METOROLOGICAL DROUGHT CHARACTERISTICS ONSETS, CESSATION, LGP AND DRY SPELL OF SEASONS IN THREE WOREDAS OF EASTERN HARERGHE, ETHIOPIA

BY: TIGABU MUCHE

Department of Meteorology

Western Amhara Meteorology Service center

By: 1. Tigabu Muche 2. Sisay Kelemu, Bahir_Dar Int'l Airport Aviation Meteorology Case Team Coordinator

E_Mail Address:- tigmet913@gmail.com,

List of Acronyms/abbrevation

AVHRR	Advanced Very High Resolution Radiometer
CMIP5	Coupled Model Inter-comparison Project Phase5
CPI	Crop Performance Index
CROPWAT	Crop Water Requerment
DEM	Digital Elevetion Model
FEDBEHZ	Finance and Economic Development Bureau of Eastern Harargea Zone
FAO	Food Agricultural Organization
FEWS NET	Famine Early Warning System Network
GC	Gregorian Calander
GCM	General Circulation Model
GIS	Geograhpic Information System
ITCZ	Intertropical Convergence Zone
JMBO	Jijiga Meteorology Branch Office
LEAP	Livestock Early Assessment And Protection
Masl	Meter above sea level
MD	Meteorological Drought
NDVI	Natural Difference Vegetation Index
NDVI mean	Mean of Natural Difference Vegetetion Index
NDVImax	Maximum of Natural Difference Vegetetion Index
NIRB	Near Infrared Band
NMA	National Meteorology Agency
PNP	Percent of Normal Precipitation
PET	Potential Evapotranspiration
Pmean	Mean of Precipitation
RB	Red Band
RF	Rain Fall
SPI	Standardized Precipitation Index
STATS	Statistics software
Temp	Temperature
WFP	World Food program
WRSI	Water Requirement Satisfaction Index

Abstract

Climate has always been dynamic affecting natural systems through the consequence of its variability and change. Agriculture is the most vulnerable and sensitive sector that is seriously affected by the impact of manifested through rainfall variability and recurrent drought. In dry land semiarid areas of Ethiopia, including in the study areas, farmers inhabiting the area experience extreme temporal and spatial variability of rainfall in cropping season with frequent and longer dry spells. This makes them vulnerable to the risk of Meteorological Drought (MD). Thus, in order to adapt and/or mitigate the impact of MD, MD assessment has to form one dimension of research to be done whereas the use of MD indices and different soft wares provides wide scope in drought risk detection and mapping. Consequently, this study was conducted in Eastern Harerghe Fedis and Deder Districts with the objective of assessing MD risk and preparing MD using Rainfall (RF). To assess and examine spatiotemporal variation of seasonal MD patterns and severity, a drought index namely, Standard Precipitation Index (SPI) anomalies are applied. To characterize temporal and spatial MD, onset, cessation, Length of Growth Period (LGP) of Seasons, rainfall data for a period of 36 years from (1980-2016) were utilized. The time of the seasonal transitions can also be an important control on drought, since a late onset or early termination and duration of sowing can initiate drought conditions. The result derived from index the annual trends of RF increased in Fedis; whereas, in Deder and Shinile woredas, it decreased with the time. The spatial distribution of drought frequency and its climate trend as well as different drought grades were obtained by employing the inverse distance weighting (IDW) interpolation method in ArcGIS 10.3.1 platform. In this study, the MD indices used to quantify the drought severity, frequency, trends, spatial pattern and its intensity. So, the annual high drought frequency mainly concentrated in the Eastern some areas of Fedis. From South to West part of Deder were observed slight to moderate drought. From slight to severe drought was largely experienced in shinile more than others study areas. Generally, the result revealed that SPI anomaly express decreased with the time over the study areas. Thus, the result indicated that the areas are classified into slight, moderate and severe MD risk zone. Thus, the MD study can be useful to guide decision making process in drought monitoring and to reduce the risk of drought on agricultural production and productivity.

Key words: MD (Meteorological drought), Meteorological drought indices, Rainfall and Geographical information system.

1. INTRODUCTION

1.1 Background

West African precipitation is strongly dependent on the southwest monsoon flow. which has the unique characteristics of high seasonal, monthly and daily variability. This variability is particularly strong in the lowest 1 km of the atmosphere. The thunderstorms and squall lines which are responsible for over 70% of the total annual precipitation over West Africa (Omotosho, 1985). The most important problems associated with rainfall variability as a result of changes in moisture availability are:

(i) The highly variable dates of onset of the rainy season at one station and from one station to another. These variations could be up to 70 days from one year to another at a single station, as will be shown later.

(ii) The temporal (monthly and annual) distribution of the precipitation at each station or over a small area. (iii) The cessation and length of the rainy/growing season. The onset dates are the most critical. Reliable prediction of onset time will greatly assist on-time preparation of farmlands, mobilization of seeds/crops, manpower and equipment and will also reduce the risks involved in planting/sowing too early or too late. Predicting the start of the rains in West Africa is a very challenging task because of the irregularities in the rainfall distribution, both in time and in space. Prediction methods have been proposed, some based on rainfall data alone (Ilesanmi, 1972; Obasi and Adefolalu, 1977; Stern et al., 1982; Fasheun, 1983; Nnoli, 1996). These rainfall models cannot address the year-to-year variations in the onset dates. Omotosho's (1990) scheme, now in operational use at the African Centre of Meteorological Applications for Development (ACMAD), is capable of addressing the year-to-year variations in the atmospheric conditions and, hence, in precipitation. However, even after crops/seeds have been planted/ sown, they will still require favorable rainfall conditions during the early stages in order to eliminate crop failure. In addition, appropriate decisions with regard to irrigation needs and their timings, as well as water conservation strategies for dams and hydro-electric power utilization, are all dependent on reliable estimates of monthly and seasonal precipitation prospects or amounts. Furthermore, a reasonable knowledge of the date of rainfall cessation enables the prediction of the length of the growing or rainy season, which is most useful for the selection of crop varieties, crop matching and cropping sequences (Kowal and Knabe, 1972). Therefore, in order to ensure maximum and sustainable agricultural productivity, as well as efficient water resource management practices, reliable predictions of the monthly and annual precipitation, the cessation date and the length of the rainy season are all equally very important. The present study is, therefore, an attempt to provide some solutions to the above critical problems.

Climate has always been dynamic, and affects natural systems through the consequences of climate variability and climate change (Bekele, 1997). Because of climate change and variability, drought has become a recurrent phenomenon in several countries across the globe. It is manifested in erratic and uncertain rainfall distribution in rainfall dependent farming areas, especially in arid and semi-arid ecosystems. Frequent and severe drought has become one of the most important natural disasters in sub-Saharan Africa and often results in serious economic, social, and environmental crises (Tadesse et al., 2008). It is marked by the creation of uncertain agricultural economics (Kandji &Verchot, 2006). Droughts are a type of environmental disaster that occur in every climatic zone, no matter if high or low rainfall area. Droughts are usually divided into four different stages. The first stage is a meteorological drought which is defined as the cumulative lack of precipitation in a region over a prolonged period of time. Second a lack of water in the soil causes an agricultural drought, which usually is accompanied by reduced crop yields or shortage of soil moisture. Third a hydrological drought is characterized by a shortage of water in surface or underground water resources (Azorin-Molina, 2012), it can be visible through dried up rivers and lakes. Finally, a socio-economic drought is apparent when the supply of good water does not meet the demand (Sirak, 2015). In addition, standard precipitation index (SPI) is meteorological drought index used to quantify the impact of rainfall deficit on soil moisture on which it responds to precipitation anomalies on a relatively short scale. In general, applications of satellite based vegetation, crop performance and climate derived drought indices become the feasible means and acceptable decision tools for timely action against the negative consequences of meteorological drought. Thus, Assessment of meteorological drought by remote sensing or ground data is believed to be very helpful for providing countermeasures as early as possible.

Ethiopia is a sub-Saharan country that has been affected by frequent drought. Millions of lives have been lost because of recurring droughts in the past several decades. Due to climatic changes, drought occurs every two years in different parts of Ethiopia (NMSA, 1996; Kandji &Verchot, 2006 ;). In addition, the drought recurrence cycle shortens over time while the affected area is widening, impacting additional parts of the country that were once unaffected (NMSA, 1996). In order to respond to the effects of drought, Ethiopia has been conducting drought assessment and monitoring missions. The Ethiopian National Meteorological Services Agency (NMSA) classified three seasons per year in Ethiopia: rainy season (June to September), dry season (October to January) and short rainy season (February to May) (NMSA, 1996). Since agricultural activities in the dry land semi-arid areas in general and study area, Fedis, Deder and Shinile woredas in particular, are influenced and controlled by seasonal rain, the study of meteorological drought analysis is carried out season-wise using climate based drought index (SPI).These index as proxies of drought, and crop and/or vegetation health condition are vital in drought assessment and hence, they are applied in this study. Problem Statement is Ethiopia's climate is influenced by general atmospheric and oceanic factors that affect the weather system (Bekele, 1997) and climatic factors such as drought has significant impact on agricultural output (Tsegaye, 1998). This makes Ethiopia vulnerable to climate variability. Climate variability over the last three decades resulted in drought and famines in Ethiopia and several other countries in Africa (Comenetez and Caviedes, 2002). Due to greater reliance on climate sensitive sectors such as agriculture, Ethiopia is vulnerable to the risk of climate variability and change such as MD. MD is a period of abnormally dry weather sufficiently for the lack of precipitation to cause

a serious hydrological imbalance and carries connotations of a moisture deficiency (Mohan and Arena, 1982 cited in Chopra, 2006). In Eastern Ethiopia, the major impact of MD is manifested through rainfall variability and recurrent drought due to climate change. The risks associated with them are generally late onset and early cessations of rainy season that cause reduction in the crops growing season in Eastern Harargea Zone Fedis, Deder and Shinile woredas respectively.
The amount and distribution of rainfall in these crops growing season is also very erratic, indeed making crops vulnerable to moisture deficit. Agriculture is one of the most vulnerable sectors to MD. The impact is redundantly stronger in the study areas in particular, where agriculture is truly important for the daily subsistence, and where adaptive capacity is low. Agriculture is the most vulnerable and sensitive sector that is seriously affected by the MD. MD is currently more pronounced in the study area. Farmers inhabiting in the study area are exposed to MD that resulted from the current climate change. This is due to the fact that most of farmers' cultivars (long duration crop variety) can no longer resist the existing MD and intra seasonal dry spell (NMA agro-meteorological bulletin, 2015). As a result, most of the cultivars have gone obsolete, and yield reduction and crop failure, death of livestock becomes common (Gizachew, 2010). Therefore, the aim of this research was to study Meteorological-Drought, to assess quantitatively climate anomalies in terms of severity, intensity (magnitude of drought), duration, frequency and spatial extent) in the introduction explained areas. Generally, studying of Meteorological drought (drought severity, intensity, frequency and duration) can be useful in this regard for the decision making process on drought monitoring and to avert its consequences on agricultural production and productivity for study areas. The main objective of the study was to investigate the spatial-temporal occurrence of meteorological drought on production in the study areas. Moreover, this study generated information about MD and facilitates exchange of this information among societies, field experts, policy makers and researchers. The study tried to investigate Meteorological drought spatial-temporal characteristics. The study therefore, would to provide significant recommendation for crop growing regions.

2. MATERIALS AND METHODS

2.1 Description of the study area

2.1.1 Location

The study areas are located in the Eastern Harerghe and Shinile Zones of Oromia and Somali Regional states respectively. Their Zonal capital, Harar and Jijiga respectively, are found 525625 kms South-East of Addis Ababa. They are two of the drought-prone and aid-dependent areas in Oromia and Somali Regional States (Bewket and Conway, 2007). The study area covers Fedis, Deder and Shinile. The altitude of the Eastern Hararge and Shinile Zones range between 1024-2144 meters above sea level (masl), with most areas lying above 1000 (masl).

Map of the study areas (by using GIS version 10.3.1 Software)

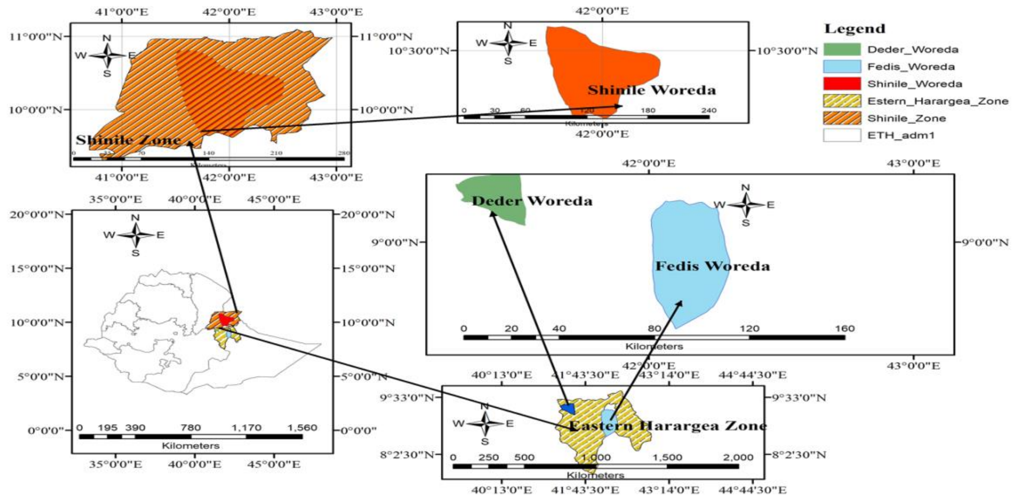

Figure 2. 1 Map of the study areas (by using GIS version 10.3.1 Software

2.1.2 Topography

Eastern Harerghe and Shinile Zones are characterized by diverse topographic features in which high mountainous and deeply incised canyons and gorges, valleys and plateaus with steep slopes dominate its most parts (Coltorti et al., 2007). Because of the diverse topography, the study area experiences different climatic conditions that range from hot and arid lowlands in the eastern part to cold and humid highlands in the western part.

Table 2. 1 Classification of Agro-Ecological zones based on Altitud

Elevation (meter above sea level)	Traditional Zone	Description
>3000	Wurch	Cold Highlands
2500 – 3000	Dega	Cool, Humid Highlands
1500 – 2500	Weina Dega	Temperate, Cool Sub-humid Highlands
300 – 1500	Kolla	Warm, Semi - Arid Lowlands
< 300	Bereha	Hot and Hyper - Arid lowlands

Source: Degefu (1987) and Gissila (2004)

Table 2. 2 Representative Meteorological stations for study areas are:-

Study areas	Latitude(N)	Longitude(E)	Altitude(m)	Area coverage (in Km^2)	Annual RF(in mm)	Annual Mean Temp (in c°)
Shinile	9^0 41' 37.2"	41^0 50' 92.8"	1024	0.50	639.0	25.7
Deder	9^0 19' 79.5"	41^0 26' 71.3"	2144	0.03	1008.1	16.4
Fedis	9^0 07' 94.4"	42^0 04' 49.7"	1699	0.11	526.1	19.5

2.2 Climate

The climate of study areas in Eastern Hareghe Zone: Fedis, Deder woreda and Shinile Zone shinile woreda studied by semi-arid and sub-humid climate based on the moisture index classification of climate. The long term average seasonal rainfall that the area receives ranges from 458 to 518 mm and according to NMA study in 1996, the study areas are characterized by bimodal rain fall distribution (those were spring and summer). The warmest temperatures are recorded during February to May, while the coldest was recorded during October to January. High temperatures between 30-35oc are recorded in low altitude areas, however in highland areas the average temperatures are between 20-22oc (Eklundh, 1996 and NMA website map-room, www.ethiomet.gov.et).

2.3 Data collection and Analysis

To achieve the objective of this study the following procedures were followed: - The study used ArcGIS version10.3.1 software to characterize spatial Meteorological Drought by imputing (analyzed) rainfall data processed by MS Excel, woredas' coordination (latitude and longitude) and woredas' base map data. The study used MS excel 2010, Instant version 3.37 and XL Instat soft wares to characterized temporal Meteorological Drought (i.e. to show rainfall trend, extent, frequency and duration in temporal characteristics of MD as output) by analyzed rainfall and crop yield data ; For this study, the study used a time series AVHRR satellite gridded and three stations rain gauges' rainfall data used to show meteorological–drought characters by helping indices such as SPI4 based (because they are used to assess meteorological season classification based on Lemaa Gonfa studied). The data obtained from National Meteorological Agency Jijiga Branch Office (NMA JBO), AVHRR gridded rainfall data have 4km by 4km spatial resolution (satellite data) in monthly and seasonally time step basis data for the period of the main rainy season (June - September) and (Mar-may). This gridded obtained from NMA and Famine Early Warning System (FEWS-NET) archive website: (http/:iridl.Ideo.columbia.edu GCM) about 37 years (from 1980 -2016 G.C) that used to fill the missing year data. The objects in this case are defined based on attributes of their physical feature and drought is a geographic object. So to characterize meteorological drought, the study used long year's meteorological data and different soft wares such as INSTAT 3.37 and ArcGIS 10.3.1 techniques, MS Excel 2010, and these woreda base map. Finally, this research is to assess impact of Meteorological drought using Meteorological Stations, satellite data and based on Meteorological drought indices and by helping different software packages (to assess quantitatively climate anomalies in terms of severity, intensity (magnitude of drought), duration, prediction and probability, frequency, temporal and spatial extent of drought).

2.4 Data sources and collection method

For this study, the daily historical meteorological data collected from Ethiopian National Meteorological Agency (NMA) for a period of 36 years (1980-2016). These include daily rainfall; gridded (Station + satellite) RF on the study area. Three meteorological weather stations shown above in Table2.2 selected for the study on the basis of spatial representative of the zone.

2.5 Data analyses

To characterize temporal and spatial Meteorological-Drought, its impact with rainfall; monthly rainfall data for a period of 36 years from (1980-2016) rearranged in a monthly, seasonally and annually time step in Microsoft excel 2010 spread sheet. For the study areas (Fedis, Deder and shinile), the trend and severity of monthly, seasonally and annually rainfall (i.e. maximum, minimum and mean rainfall) were analyzed. The rearranged data averaged over more than thirty years' time span and analyzed in order to examine the seasonal, monthly, seasonal and annual Meteorological-drought characteristics by using the following indices and different soft wares. The parameters used in this study are used described in the following sections.

2.6 Standard Precipitation Index (SPI)

SPI is an index that is developed to quantify precipitation deficit at different time scales, and can also help assess drought severity of MD by helping MS Excel and by using ArcGIS version

10.3.1 software analyzed spatial pattern of drought. The SPI is simplicity (only rainfall data is required for calculation). SPI is also used to analyze the impact of rainfall deficiency on crop development. Different time scales reflect the impact of drought on the availability of the different agricultural crops. According to Edwards and McKee in 1997, the mean SPI for the location and desired period is represented zero and also it represented water deficit or excess (i.e. positive SPI represents that water has been available to plants whereas negative SPI or rainfall deficiency is reflected on crop production through yield reduction). Yield reduction due to moisture deficiency is clearly explained in this issue. The formula of SPI is:

SPI = (Xij – Xim)/δ ---------------------- (2.1)

Where, *Xij*= is the seasonal precipitation and, *Xim* is its long-term seasonal mean and δ is its standard deviation. The final result of SPI based drought severity class are: >0=No drought, 0.0 to -0.99= Slight drought, -1.0 to -1.49= Moderate drought, -1.5 to -1.99= Severe drought, -2 and less, Very severe drought.

Table 2. 4 SPI based drought severity class (Gizachew, 2010).

SPI Value	Drought severity class
Above 0	No drought
0.0 to -0.99	Slight drought
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2 and less	Very Severe drought

So, it is used to see the duration, severity, frequency of meteorological-drought.

2.7 Characterizing the Meteorological-Drought

From the daily of long term rainfall data, the onset and cessation dates, trend analysis, and dry spell risk analyzed. All these Meteorological-Drought indices identified different soft wares, such as INSTAT tools version 3.37, and SPI4 and the data captured by MS Excel 2010 soft wares. In order to examine the MD of study areas for more than a thirty years (1980-2016) climatological period Statistical tools like mean, standard deviation, coefficient of determination (R2), coefficient of variability (CV) and p-value comparison used in ISTANT (v 3.37) statistical software. Coefficient of variability (CV) used to classify the degree of MD (rainfall) events as less, moderate and high. When CV < 20% it is less variable, CV from 20% to 30% is moderately variable, and CV > 30% is highly variable. Areas with CV > 30% are said to be vulnerable to drought (Gebremichael et al., 2014).

CV = $(\frac{SD}{\ddot{X}})$*100, where $\ddot{X} = \frac{\sum Xi}{N}$ and SD = $\frac{\sqrt{(Xi - \ddot{X})2}}{N - 1}$------------------------------ *(2.7)*

Where from equation (5) CV is the coefficient of variation, SD is standard deviation, Ẍ is long year mean and N is total number of year during observations, Xi is rainfall of each month or season. The coefficient of determination (R2) also indicates the variation of the climate variable with time in the linear regression model which is defined as:

$R^2 = SSR/SST$ OR 1 – SSE/SST ---------------- **(**2.8)

Where, SSE is the Sum of Squared Error, SSR is the Sum of Squared Regression; SST is the Sum of Squared Total. R2 measured how successful the fit was in explaining the variation of the data. P-value is a statistical measure that used to determine whether the hypotheses were correct. Usually, if the p-value of the dataset was below the pre-determined amount (say 0.05 which is the 95% confidence interval), the variability of the dataset has meaningful effect on the result (Wilks, 2006).

2.8 Trend analysis

For trend analysis, the monthly and annually data series of the study areas weather station more than 30 years long year data analyzed and test for the existence of significant trend by correlation and regression analysis using INSTAT software. To determine the trend of rainfall in the study areas, sequential plot time series analysis used. This can be mathematically denoted using the functional relationship below:

Y =f (i) (Equation 1)

Where, *Y* is the value of the variable under consideration at time *i*.

Suppose that Y_i is the estimated value of the dependent variable Y_i at time *i*, then Y_i can be predicted from the simple linear equation.

The model can be written as

Yi = βo + β1Xi + εi *(Equation 2)*

Y_i = the estimated value of the dependent variable(maize yield); *βo* = the Y intercept measuring the value Y_i at time *i*, *β1Xi* = the slope of the line measuring the change in the variable Y_i that results from a units change in time *i*, *i* = the independent variable (time) *i*=1, 2, 3, 4…30 and *Ɛi* = Random error. It hypothesize that there is no trend in *the amount* of rainfall over time. Thus the null hypothesis will stated as; *H0: β1 = 0*. Variability of annual and seasonal rainfall will be assessed using CV and Analysis of Variance (ANOVA) techniques. Standard rainfall will plotted against time (in years) to visualize the time series variation of annual and seasonal rainfall.

The regression model for the study rain fall effect will be computed as:

Y= a+ bx (Equation 3)

Where

Y = the value of the dependent variable

a = *Y* intercept

b = regression coefficients (each b represents the amount of change in *Y* (yield) for one unit of change in the corresponding x-value when the other *x* values are held constant; *x* = the rainfall independent variables (*i.e.* rainfall) and *e* = the error of estimate or residuals of the regression.

Pearson Correlation coefficient (r) analyses will be used to analyze the correlation between times(expressed in year) and rainfall characteristics, value of r ranges between -1 to +1, a correlation coefficient close to +1 indicates a strong positive correlation, a correlation coefficient close to -1 indicates a strong negative correlation similarly a correlation coefficient of 0 indicates no correlation.

3. RESULTS AND DISCUSSION

3.1 Spatial and temporal patterns of drought Conditions using Indices

3.1.1 Standard Precipitation Index (SPI)

Drought characteristics included various drought conditions, such as duration, severity, and intensity. The SPI was determined based on seasonal classification of Ethiopian (NMSA 1996, Babu 1999a, 63) which mainly include Belg (Feb-May), Bega (Oct – Jan) and Kiremt (Jun- Sep). The results of SPI4 analysis are given below in Table 3.1 and Figure 3.1. The point RF was used to talk woreda based because the NMA station RF data represent about fifty Kilo meter radius coverage.

The analysis of SPI4 for Shinile woreda showed that drought has occurred at different level from 1980 to 2016 rainy season. In the below Figure 3.1, the drought happened in the years 1980, 1981, 1984, 1985, 1988, 1989, 1990, 1991, 1995, 1999, 2000, 2002, 2003, 2004, 2005, 2008, 2009 2011 and 2015 (see Appendix 5). There were very severe droughts years and with their more intensity and duration. These years were 1984, 2000, 2005, 2009, 2011 and 2015 those were explained with their SPI values that range from -2 to -1. The results indicated that during those years, there was rainfall deficit in the growing season and therefore, there was the worst dry season. SPI can be used to identify not only drought years but also wet years. In this regard, using SPI analysis, wet years were identified. As the maps were shown in the Figure 3.1, the years 1982, 1983, 1986, 1987,1992, 1993, 1994, 1996, 1997, 1998, 2001, 2006, 2007, 2010, 2012 and 2013 were very wet years in Shinile woreda, and based on SPI4,among these years the extreme wettest years were 1983, 1997, 1998, 1996 and 2010. Besides analysis of the 36 years (1980-2016) annual RF showed a coefficient of variation ranging from 70.4 – 157.2 %.

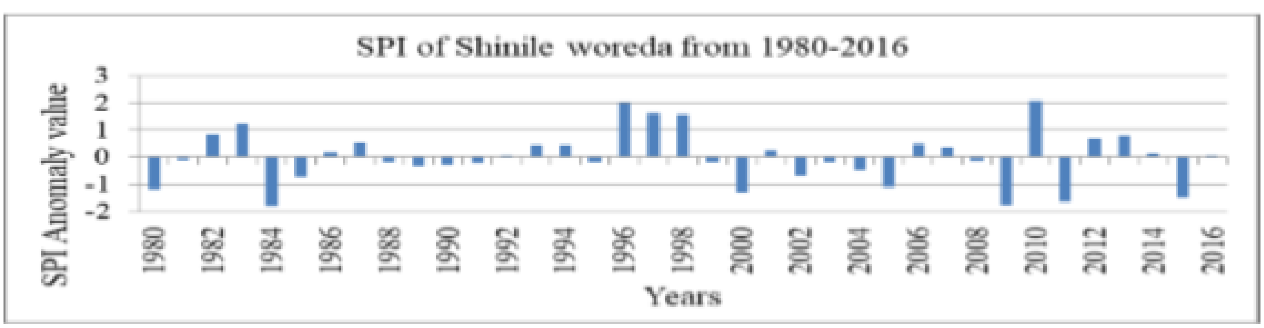

Figure 3.1 SPI RF anomaly of Shinile woreda for the period of 1980-2016

The analysis of SPI4 based for Deder woreda, from Figure 3.2, the years 1984, 1985,198, 1987, 1991, 1994, 2004, 2005 and 2007 to 2015 were droughts. There were very severe droughts with their SPI values ranges from -1.0 to -1.5 those were the years 1984, 1994, and 2007 to 2013. The results indicated that during those years there was rainfall deficit in the growing season and therefore, there were the worst dry years. Considering of the most severe droughts years above mentioned period was a better illustration of the drought extent and intensity in this area. So based on this index, the extreme wet years were 1999, 1998, and 1997 with SPI values greater than 1.0. Besides analysis of the 36 years (1981-2016) annual RF showed a coefficient of variation ranging from 70.8 – 139.0 %. This was highly variation of RF.

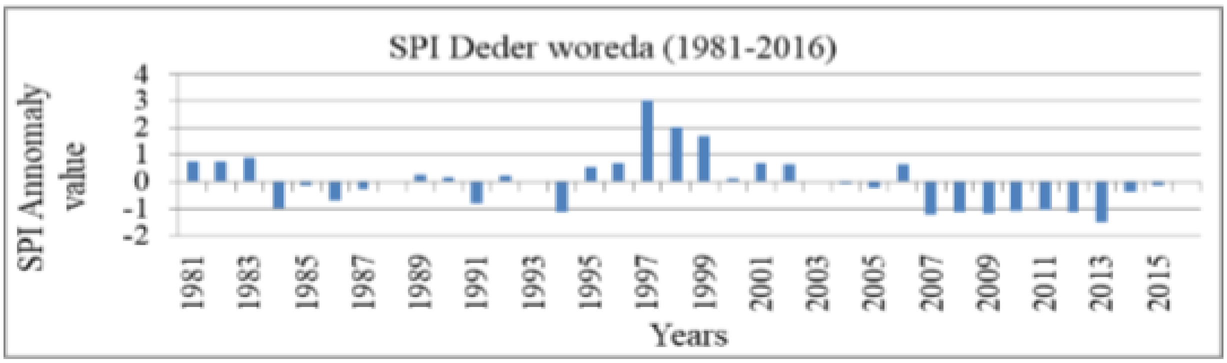

Figure 3.2 SPI RF anomaly of Deder woreda for the period of 1981-2015

The result of the analysis of SPI4 for Fedis woreda is given in Figure 3.3. As it can be seen, the droughts occurred in the years 1980, 1982 - 1986, 1990, 1991-1993, 2005, 2007, 2010, 2011, 2012 and 2015. There were very severe droughts in the years 1980, 1982 - 1985, 1986, 2010 and their SPI values range from -1.5 to -2.0. The results indicated that those years were rainfall deficit in the growing season and therefore, there were the worst dry seasons in Fedis woreda. Considering of the most severe droughts above mentioned period were the better illustration of the droughts extent and intensity in Fedis woreda. The years 1988, 1989, 1995, 1996, 1997, 2009 and 2014 were also extreme wet with SPI values greater than 1.0. Besides analysis of the 36 years (1981-2016) annual RF showed a coefficient of variation ranging from 75.6 – 202.7 %.

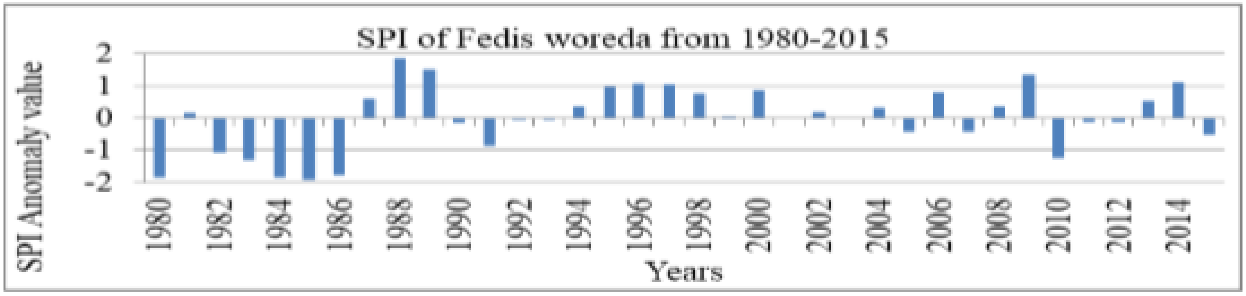

Figure 3.3 SPI RF anomaly of Fedis woreda for the period of 1980-2016

During Kiremt season (Jun – Sep), in the Figure 3.4, based on SPI4 for Deder in the years 1984, 1987, 1991, 2010 and 2013 were found to be the extreme drought; whereas, during this season the years 1983, 1988, 1998, 1999, 2000, 2001 and 2002 were found to be extreme wet and based on vegetation (NDVI index) trend data these years were good production years. As the Figure 3.4 indicates, most years have shown more frequent drought than wet years and also drought occurrence was frequent in 1980s and 2010s;this indicates the earliest time is returned now and the RF performance is shown decreasing trend.

Figure 3. 4 Kiremt Season (Jun – Sep) RF SPI of Deder woreda for the period of 1981-2015

During Kiremt season (Jun – Sep) in the Figure 3.5, based on SPI4 for Fedis woreda in the years 1980-1986, 1990-1993, 2001, 2005, 2007, 2010, 2012 and 2015 were shown droughts (the SPI4 values range from -0.1 to -2.0). Among these years, 1980, 1984,1985 and 1986 were very severe droughts (SPI4 values range from -1.6 to -2.0); whereas, the years 1987-1989, 1994-2000, 2002, 2006, 2008, 2009, 2011, 2013 and 2014 were wet (the SPI4 values range 0.3 to 1.6). Among these years, 1988 and 2009 were good cropping years because these years were found to be extreme wet years than others. As the below Figure 3.5 has shown frequency of droughts years were more than wet years and also drought occurrence was frequent in the first years (1980's).

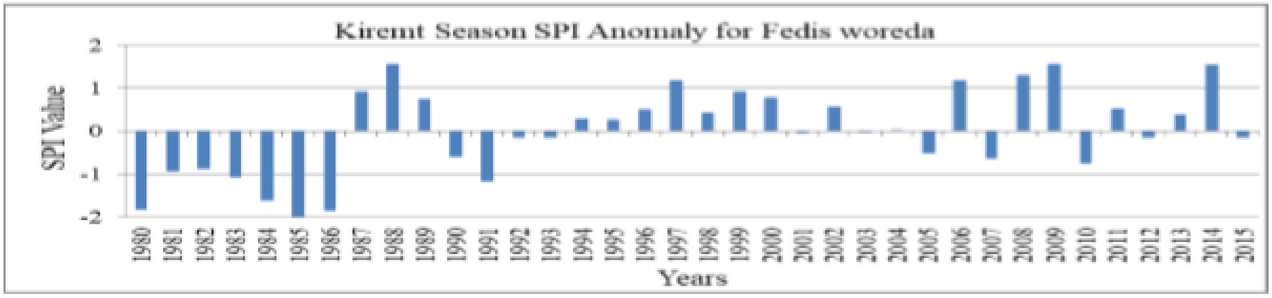

Figure 3. 5 Seasonal (Jun – Sep) RF SPI of Fedis woreda for the period of 1980-2015

During Kiremt season (Jun – Sep) in the Figure 3.6, based on SPI4 for Shinile woreda, in the years 1980-1982, 1984-1987, 1989-1991, 1993, 1995, 1997, 2002, 2004, 2009 and 2015 were the droughts (the SPI4 values range from -0.2 to -2.1). Among these years, 1991 and 1987 were very severe droughts (the SPI4 values range from -1.6 to -2.1); whereas, the years 1984, 1996, 1998, 2001 and 2010 were extreme wet and these years were good cropping years because these years were more wet years than others. So, as the below figure 3.6, based on SPI4 has shown frequency of drought years were less than wet years and also drought occurrence was frequent in the first years (1980's).

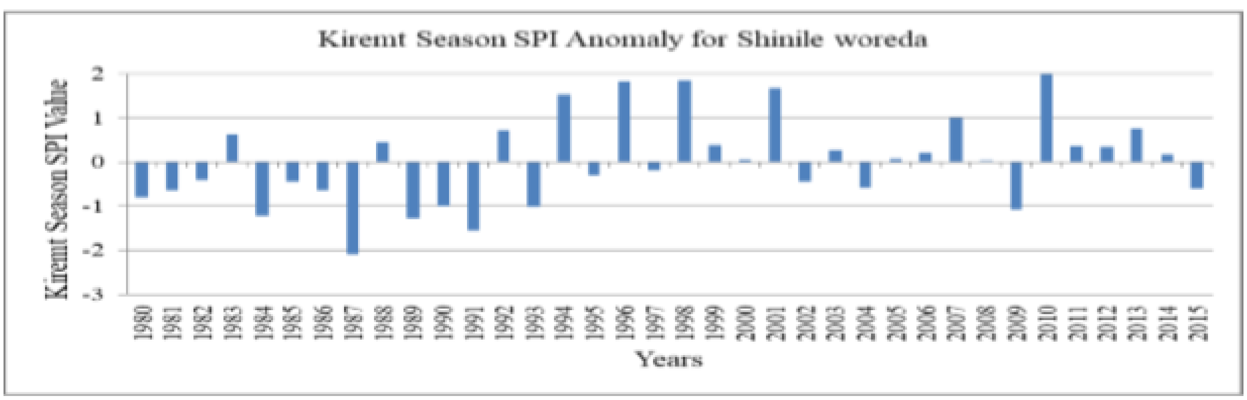

Figure 3. 6 Kiremt Season (Jun - Sep) RF SPI of Shinile woreda for the period of 1980-2015

As it can be seen from Figure 3.7, the SPI4 values for Belg season (Feb – May), ranged from 0.1 to -1.6 for Shinile woreda, during the years 1980, 1984, 1985, 1988, 1992, 1994, 1999-2005, 2007, 2009, 2011-2013 and 2015. These values indicate drought of different levels. Based on the classification given by equation 3.3, SPI values between -

1.5 and -1.6 are considered as severe droughts. In line with this, the years 2000, 2009, and 2011 are classified severe droughts. The earliest years (2000's) were characterized with more frequent drought events whereas the years 1981, 1983, 1986, 1987, 1996 and 2010 were wet and there were good cropping season.

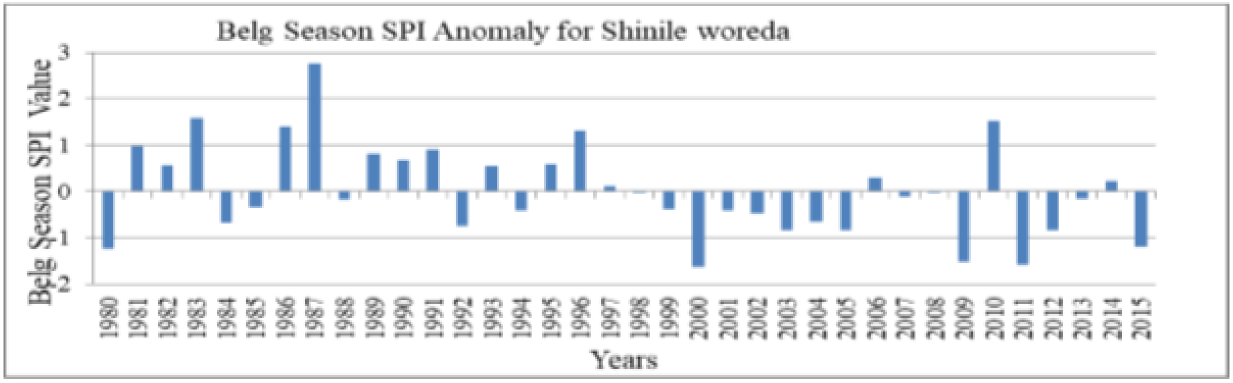

Figure 3. 7 Belg Season (Feb - May) RF SPI of Shinile woreda for the period of 1980-2015

During Belg season (Feb – May), in the Figure 3.8, based on SPI4 for Deder woreda, in the years 1984, 1986, 1988, 1992–1994, 2000-2005, 2007-2009, 2011-2015 were shown drought. Among these years, the years 1988, 1994, 2007, 2009, 2011-2013 were shown from moderate to severe drought (the SPI4 values range from -1.0 to -1.6). The recent years were more frequent the drought years whereas from figure 4.5 the years 1981-1983, 1985, 1987, 1989-1991, 1995-1998, 2006 and 2010 were wet (the SPI4 values range from 0.1 and 3.3). Among these years, in 1997 was the wettest year and expected good cropping season.

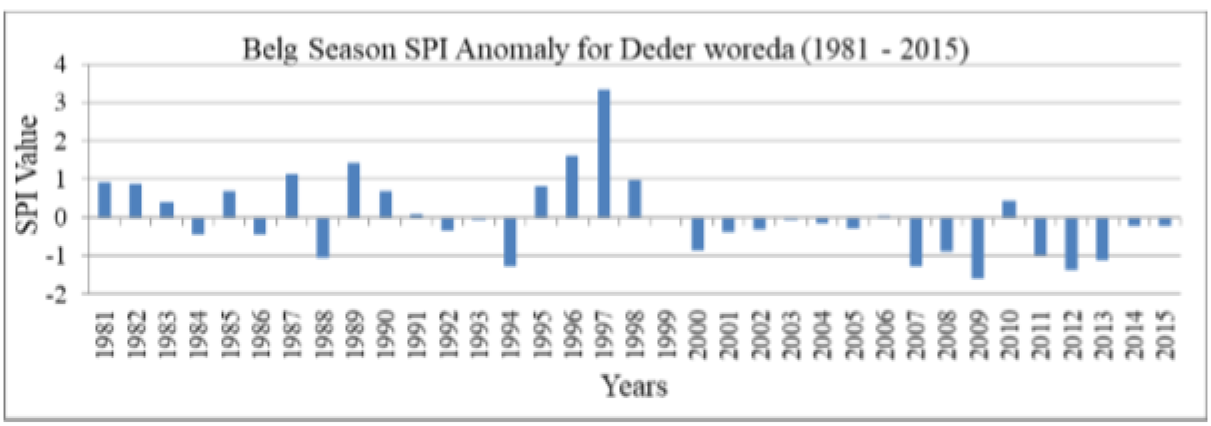

Figure 3. 8 Belg Season (Feb - May) RF SPI of Deder woreda for the period of 1981-2015

During Belg season (Feb – May), in the Figure 3.9, based on SPI4 for Fedis woreda, in the years 1980, 1982-1986, 1991,1999, 2001, 2002, 2005, 2008, 2010, 2011 and 2015 were shown droughts (the SPI4 values range from -0.1 to -1.5). Among these years, the years 1980, 19821986, 1999, 2008, 2010 and 2015 were shown moderate droughts (the SPI4 values range from -1.0 to -1.5) specially 1984 were severe drought. The earliest years (1980's) were more frequent the drought years; whereas, in the Figure 3.9, the years 1981, 1988-1990, 1995-1998, 2000, 2003, 2004, 2007, 2009 and 2014 were wet (the SPI4 values range from 0.1 and 2.0). Within line this, 1998 and 1989 were found to be the extreme wet years and there were expected good cropping season.

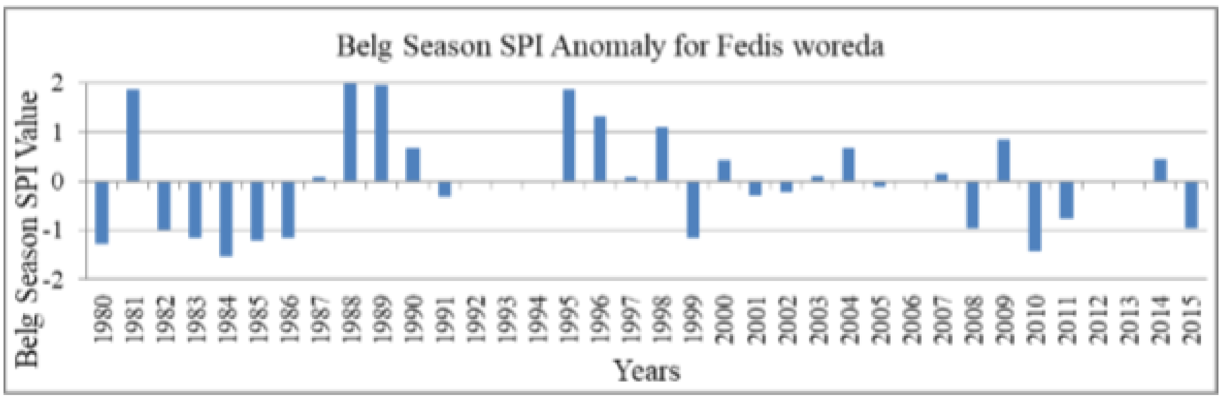

Figure 3. 9 Belg Season (Feb – May) RF SPI of Fedis woreda for the period of 1980-2015

So, the implication of the above result indicated that the drought pattern such as drought frequency, severity and intensity explained by using SPI4 index in study areas. It used to know the drought years, its frequency time and its magnitude in study areas.

3.2 RF Trend Analysis in the study areas

As can be seen in Figure 3.10, annual total rainfall trend in Fedis woreda for the period 1980 to 2016 was positively increased with the time. Based on the result in Figure 3.10, during the above mentioned period, the highest amount of RF was 923.3 mm in the year 1988; whereas, the lowest total amount of rainfall was 89.4 mm in the 1985 and also the mean total RF was 514.7mm. The trend of total rainfall amount was increased with the time (see Table 3.1 Appendix 2). Whereas, the annual total rainfall trend in Figure 3.11, for Deder woreda for the period of 1981 to 2016 was decreased and the highest total RF recorded in the year 1997 with the value 1933.7mm but the minimum total amount of rainfall recorded in 1985 with the value 425.0 mm. The mean total RF was 992.95 mm (see Table 3.3 Appendix 2). As shown in Figure 3.12, the annual total rainfall trend in Shinile woreda for the period of 1980 to 2016 decreased and the maximum total rainfall was 965.9 mm in 2010; whereas, the minimum total amount of rainfall was 348.6 mm in 2015 and the mean total RF was 639.0mm. The study showed that the trend of total rainfall amount decreased with the time. Statistically, significant all trends were detected for precipitation on annual based (see Table 3.2 Appendix 2).

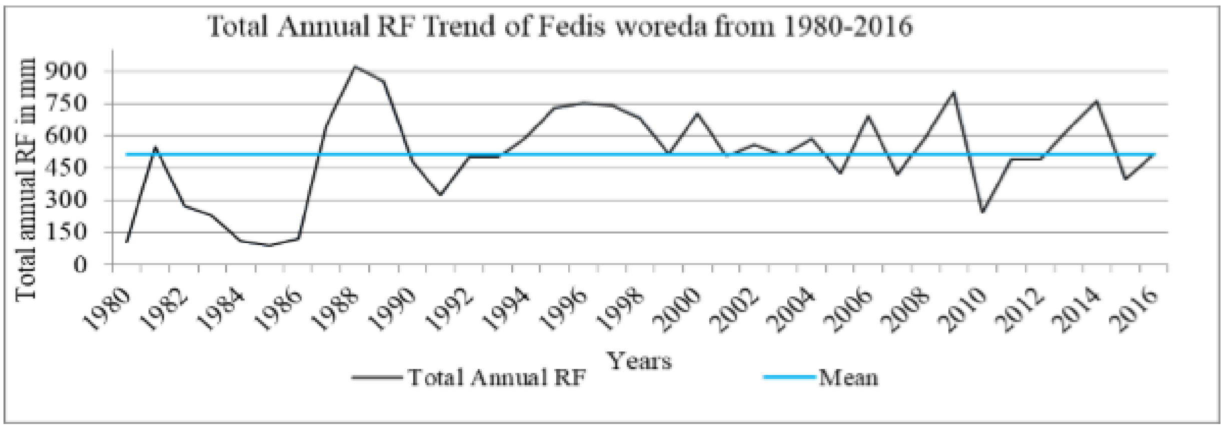

Figure 3. 10 Total Annual RF Trend of Fedis woreda for the period of 1980-2016

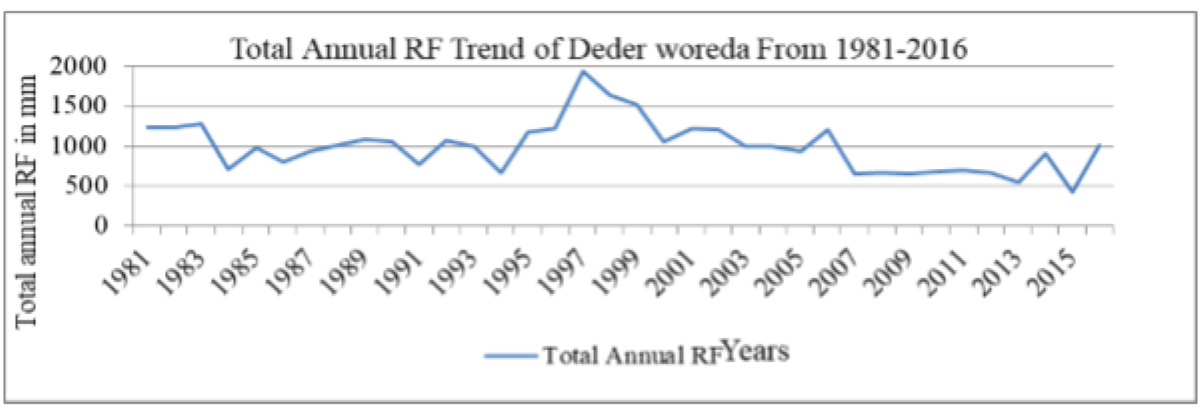

Figure 3. 11 Total Annual RF Trend of Deder woreda for the period of 1981-2015

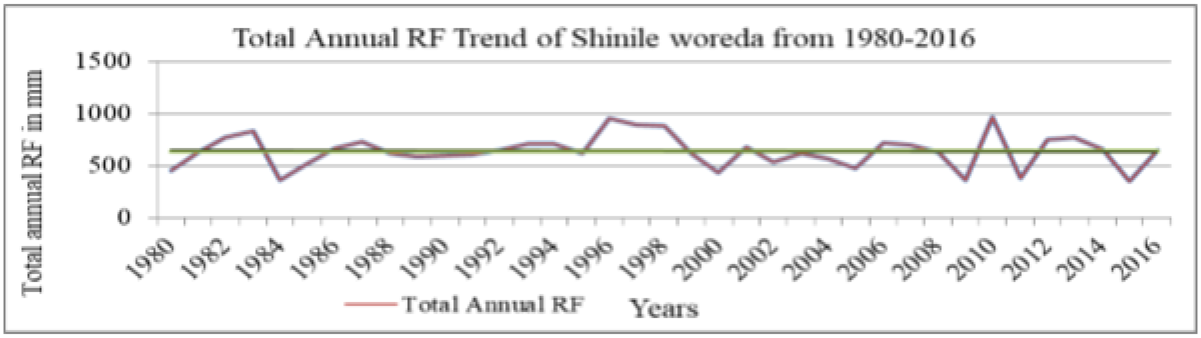

Figure 3. 12 Total Annual RF Trend of Shinile woreda for the period of 1981-2013

3.4 MD Characteristics Onsets, Cessation, LGP and Dry spell of Seasons

Most prediction studies focus on the total seasonal rainfall amount, however, the time of that rainfall is equally important to agriculture. For example, pastoralists in northern Kenya and southern Ethiopia have identified the spring onset date as the single most desirable piece of forecast information (Luseno, 2003). The time of the seasonal transitions can also be an important control on drought, since a late onset or early termination and duration of sowing can initiate or exacerbate drought conditions. The magnitude of drought impact is closely related to the time of the onset of the precipitation shortage, its intensity, and the duration of the event. As droughts extend from one season to another and from one year to another, potential impacts are magnified since surface and subsurface water supplies continue to be depleted and a larger number of users are affected. Frequent and multi-year drought events offer no opportunity for natural and managed systems to recover, a critical problem for fragile arid and semiarid ecosystems (Edward M. Mugalavai, Dirk Raes, Manchiraju S. Rao, (2008). So in the Figures (3.16 and 3.18) the Starting of Season (SOS) of Belg (Feb to May) for Fedis woreda most of years was started during third dekad of February and the End Of rainy Season (EOS) was stopped or ended during May third dekad, and from Figures (3.16 and 3.18) the Starting of Season (SOS) of Belg (Feb to May), for Deder woreda most of the years was started during first dekad of March and the End Of rainy Season (EOS) was stopped or ended during May third dekad. In the Figures (3.16 and 3.18) the Starting of Season (SOS) of Belg (Feb to May) for Shinile woreda most of years was started during third dekad of

February and the End Of rainy Season (EOS) of Belg for Shinile was ended during May third dekad. On the other way the starting of rainy Season (SOS) of Kiremt (Jun to Sep) for Fedis woreda from Figure (3.17 and 3.19) most of the years was started during first dekad of Jun and the End Of rainy Season (EOS) was stopped or ended during September third dekad; the starting of rainy Season (SOS) of Kiremt (Jun to Sep) for Deder woreda from Figure (3.17 and 3.19) most of the years was started during third dekad of Jun and the End of rainy Season (EOS) was stopped or ended during September third dekad and the starting of rainy Season (SOS) of Kiremt (Jun to Sep) for Shinile from figure (3.17 and 3.19) most of the years was started during second dekad of Jun and the End Of rainy Season (EOS) stopped or ended during September third dekad.

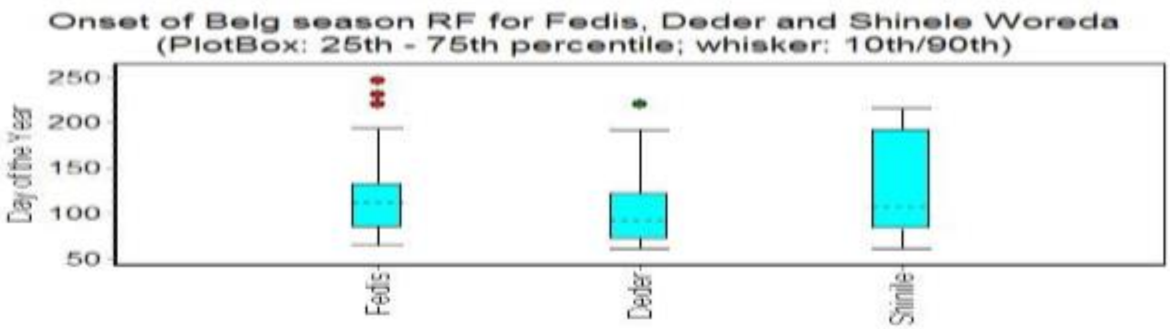

Figure 3. 16 Belg season onsets of rains in days for Fedis, Deder and Shinile woreda

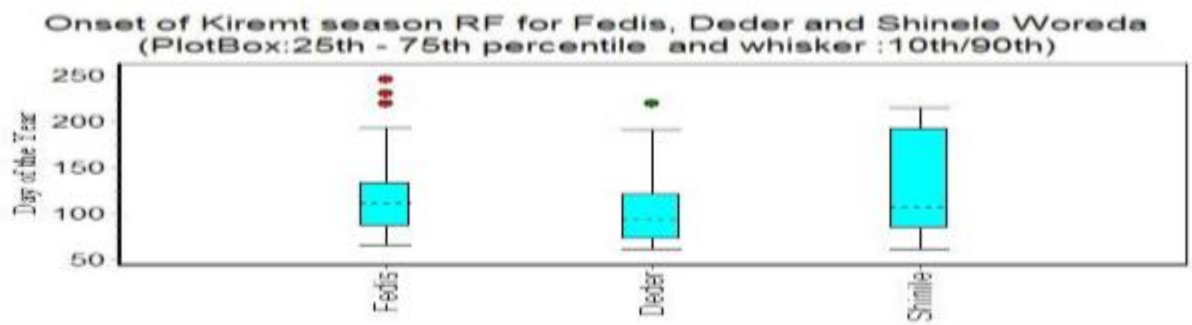

Figure 3. 17 Kiremt season onsets of rains in days for Fedis, Deder and Shinile woreda

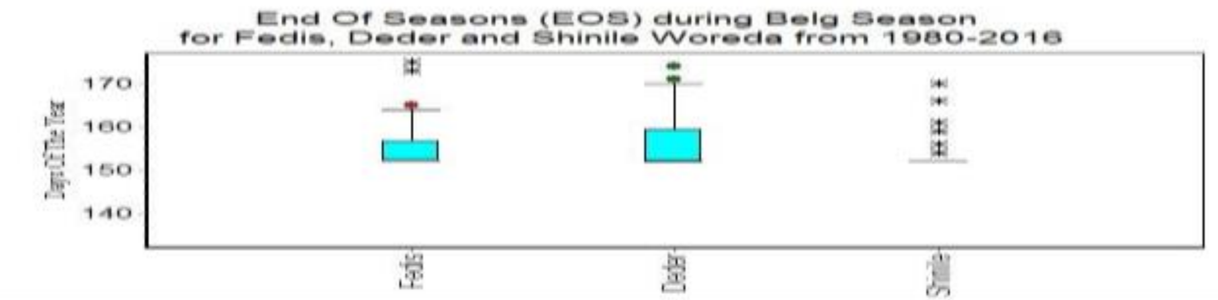

Figure 3. 18 Belg season End of rains in days for Fedis, Deder and Shinile woreda

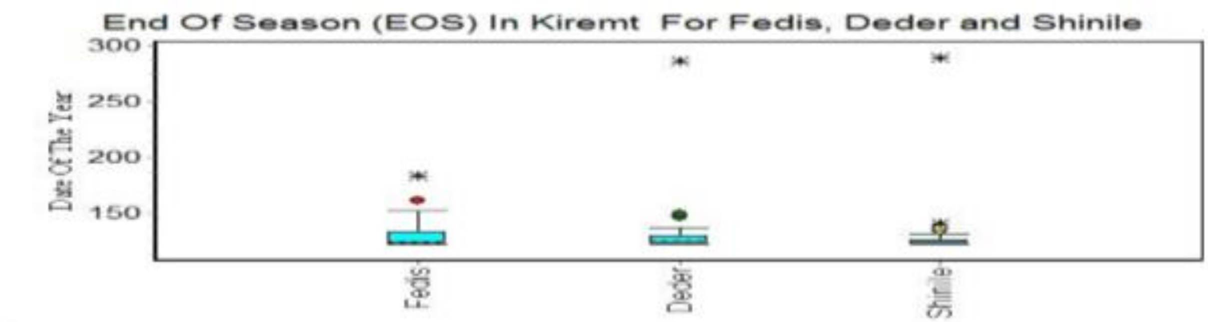

Figure 3. 19 Kiremt season End of rains in days for Fedis, Deder and Shinile woreda

The duration of the rainy season was defined as the difference of the onset and cessation dates of rainfall (length = cessation−onset). Length of Growing Period (LGP) or rainy length time (from Figure 4.20), during Belg season for Shinile was 40-80 days, for Deder about 80 – 100 days and for Fedis woreda there was about 100 – 120 days. Length of Growing Period (LGP) or rainy length time (from figure 4.21) during Kiremt season for Shinile 70 – 90 days, for Deder about 80 – 100 days and for Fedis woreda there was about 100 – 120 days.

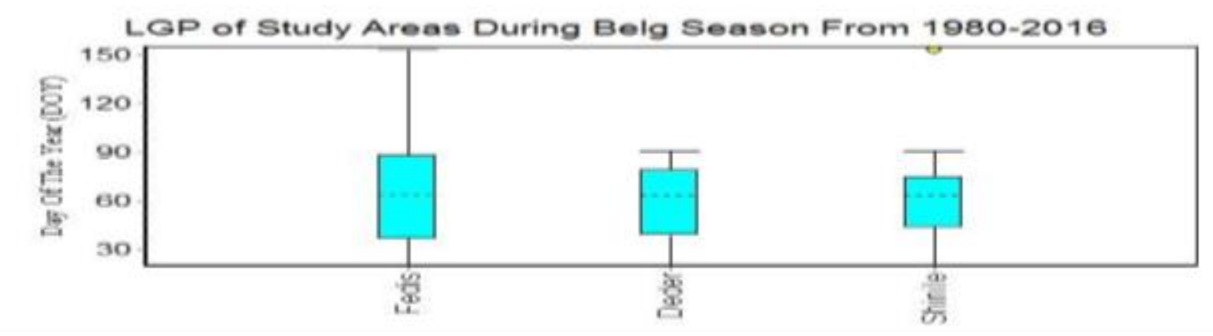

Figure 3. 20 LGP during Belg season in the study areas

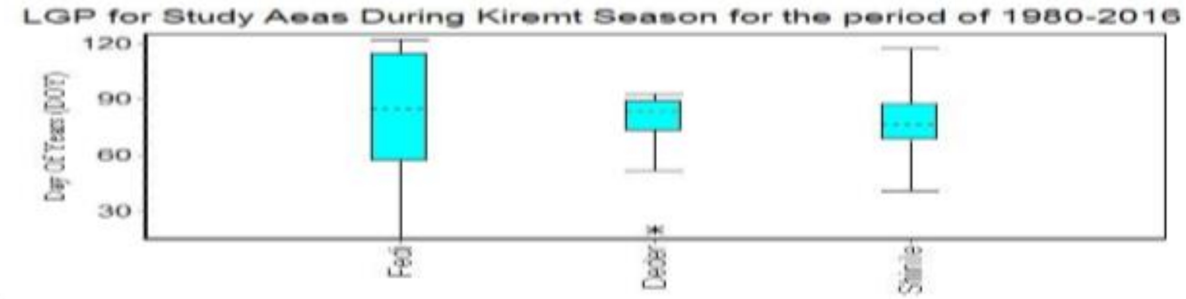

Figure 3. 21 LGP during Kiremt season in the study areas

As it can be seen from Figure 3.22, the dry spell of the Fedis woreda decreases at the end of April and starting of May in range 0-20%, 40-60%, 75-80%, 85-100% in 15, 10, 7 and 5 days respectively. With line this, the dry spell also decreases at the end of August and starting of September in range 0-15%, 20-30%, 50-60%, 80-90% in 15, 10, 7 and 5 days respectively. But during June and September, the dry spell days increased about more than 20% in all days.

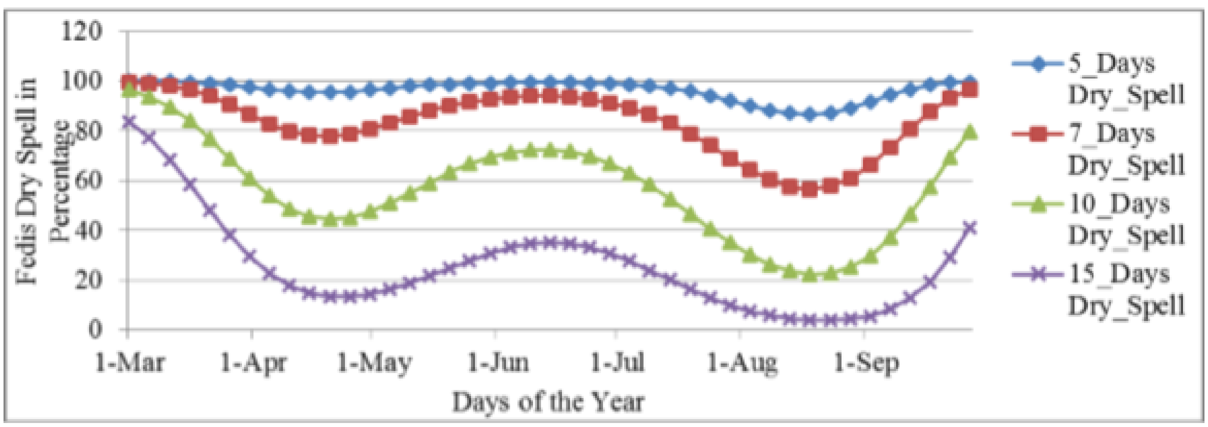

Figure 3. 22 Dry spell in percentage in Fedis Woreda for the period of 1980 – 2016

As it can be seen from Figure 3.23, the dry spell of in Deder woreda decreases at the end of March and starting of April in range 0-20%, 30-40%, 60-70%, 85-100% in considering 15, 10, 7 and 5 days respectively. With line this, the dry spell also decreases at the half of July and end of August in range 0%, 0%, 0-20%, 40-45% in 15, 10, 7 and 5 days respectively. But during May and September, the dry spell days increases about more than 30% in all days. In general, the dry spell in Fedis woreda was less than others woreda whereas in Shinile woreda it was more than others woreda.

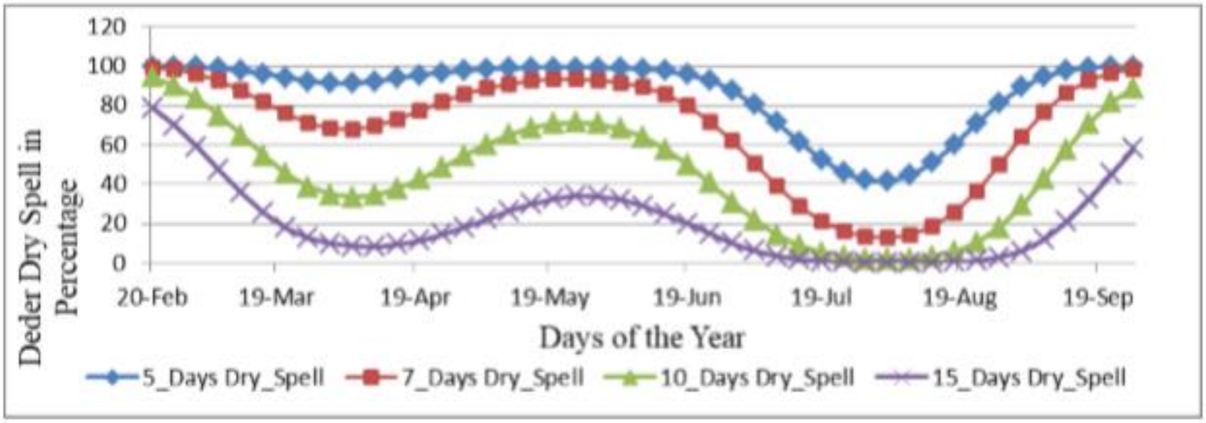

Figure 3. 23 Dry spell in percentage in Deder Woreda for the period of 1981 – 2016

As it can be seen from Figure 4.24, the dry spell of Shinile woreda decreases at the end of March and starting of April in range 20%, 50-60%, 80-90%, 95-100% in 15, 10, 7 and 5 days respectively. With line this, the dry spell also decreases at the month of August and end of August in range 0%, 5%, 20-25%, 55-60% in 15, 10, 7 and 5 days respectively. But during May, June and September, the dry spell days was increased about more than 60% .

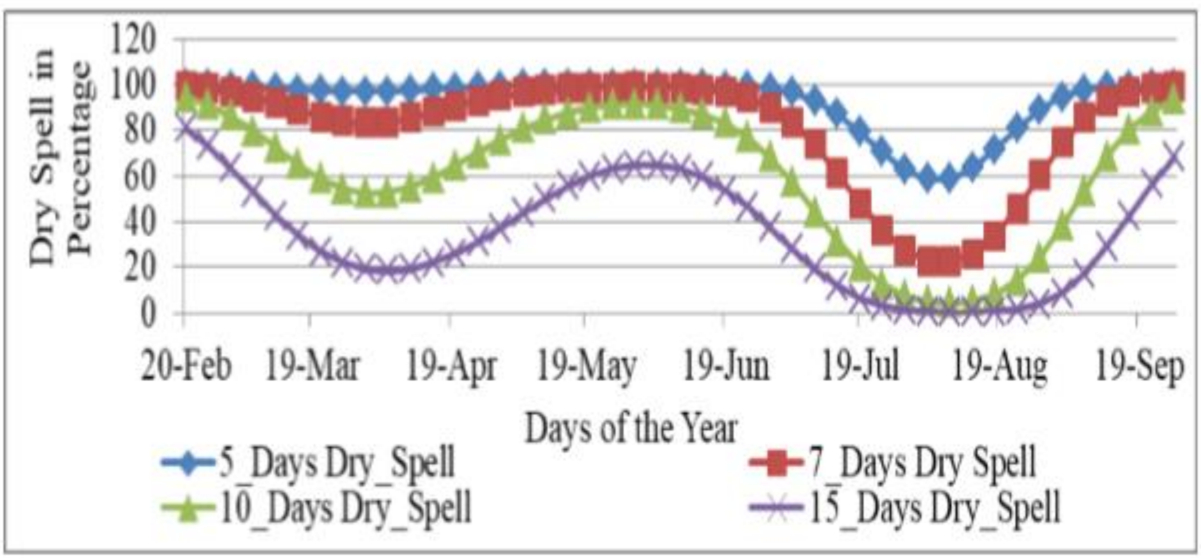

Figure 3. 24 Dry spell in percentage in Shinile Woreda for the period of 1981 – 201

4.5 Analysis of Variance (ANOVA) techniques

Table 3. 1 ANOVA of Study Areas

St. Name	MK_Slope	Season	Mann_Kendal's Trend Test		
			Kendall's Tau	Sen's Slope	P Value
Shinile	-111	Belg	-0.19	-0.075	Sig
	-76		-0.12	-0.841	Sig
	-114		-0.18	-1.919	Sig
	-101		-0.16	-0.767	Sig
	161	Kiremt	0.26	0.538	NonSig
	188		0.30	1.580	NonSig
	73		0.12	0.737	Sig
	23		0.04	0.206	Sig
Deder	-197	Belg	-0.34468	-0.82857	NonSig
	-63		-0.10734	-0.74	Sig
	-106		-0.17921	-1.5167	Sig
	-117		-0.20144	-1.55333	Sig
	90	Kiremt	0.154003	0.447815	Sig
	6		0.010179	0	Sig
	-52		-0.08791	-0.75	Sig
	-53		-0.0903	-0.26496	Sig
Fedis	4	Belg	0.007057	0	Sig
	49		0.0795	0.1579	Sig
	-65		-0.10443	-0.6057	Sig
	190		0.308521	0.126798	NonSig
	123	Kiremt	0.197605	0.815302	Sig
	170		0.271135	1.432248	NonSig
	165		0.263372	1.837037	NonSig
	5		0.008007	0	Sig

Sig: significant, NonSig: Non significant, MK: Mann Kendall

4.2 CONCLUSIONS

There have been many climate related disasters, such as drought, that have led to famine in Ethiopia. The experience has led to the evolution of an excellent early warning and response mechanisms in Ethiopia. The NMSA provides weather forecasts and the DPPB provides the famine early warning system and assesses the food supply in the country. The situation of the 1980 to 2016 case teaches us that drought studies are very important for study areas because these areas are aid dependent and recurrent drought experienced. Drought early warning based on onset, secession, LGP and dry spell information have to be practiced by study areas. So with credible drought information with a longer lead time, the national government can use it to manage the national food supply. The findings of this study have implications for drought management, early warning system, preparedness and contingency planning and climate change adaptation. In real sense, drought is a climatic event that cannot be prevented very easily, but interventions and preparedness to drought can help to cope with drought by developing more resilient ecosystems, improving resilience to recover from drought and taking various adaptation strategies like water harvesting, making irrigation system more efficient and a geographical shift of agricultural system. It can advise farmers to produce more food instead of cash crops; it can also advise farmers what, where and when to plant and help reduce losses of crops during the process of replanting when the rain returns. The results indicate that the occurrences of drought in study areas showed temporal variation.

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References

A. Sadiq1*, W. S. Williams1 and A. I. Tukur1 (2020). Application of Percent of Normal Precipitation Method for Meteorological Drought Intensity Assessment and Its Impact on Agricultural Production Adamawa State, Nigeria

Alemayehu Kassa (1999).Drought risk monitoring for Sudan using NDVI 1982. 1993. Msc. Thesis, University College, London.

Amare Degefaw (2007). Application of remote sensing for delineation of drought vulnerable areas in Agro-met bulletin, 2015, Addis Ababa NMA).Amhara region. Msc. thesis, Addis Ababa University, Addis Ababa.

Bekele Feleke (1997). Ethiopian use of ENSO information in its seasonal forecast. URL: www.brad.ac.uk/research/ijas/ijasno2/ijasno2.html

Beyene Ergogo (2007). Drought assessment for Nile Basin using Meteosat Second Generation data with special emphasis on the upper Blue Nile Region. Msc. Thesis, ITC, Enschede.

Ceccarelli, S. and Grando, S. (1996). Drought as a challenge for the plant breeder. Plant Growth Regulation, 20: 149-155.

Comenetz, J. and Caviedes, C. (2002). Climate variability, political crises, and historical population displacements in Ethiopia. Environmental Hazards, 4: 113-127.

Early Warning System. (2003).Food supply prospect. URL: www.dppc.gov.et.

FEWSNET. (2009). Ethiopia food security update. URL: http://www.fews.net/docs/Publications/ethiopia_fsu_06_2009_final.pdf

FAO. (1977). Crop water requirements. In: FAO Irrigation and Drainage Paper No. 24. FAO, Rome. pp. 69-70.

FAO. (1979). Agro-meteorological crop monitoring and forecasting. In: FAO Plant Production and Protection paper No. 17.

FAO, Rome. p. 212. Finance and Economic development Bureau of Oromia (2007). Socio-economic profile of Eastern Harargea zone. Harar.

Flood and Climate Basics. (2004). Environmental Science published for everybody round the Earth. URL: http://www.atmosphere.mpg.de/enid/26b.html

Gesch, D.B., Verdin, K.L. and Greenlee, S.K. (1999). New land surface digital elevation model covers the Earth. Transactions of the American Geophysical Union, 80:69-70.

Guttman, N.(1998). Comparing the palmer drought severity index and standardized precipitation index. Journal of the American Water Resources Association 34:113-121.

Herrmann, S. M. and Anyamba, B. (2004). Exploring relationships between rainfall and vegetation dynamics in the Sahel using coarse resolution satellite data.URL: http://www.isprs.org/congresses/beijing2008/proceedings/7_pdf/5_WG-VII-5/41.pdf

Hoefsloot,P.(2008). Livelihood early assessment (LEAP) version 2.1 and 2.9. URL: http://vam.wfp.org/LEAP

Jeyaseelan, A.T. (2004). Drought and flood assessment and monitoring using remote sensing and GIS.URL: http://www.wamis.org/agm/pubs/agm8/Paper-14.pdf

J. bayo Omotoshoa,*, A.A. Balogunb and K. Ogunjobib (1999). Predicting monthly and Seasonal rainfall, onset and cessation of the rainy season in west africa using only surface data

Kinde Tesfaye (2004).Field comparison of resource utilization and productivity of three grain legumes under water stress. PhD thesis, University of Free State, Bloemfontein.

Kinde Tesfaye and Walker, S. (2004). Matching of crop and environment for optimal water use: the case of Ethiopia. Physics and Chemistry of the Earth.29:1061-1067.

Kogan,F.N. (1997). Contribution of Remote Sensing to Drought Early Warning.URL:

http://drought.unl.edu/monitor/EWS/ch7_Kogan.pdf
Komuscu, A. U. (1999). Using the SPI to analyze spatial and temporal patterns of drought in Turkey. Drought Network News, 11: 7-13.
Lemma Gonfa (1996). Climate classification of Ethiopia. In: Meterological Reserch Report Series No.3. Addis Ababa, pp.1-8.
McKee, T.B., Doesken, N.J. and Kleist, J. (1993). The relationship of drought frequency and duration to time scales. In: Proceedings of the 8th Conference on Applied Climatology. American Meteorological Society, Boston, pp. 179184.
Mokhtari, M. H.(2005). Agricultural drought Impact assessment using Remote Sensing: A case study Borkhar district Iran. Msc. thesis, International Institute for Geo-Information Science and Earth Observation, Enschede.
Murali, K., G.Ravikumar and M.Krishnaveni.(2008). Remote sensing based agricultural drought assessment in Palar basin of Tamil Nadu State, India. Journal of the Indian Society of Remote Sensing, 37:9-20.
National Meteorological Service Agency (NMSA). (1996). Assessment of drought in Ethiopia. In: Meteorological research report series No.2.Addis Ababa.
Nnoli NO. (1996). Mean onset and cessation dates of rainy season in Nigeria. Proceedings of the 11 th Nigerian Meteorological Society Conference on Climate Change and its Impacts on Agriculture. IITA –International Institute for Tropical Agriculture, 24–25 October 1996, Ibadan, Nigeria
Obasi GOP, Adefolalu DO (1977). Maps of Mean Onset and Cessation Dates of Rainfall in Nigeria. Nigerian Meteorological Research Publishers: Lagos.
Omotosho JB (1990). Onset of thunderstorms and precipitation over Northern Nigeria. International Journal of Climatology 10: 849–860.
Omotosho JB. 1992. Long-range prediction of the onset and end of the rainy season in the West African Sahel. International Journal of Climatology 12: 369–382.
Omotosho JB. 1996. The validation of prediction models for onset of rainfall and prospects for West African Sahel. Report. A contribution to the ACMAD Demonstration period (96), ACMAD, Niamey, Niger.
World Meteorological Organization. 1996. Climatological Normals (Clino) for the period 1961–1990. WMO No 847.

Appendices Appendix 1

Questionnaire

1. What are the others factors those have contribute to define the study areas of yields for Common maize and sorghum sowing in future?

1. How is a rainfall characteristic in terms of amount and distribution as well as time of occurrence related to crop requirement?
2. Is there yield reduction due to mismatch of rainfall and crop water needs at different growth stage? How was the impact of MD on yields in study areas?
3. How was rainfall pattern in terms of amount and distribution in study areas about the last 36 years? How was the LGP, Onset, Cessation, LGP and Dry spell of RF in study areas?
4. How the pattern of meteorological drought was looks like in the past growing seasons?

Appendix 2

Table 3.2 Long year monthly and annually RF statically summary over Fedis woreda

Long Year RF Statistical Summary of The Study Areas													
Fedis													
Sum. Stas	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annually*
Mean	3.4	1.8	54.9	103.7	5.7	50.9	66.0	80.5	87.8	54.5	14.2	3.1	526.1
SE	0.8	0.5	7.7	12.5	0.6	5.1	6.5	9.1	9.1	8.9	3.4	1.4	34.5
Median	0.6	1.4	53.5	101.7	5.6	49.8	64.5	77.0	86.0	50.9	6.3	0.0	515.4
Mode	0	0	53.5	101.7	5.6	49.8	64.5	58.3	86	51.5	0	0	502.4
SD	5.0	3.2	46.3	75.0	3.6	30.8	38.8	54.8	54.6	53.1	20.1	8.1	207.0
SV	25.1	10.0	2139.4	5632.4	13.0	946.3	1502.3	3001.8	2985.9	2819.8	405.0	65.8	42863.4
Kurtosis	-0.1	17.4	1.1	0.3	1.9	2.1	0.0	0.3	1.8	1.9	1.9	23.7	-0.2
Skewness	1.3	3.8	1.1	0.8	1.2	0.9	0.6	0.8	0.8	1.4	1.7	4.7	-0.4
Range	13	17.4	175.2	284.7	16.9	152.2	155.4	215.9	263.1	223.7	71.8	46.0	833.9
Minimum	0	0	0	0	0	0	3	0	0	0	0	0	89.4
Maximum	13.0	17.4	175.2	284.7	16.9	152.2	158.4	215.9	263.1	223.7	71.8	46.0	923.3
Sum	124.1	64.0	1977.5	3734.3	205.5	1833	2375.4	2896.7	3160.8	1960.5	497.7	111.2	18940.3
Count	36	36	36	36	36	36	36	36	36	36	35	36	36
CI (95.0%)	1.7	1.1	15.6	25.4	1.2	10.4	13.1	18.5	18.5	18.0	6.9	2.7	70.1

Table 3. 1 Long year monthly and annually RF statically summary over Shinile woreda

Shinile													
Sum. Stas	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annully*
Mean	21.5	22.5	75.8	112.1	51.0	24.1	82.5	114.5	71.4	31.0	20.8	11.7	639.0
St. Error	5.06	5.39	9.02	11.92	7.71	3.66	7.23	7.42	6.15	7.81	7.66	4.19	25.83
Median	7.4	5.5	69.8	107.9	40.8	16.8	81.1	112.4	69.6	17.7	4.7	0.1	624
St. Deviation	30.77	32.77	54.89	72.52	46.91	22.25	43.95	45.13	37.43	47.48	46.57	25.47	157.13
SampVariance	947	1074	3013	5259	2201	495	1932	2037	1401	2254	2169	649	24689
Kurtosis	3.23	3.12	-0.21	-0.72	6.93	-0.10	1.19	0.43	5.47	16.95	24.62	12.77	-0.11
Skewness	1.79	1.81	0.73	0.39	2.14	1.08	0.70	0.79	1.62	3.64	4.65	3.30	0.05
Range	128.2	135.2	212.5	266.1	243.5	75	204.6	189.9	215.2	266.9	271.9	129.8	617.3
Minimum	0	0	9.5	0	0	0	2.3	51.6	0	0	0	0	348.6
Maximum	128.2	135.2	222	266.1	243.5	75	206.9	241.5	215.2	266.9	271.9	129.8	965.9
Sum	796.6	832.8	2805.6	4149.3	1887.1	890.4	3052.8	4237.2	2641.7	1147.3	768.8	433.3	23642.9
Count	37	37	37	37	37	37	37	37	37	37	37	37	37
CI(95.0%)	10.26	10.93	18.30	24.18	15.64	7.42	14.65	15.05	12.48	15.83	15.53	8.49	52.39
Long Year RF Statistical Summary of The Study Areas													

Table 3.3 Long year monthly and annually RF statically summary over Deder woreda

Long Year RF Statistical Summary of The Study Areas													
Deder													
Sum. Stas	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annually*
Mean	16.1	24.5	84.6	128.2	103.3	54.0	171.9	214.1	146.6	40.2	13.2	11.5	1008.1
St. Error	5.0	6.3	9.4	12.2	11.1	6.4	11.0	17.9	11.7	8.4	2.9	2.8	50.1
Median	4.8	21.7	76.0	128.0	103.3	52.3	168.7	214.1	146.6	35.9	13.2	9.3	999.5
SD	29.7	37.7	56.6	72.9	66.8	38.4	65.8	107.2	70.3	50.7	17.2	16.6	300.5
SV	884	1421	3209	5317	4457	1475	4331	11497	4937	2570	297	276	90282
Kurtosis	14.3	16.7	-0.5	0.9	3.7	6.4	-0.4	0.2	2.7	8.4	6.0	9.8	1.5
Skewness	3.5	3.7	0.3	0.8	1.5	2.1	0.2	0.3	1.2	2.7	2.2	2.8	0.9
Range	156.1	209.3	208.4	318.5	340.0	202.6	268.8	462.6	375.0	239.9	80.9	83.4	1393.3
Minimum	0	0	0	0	4.1	2	30.2	0	0	0	0	0	540.4
Maximum	156.1	209.3	208.4	318.5	344.1	204.6	299	462.6	375	239.9	80.9	83.4	1933.7
Sum	580.4	882.7	3047.2	4614.0	3718.6	1945	6187.6	7707.1	5276.4	1447.0	474.3	413.2	36293.3
Count	36	36	36	36	36	36	36	36	36	36	36	36	36
CI(95.0%)	10.1	12.8	19.2	24.7	22.6	13.0	22.3	36.3	23.8	17.2	5.8	5.6	101.7

SD: Standard Deviation, StdE: Standard Error, SV: Sample variance, CI: Coefficient of Interval, CV Coefficient Variance

Simple linear regression between rainfall and years starts from 1980-2016 in Shinile woreda.

Fitted equation: y = -0.0028 * RF + 1999.8 R-squared: 1.0

ANOVA Shinile District								
	Df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	6.908	6.908	0.0574	0.812028			
Residual	35	4211.092	120.317					
Total	36	4218						
	Coeff	*SE*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1999.781	7.650	261.403	0.000	1984.251	2015.312	1984.251	2015.312
RFAnnualy	-0.003	0.012	-0.240	0.812	-0.026	0.021	-0.026	0.021

Appendix 3

Simple linear regression between rainfall and years starts from 1980-2016 in Deder woreda. Fitted equation: y = -0.0106 * RF + 2009.2 R-squared: 1.0

ANOVA Deder Woreda

	Df	*SS*	*MS*	*F*	*Significance F*		
Regression	1	357.2	357.2	3.4426	0.072222555		
Residual	34	3527.8	103.759				
Total	35	3885					
	Coeff	*SE*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*
Intercept	2009.219	6.021	333.686	0.000	1996.982	2021.456	1996.982
RFAnnualy	-0.01063	0.006	-1.855	0.072	-0.022	0.001	-0.022

Appendix 4

Simple linear regression between rainfall and years starts from 1980-2016 in Fedis woreda.

Fitted equation: y = 0.0161 * RF + 1989 R-squared : 1.0

ANOVA Fedis Woreda RF

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	1	433.7415	433.7415	4.011605	0.052981051
Residual	35	3784.259	108.1217		
Total	36	4218			

	Coeff	*SE*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*
Intercept	1989.71	4.48	444.37	0.00	1980.62	1998.80	1980.62
RFAnnualy	0.02	0.01	2.00	0.05	0.00	0.03	0.00

Appendix 5

Drought Years in study areas using different Indices							
SN	Period Analyzed	Parameters	Study areas	Season	Drought Years	Index Values	Index
1	1980 - 2016	RF	Fedis	Kiremt	1980-1986,1990-1993, 2001,2003,2005, 2007,2010,2012 &2015	< 0, 0 to -0.99, -1 to 1.49, -1.5 to -1.9, < -2.0	SPI
				Belg	1980,1982-1986,1991,1999,2001,2002, 2005, 2008,2010,2011 &2015		
2	1980 - 2016		Shinile	Kiremt	1980-1982,1984-1987,1989-1991,1993, 1995,1997,2002,2004,2009 &2015		
				Belg	1980,1984,1985,1988,1992,1994,1999-2005, 2007,2009, 2011-2013 &2015		
3	1981 - 2016		Deder	Kiremt	1984-1987,1989-1991, 1994,2007-2015		
				Belg	1984,1986,1988,1992-1994, 2000-2005,2007-2009, 2011-2015		