NAF-IRN
Natural Resources, Agricultural Development and Food Security
INTERNATIONAL RESEARCH NETWORK

NAF

International Working Paper Series

Year 2017 paper n. 17/01

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The online version of this article can be found at:

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ISBN 978-88-96189-46-7

Analysis of Long-term Climate Patterns in Eastern and Southeastern Ethiopia

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Abstract

The purpose of this paper is to analyze trends of climate risks (rainfall variability, frequency of drought years, precipitation concentration and temperature increase) in eastern and southeastern parts of Ethiopia. This part of the country appears severely affected by recurrent droughts, erratic rainfall and increasing temperature condition. Particularly, erratic rains and moisture stresses have been forcibly threatening and shoving the people over many decades coupled with unproductive policy frameworks and weak institutional setups. These menaces have been more severe in dry-lowlands where rainfall is more erratic and scarce. Long-term climate data of nine weather stations in eastern and southeastern parts of Ethiopia were obtained from National Meteorological Agency of Ethiopia (NMA). As issues related to climate risks are very intricate, different techniques and indices were applied to deal with the objectives of the study. It is concluded that erratic rainfall, moisture scarcity and increasing temperature conditions have been the main challenges in Ethiopia. In fact, these risks can be eased by putting in place efficient integrated rural development policies, environmental rehabilitation efforts in overworked areas, enhancement of irrigation schemes, suitable water harvesting techniques, and well thought-out and genuine resettlement schemes.

Keywords: Rainfall variability, erratic rains, PCI, climatic pattern, Ethiopia

1. Introduction

Ethiopia is a country where 90,078,055 people /50.4 percent male/ lives (CSA, 2015). It is a country where about 70, 829, 629 (84%) of the people live in rural areas driving their livelihoods mainly from plow-based peasant agriculture, a sector suffering from anomalous weather conditions. Ethiopia is located at the latitudes of about 3^0N to 15°N, and its climate is typically tropical in the south-eastern and north-eastern lowland regions, and cooler in the large central highland regions. Mean annual temperature is around 15-20°C in these high altitude regions, whilst 25-30°C in the lowlands such as Afar, Borena, Bale lowlands and the Ogaden Plain. Most parts of Ethiopia experience one wettest season (mainly June, July and August). The eastern and southeastern parts of the country have two wet seasons: *autumn* (mainly coincides with the months of September, October and November) and *spring* (March, April and May). The rainfall amount during these two seasons is usually sporadic and considerably lesser than the case in the summer season. Areas in northeastern part of the country (such as vast areas on all sides of Afar Depression) are the hottest and driest part in the country receiving very small amount of rainfall in winter season.

Ethiopia and the surrounding areas in the Horn have a prolonged and frequent history of drought climatic conditions and drought-related enormously distressing famines. Surprisingly, as Woldeamlak (2009) quoted Dercon (1999), 'one every three or four years is a drought year' at present in Ethiopia. These climate-induced risks are basic causes of persistent food shortfalls, particularly in water-stressed lowland areas in southern, eastern and southeastern parts. The existing erratic annual rain and the sharply increasing temperature condition are thought to be exacerbating the hunger and food insecurity risks in the country. It is also assumed to be a cause for other adverse ecological incidences of which the most notable ones are exhaustion of soil fertility, water depletion (such as the entire disappearance of Lake Haramaya, near the city of Harar), shrinking of vegetated lands, expansion of desert ecological conditions, disturbance of local and/or regional climates and loss of biodiversity.

It is with this general understanding that the researchers have tried to investigate the nexus between and trends of climate patterns and food gaps in Ethiopia with special emphasis to eastern and southeastern Ethiopia.

2. Study Objective

Frequent drought incidences are thought to be the critical driving forces for various major famine occurrences threatening millions of rural population over years in Ethiopia. Given the scale of climate change and variability impacts on food insecurity and hunger, it is important to look into climate conditions ranging from short-term weather forecasts to seasonal climate outlooks and climate change projections for timely and appropriate decisions. It is indispensable to have more information on drought incidences through drought assessment based on long-term rainfall and temperature data. Thus, the central objective of this paper is to assess the trends of food gaps and long-term climate conditions (inter-annual and seasonal rainfall variability, precipitation concentration and trends of temperature) in eastern and southeastern dry-lands in Ethiopia.

3. Methods and Materials

The main data for this study was the unprocessed rainfall and temperature data obtained from nine weather stations (such as Adama, Arba Minch, Ciro, Dire Dawa, Gode, Jigjiga, Moyale, Yabello and Ziway) in eastern and southeastern dry-lands in Ethiopia. This was used to analyze the long-term temperature conditions, and the trend and variability of rainfall in this sub-section of the country. The analysis of climatic condition involved the use of various mathematical procedures and techniques. Some of the analyses were used to find solutions to varied mathematical problems such as long-term monthly, seasonal and annual mean values, precipitation concentration index (PCI) and coefficient of rainfall variability.

In order to analyze the heterogeneity of precipitation and the relationship between variability and distribution of yearly precipitation, the precipitation concentration index (PCI) was used in this study. Precipitation concentration index (PCI) was computed to look into the level of annual rainfall distribution (concentration or uniformity) throughout the months of a year. Generally, the lower the annual precipitation, the more variable is the monthly precipitation, and the greater the value of the PCI, the more variable is the yearly precipitations (de Luis *et al*, 2011; Zhao *et al*, 2011).

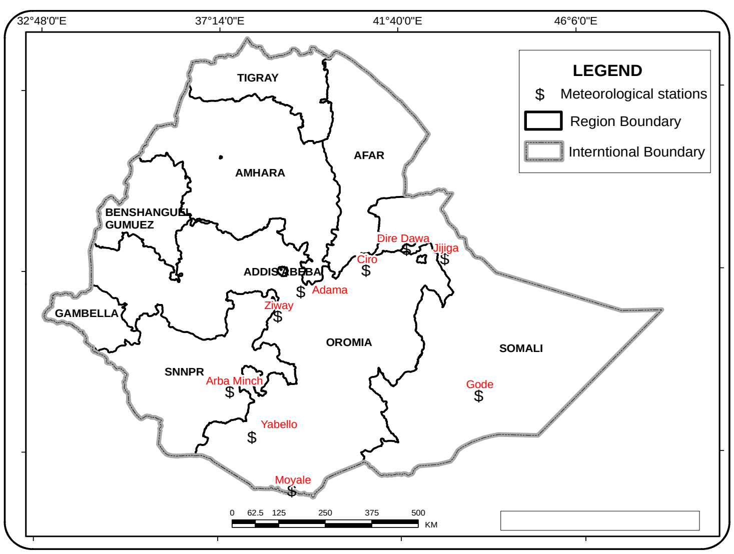
The PCI is described as:

$$PCI = 100 \times \frac{(\sum P_i^2)}{(\sum P_i)^2}$$

Where, P_i = is the monthly precipitation in month i

In this analysis, PCI values of less than 10 represent a uniform distribution of rainfall (i.e. low precipitation concentration); PCI values between 11 and 15 denote a moderate precipitation concentration; values from 16 to 20 denote irregular distribution and values above 20 represent a strong irregularity (i.e. high precipitation concentration) of precipitation distribution (de Luis *et al*, 2011)

Figure 1: Location of sample weather stations in eastern, southern and southeastern Ethiopia



Source: Produced based on Ethio-GIS database

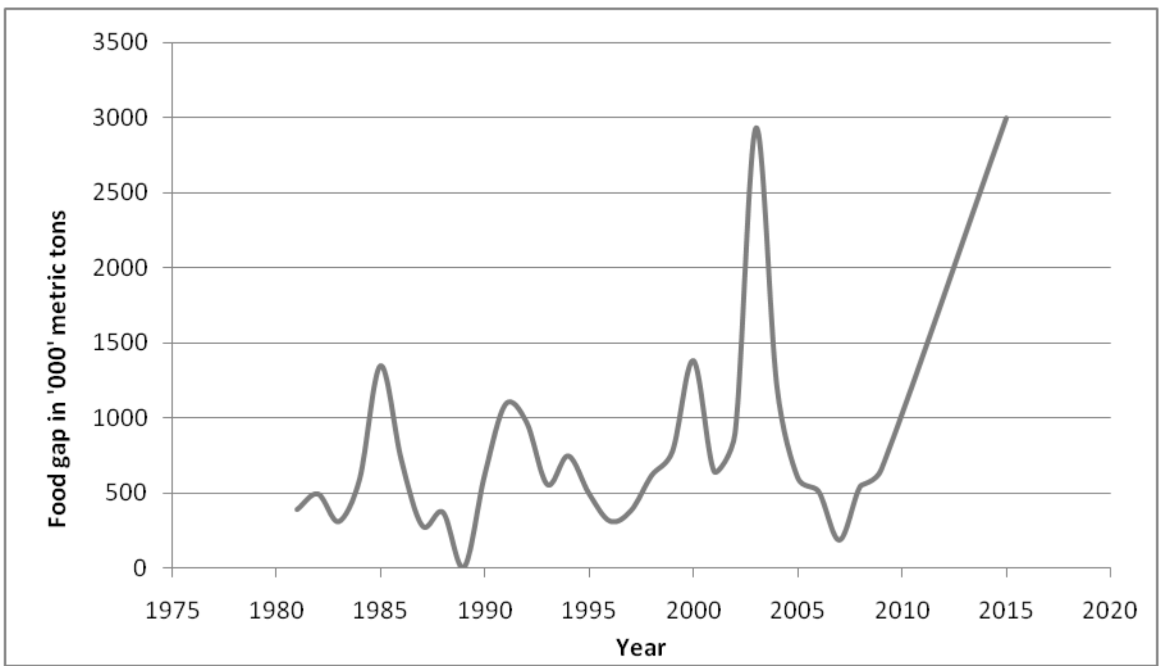
Rainfall variability over a period of time was analyzed by calculating the coefficients of variability of the rainfall values at different time scale. Hence, the coefficients of variability of annual and monthly rainfall for each station were calculated. Moreover, graphs were widely used to depict the climate trends. Microsoft EXCEL and SPSS softwares were extensively employed to manage and analyze the data as well as to produce appropriate graphs for visualization of the trends of the variables.

4. Results and Discussions

4.1. A glance at food gaps and rainfall variability nexus in Ethiopia

The sporadic nature of rainfall along with other adverse socioeconomic and agro-climatic conditions had plunged the country into a widespread poverty and precarious livelihood situation over years. Some (Desalegn, 2004/2009; Mesfin,1986/1991) believe that a range of natural and man-made hazards like environmental degradation, erratic rainfalls, epidemics, poor but currently improving governance, rapid population growth rate (currently about 2.6 percent per annum), low purchasing power of the rural community, inappropriate market linkage, unfair distribution of food to the disadvantaged group of people and political nepotism have been critical factors for the persisting and severe food crises in Ethiopia.

Figure 2: Trends of food gap in Ethiopia (1974-2015)

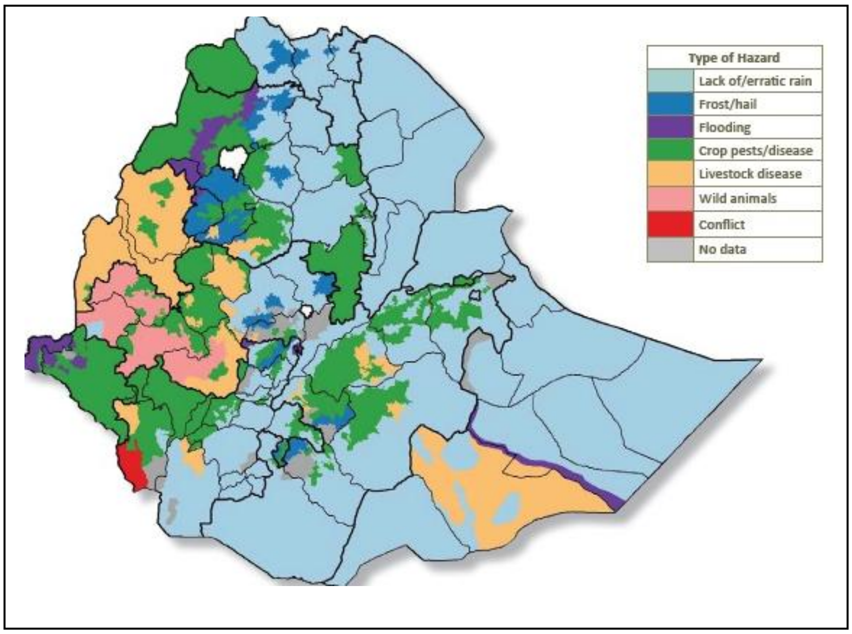


Source: Disaster Risk Management and Food Security Sector (DRMFSS) of Ethiopia

Especially, the livelihoods situation of most rural residents has been insecure and vulnerable to weather conditions. These groups of people derive their livelihoods from subsistence rainfed agriculture, which is highly susceptible to change in weather conditions such as rainfall variability and water scarcity.

As can be seen in the Figure 2, Ethiopia is known for its long-lived agroclimatic-induced annual food gaps for its people. This has immersed millions into hunger-caused diseases or physical weaknesses and biological miseries like stunting, wasting and underweight. Others have been forced to abandon their original residences and resettle somewhere either in urban areas or other rural parts of the country where they hoped to be better-off in landholdings, soil fertility, rainfall distribution, forest cover and water supply.

Figure 3: Main constraints to crop production in Ethiopia



Source: USAID & MoARD (2010)

As shown in Figure 3, the east-west divide (along the main Rift Valley Basin) is quite clear on a grand scale in the cropping zone, with rainfall generally higher and markedly more reliable in the west than in the east in comparable altitude bands. The dry-lowlands of East Hararge, Arsi, Borena, Somali, Afar and Bale lowlands are where the most feared rainfall irregularities occur in the country. Eventually, the eastern, southeastern and northeastern parts of the country have been the scene of frequent rainfall irregularities and severe agricultural droughts in Ethiopia.

As noted in USAID and MoARD (2010), there are two climate-induced elements in play in deteriorating the agricultural output in dry-lowlands of Ethiopia: the perennial fact of relatively low rainfall by comparison with other places and the threat of frequent and/or severe droughts within that regime. These are places of high rainfall scarcity and variability in the country. Though pastoralism is designed to live with very low annual precipitation in these areas, minor disturbances can have big effects on the pastoral community, especially the late arrival of pasture-reviving rains after long, hot dry seasons. It is a serious matter for croppers to have a diminished harvest, but when the rain comes back next season a new harvest is prepared. However, when pastoralists lose much livestock it takes several years to regain the herds, especially cattle (USAID and MoARD, 2010).

The central, southwestern and western Ethiopian highland and lowlands are receiving a relatively better amount of rainfall on more regular basis. Frost and hail are major problems among the highlanders, though not as damaging rainfall scarcity and variability. Hail is what highlander farmers fear more widely, particularly in the immediate pre-harvest period when it hits the standing crop (USAID and MoARD, 2010).

Several documents (Cochrane, 2011; Degefa, 2005; Desalegn, 2004/2009; Mesfin, 1986/1991; Messay, 2012; Markos, 1997, Webb *et al.*, 1992) indicate that persistent famine incidents affected millions of people making Ethiopia by far the most severely affected country in Africa. Over 25 major famine cases have been recorded from 1800 to 2012 and about 12 such cases have been documented to have occurred since 1950 alone in the country. The humanitarian famine-induced crises of 1958, 1973, 1984-86 and 2002, for instance, are among the most grievous recent cases, although Ethiopia has a long history of famine dating back to 240s BC. These were among the worst famine incidences in African history both in intensity and spatial coverage.

Table 1: Chronology of major drought-induced famine incidences in Ethiopia since 1950s

Drought years	**Major incidences**
1953	Destructive drought and famine in Wollo and Tigray
1957-58	Devastative famines in Tigray, Wollo, and south-central Shewa. About 1,000,000 farmers in Tigray might have been affected of which about 100,000 peasants migrated and 100,000 of them are said to die.
1962-66	Many parts of the northeastern Ethiopia suffered from droughts and famine. Tigray and Wollo were severely hit.
1973-74	This was one of the most widespread famine in which many parts of Eastern Hararge, Southern Region and Bale lowlands were severely hit. About 100,000 to 200,000 peoples died of this extensive famine.
1977-78	Most parts of the Wollo were severely hit by famine owing to shortage/excess famine, pest damage, and frost actions. About 500,000 peasants were said to be affected.
1984-85	Most parts of Ethiopia including the so-called famine-free areas like Walaita, Kambata and Hadiya were hit by famine. The causes were drought and crop diseases. It is estimated that about 1,000,000 people died though some estimate the death to be about 500,000.
1987-88	Tigray, Wollo and Gonder were severely affected by famine owing to drought incidence and civil wars.
1990-92	Rain failure and regional conflicts, estimated 4,000,000 people suffering food shortages
1993-94	Very severe and widespread famine occurred. But no or little deaths and displacement were reported because of the responses by the government and international aids
2002-2003	One of the major drought occurred in Ethiopia. This resulted in widespread famine. No death was occurred because of quick responses by the government and international aids
2010-2011	One of the major drought occurred in Ethiopia leaving the country home to 2.8 million people in need of emergency food aid. No death was reported. Severe famine occurred in southeastern lowlands of the country.
2015/16	Over 10.2 million people affected by severe food shortfalls due to El Ni·ño-induced drought in Ethiopia. No death has been reported.

Source: Compiled based on the data obtained from DRMFSS, Markos (1997), Webb *et al.* (1992), Cochrane (2011) & Messay (2012)

An estimated 250,000 to 300,000 peasants of Tigray and Wollo died during the 1973/4 famine alone; whereas, more than 1 million people again died, and over 8 million suffered from severe hunger as a result of the 1984/5 drought hazard. The 2002 drought caused food shortage distresses to 14.3 million Ethiopians though no considerable number of deaths was reported

(Degefa, 2005; Messay, 2012). Similarly, due to the shortage of rainfall in 2011 in most southern and southeastern lowland areas of Ethiopia, over 4.5 million inhabitants have been severely affected by food shortage. The government also recently (in January 2016) reported that over 10.2 million Ethiopians are in need of food aid mostly owing to severe and prolonged drought incidences Generally, food insecurity and malnutrition have remained the greatest threat to the people in Ethiopia thus far despite the government's earnest effort to develop the agricultural sector.

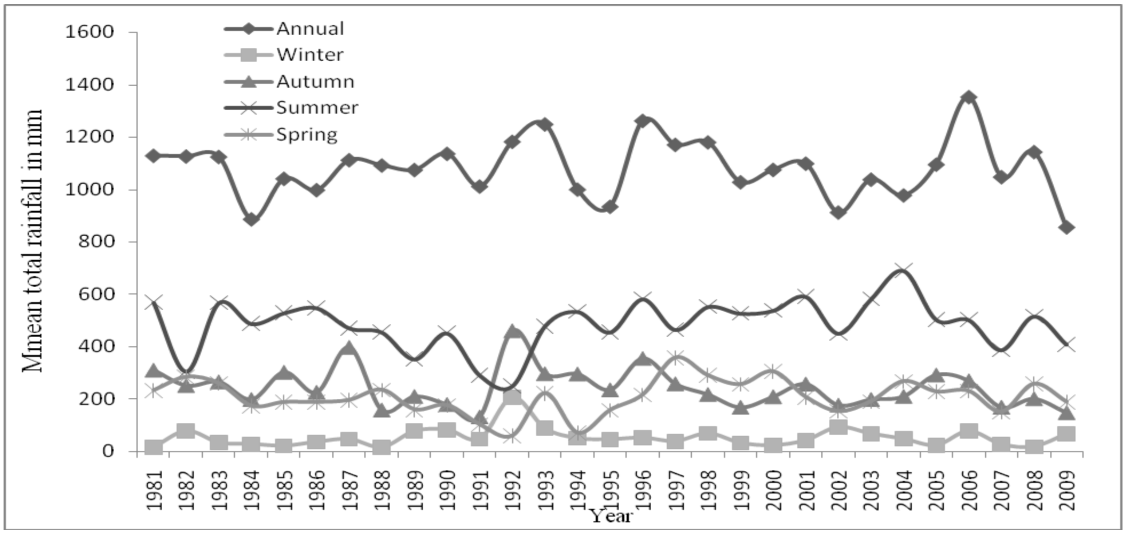
4.2. Temporal and spatial patterns of rainfall in eastern and southeastern Ethiopia

Figure 4 indicates that the inter-annual rainfall variability in eastern and southeastern Ethiopia seems enormous. The mean annual rainfall in the area is as low as 650mm and the inter-annual coefficient of variation is 20%, showing moisture scarcity and considerable inter-annual rainfall variability in this part of the country. This indicates that the climate-induced risk in eastern and southeastern Ethiopia is mainly not only the scarcity in total annual rainfall but also the inter-annual rainfall variability and unpredictability of the rains. In fact, the relatively low rainfall during drought years of the 1984/5, 1998, 2002 and 2011 are clearly visible from the figure.

By variability or reliability is meant the likelihood of a given amount of rainfall being repeated each season and year. According to Aguilar *et al.* (1998) and Odekunle *et al.* (2007) $values of\ CV < 20,\ 20 to 30 and > 30\ percent$ indicate less, moderate and high rainfall variability, respectively. NMSA (1996) also notes that areas with $CV > 30$ percent are vulnerable to drought-induced agroclimatic disaster such as famine.

Rainfall variability is very high during dry seasons and lower during wet seasons. Generally, inter-annual rainfall variability is higher in winter (dry season: December, January and February) and spring (season of small rainfall: March, April and May) than the case for summer (rainy season: June, July and August) and autumn (September, October and November) rainfalls. The inter-winter coefficient of variation is computed to be 0.69, while the variation between autumns, summers and springs is 0.31, 0.20 and 1.61, respectively. Similar conclusions were reached by Messay (2012) and Xuemei *et al.* (2010) in their spatial and temporal variability analysis of precipitation, and Woldeamlak (2009) in his rainfall and crop production study in Ethiopia.

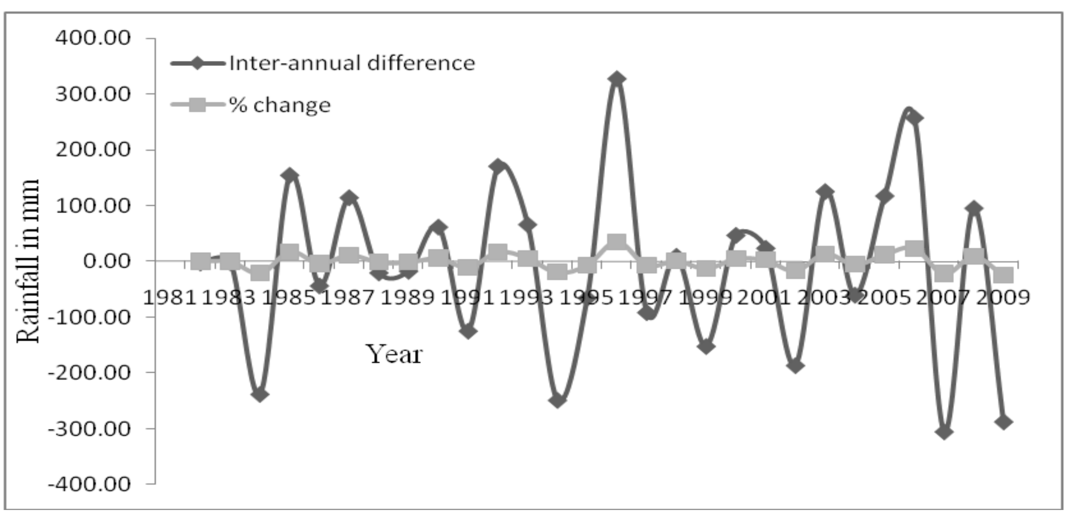
Figure 4: Long-term mean annual and seasonal rainfall in southern and southeastern Ethiopia



Source: Computed based on raw data from National Meteorological Agency (NMA) of Ethiopia

Woldeamlak (2009) also cites Engida (1999) who ascertained the reality of more rain variability in low rainfall seasons and areas in Ethiopia. Inter-annual rainfall variability is found to be less than the intra-annual (seasonal) variations in Ethiopia. Generally, the long-term (1975–2011) inter-seasonal variation of rainfall for the sample stations is high. This high seasonal anomaly (irregularity) in rainfall is said to be a major cause for the recurrent famine risks in this section of the country.

Figure 5: Inter-annual rainfall differences in southern and southeastern Ethiopia



Source: Computed based on raw data from NMA of Ethiopia

This fluctuating nature of rainfall, no doubt, adversely affects the agricultural practices and livelihoods systems of the people in Ethiopia. Particularly, sowing periods are entirely unpredictable owing to these highly erratic rains in these parts of the country. Regarding this, some researchers (Riché, et al; CAFOD et al, 2011) indicate that the small-scale producers in this section of the country condemn the unpredictability of the onset and termination of rainfalls as one of the primary reasons for the frequent impoverishment risks and food shortfalls in the area. These erratic rainfall circumstances, together with recurrent droughts and natural resource degradation, have been principal causes of impoverishment and subsequent chronic food insecurity among sizable proportion of the people in this part of the country.

4.3. Analysis of Precipitation Concentration Index

High concentration of precipitation to small number of (one or two) months of a year is one of the most critical climate-induced risks directly affecting the availability of water resources. This, in turn, has adverse implications on agricultural practices and productivity, availability of feed and water for livestock, and food security at household level. The precipitation concentration index (PCI), calculated on annual scale, varies across the area under study from values of about 11% at Arba Minch (relatively higher in altitude) to slightly over 21% at Gode (in Ogaden lowland). In general, lower values are detected in relatively high altitude areas, while higher PCI values are found in the lowland areas. As indicated above, PCI values between 11% and 15% denote a moderate precipitation concentration; values from 16% to 20% denote irregular distribution and values above 20% represent a strong irregularity of precipitation distribution (de Luis *et al.*, 2011). Based on this category, five of the sample sites (Arba Minch, Ciro, Dire Dawa, Jigjiga and Ziway) lie within moderate precipitation concentration; while two of them (Adama and Moyale) are characterized by irregularity of rainfall. The PCI value of Gode is over 20% denoting a strong irregularity of precipitation distribution in the area.

Table 2: Sample weather stations by PCI

Variables	Weather stations								
	Adama	A/Minch	Ciro	D/Dawa	Gode	Jigjiga	Moyale	Yabello	Ziway
Mean annual total rainfall in (mm)	859.90	889.70	928.99	611.00	236.00	698.18	723.30	*	748.85
PCI (%)	15.61	10.96	11.74	11.79	21.25	11.46	15.60	*	12.52

Source: Computed based on the raw data from NMA of Ethiopia (Note: *the data for Yabello is discontinuous)

4.4. Analysis of long-term annual rainfall and temperature conditions in selected meteorological stations

Subsequent discussions and figures indicate the trends of rainfall and temperature at the sample weather stations located in eastern and southeastern parts of the country. An attempt was made to look into to the trends of rainfall and temperature at each station. The graphs indicate years of maximum and minimum rainfall or drought years across the areas. One can learn from shape of the lines in how many years such droughts (lowest total annual rainfall) could take place.

4.4.1. Adama

Adama Weather Station is located in east-central Ethiopia at about $8^{0}35$`N latitude and $39^{o}16^{'}$E longitude. It is found within the Wonji Fault Belt of the Ethiopian Rift Valley System. Adama is regarded as seismically active area concerning earthquake hazards with the probability occurrence of 0.99 in every 100 years. The altitude of Adama town varies from about 1600m to 1970m above mean sea level (Messay, 2010). The long-term annual total rainfall values at Adama do not show a clear pattern of increase or decrease. In fact, the graph shows that the lowest annual rainfall value within 30 years was recorded at Adama in 2010. Average temperature values at Adama show steady increase over years. The lowest value was recorded in 1993 (20.8^{0}C) while the highest value was documented in 2002 (22.6^{0}C). The second highest average temperature record was that of 2009 (22.4^{0}C).

4.4.2. Arba Minch

Arba Minch is a city in southern Ethiopia at an elevation of 1285 meters above sea level. Its topography is known for its numerous springs and forests in close proximity. Located at the base of the western side of the Great Rift Valley, Arba Minch borders two lakes, Lake Abaya and Lake Chamo. The annual total rainfall values over years have no defined pattern of increase or decrease. It ranges between 600mm and slightly over 1200mm, indicating very high inter-annual variations. Arba Minch Weather Site received very small annual rainfall amount in 1987, 1990/91, 2004 and 2010. The average temperature values over years do not show a definite pattern of increase or decrease, ranging between 23.2^{0}C and 24.8^{0}C during the period of 1985 to 2010. The highest value of average temperature was recorded in 2009. The overall increase in average temperature at Arba Minch is computed to be about 0.64^{0}C per decade.

4.4.3. Ciro

Ciro Weather Station is located in east-central Ethiopia at about 1825 meters above sea level. Situated in the Amhar Mountains, it has a latitude and longitude of 9^{0}05$^{'}$N and 40^{0}52$^{'}$E, respectively. The long-term mean maximum and mean minimum temperature values in Ciro are 28^{0}C and 14^{0}C, respectively. The average temperature value is 21.3^{0}C. The data with some years missing that was obtained from National Meteorological Agency of Ethiopia (NMA) indicates that the temperature values at Ciro are steadily increasing over years. The average temperature value at Ciro increased to 22^{0}C in 2010 from 20.4^{0}C in 1991. In fact, the highest value was recorded in 2003 (22.4^{0}C). Rate of temperature increase at Ciro is computed to be about 0.8^{0}C per decade. The rainfall condition is highly erratic and unpredictable.

4.4.4. Dire Dawa

Dire Dawa Weather Station is located at about 1260 meters above sea level. It is located in the eastern part of Ethiopia within the eastern margin of Awash River Basin. It is located at the foot of a mountain chain. The climate is warm and dry with relatively low precipitation. Rainfall is erratic both spatially and temporally. The long-term mean annual total rainfall is only about 623mm, while the long-term mean maximum temperature is about 32^{0}C. The rainfall pattern is bio-modal with August as the rainiest month (mean annual rainfall of about 106mm) and April is the second rainiest month (mean annual rainfall of about 104mm). The mean annual temperature is sharply increasing. The 25^{0}C average temperature value in 1981 was sharply increased to 26.4^{0}C in 2009. This increase is computed to be about 0.47^{0}C per decade.

4.4.5. Gode

Gode Weather Site is located in Ogaden Dry-land of Eastern Ethiopia at a latitude and longitude of about $5^0 57^'$N and $43^0 27^'$E, respectively. Ogaden Plain is mostly characterized by arid environment. The trend of rainfall in this area is highly erratic. Years of minimum amount of rainfall are 1974 (71mm), 1986 (148mm), 2001 (136mm), 2005 (165mm) and 2009 (154). The long-term average annual rainfall of the station is about 229mm. In more recent years the area has been suffering from increasingly scant and erratic rainfall patterns which has led to an increasing frequency of major droughts, during which pastoralists claim to have a greatest proportion of their livestock resources.

4.4.6. Jigijiga

Jigjiga Weather Station is located in eastern Ethiopia at about $9^0 21^'$N and $42^0 48^'$ and elevation of about 1609 meters above sea level. It is found in hot-arid environment where erratic rainfall is a critical challenge to agricultural activity. The discontinuous climate data obtained from NMA indicates that annual rainfall is highly inconsistent over years. The long-term mean annual rainfall amount is computed to be about 710mm. The lowest rainfall years were 1955 (398mm), 1984 (401mm), 1985 (516mm), 2001 (553mm) and 2008 (432mm). Unusually the highest annual total amount of rainfall was recorded at this station in 1976 (1825mm). Values of average annual temperature condition at this station are sharply increasing over years. The highest average annual temperature was recorded in 2010 (21.1^0C), whereas the lowest value was that of 1974 (17.7^0C).

4.4.7. Moyale and Yabello

Moyale Weather Station is located in the town of Moyale, a border town between Borena (southern Ethiopia) and Kenya. It is located in arid-land where rainfall scarcity and variability is a critical challenge to the livelihoods systems in the area. Yabello is a town located in Borena in southern part of Ethiopia. This town has the latitude and longitude of $4^0 53^'$N and $38^0 50^'$ E and elevation of about 1857 meters above sea level. Both the rainfall and temperature condition of these weather stations is highly discontinuous to present the trends of weather elements in graphs.

4.3.7. Ziway

Ziway Weather Site is located around the middle of Ethiopian Valley. The area is characterized by low-lying flat terrain and hot climatic conditions. The long-term mean annual temperature of the area is about 21^{O}C while the long-term mean annual total rainfall is about 743mm. It is located nearby major Rift Valley lakes of Ziway, Abijata and Langano. The long-term mean annual rainfall at Ziway Station ranges from about 517mm (in 1994) to about 959mm (in 1993). The station received less than 600mm annual total rainfall in 1987, 1994, 1995, 1999 and 2001. The mean annual temperature is sharply increasing over years. The data from NMA shows that the average annual temperature is increasing at the rate of 1.4^{0}C per decade.

4.4. Analysis of trends of spring (*belg*) rains

Belg rain is the short rainy season, which extends roughly from February to May in the area under study. Although *belg* crops contribute less to the total grain production in the country, *belg* rains are crucially important for growing *belg* crops, seed-bed preparation for short and long-cycle crops, planting of long-cycle cereal crops (such as maize and sorghum), replenishment of pasture and drinking water for livestock in both crop dependent and pastoral areas, formation and development of the inflorescence of coffee crop and both for crop and livestock production. *Belg* rains in the area under study have been highly erratic and irregular. Particularly, the irregularity of *belg* rains is more severe in lowlands such as Gode, Jigijiga and Moyale. The negative impact of this irregularity on grazing and water supplies have had serious implications for livestock in areas where mixed farming is important.

4.5. Seasonal trends and concentration of rainfall

The analysis of long-term rainfall and temperature conditions in eastern and southeastern dry-lands of Ethiopia show a scant and erratic rainfall and a sharply increasing temperature across the region. This section of the country receives mean annual total rainfall ranging from about 219mm at Gode Station to 935mm at Ciro Station as shown in Table 3. The analysis also shows that this section of the country is characterized by drought hazard occurring almost every 10 years.

Table 3: Long-term mean annual rainfall and temperature values of the stations

Climatic conditions	Meteorological Sites							Average
	Adama	A/Minch	Ciro	D/ Dawa	Gode	Jigjiga	Ziway	
Mean Max Temp. (^{0}C)	28.5	30.4	28.0	32.0	34.8	27.5	27.0	29.7
Mean Min Temp. (^{0}C)	14.7	17.3	14.0	19.1	23.5	11.3	14.0	16.3
Average Temp. (^{0}C)	21.6	23.9	21.3	25.5	29.8	19.4	21.0	23.2
Mean annual rainfall (mm)	859.9	889.7	934.3	623.6	218.4	709.7	743.0	711.2

Source: Computed based on raw data from NMA of Ethiopia

The calculated seasonal rainfall for each weather station indicates that there are four distinct rainfall seasons in the area ranging from the wettest to the driest conditions. The weather stations nearby the central parts of the country receive maximum rainfall during summer season. Adama and Ciro, for instance, receive about 59% and 49%, respectively of the annual total rainfall during summer season.

Table 4: Long-term mean seasonal values of the stations

Meteorological Sites		Seasons				
		Summer	Autumn	Winter	Spring	Annual
Adama	Amount of rainfall (mm)	518.5	133.6	59.2	171.7	883.0
	%	58.7	15.1	6.7	19.4	100.0
Arba Minch	Amount of rainfall	153.3	311.9	116.9	354.6	936.7
	%	16.4	33.3	12.5	37.9	100.0
Ciro	Amount of rainfall	551.2	208.2	56.3	312.6	1128.3
	%	48.9	18.5	5.0	27.7	100.0
Dire Dawa	Amount of rainfall	212.6	110.1	61.9	226.7	611.3
	%	34.8	18.0	10.1	37.1	100.0
Gode	Amount of rainfall	1.7	110.9	4.5	119.0	236.1
	%	0.7	47.0	1.9	50.4	100.0
JIjiga	Amount of rainfall	253.7	157.5	52.2	234.8	698.2
	%	36.3	22.6	7.4	33.6	100.0
Ziway	Amount of rainfall	356.7	123.6	57.4	211.1	748.9
	%	47.6	16.5	7.7	28.2	100.0

Source: Computed based on raw data from NMA of Ethiopia

The stations in the eastern and southern extreme sections (such as Gode and Arba Minch) receive the highest amount of rainfall in autumn and spring seasons. For instance, Gode Station receives about 97.5 percent of the annual total rainfall during autumn and spring. Jigjiga receive 34 percent of the total annual rainfall during Spring Season. This indicates that the eastern and southeastern section of Ethiopia experience two distinct minor wet seasons (autumn and spring) which occur as the Inter-Tropical Convergence Zone (ITCZ) passes through this more southern position, as noted in McSweeney *et al* (undated). The movements of the ITCZ are sensitive to variations in Indian Ocean sea-surface temperatures and vary from year to year, hence the onset and duration of the rainfall seasons vary considerably inter-annually, causing frequent drought in this section of Ethiopia.

5. Concluding remarks

The data gathered from the local weather stations across eastern and southeastern Ethiopia doesn't clearly show a decline in annual total rainfall over years. Rather it shows a sharp increase in temperature, considerable inter-annual rainfall variability, recurrent droughts and meager rains at most stations. Surprisingly, five of the stations (Ziway, Gode, Dire Dawa, Ciro and Adama) show a sharp decline in spring (*belg*) rains. This gives the impression that the climate is getting worse because even small changes in *belg* rain can have terrible impacts. That of Arba Minch and Jigjiga is almost invariable. The declining *belg* rains over years, no doubt, results in a significant adverse impact on the livelihoods of both pastoralists and sedentary farmers inhabiting in this part of the country. Small changes in the amount, onset and cessation of rain over days and/or months in this season can make a big difference in the livelihoods of the people. It negatively impacts crop production, livestock, forestry, energy, water and health among small-scale farmers and pastoralists. This had much implication for the livelihood and food security of the people.

A further key finding of the analysis is that this part of the country has been more severely affected by recurrent droughts and sharply increasing temperature conditions. Rainfall condition recoded at most stations in this region is inadequate and highly erratic. Particularly, the eastern most extreme areas (such as Gode and Jigjiga) are characterized by insufficient and highly erratic rains. The average annual total rainfall at Gode Weather Station, for instance, is computed to be only about 261.5mm which is very low compared to the average annual total rainfall of Ethiopia i.e. about 1200mm. Dire Dawa and Jigjiga stations also receive only about 611mm and 698mm annual total rainfall, respectively.

Most part of this section of Ethiopia experience two distinct minor wet seasons (autumn and spring) which occur as the ITCZ passes through this more southern position. The stations in the extreme eastern and southern sections (such as Gode and Arba Minch) receive maximum amount of rainfall in autumn and spring seasons. Gode Station, for instance, receives about 97.5% of the annual total rainfall during autumn and spring. Jigjiga receives 34% of the total annual rainfall during Spring Season alone.

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