Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.7, No.9, 2017
www.iiste.org

Climate Variability and Drought in the Past 30 Years in Central Rift Valley of Ethiopia

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Abstract
The study carried out in order to analyze climate variability and drought in Rift Valley of Ethiopia. Hence, a number of analyses, such as: the Precipitation Concentration Index (PCI) and Coefficient of Variation (CV) methods are used for rainfall variability, Markov chain second order method were used in order to analysis dry spell length, while standardized rainfall anomaly were used for drought severity class. From the analysis the annual rainfall was less variable for all stations; while the seasonal variability was higher as computed using both PCI and CV methods. When the main rainy season variability was compared with the second rainy season "*Belg*", the second rainy season was more variable for all stations. As a result, PCI value showed that *Belg* rainfall varied from moderate concentration to high concentration. By using INSTAT software, the historical onset and cessation date and characteristics of dry spells were investigated. It is understood that the main rainy season starts on the 174th day of the year and stops on the early second decade of September. But the variability of onset rainfall is high it may lag up to 1 month while cession data is not exceed 15 days for all stations. The 5 day probability of dry spell in the area is more than 75% even during rainy season, while 30 day dry spell is not exceed 50% even during dry season. Most of the drought years were associated for each station; even if for some station the occurrence of drought year varies by one year. But 1965, 1972-73, 1978, 1980, 1984, 1994, 1995, 2001-02, 2009 and 2014/15 show that almost all station indict there was drought index in the study area even though the drought severity degree was different. The drought frequency and intensity in central rift valley of Ethiopia is increasing trend, among 31 severe droughts 21 of them happened before 1980.
Keywords: Rainfall variability, Drought, SPI, PCI, Dry spell

1. Introduction

Temperature, humidity and precipitation are the atmospheric features that have significant influence on the climate of a given region. The impact of climate change on precipitation is one of the major concerns in many scientific research studies (Lima, et al., 2010). Rainfall and temperature studies are of utmost utility for understanding nature and hence the behavior of climate changes (Maragatham, 2012).

Ethiopia is one of the countries which have diverse climatic regimes, due to its diverse topographic feature (Yohannes et.a.l., 2004). It is stated that in UNDP (2008) Ethiopian climate is typically tropical in south-eastern and eastern lowland regions, but much cooler in the large central highland regions of country. The mean annual temperature ranges between 15-20 0C in the regions characterized by high altitude, while the mean annual temperature ranges between 25-30 0C in those regions characterized by low latitudes (McSweeney, et.al. 2008).

In the recent year, climate change has become the major concern of the world. Climate change represents one of the greatest environmental, social and economic threats facing the planet today. In the East African countries, climate change is a major threat to sustainable development and to food security (Christensen et.al. 2007). This is especially true for those communities who live in the dry lands of Africa and also rely mostly on rain-fed agriculture for their livelihoods (Peter, et al., 2010). This community who practices irrigation may also affected by the climate change because of the declining trend of sustainable water resources and consequently the increasing demand of water due to population growth. Ethiopia is an (agrarian) country which is dependent on rain-fed agriculture and this sector is in fact highly vulnerable to climate variability and climate change.

According to Christensen et.al. (2007), the disaster of climate change would be increasing throughout the world. The adverse impact would be high in those countries which are very sensitive to the shocks of climate. Since the majority of Ethiopian livelihoods are dependent on rain-fed agriculture and this makes them highly vulnerable to climate variability and change. Climate variability is the most frequently occurring of climatic fluctuation affecting the natural climate features. Common drivers of climate variability include *El Niño* and *La Niña* events, which are shifts of warm, tropical Pacific Ocean currents that can dramatically affect Ethiopian rainfall and temperature highly. According to Hayman (2007), climate variability is a natural resource and unavoidable aspect of rain-fed farming all over the world. From the scientific perspective, climatic variability can be described as the annual difference in values of specific climatic variables within averaging periods such as a 30-year period (Melillo et al., 1990). These climatic variations will have unexpected consequences with respect to frequency and intensity of precipitation and temperature variability for many regions of the Earth

(Karabulut, 2008). Impact of climate variability was found to be very high on Ethiopian agriculture. There is an argument that in Ethiopia, the occurrence of severe drought is periodic and repeated at least once in 10 year. One of the characteristics of Ethiopian rainfall is that it exhibits high variability in time and space (Elisabeth, 2004). Climatic variability plays an important role on agricultural productions with a significant impact on crop growth, development and yield, making the agricultural activity one of the most sensitive and vulnerable sectors among the anthropic activities (Ventrella, et.al. 2012).

For climate variability the Precipitation Concentration Index (PCI) is a powerful indicator of the temporal distribution of precipitation in annual scale and seasonal scale in different part of the world. This method is recommended as it can provide information on long-term total variability in the amount of rainfall received for a given area (Oliver, 1980). De Luis (2011), analysed the climate variability of seasonality, supra-seasonal scales for wet and dry and annual variability by using PCI. The other way to analyze the rainfall variability was coefficients of variations method over regions.

Drought is a natural and recurrent feature of climate (Isabella et al., 2001).Even if its characteristics vary significantly from one region to another, and differs from aridity that is a permanent feature of climate restricted to low rainfall areas drought occurs in all climatic zones. Drought originates from a deficiency of precipitation (less than normal) over an extended period of time, usually a season or more (Wilhite and Glantz, 1985; Bordi and Sutera, 2007). According to Isabella et al. (2001), drought is one of climate extreme events which damage the economic and social value of one society. They are a number of methods to analyze drought in many part of the world; from this, Standardize precipitation Index (percent of Normal, Deciles (SPI)) as mentioned by colloquies (2001). Ethiopia is one of the countries which highly affected by drought event. According to Haile (1986) drought occurs every 3-4 years in the northern and 6-8 years in other parts of Ethiopia.

Drought analyses can provide information to farmers, other stakeholders and policy makers on the risks that can be evaded and opportunities to be exploited for sustained agricultural production and current and future economic growth (Njiru et al., 2010).

2. Methodology

2.1. Study area

The Central Rift Valley (CRV) of Ethiopia is located between longitude of 38°00'-39°30' East and latitude of 7°00'- 8°30' North. The altitude of the CRV varies from 900 meter to 2500 meter above sea level. Climate of Ethiopia is strongly influenced by the effects of elevation, which gives rise to distinct zones and characteristics. The annual rainfall in CRV varies from about 600 mm near the lakes at the valley floor to 1250 mm in the higher elevations near the borders of the basin. About 65% of the rainfall occurs during the long rainy season (June to September). But there is a short rainy period in the region which is not sufficient for crop production (in March-May). The mean monthly temperature varies between 15°C to 29.8°C. The average annual minimum temperature is varied between 11°C to 18°C, while the average annual maximum temperature varies between 25°C to 34°C. The lower altitude is hotter than that of elevated areas.

2.2. Data Source

Meteorological data was obtained from Adamitullu research center and from the National Meteorological Agency of Ethiopia (NMA). In climate data analysis, the big problem is missing of the observed daily data. Most of the agro-hydrological models require daily climate data to run. However, in many sites in the Sub-Saharan Africa there are no consistent data records, data may exist for short periods, with long periods of missing data (Mzirai, et al., 2003). To curb this gaps (missing observations) there are a number of technique currently used for interpolation of data. For this study, arithmetic mean method and inverse distance method are used.

2.3. Data analysis

2.3.1 Climate variability

Africa has often shown rainfall variability and associated droughts leading to food shortages. It is reported that a 10% deviation of seasonal rainfall from the long term average rainfall leads to a 4.4% decrease in food production in Africa (Manickam et al., 2013). Hence, knowing the rainfall variability in the study area has dual purposes; to know the impact of rainfall variability and its impact on food production.

Here, techniques are employed to investigate the detection of trends and change point for rainfall variability. In this case, the Precipitation Cumulative Index (PCI) and coefficient of variation (CV) method had been applied for this study. They are frequently used as statistical descriptors of rainfall variability. For this study, daily precipitation values for the 30-year period (1980-2015) were used from selected stations in the CRV of Ethiopia. The selection of stations was based on the quality, representativeness of the area and periods of observation of data in the study area. The missing data was interpolated by using the methods mentioned above.
For inter-annual rainfall variability, the PCI method is expressed as;

$$PCI = 100 * \frac{\sum_{i=1}^{12} (P_i)^2}{\left(\sum_{i=12}^{12} (P_i)\right)^2} \text{ ------1}$$

Where, PCI is precipitation concentration index, P_i is the rainfall amount of the i^{th} month; and Σ = summation over the 12 months for annual rainfall variability while 4 months for seasonal variability.

According to De Luis (2011), the seasonal scale of PCI was calculated using equation 2. Most of the seasonal rainfall variability is used by CV especially in Ethiopia but in the different part of the world PCI was also applied. Many scholars divided seasons in to four but in this study the season was divided in to three. Because in the study area there are only three distinct seasons. The PCI is also calculated on a seasonal scale for *Belg* (Feb to May), *Kiremt* (Jun to Sept) and *Baga* (Oct to Jan).

$$PCI = 33.333 * \frac{\sum_{i=1}^{4} (P_i)^2}{\left(\sum_{i=12}^{4} (P_i)\right)^2} \text{ -------2}$$

PCI Value below 10 indicts uniform distribution (low precipitation concentration), values from 11 to 15 denotes seasonality in rainfall distribution (indicates moderate precipitation concentration); PCI between 16 and 20 indicates irregular distribution and finally, PCI > 20 indicates a strong irregularity (i.e., high precipitation concentration) (Oliver, 1980; De Luis, et al., 2011; Valli et al., 2013).According Seleshi and Zanke (2004), the rainfall is variable when the Coefficient of variation value is above 30%. The Coefficient of variation can be calculated by dividing standard deviation to the long-term mean precipitation (Karabulut, 2009).

$$\text{Coefficient of variation (CV)} = {}^{\text{Standard deviation}}/_{\text{Historical mean}} \text{ ------3}$$

2.3.2 Drought Analysis

Drought definitions depend mainly on the types of drought. But all have argued that the primary characteristic of drought is a reduction in precipitation (Agnew and Chappel, 1999). There are four types of droughts; these are Hydrological drought, Agricultural drought, Economical drought and meteorological drought. The present study is mainly concerned with meteorological drought. Meteorological drought occurs due to lack of precipitation (Woldeamlak, 2009). As Bruins and Berliner (1998), drought occurs when rainfall is 'below average' for the area.

Standardized anomalies of rainfall were calculated and used to assess frequency and severity of droughts, as in Woldeamlak (2009). Many authors (Mulugojjam and Ferede, 2012) mentioned that drought frequency and intensity is used to evaluate inter annual fluctuations of rainfall and the drought with different severity index as give bellows

$$S = \frac{(Pt - Pm)}{\delta} \text{----------4}$$

Where, S= standardized rainfall anomaly.

P_t = annual rainfall in year t.

P_m = long-term mean annual rainfall, over a given period of observation.

Σ= standard deviation of rainfall over the period of observation.

The drought severity classes are extreme drought (S< -1.65) with 95 percentile, severe drought (-1.28 > S> -1.65) with 90 percentile, moderate drought (-0.84 > S> -1.28) with 80 percentile, and no drought (S> -0.84). The class intervals correspond with the 95, 90, and 80 percentiles assuming that annual rainfall data are normally distributed Agnew and Chappel (1999). It is also mentioned thatthese values have no meaning other than an expected frequency of occurrence (Woldeamlak and Declan, 2007).

3. Result and Discussion

The characteristics of rainfall in the study area varied from the very low land to uphill with increase order. As it was tried to reveal in the methodology, elevation increment and historical average rainfall increment was related by about 70 percent. Moreover, the spatial distribution of rainfall in Ethiopia is significantly influenced by topography (NMSA, 1996; Camberlin, 1997; Taddesse, 2000), which also has many abrupt changes in the Rift Valley. It was also mentioned by Seleshi and Zanke in 2004 that altitude greatly influences the climate of Ethiopia, with the creation of microclimates ranging from cool highlands to hot desert climate. All stations found in the study area have shown bimodal rainfall patterns with the *kiremt (*Jun to September) shares 65% of total annual rainfall.

3.1 The onset and cessation date of the study area

For the study area it was tried to see the characteristics of these main rainy seasons. It was indicated in

Mulugojjam Taye and Ferede Zewdu, (2012) that characterizing the onset date and cessation date of rainfall for specific are. As the information gained from the elders in the study area and weather data from nearby station, the main rainy season day was fixed for the onset day and cessation dates. The variability of rainfall for the period of onset of rainy season was high and even difficult to find the exact day for some years, especially during drought periods. The onset date variability was high in the CRV region of Ethiopia. Using the observed rainfall data of the stations found in the region, the main rainy season average onset day was fixed. It was understood that the mean of onset date for main rainy season at Meki is on 171th day and Adamitullu is on 163th day and with standard deviations of 25 to 30 days, respectively. The end of the growing season was mainly dictated by the stored soil water and its availability to the crop after the stop of rain (Mulugojjam Taye and Ferede Zewdu, 2012). For the end of rainy season, any day after the first of September, the soil water reaches zero. For all stations found in the study area, the cessation of rainy days hadn't high variability as onset days. As it can be seen from Figure (1), only a few stations have above 10 days standard deviation. The historical mean of rainfall data shows that the main rainy season is terminated early second decade of September month between 262th to 260th date with standard deviation of 4 to 5 days for Meki and Adamitullu stations, respectively. The Historical standard Deviation of rainfall onset of all stations in the CRV is greater than 20 days.

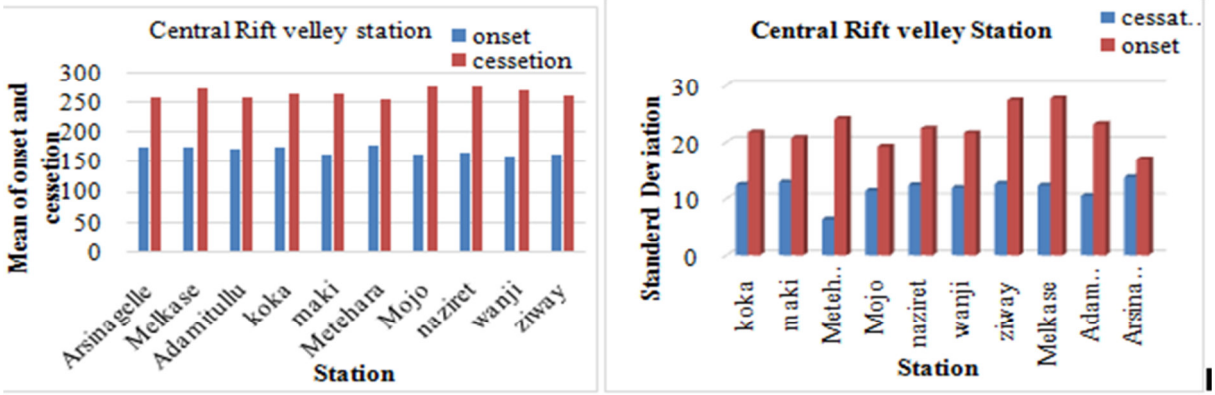

Figure 1. Onset and cessation date of rainfall in central rift valley

At Adamitullu, onset day of rainy season varies from 150th to 195th day of the years and the historical average onset day is 171th day and in some years the onset day may be as early as the 105th day and let to 200th day of the year. While cessation date of rainfall period varies from 268th to 280th day of the year and with outliers' day of 260th to 288th days of the year. Meki station data also shows the same day but the variability of onset day is lower as compared to that of Adami Tullu station. The onset of rainy day at Meki varies from 151th to 191th day and the cessation seems not clear and not even more than 10 days.

3.2 Dry spell probability for the study Area

Dry spell was a period where the weather has been dry, for an abnormally long time, shorter than and not as severe as a drought (Mathugama SC and Peirwas TSG, 2011). Dry spell was seen as the zero rainfall per day taking threshold value of zero rainfall and other may use 0.1mm per day as the threshold because it was often used with respect to the usual precision of rain gauges (Mathugama SC and Peiris TSG, 2011). But in this study the value was less than 0.85mm rainfall per day was taken as dry day by using "Instat+3.37" software by Markov chain method in the second order case**.** Analyzing the characteristics of dry spells was also helpful to manage water supply effectively and efficiently for irrigation as well. From this point different dry spell lengths probability was examined. Annual probability of different dry spells longer than 5, 7, 10, 15 and 20 days were analyzed. Figure (2) of dry spell has shown a parabola-type graph. The depth of the curve depicted in the figure has shown the probability occurrence of each dry spell. High probability occurrence of long dry spell causes dry season while very low probability of dry spell happens during rainy seasons. As it was shown in Figure (2), the probability of occurrence of 5 day dry spells is not less than 70%. This shows that even during main rainy season, the probability of 5 day dryness is significantly very high. While the probability of 7 day dry spells doesn't exceed 40% during rainy season and reach about 100% in the period of dry season. The 10, 15 and 20 dry spell probability of occurrence during main rainy season are 15%, 5%, and 0%, but during dry season the probability of occurrence are above 90%, 80% and 70% , respectively. The probability of 30 days without rain during main rainy season is almost nil and even during the dry period it does not exceed 40% in the history for the study area.

As depicted in figure 10, the dry spell analyses conducted in both Adamitullu and Alemtena showed high probability of occurrence of long dry spell during dry seasons and low probability of occurrence of longer dry spell during rainy season. The figures further depict that, the probability of occurrence of 5 day dry spell is greater than 70 % in Adamitullu and greater than 50% in Alemtena. This show that even during the main rainy season the probability of 5 day dryness is high. Similarly the 7 day dry spell does not exceeded 40% in both

Adamitullu and Alemtena during the main rainy season and reach about 100% during the dry season. As it was given the figure (2), the dry spell is different months of the year. The probability occurrence of 5, 7, 10, 15, 20 and 30 day dry spells are high during months of January, February, March, and April with decreasing probability of occurrence but in the months of May, June, July, August and September.

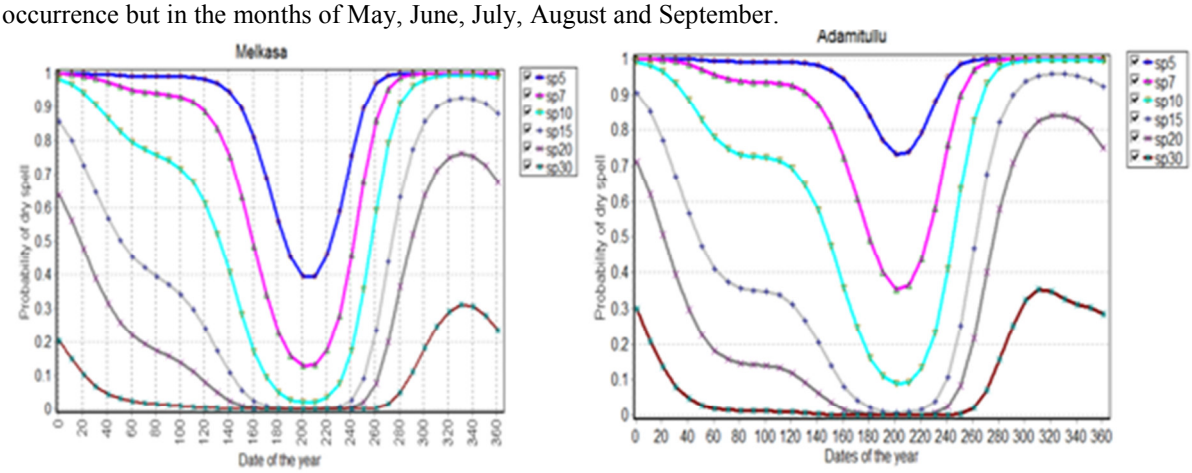

Figure 2. Dry spell probability of 5, 7, 10, 15, 20, 30

3.3 Climate variability in the study area

The precipitation concentration index (PCI) was used to calculate rainfall variability at annual and seasonal scale across different part of the world. To analyze climate variability many scholar use different methods from these methods PCI and using Coefficient of variation were highly used by in Ethiopia (Seleshi and Zanke, 2004, Woldeamlak Bewket, 2009 and Conway, 2000). As it was stated by Seleshi and Zanke (2004) the climate of tropical semi-arid and arid areas such as Ethiopia was characterized by high inter-annual variability of rainfall. The rainfall is highly variable both in amount and distribution across regions and seasons (Tesfaye, 2003, Tilahun, 1999; Mersha, 1999). The climate variability within a season was high, especially in the *Belg* season. It was true that the standard deviation from the mean was high, when compared to other seasons even in some stations the standard deviation of *Belg* season was higher than annual standard deviation. The Coefficient of variation also revealed the same in all stations. Precipitation is characterized by a typical annual pattern with low rainfall totals during *Belg* and Bega seasons and high during Kiremt season in the CRV stations except at Annual mean precipitation of all stations in the study area varied between 560 to 920mm. From total annual precipitations view point, Kiremt season shares about 50% of annual rainfall totals. It was also known that many scholars stated that the central rift valley stations have insignificant variability of annual rainfall while there was significant seasonal variability even during the main rainy season (Seleshi and Zanke, 2004 and Cheung, et.al, 2008).

Table 1. The historical Annual Average PCI and CV of the stations in the study area

Station	Adamitullu	Alemtena	Awashmelka	koka	Maki	Melkasa	Metahara	Mojo	Nazareth	Wanji	Ziway
Annual PCI	16.5	20	19.1	21.2	19.3	17.5	18.2	20.5	20.2	19.2	16.6
Annual CV	0.24	0.20	0.27	0.48	0.26	0.19	0.25	0.21	0.21	0.23	0.23

A PCI values noted between 10 and 22 indicate that, rainfall in CRV region is characterized by high to very high monthly rainfall concentration especially during dry year. PCI values of less than 10 indicate uniform monthly distribution of rainfall, while values ranging between 11 and 20 indicate high concentration and above 21 indicate very high concentration Oliver (1980). Generally, the PCI of the area indicated that the area have strong rainfall seasonality. For instance among the stations included in this study, Koka, Naziret and Mojo showed a considerable variation in the distribution of annual rainfall. For all stations the computed PCI values showed irregular distribution of annual rainfall during all seasons of the year. According to Valli et.al. 2013 if PCI >16 and < 20 the rainfall in the region indicates irregular distribution, thisis true except few wet years. The precipitation concentration index calculated at annual and seasonal level showed values >11 in the last 30 years, but Kiremt season was more uniform than both *Belg* and *Bega* seasons. As it was stated in methodology the values from 11 to 15 denotes seasonality in rainfall distribution (indicates moderate precipitation concentration) this was true that the rainfall in the study have seasonality. It was also seen that the PCI value was high during dry years of the study area.

Generally the examined Annual variability of rainfall which was calculated by precipitation concentration index (PCI) shown that for all stations there was consistent precipitation, with high variability during dry years. The climate variables have high impact on agriculture and social livelihood in money ways. So

the variability was seen in both annual and seasonal wise; for both periods by using precipitation concentration index (PCI) and Coefficient of variation (CV) methods.

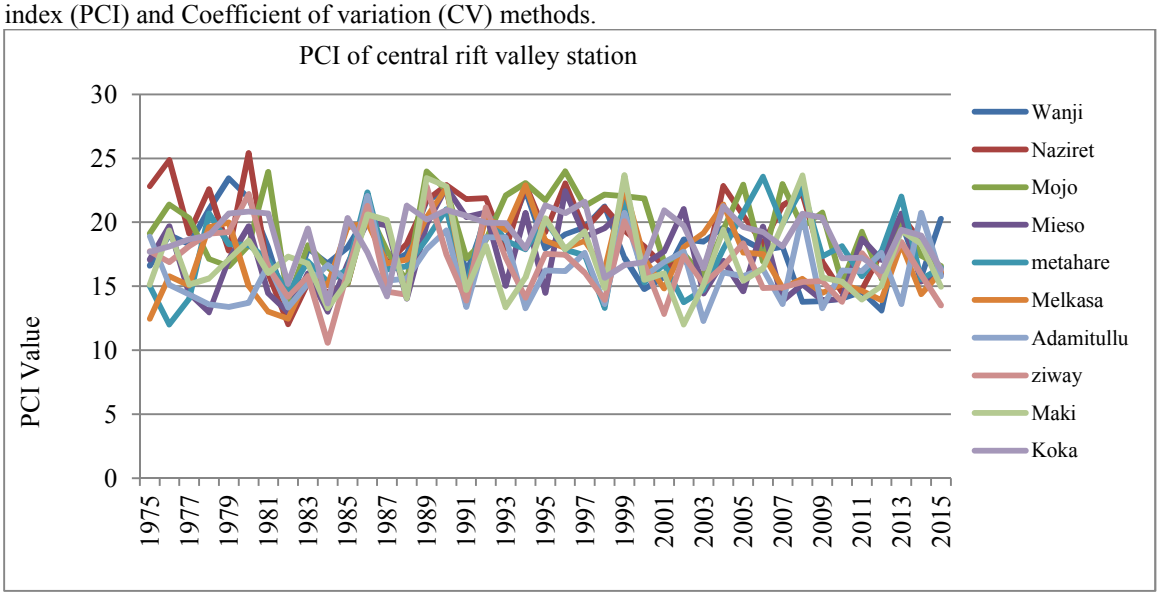

Figure 3. Annual PCI Value of rainfall variability in central rift valley

By using Coefficient of variation annual coefficient variation computed is smaller than that of all seasons for all stations found in CRV of Ethiopia. But for some stations such as Adamitullu and Melkasa annual coefficient of variation is larger than Kiremt. As given in Table (2) the coefficient of variation was high during Bega season and exceeded 100%. Bega season (which includes months of October, November, December and January) have little contributions for total annual rainfall of the study area and it is known as the driest season of the region. The correlation between annual rainfall and Bega season is very weak for all stations. An annual CV exceeded about 10%, while CV is substantially exceeded 26% for the *Kiremt* season. The *Belg* season is highly variable in the Rift Valley region. With the exception of Adamitullu, Arsinagelle, Ziway, Melkasa, Metahara, and Wanji, where CV exceeded 46% for the remaining stations. CV is also extremely high and above 50% for the *Belg* season. The correlation between *Belg* rainfall and *Kiremt* rainfall has found to be about 0.81. Nevertheless, the Belg rainfall was more variable than the main rainy season of *Kiremt* and annual variability was more affected by *Kiremt* season rainfall.

Table 2. Rainfall variability as computed based on PCI and CV for CRV stations

Stations Name	*Belg*		*Kiremt*		*Bega*	High season correlated with annual rainfall	Coefficients of determination (R^2): Annual V_s biggest season
	CV	PCI	CV	PCI	CV		
Adamitullu	0.47	13	0.24	10.7	1.01	0.69***	0.483***
Alemtena	0.65	14.1	0.47	11.7	1.21	0.47**	0.218**
Arsi nagele	0.25	12	0.23	9	0.48	0.84**	0.705**
Awashmelka	0.52	13	0.32	10	0.79	0.91**	0.831**
Koka	0.79	16	0.51	11.3	1.09	0.95**	0.891**
Maki	0.61	17.8	0.41	12	0.65	0.63**	0.396**
Melkasa	0.47	14	0.19	10.5	1.00	0.71**	0.508**
Metehara	0.47	14	0.28	12	1.19	0.70**	0.496**
Mieso	0.69	17.4	0.39	13	0.71	0.7***	0.443***
Mojo	0.56	14	0.24	11	1.18	0.82**	0.612**
Nethiret	0.55	14	0.24	10.8	1.11	0.82**	0.669**
Wanji	0.47	14	0.27	11	0.86	0.89**	0.798**
Ziway	0.45	14.7	0.25	10	1.04	0.71**	0.503**

Bega* Kiremt** Belg***

3.4 Drought

Drought was a three dimensional natural phenomenon characterized by its severity, duration and areal extent (Tsakirwas, et.al, 2007). It was to be noted that the major drought years of 1965, 1972–73, 1983–84, 1987–88 and 1997 and 2001 covered the whole of Ethiopia (Seleshi and Zanke, 2004) and Cheung and his colloquies' in 2008 claims that well-known drought period that occurred from 1978 to 1986 this was true that, the historical

data from National meteorology agency shows central rift valley of Ethiopia was also affected by drought in the mentioned years. Most of the drought years were associated for each station; even if for some station the occurrence of drought year varies by one year. But 1965, 1972-73, 1978, 1980, 1984, 1994, 1995, 2001-02, 2009 and 2014/15 show that almost all station indict there was drought index in the study area even though the drought severity degree was different. This study also found several dry and wet periods for central rift valley of Ethiopia. There was Dry periods from 1951s to early 1970s, from the late 1970s to early 1990 there was a wet period in between there was dry periods, again from late 1990s to current years there was wet conditions happened, even if there was drought years in between.

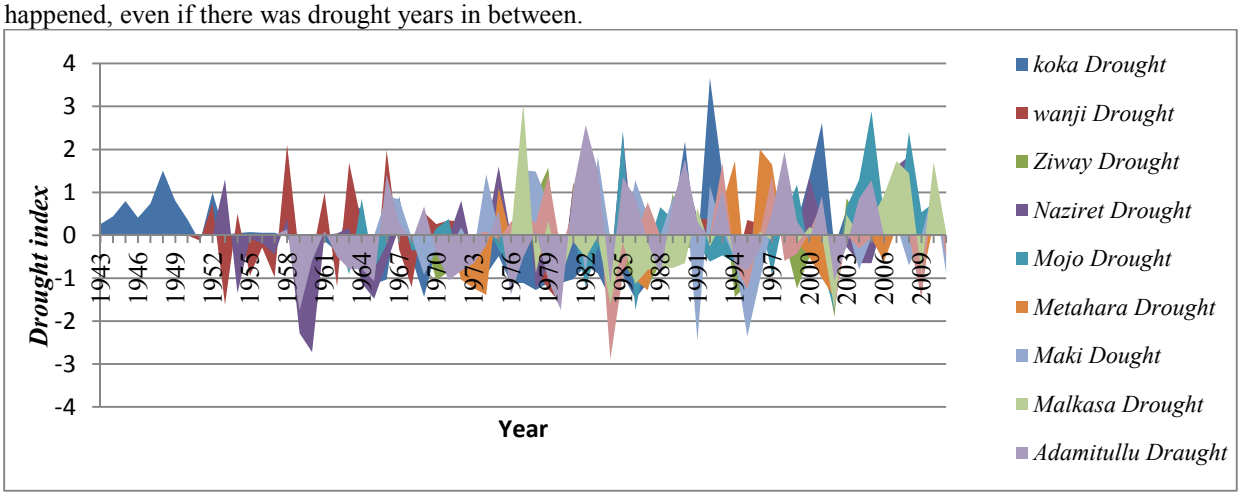

Figure 4. Drought index of central rift valley

Ethiopia is classified under dessert or drylands of Africa were susceptible of drought and desertification high. Climate change is set to increase the area susceptible to drought, land degradation and desertification in the region. Seventy percent of Ethiopia is reported to be prone to desertification (UNDEC, 2006). As it is given in the table blew drought will occur once every 3 to four years with the extent of moderate to very Sevier. It is understood that in every four year the probability of being drought is above 90% in central rift valley of Ethiopia. As it is given above the intensity and cover of drought in central rift valley is increasing trend, From the 31 severe drought occurred in central rift valley, 77.4% of them are after 1980's as it is given in the table below.

Table 3. Historical drought event in central Rift valley

Station Name	very Sevier (SPI< -1.65) years	Sevier Drought (-1.28 > SPI> -1.65) years	Moderate Drought (-0.84 > SPI> -1.28) years
Koka	No	1984, 1986, 1969, 1978,2014/15	1973, 1976,1965, 1980, 1979, 1977, 1987, 1966, 1981, 1994, 1972, 1985, 1974
Wanji	1953, 1980	2002, 1965	2009, 1979, 1968,1962, 1974, 1957, 1955,19594, 1978, 1976, 1984, 1973,2014/15
Ziway	2002,	1994, 1980	1987, 1995, 1986, 1984,1970, 1976, 1971, 1988,2014/15
Nazareth	1960-1959	1965, 2009, 1954, 1978	1964, 1980, 1984, 2002, 1979, 2014/15
Mojo	2002, 1986	1995	1982, 1984, 1972, 1997, 1963, 1976, 1965, 1973, 1980, 2002, 2014/15
Metehara	1984	2002, 1974, 1987	1973, 2009, 1986, 1972, 2001, 1978, 1980, 2014/15
Meki	1991, 1995	2002, 1980, 1978	1996, 1982, 1969, 2004,2009,2014/15
Melkasa	2002	1984	1986, 1980, 2009, 1978, 1987, 1989
Adamitullu	1959, 1980	1976	1984, 1965, 2002, 1971, 1979, 1988, 1972, 1995, 1963, 1964, 2014/15

4. Conclusion

Climate change represents one of the greatest environmental, social and economic threats facing the planet today. This is especially true for those communities who live in the dry lands and rely entirely on rain-fed agriculture for their livelihoods. To study climate change the most appropriate approach is first to detect variability of weather variable of the regions. PCI and CV are more applied to trace the nature of rainfall variability. The annual rainfall variability of the region was very low when evaluated using CV, while the precipitation concentration (PCI) showed mostly as there is seasonality in the study area. But the Belg season which is second

rainy season had moderate rainfall variability. The CV also showed that the existence of high rainfall variation during the second rainy season (CV=45%). Generally, Belg season is more variable than the main rainy season, which is Kiremt season in this case. The onset date of rainy season is more variable than the cessation date. Using the observed rainfall data of the stations found in the region, the starting date of rainy season on average varied from 170th to 175th day with the standard deviations of 20 to 35 days. On the other hand, the more dry spells were detected by using Markov chain methods in the INSTAT analysis tool. The probability of 5, 7, 10, 15, 20 and 30 days were computed with the probability of 5 days were not less than 60% even during rainy season and the probability of 30 dry days of less than 40% during dry seasons. Dry years in the study area were 1965, 1972-73, 1978, 1980, 1984, 1994, 1995, 2001-02, 2009,2014/15 as most of the stations experienced low rainfall as examined using SRA method.

Conserving the forests which exist today and Making the people more aware about the impact of climate change and encouraging the farmers towards planting of multipurpose perennial plants which have multiple uses including carbon sequestration and reduction of greenhouse gasses from the atmosphere is important. There is lack of energy source as the farmers obliged to use trees for fuel and cooking at home, so the government should provide other alternative energy sources for the community living in the Central Rift Valley of Ethiopia.

Acknowledgement
I would like to thank Yaballo Research Centre and Oromia Agriculture Research Institutes (IQQO)

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