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RAINFALL TRENDS AND VARIABILITY IN SELECTED AREAS OF ETHIOPIAN SOMALI REGIONAL STATE, SOUTHEASTERN ETHIOPIA

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Abstract

The pastoral and agropastoral communities are among the most vulnerable to climate changes and variability. The adverse effect of such variability and change is accelerating the already existing pastoral livelihood insecurity. Given the range of negative repercussions of current climate hazards on the livelihoods of these communities, the implications of climate change must be taken into account to ensure their longer-term survival and sustainability. The paper reports on the rainfall variability and trends in the Ethiopian Somali Regional State by taking three major meteorological records from Gode, Jigjiga and Shinile that recorded in the last two decades (1997-2015). Mean annual rainfall distribution, trend, class interval of raindays versus amount of rainfall, number of raindays, annual rainfall, and dry and wet years are considered using probability of wet and dry days, mean, standard deviation, coefficient of variation, deviations from mean and trendline regression analyses with the help of SPSS 16.0 and Microsoft Office Excel 2007 Software. Accordingly, it is identified that there are remarkable changes: both number of raindays and annual amount of rainfall received increased from Gode (103days and 1365.6mm) to Jigjiga {185days and 1565.1mm) and latter falls towards Shinile (135days and 1274.2mm) respectively. Eleven to twelve out of eighteen years (i.e. 60% to 70% of the years) rainfall records were close to normal. Thus, proper water harvesting technology, including efficient underground water resource exploration systems, better devised to sustain life and livelihood of the pastoral and agropastoral community in the region. Moreover, proper spatial distribution of meteorological stations together with early warning system are required to further support local adaptive and coping strategies that the community designed towards rainfall variability in particular and climate change/disaster and risk at large.

Key Words: *Ethiopian Somali Region, Gode, Jigjiga, Rainfall variability, Shinile, Trend*

Introduction

Over the years the frequency of the climate variation in terms of temperature and rainfall has been increasing (Chibinga *et al.,* 2012). Climate change is a major threat to sustainable development, particularly in sub-Saharan Africa, that is anticipated to be most vulnerable because of low adaptive capacity and high dependency on climate sensitive resources such as water resources and ecological systems (Kpadonou *et al.,* 2012). Ethiopia is experiencing the effects of climate change including the direct effects such as an increase in average temperature or a change in rainfall patterns (FDRE, 2011).On an aggregate level, the economy of Ethiopia will remain highly vulnerable to exogenous shocks (Levine *et al*., 2011) and hence climate change is likely to exacerbate this situation and makes extreme weather events in the country more frequent and intense that in turn enhances water stress (Tongul and Hobson, 2013). The adverse effect of such variability and change is accelerating the already existing pastoral livelihood insecurity.

Pastoral and agro-pastoralists are very vulnerable to ecological disturbance due to increasing climate variability. They are unable to adequately feed their animals in times of extreme weather conditions of floods and droughts thereby causing a disruption in their major source of livelihood (Chibinga *et al.,* 2012). Given the range of negative repercussions of current climate hazards on the livelihoods of these communities, the implications of climate change must be taken into account to ensure long-term survival and sustainability of these communities (SRS/EPEMRDA 2011).

Causes and characteristics of rainfall in Ethiopia are influenced by the summer monsoon (Inter-tropical Convergence Zone); tropical upper easterlies; and local convergence in the Red Sea coastal region (Griffiths, 1972 and Gamachu, 1977 cited in Conway, 2000). Despite this fact, detection of long-term rainfall trends in Ethiopia is difficult as a result of high inter-annual and inter-decadal rainfall variability. Furthermore, there are insufficient daily rainfall records to identify trends in daily rainfall variability and changes in rainfall intensity (Levine *et al.,* 2011). The current study assessed major distribution and variability of annual rainfall in the Ethiopian Somali Region.

Methodology

Study Area

The Ethiopian Somali Region is the second large state of Ethiopia, after Oromia Regional State, having nine administrative zones (Fig. 1). Generally, there are two major trends of rainfall regime in the region: those areas south of Jigjiga (mainly dominated by lowlands) and those areas north of Jigjiga (the relatively higher areas of the region) (EMPDA, 1981). According to Engida (2000), the Ethiopian Somali Region has three major moisture zones: hyper arid, arid and semi-arid zones. The hyper-arid zone covers southern part of the region that has marginal rainfall and known with a high seasonal and annual variability. The arid zone generally favorable for pastoral and rangelands but has high annual variability and it covers most parts of the region, including Shinile zone. The semi-arid zone is in the northern part of the region that is also known for maize and sorghum production.

The region has altitude ranging from 200m in the southern/central parts, to 1,800m in Jigjiga Zone. Its temperature ranges from 19°C (Jigjiga Zone) to 40°C particularly in the Shebelle, Dawa and Genale river basins in the southern zones. The Annual rainfall varies from 150 to 1,000mm per year. As disclosed in the Population projection of Ethiopia for all Regions from 2014– 2017, the Ethiopian

Somali Regional State accounts for 6.09% (5748998 of 94351001) of the total population of the country (CSA2013). Of these, males are 3094002 (53.82%) and the remaining is female gender.

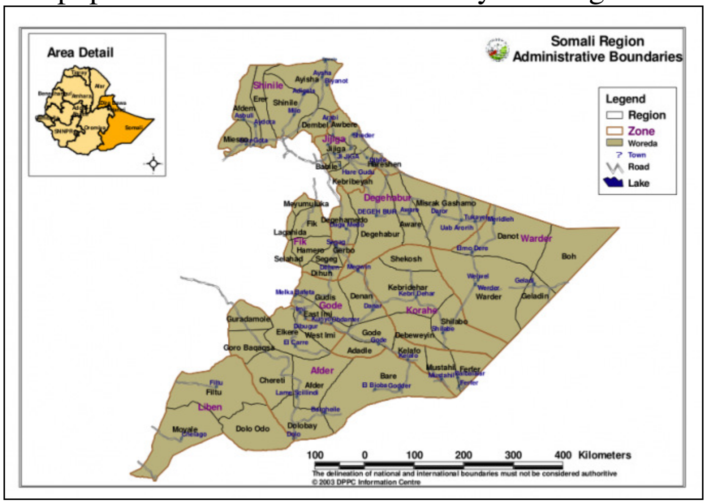

Fig.1: Relative Location of the Administrative Boundaries of Ethiopian Somali Regional State

Methodology of Data Collection and Analysis

Rainfall data from three meteorological stations, namely: Gode, Jigjiga and Shinile stations, are used to discuss about the topic at hand. According to NMSA sources, Jigjiga station was established in 1968 and it is categorized under the 1st Class Level (Synoptic Station) where the numerous meteorological details are recorded at every hour or 24hours while Gode station is among those which are categorized under the 3rd Stations (Ordinary Stations) where major elements of meteorological features are recorded (Table 1 and Fig. 1).

Table 1 Brief Profile of the three Meteorological Stations

No	Name of the Station	Name of the Zone		Location		Station Class*	Establishment		Duration of Record
		Previous	Current	N	E		Year	Status	
1	Jigjiga	Jigjiga	Faafan	9.35	42.79	1st	1968	Active	1997-2015
2	Gode	Gode	Shebelle	5.9	43.58	3rd	1967	Active	1997-2014
3	Shinile	Shinile	Siti	9.68	41.85	NA	NA	Active	1997-2015

Source: Extracted from NMSA; **NB:** *1st= or synoptic stations; 3rd= or Ordinary Station;
NA: Not Available

For analysis of rainfall, amount, distribution, trend and variability, retrospective time serious rainfall data from 1997 through 2015 were obtained from National Meteorological Service Agency (NMSA). The descriptive and trendline regression analyses were made using SPSS 16.0 and Microsoft Excel 2007 software. The rainfall amount, trends and variation were analyzed and interpreted on the basis of annual time duration including mean annual rainfall distribution, trendline analysis, deviations from the mean, probability of wet and dry days, class interval of raindays versus amount of rainfall, and number of raindays. Descriptive techniques with simple algebraic mathematics including mean, average deviation, standard deviation, and coefficient of variation (CV) were computed to determine relative variability and deviations in the annual and decadal rainfall. Statistical reports, published/unpublished information and archives from numerous public and private institutions were consulted to substantiate primary data.

In terms of climatology, the term rain day indicates a day on which a measurable amount of rain i.e. 0.1 mm or more has been recorded at any station (Patel and Shete 2015). The probability of wet days were calculated by taking a daily rainfall amount of > 0.1 mm as a threshold to identify a wet day (Bewket and Conway 2007) and the others below the threshold are identified as dry days. Accordingly, the formulae used to determine the probability of wet and dry days are:

$$P(w) = n(w)/N$$
$$P(d) = n(d)/N$$

Where; P (w) is the probability of wet day

N (w) is the number of wet days

P (d) is the probability of dry days

N (d) is the number of dry days

N is the total number of days (=wet + dry days)

The annual rainfall distributions are computed using simple booking methods by taking the means of the daily rainfall amounts of 365days of the year and 366days of the leap year. Together with this, rainfall variability is computed to demarcate rainfall distribution over a given period of time and for proper remedial interventions (Solomon 2013). In most cases, there is variation between the normal annual total and the statistical annual average. The measure of variability is examined by taking the average deviation of each yearly value from the mean value (Strahler and Strahler 1997). Linear trend analysis is used to assess the temporal distribution of rainfall. The mean, standard deviation and CV are values that give basic data about the data and its variability (Starhler and Starhler 1997). Deviations or Anomalies are also computed using simple book keeping methods (Raju 2012 cited in Solomon 2013). At stated there, it is used to determine the wet and dry periods of the given time duration when the deviations are above 25% and below -25%, respectively. However, the CV is preferably important to examine relative variability in rainfall since the mean and standard deviation tend to change while CV is relatively more stable, constant and easy to remember than that of standard deviations in the assessment of relative variability (Strahler and Strahler 1997; Snedecor and Cochran 1989). This is computed as:

$$CV = \sigma/\bar{x}$$

Where CV= Coefficient of Variations

σ = Standard Deviation

$\bar{x}$ = Mean

Likewise, following Bewket and Conway (2007), inter-annual variability is evaluated by calculating Standardized Rainfall Anomalies using: $SRA = (Pt-Pm)/\sigma$

Where

SRA= Standardized Rainfall Anomaly

Pt= rainfall amount of a given period

Pm=Long term mean rainfall over the period σ=standard deviation of rainfall over the period

The drought severity classes are categorized as extreme drought (SRA < -1.65), severe drought (-1.28 > SRA > -1.65), moderate drought (-0.84 > SRA > -1.28), and no drought (SRA > -0.84) (Ayalew *et al*., 2012).

Results and Discussion

Number and Probability of Raindays

The present study deals with retrospective analysis of temporal distribution of precipitation by taking three meteorological stations. The precipitation data are distributed among different classes from 0.1–0.9 mm with class interval of 1. The highest frequencies of precipitation in each class and the total amounts of precipitation per the interval observed during the study period (1997-2015) are presented in Table 2.

Table 2: Ranges of Rainfall (mm) by Class Intervals and Frequency of Raindays and Meteorological Rainfall Stations (1997-2015)

Area	Total Rainfall Days	Total Amount of Rainfall	Highest Class Intervals of Precipitation	Ranges of Precipitation per Class Intervals of Raindays		Highest Frequency of Raindays	Percentage (%) of Total	
				Lowest	Highest		Rainday	Precipitation
Gode	105	1365.6	59.0-59.9	4	87.04	49	33.33	0.74
Jigjiga	184	1565.1	45.0-45.9	16.85	56.49	44	28.26	1.08
Shinile	133	1274.2	52.0-52.9	12.66	50.12	44	31.58	0.99

As can be seen from Table 2 and Fig 2a to 2c, the highest record was observed at Jigjiga with a total of 184 rainy days during the study period amounting to 1565.16 mm of precipitation. A total of 52days were recorded with 0.1 to 0.9 mm of precipitation representing 28.26 % of total 184 rainy days and having just 1.08% of total precipitation. The overall percentage of both raindays and precipitation showed similarity as the first class of precipitation cover from 28 to 33% of the total precipitation received per annum (Table 2). Maximum rainiest day is observed in the class of 59.0-59.9 with frequency of one at Gode station but it decreases as one ascends towards Jigjiga but with slight rise towards Shinile. Conversely, the total rainfall day increases 105 at Gode station to 184 at Jigjiga station but falls to 133 days at Shinile station.

Similarly, the trend of highest amount of precipitation record per class of rainday shows similar trends as one move from Gode through Jigjiga to Shinile. The highest was for Gode (87.04mm) at precipitation amount of 43.0-43.9mm while at Jigjiga it falls to 56.49mm of having highest class interval of 45.0-45.9mm intervals. In the case of Shinile, this value tends to rise to 50.12mm with highest interval of 52.0-52.9mm (Table 2 and Fig 2a- Fig 2c). Regarding the temporal distribution of the total number of raindays, there are negative trends of both Jigjiga and Shinile stations while there is gradual increase in the case of Gode station although all of these trends are not significant as the R value is below 0.5 (Fig. 3).

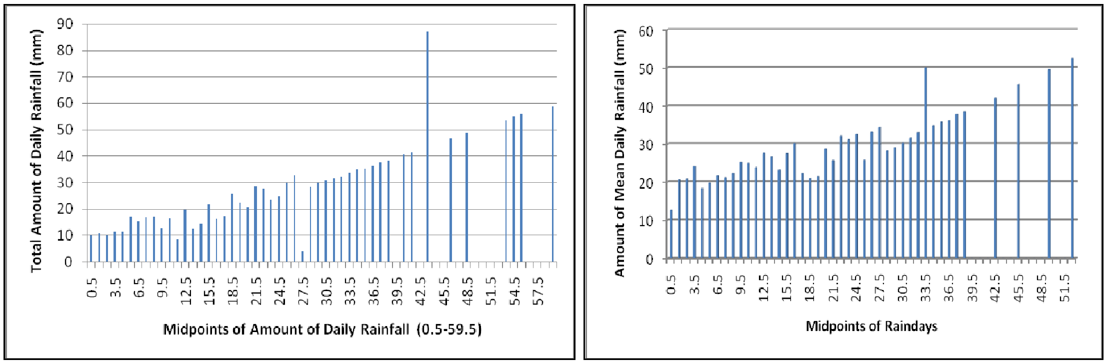

Fig. 2a: Total Amount of Rainfall Recorded by Midpoint of Rainfall at Gode (Left) and Shinile (Right)

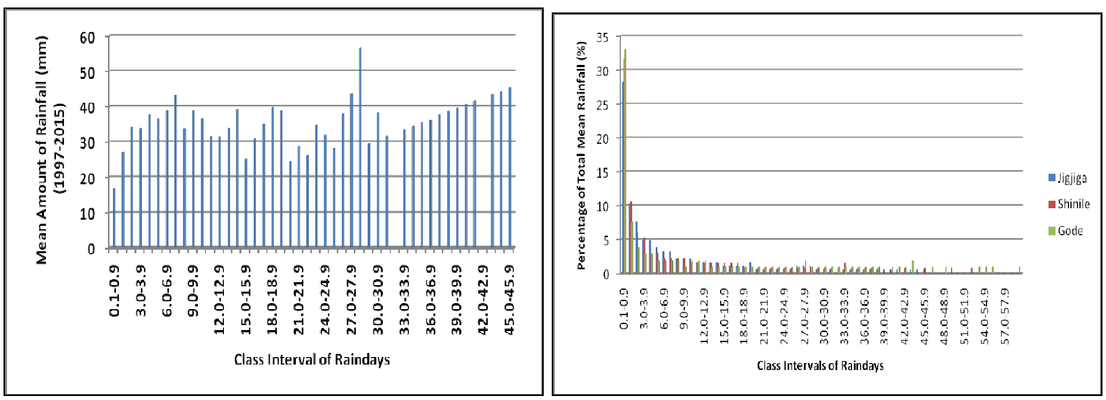

Fig. 2b: Amount of Rainfall by Midpoints of Raindays at Jigjiga (Left) and all areas (Right)

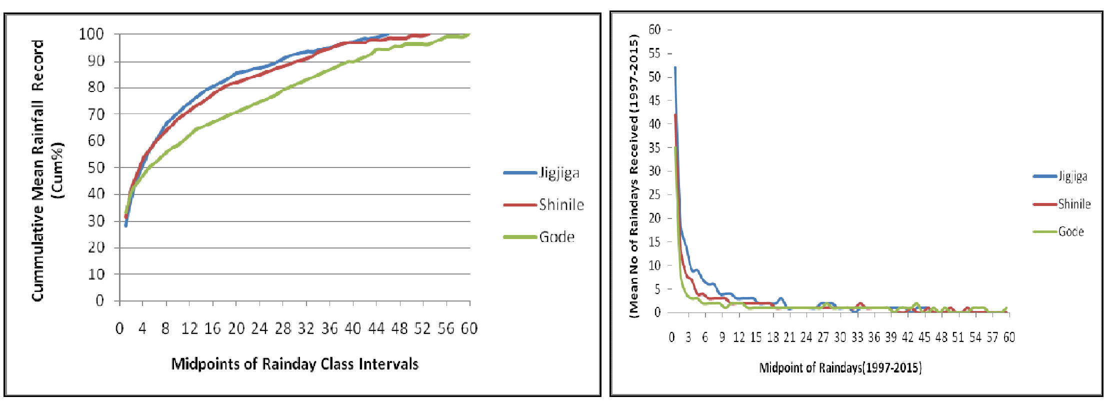

Fig. 2c: Cumulative Mean Rainfall by Midpoints of Raindays (Left) & Mean No of Raindays (Right)

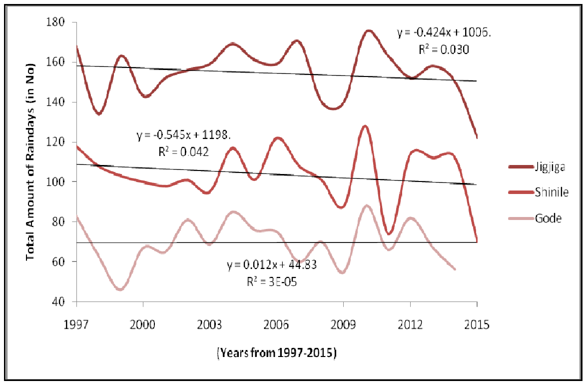

Fig. 3: Time series analysis of total amount of Raindays (1997-2015)

The probability of wet and dry days are computed for the three stations and presented in Fig.4a and Fig.4b. The probability of wet days is lowest for Gode station falling between 10% and 25% of the total days (or from 40 to 80days of the year) in 1999 and 2010, respectively. But this value is relatively the highest for Jigjiga station ranging from 120 to over 170raindays in 2015 and 2010, respectively (Fig.4a). Conversely, the probabilities of dry days are highest Gode station while it is lowest in Jigjiga stations (Fig. 4b).

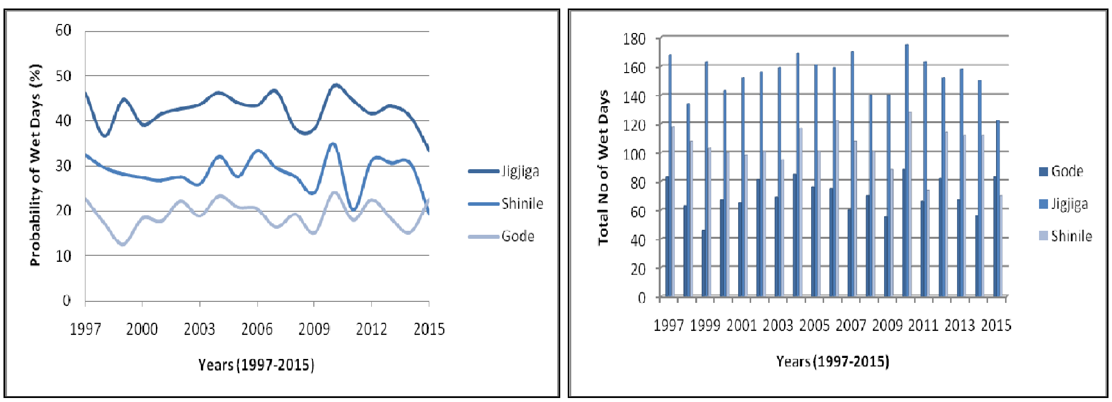

Fig. 4a: Probability and Total Number of Wet Days in the Study Areas (1997-2015)

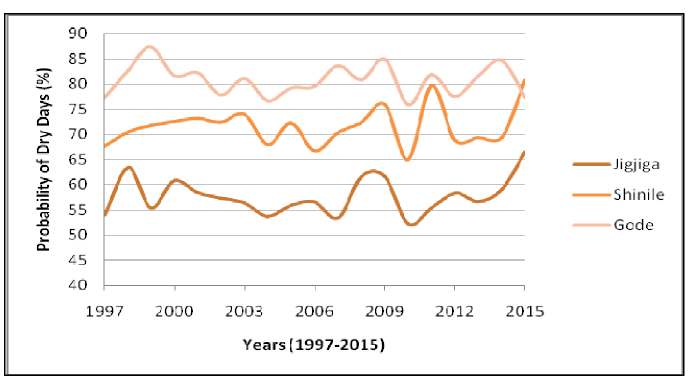

Fig. 4b: Probability of Dry Days in the Study Areas

Patterns of Rainfall Distribution

The temporal distributions of mean annual rainfall of the three areas are presented in Fig.5a and Fig.5b. The highest amount of rainfall are recorded at Jigjiga station ranging from 605mm (1998) to 1091mm (2012) while it is relatively the lowest at Gode station ranging from 170mm (2001) to 555mm (1997). Therefore, it can be concluded here that as one ascends from Gode to Jigjiga the annual amount of precipitation increases but latter tends to decline towards Shinile. As the wind direction for rain bearing southeasterly trade winds from the Indian Oceans commonly beings to give rain from Gode onwards, the total amount of rainfall tends to increases towards Jigjiga to then decline towards Shinile. Despite this fact, the total amount of rainfall received in Shinile area is in the intermediates between the other two stations.

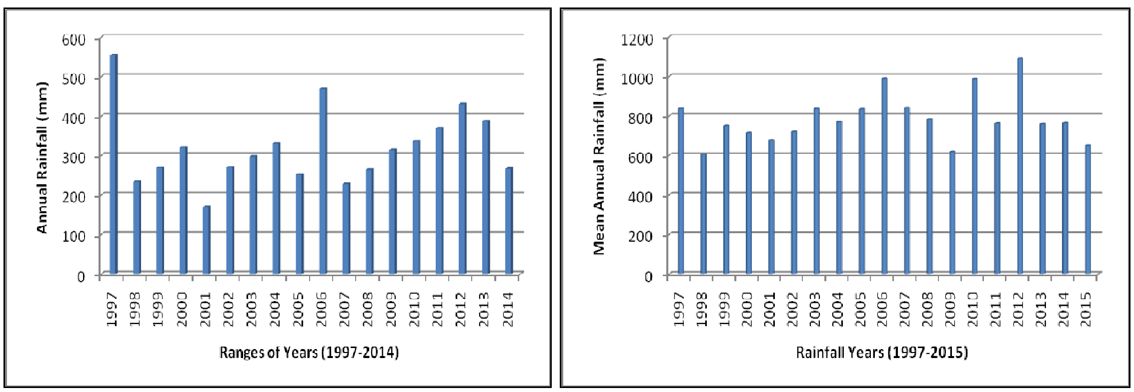

Fig. 5a: Mean Annual Rainfall Distribution of Gode (Left) and Jigjiga (Right)

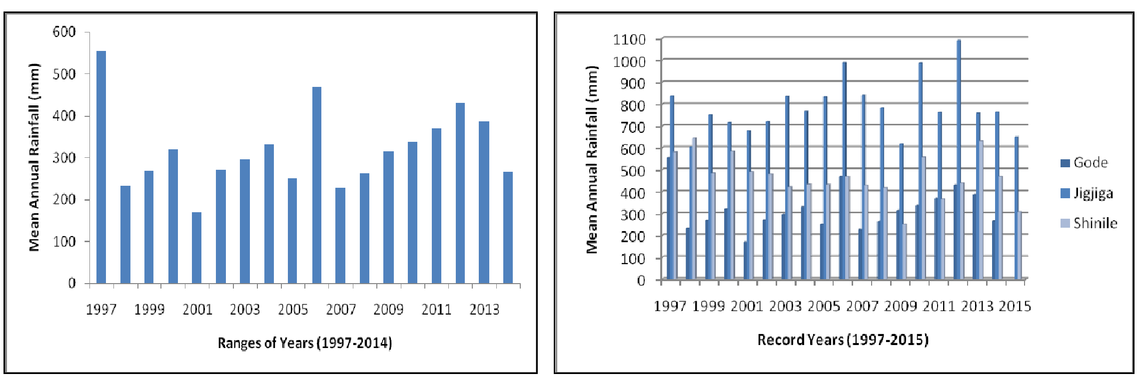

Fig. 5b: Mean Annual Rainfall Distribution of Shinile (Left) and the three stations altogether (Right)

Trends of Rainfall Variability

Trend of rainfall distributions has slight variations as one move from Gode through Jigjiga to Shinile. There is slight decline in the trends of the rainfall distribution at Shinile but there is insignificant slight increasing trend at Jigjiga and Gode stations (Fig. 6a, 6b and Table 3). In this regards, the CV value for the stations ranges from 8.61% to 28.69%

as indicated in Table 3. According to Hare (1983) and ABoM (2010), CV with value of below 20% is found less variability that holds true to Jigjiga (Table 4). While the other two stations have CV that falls between 20% and 30% implying moderate variability in rainfall.

Table 3: Linear Equations and Regression Values of the Study Stations

Stations	Linear Equations	Regression Values (R^2)	R Value
Gode	y = 1.650x – 2989	R^2 = 0.008	R= 0.09
Jigjiga	y = 4.874x – 8988	R^2 = 0.046	R= 0.21
Shinile	y = -8.006x + 16529	R^2 = 0.197	R= 0.44

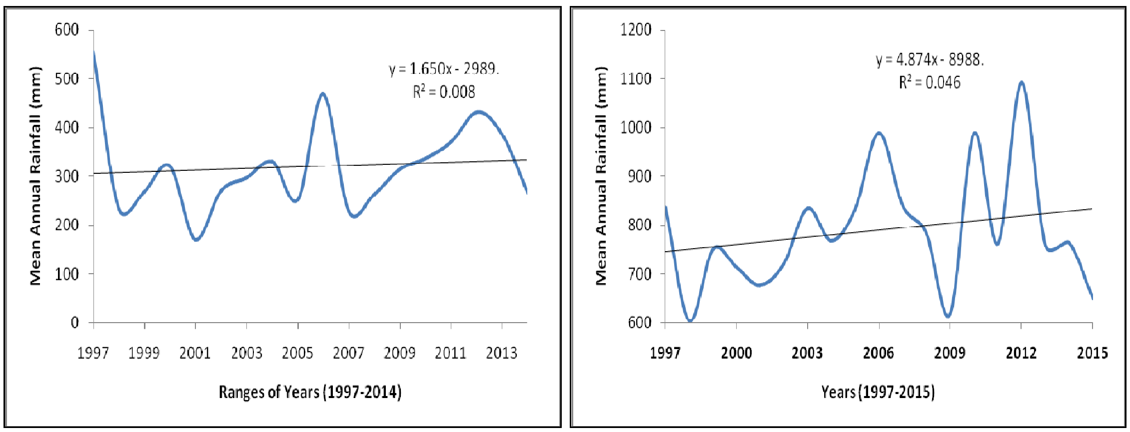

Fig. 6a: Trends of Mean Annual Rainfall Distribution of Gode Area (Left) and Jigjiga (Right)

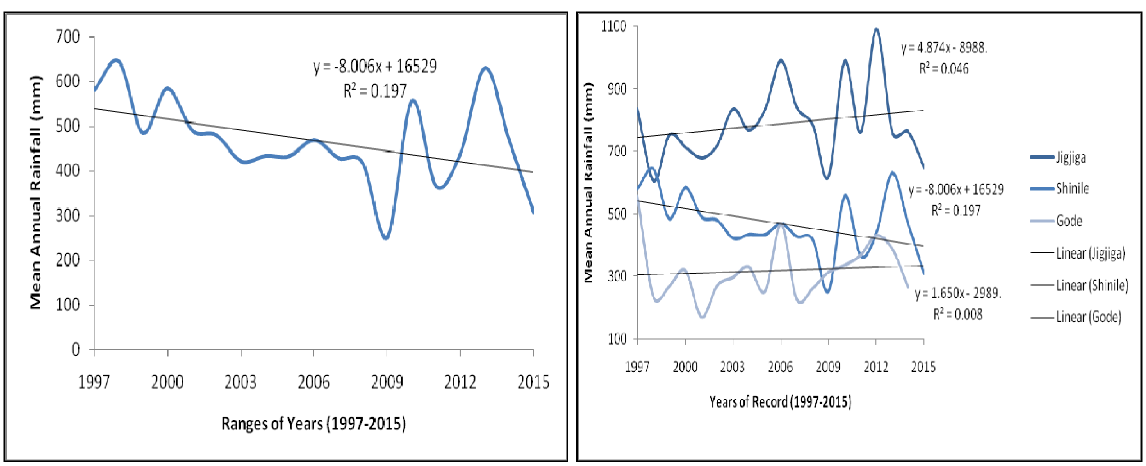

Fig. 6b: Trends of the Annual Mean Rainfall at Shinile (Left) and of the three areas (Right)

By using standard deviations values, growing season stability of a given area can be determiend as used by Reddy (1990). Accordingly, the stations whose standard deviations of the rainfall distribution are above 40 are categorized as with less stability growing season, which is true in the case of Gode and

Jigjiga. On the otherhand, standard deviation of Jigjiga station falls in the interval of 10%-20% that is with high stablity growing season (Table 4). This seems in congruent with traditional knowledge of the community whereby Jigjiga area is not only relatively highest point of the region but it is also among the most preferred for cereal crop and livestock rearing as well as settlement in the region.

Table 4: Coefficient of Variation of the Mean Annual Rainfall of the Study Stations

Stations	Mean	Std. Dev	CV	CV (%)
Gode	320.2	91.87	0.2869	28.69
Jigjiga	154.4211	13.29	0.0861	8.61
Shinile	468.22	96.87	0.2069	20.69

Deviations of the Statistical Mean from the Normal Mean Values

As disclosed in Table 5, Fig. 7a and 7b, the summary of deviations of normal means from statistical means of the three stations of the Ethiopian Somali Regional State identified 1998 and 2015 as dry years while 2006 and 2012 as wet years. Despite this fact, 2009 and 2010 are identified as dry and wet years in Jigjiga and Shinile areas, respectively. Nearly similar trends of rainfall variability of Haramaya, Harar, Dire Dawa, Bedesa and Jigjiga stations were reported by Solomon (2013).

Table 5: Major Dry and Wet Years at the Three Stations

Area	Dry Years	Wet Years
Gode	1998, 2001, 2005, 2007, 2008, 2014,	1997, 2006, 2012
Jigjiga	1998, 2009, 2015	2006,2010, 2012
Shinile	1998, 2009, 2015	2006, 2010, 2012

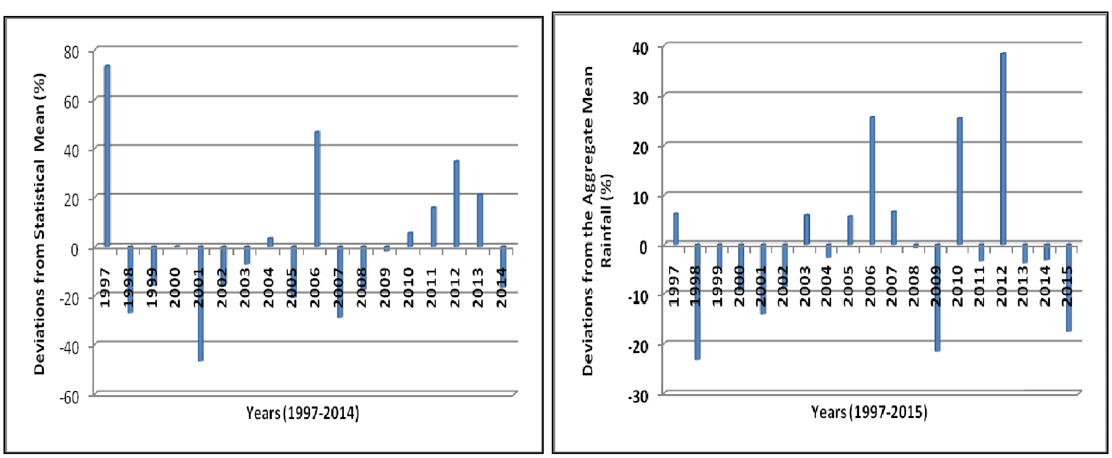

Fig. 7a: Deviations from the Statistical Mean for Gode (Left) and Jigjiga (Right) Areas

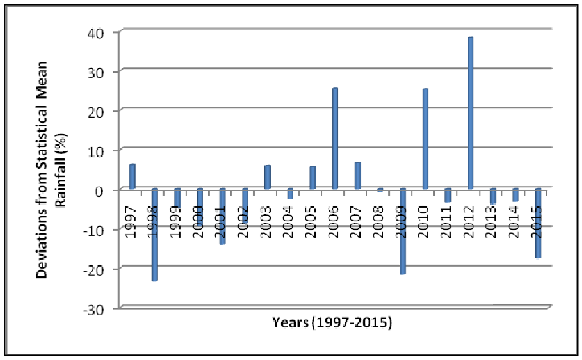

Fig. 7b: Deviations of the Annual Normal Mean Rainfall from the Statistical Mean at Shinile

Standardized Rainfall Anomalies

In order to have further identification of the wet and dry years and thereby substantiate the result, SRA for these stations were computed. The result of the anomalies indicated in Fig. 8a and 8b and compiled in Table 6. Accordingly, there are slight variations among the three stations in inter-annual rainfall variability.

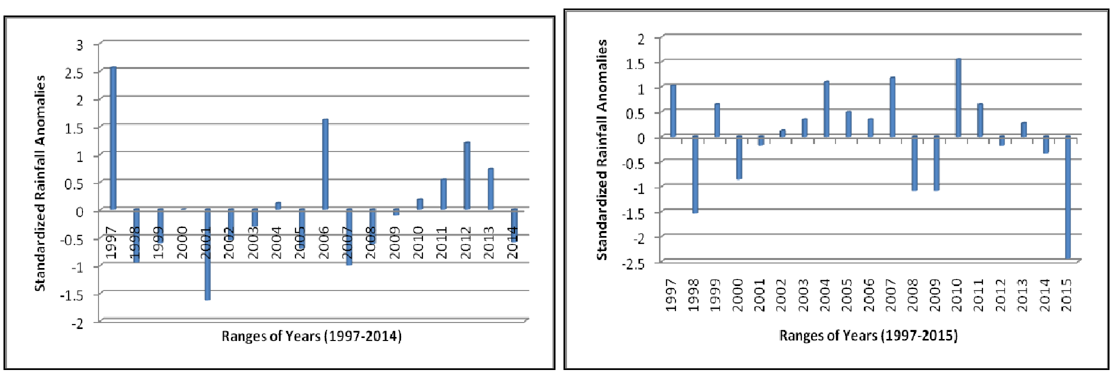

Fig. 8a: Standardized Rainfall Anomalies of Gode (Left) and Jigjiga Stations (Right)

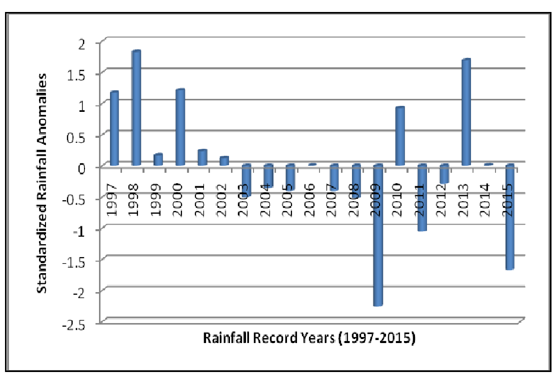

Fig. 8b: Standardized Rainfall Anomalies of Shinile Station

Table 6 Categories of Dry and Wet Years Based on SRA

SRA Value	Category	Gode	Jigjiga	Shinile
< -1.65	Extreme Drought	2011	2015	2009, 2015
-1.28 > SRA > -1.65	Severe Drought	-	1998	-
-0.84 > SRA > -1.28	Moderate Drought	1998, 2007,	2000, 2008, 2009	-
> -0.84	No Drought	1997, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2012, 2013, 2014	1997, 1999, 2001,2002, 2003, 2004, 2005, 2006, 2007, 2010, 2011, 2012, 2013, 2014	1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2010, 2011, 2012, 2013, 2014

Source: Based on Agnew and Chappel (1999 cited in Ayalew *et al.,* 2012)

The status of drought that occurred in the dry years are substantiated by using the SRA and presented in fig. 8a, 8b and Table 6. It is found that 2015 is extreme drought period around Jigjiga and Shinile stations but can be identified as there is no data for Gode station to verify this. While 1998 is found moderate, severe and no drought period in Gode, Jigjiga and Shinile stations, respectively. This varies from the report for Bahir Dar (Ayalew *et al.,* 2012) and for some stations of Tigray region, northern Ethiopia (Hadigu *et al.,* 2013). In general, the no drought seasons are found in 15/18 years (83.3%), 14/19 years (73.7%), and 17/19 years (89.5%), respectively. This is found higher than those reported for the Amhara region that ranges in proportion from 46.66% for Debark to 63.33% in Gondar and Metema (Ayalew *et al.* (2012). However, this report seems slightly different as some of these years are identified as drought years instead of close to normal rainfall years (Haji and Solomon 2016; Tsegaye *et al.,* 2015).Therefore, further study should be made to verify the current findings.

Summary and Conclusions

In the survey used to identify issues related to annual rainfall trend and variability in the Ethiopian Somali Regional States, it was identified that there are slight variations in the overall rainfall features: total amount, trends, variability, probability of wet and dry days, percentage of number of raindays, and amount of rainfall. Despite this fact, these stations experienced comparable periods of dry, wet, and close to normal years. Jigjiga area found relatively better amount of rainfall compared to the rest in terms of high probability of wet days, and high stability growing seasons. This seems in congruent with traditional knowledge of the community whereby Jigjiga area is not only known for its highest point but it is also among the most preferred for cereal crop production, and livestock rearing as well as settlement in the region. As about 60% and 70% of the 18years in the study areas recorded close to normal rainfall, issues related to water harvesting and management techniques become under question marks. Thus, proper water harvesting technology including efficient underground water resource exploration systems better devised to sustain the life and livelihood of the community in the region. Moreover, proper spatial distribution of meteorological stations together with early warning system are required to further support local strategies that the community designed in their adaptive and coping strategies towards rainfall variability in particular and climate change and variability at large.

As the current study is based on annual rainfall data of only three meteorological stations and eighteen years data, it calls for further studies by taking representative stations, spatio-temporal dimension of the element, and other relevant topics to produce comprehensive information for the benefit of different stakeholders.

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