-forestry practices, changes in farm location, reduction in herd and farm sizes, and food storage, crop and animal diversification, controlled grazing, selling of assets, herd supplementation, communal holding of grazing lands which facilitate free mobility in pastoral areas, culling of animals, and indigenous early warning and forecasting systems.

Adaptation Requirements

Since climate is changing and climate variability is expected to increase in frequency and intensity (IPCC, 2001b), it will be expected that current coping strategies may not be considered as sufficient adaptation strategies in the future. Therefore, far more work is needed if adaptation itself has to be seen as an essentially dynamic, continuous and non-linear process (ILRI, 2006).

Improved use of climate knowledge and technology

The development of monitoring systems and response mechanisms to current weather, both at farm and government level, is an essential adaptation mechanism. Better forecasting and early warning systems have been identified as a prerequisite for adaptation, particularly to predict and prevent the effects of floods and droughts, and disease outbreaks in areas that are prone to epidemics as well as for indicating the planting dates to coincide with the beginning of the rainy season (Tarhule and Woo, 2002; Kovats *et al*., 2000). There are potentially wide ranging opportunities to benefit from improved forecasting skills, not only for extreme events but also for less extreme and more localized rainfall variability in East Africa (Conway *et al*., 2005).

Applying ENSO based drought early warning to local conditions could reduce the impact of drought on society to a great extent. Farmers could be warned before the advent of drought so that they could be able to adjust their crop and animal management practices and their farm and household decisions. Such information helps the government reorganize its resources before the impact of drought is felt. However, this requires credible and reliable early warning and adequate information could flow between government agencies, extension workers and farmers. It also requires the effectiveness of ENSO information dissemination to the local users and the confidence of the users in the information provided (Wolde-Georgis, 1997).

Ethiopia has developed a comprehensive Famine Early Warning System (FEWS) after the 1984 disaster, which integrated climate forecasts for Ethiopia with other information such as harvest assessments, vegetation indices and field reports. Early warning information helped to avert the major famine crisis in the 1990s, 2000 and 2003 due to drought. The FEWS played a significant role in sensitizing the government and the famine early warning community. This also encouraged small participatory actions by affected populations, which improved their coping capacity (Board and Agrawala, 2000).

Education and awareness

Education and awareness creation on climate change and variability among governments, institutions and individuals should be viewed as a necessary step in promoting adaptation to climate change (ILRI, 2006). The issue of climate variability and climate change has to be incorporated in the country's education system in general and in the curriculum of Higher Learning Institutions in particular.

Decision support system

Huq and Reid (2005) highlighted the importance of linking research to policy-making, with an emphasis on getting research messages to appropriate target groups; linking research to existing local knowledge of climate related hazards and involving local communities in adaptation decision-making. Washington *et al.* (2004) discuss the need for effective communication between the supply-side and demand-side communities of climate information in Africa, and the need to work on means by which climate information can be incorporated into the livelihood strategies of potential users.

Now a days, decision support tools based on simulation analyses are available at the field and farm level to provide objective assessments of management alternatives for specific crops and locations (e.g., Keating and Meinke, 1998; Nelson *et al.*, 2002). Combination of systems analysis, climate science, quantitative simulation tools, and discussion support and community interactions can be an extremely effective way to reduce vulnerability to climate risks and to realize societal benefits based on climate knowledge.

Proper communication of climate information

In communicating weather and climate information to the end users, there is a considerable gap between the producers of climate information and the ability of the decision makers and vulnerable stakeholders to interpret and react to such information. Deficiencies commonly remain in the awareness and understanding of climate change risks. Early warning information must be disseminated in a timely way to all stakeholders in formats they can understand or appreciate. Sewell and Smith (2004) emphasized the need for building credibility of rainfall forecasts and improving their dissemination and use, especially by people in the drought prone areas of Africa.

Owing to its cultural, climatic and natural resource diversities, farming in Ethiopia is complex. Therefore, it is difficult to make generalized crop and livestock management recommendations because of wide differences in a distance of a few miles (Wolde-Georgis, 1997) compelling that those who advise farmers, agro-pastoralists and pastoralists should know the detail of local weather, soil types, water resources, farming systems and the culture and beliefs of the community (Wolde-Georgis, 1997; Osman and Sauerborn, 2002).

Policy consideration and sectoral integration

Drought is the main climate-related risk in Ethiopia, but there is no national-level drought strategy in the country. Moreover, Ethiopia's development strategies do not explicitly factor in the issue of climate change, and efforts of public agencies are not well coordinated (Admassie, 2007). The issue of climate change should be mainstreamed in the development agenda of the country. Coping with climate variability requires that climate information be integrated into development planning and practice for both operational and strategic time frames (Meinke *et al*., 2003). Thus, the inclusion of climate change and vulnerability considerations in sectoral and development planning and policies is an important way through which adaptation may be promoted.

Conclusion

It is evident from the foregoing review that climate is highly variable in Ethiopia. It is also learned that climate change will further aggravate the variability by increasing the intensity, frequency and severity of unusual climatic events. Drought, which is highly linked to ENSO episode, is the most important climatic event in Ethiopia with devastating consequences. Floods and extreme temperatures are also becoming important in affecting the livelihood of several communities in the country.

The Ethiopian economy, which is dominated by the agriculture sector, is highly coupled with climate. Efforts made to partly decouple the economy from climate variability are not yet satisfactory because of little hydraulic infrastructures, weak water management practices and poor integration of activities across sectors. Disasters caused by climate variability are posing huge challenges on the attainment of the Millennium Development Goals in Ethiopia

Through time, Ethiopians have developed their own adaptation mechanisms to climate variability. However, current adaptation and coping mechanisms may not be considered as sufficient adaptation strategies in the future because of their limited capacity to resist extreme events and the impacts of climate change. In order to better manage and cope with climate variability and climate change in Ethiopia, the following adaptation strategies are suggested:

- Improved use of climate forecasting information at national, regional, local and farm levels;
- Designing ways and means to deliver reliable weather and climate information when and where it is needed;
- Education and awareness creation on climate change and variability among institutions and individuals;
- Incorporation of climate change and variability in the country's education system, particularly in the curriculum of Higher Learning Institutions;
- Improving research in agroclimatolgy, systems analysis and farm decision support system;
- Effective integration of systems analysis, climate science, quantitative simulation tools and community participation;
- Integration of climate change and variability into the development planning and practice of the country at both tactical and strategic time frames;
- Integration and effective collaboration of all sectors and stakeholders; and
- Establishment of national/regional climate change and adaptation research unit.

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