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Analysis of Rainfall Variability and Farmers' Perception towards it in Agrarian Community of Southern Ethiopia

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Abstract
Rainfall variability has historically been a major cause of food insecurity and famines in Ethiopia. Obtaining scientific evidence regarding the annual and seasonal rainfall variability through statistical rainfall analysis and farmers' perceptions about rainfall variability in the region provides a credible information to decision makers and end users. The present study focuses on five selected agriculture dominant areas (Hadiya, Alaba, Kambate Tambaro, Gurage and Silte zones) of the Southern Ethiopia. Seasonal and annual rainfall data extending from 1983-2012 has been analyzed using two rainfall indices (Precipitation concentration Index (PCI), Rainfall Anomaly Index (AI)) and Mann-Kendall trend test method. A total of 80 household respondents are accounted to assess rainfall variability with respect to farmers' perspective. The years of occurrence of the maximum and minimum AI values in any particular season are not uniform for all the stations during the analysis window which is characteristic feature of high rainfall variability. The frequency of the minimum AI values is more in Kiremt and Belg season, whereas, maximum AI values are more palpable in Bega The annual PCI for all the stations is highly variable which entails year to year non-uniform rainfall concentration over the stations. The PCI variability is more pronounced during the Bega season. Annual rainfall series at Alaba, Angacha, Fonko, Hossana and Wulberag stations show an increasing trend over the study period, however, for all other seven station there is no statistically significant trend observed. In view of farmers' perception towards rainfall variability, on average 80 % of the respondents opined that there were rainfall variability in magnitude and frequency, while 11 % perceived as no change in rainfall pattern and 4 % responded that they do not know whether it exists or not over the past 20 years. Majority of the respondents (80%) agree that the rainfall variability is due to combined effect of natural and man-induced impacts.
Keywords: Rainfall variability, concentration index, anomaly index, Farmers' Perception, Trend analysis.

1. Introduction

Rainfall variability has historically been a major cause of food insecurity and famines in Ethiopia Pankhurst (1966; Wood,1977; Degefu, 1987). Ethiopian agriculture is mostly rainfed whereas observed inter-annual and seasonal rainfall variability are high and droughts are frequent in many parts of the country. In the country whose economy is heavily dependent on low productivity rainfed agriculture, rainfall trends are often cited as one of important factors in explaining various socio-economic problems associated to food insecurity and livelihood (Seifu A., 2004). In the Central rift valley of Ethiopia, fluctuations in precipitation and temperature rates are directly affecting the production and productivity of the agricultural systems (Deschenes & Greenstone, 2006, Degefu and Bewket, 2014).

Climate variability and its associated impacts induce frequent crop failures, and decline in livestock production and productivity leading to aggravated rural poverty in the region. It also indirectly affects the agricultural production by influencing the emergence and distribution of crop pests, livestock diseases, aggravating the frequency and distribution of adverse weather conditions, reducing water supplies and enhancing severity of soil erosion (Watson et al., 1998). Scientific evidences suggest that higher temperatures and changing precipitation levels as a result of the changing climate will further depress agricultural production in many arid- and semi-arid parts of Ethiopia over the coming decades (Mintiwab et al., 2010). This is also a characteristic feature of the South and Central part of Ethiopia (Funk et al., 2012; Kassie et al., 2014).

Temporal and spatial variability of rainfall over Ethiopia remain a major concern and recent studies have been providing scientific evidences (Sileshi & Zanke, 2004; Cheung et al., 2008; Rosell, 2011; Wagesho et al., 2012, 2013; Williams et al., 2012; Gebrehiwot, and Veen, 2013; Onyutha and Willems, 2015; Addisu et al., 2015; Game & Korecha , 2015) that could foster better adaptive strategies against its ill-effects. The Kiremt rains of Ethiopia vary due to large scale synoptic features such as the tropical easterly jet, African easterly jet, Quasi Biennial Oscillation, inter tropical convergence zone (ITCZ), East African Low Level Jet, Azores high, humidity anomaly over Red Sea and Gulf of Guinea and low level wind anomalies from Atlantic and Indian ocean to Africa and El Niño–Southern Oscillation (ENSO). Similarly for the Belg rainy season the large scale features associated with rainfall variations are the subtropical westerly jet, ITCZ, ENSO, Arabian high humidity anomaly over eastern Africa and low level wind anomalies from the Indian and Atlantic Ocean Tefera, et al. (2011).

The spatial distribution of rainfall in Ethiopia is significantly influenced by topography that resulted in many unprecedented changes in the central Rift Valley. Central rift valley (CRV) encompasses various endorheic lakes and is one of environmentally vulnerable areas in Ethiopia. Being a closed basin, relatively small interventions in land and water resources can have far reaching effects on the management of ecosystem goods and services.

Local knowledge towards precipitation variability and adaptive mechanisms the farmers have been undertaking to combat against undesirable changes are often neglected in many planning and implementation phases of agricultural activities. However, since the inception of Intergovernmental Panel on Climate Change reports indigenous knowledge became more important function in drought and flood prone parts of the world. The adaptive mechanisms suggested by the policy makers sometimes might not be favorable to the local farmers as it lacks the local and/or traditional human and ecological knowledge. This basic information the farmer experiences through long years of experience easily match with time, location and cultural diversity of the people. This in turn helps the farmer better understand the climate change implications and respond to adverse effects strategically (Ovuka and Lindqvist 2000; Reed et al., 2006; Phillipo et al., 2011; Ogalleh et al., 2012; Rao et al., 2012; Moyo et al., 2012, Mamba et al., 2015).

The present study is devoted to statistical analysis of annual and seasonal rainfall variability and farmers' perception towards such variability over the past 20 years (1983-2012) in five contiguous regions of Southern Ethiopia.

2. The Study Area

The Southern Nations Nationalities and People's Region is located in the Southern and South-Western parts of Ethiopia. Geographically, it roughly lies between 4º.43'N to 8º.58'N and 34º.88'E to 39º.14'E. It is bordered with Kenya in South, the Sudan in South West, Gambella region in North West and Oromia region in North West, North and East directions. The total area of the region estimated to be 110,931.9 km^2 and inhabited by a multi-ethnic indigenous groups with a population of over 15.8 million that accounts nearly one-fifth of the total population of the country. The population density of the region became 142 persons per km^2, which makes the region one of the most populous parts of the country (Ethiopian Demography and Health, 2006). The region is characterized by arable highlands, midlands, lowlands and pastoral rangelands. The North-Western part of the region gains the highest average annual rainfall magnitude (over 2000 mm) while the Southern tip earns as low as 600 mm. The present study area includes Hadiya Zone, Alaba special woreda, Kambate Tambaro (KT) Zone, Gurage zone and Silte Zone, whose geographic locations are given in the Table 1.

Table 1 **Geographical locations and associated attributes of the study area.**

Zone	Latitude	Longitude	Elevation(m)	Area (sq.km)	Population(2007)
Hadiya	7^0 1' - 7^0 6'	37^0 2'- 38^0 1'	1500 to 3000	8550.2	1,412,347
Alaba	7^0 20' - 7^0 61'	38^0 5' - 38^0 44'	1501 to2500	855.0	222,706
Kembata-Tenbaro	7^0 10' –7^0 61'	37^0 34'- 38^0 07'	501 to 3000	1523.6	768,300
Silte	7^0 10'- 7^0 5'	37^0 86'- 38^0 53'	1501 to 3500	2537.5	840,598
Gurage	7^0 99' - 8^0 27'	38^0 26'- 38^0 57'	1000 to 3600	5932	1,533,279

(Source: CSA 2007; Ethiopian Demography and Health, 2006)

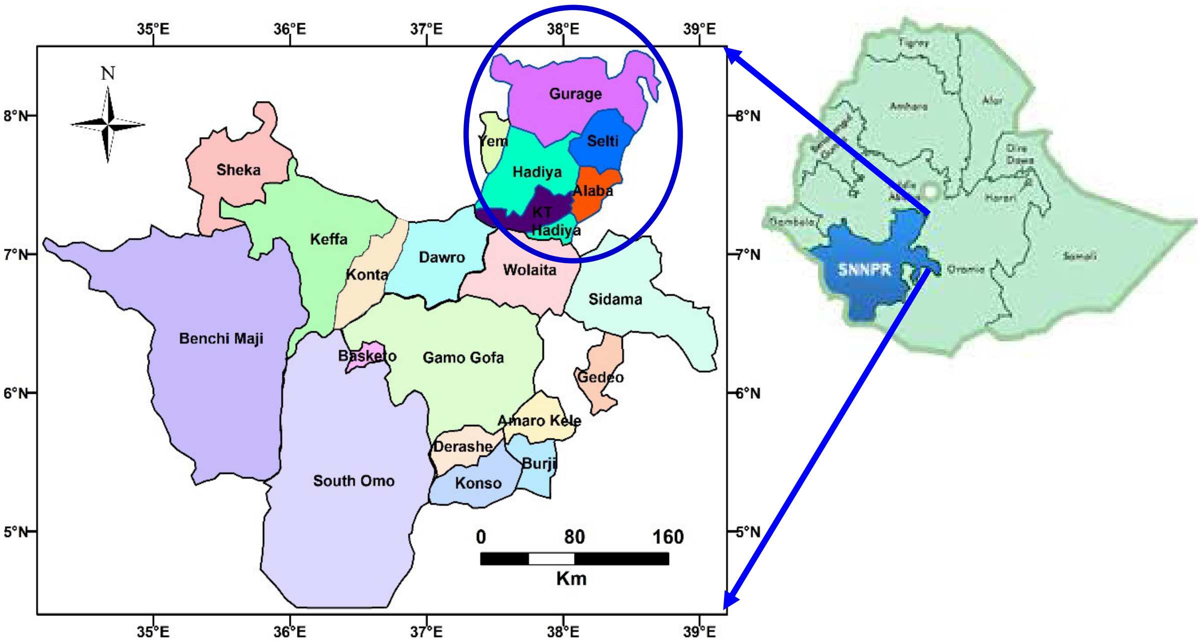

Fig. 1 The geographical location map of study area.

3. Materials and Methods

Rainfall data was obtained from the National Meteorological Service Agency (NMSA) Hawassa Branch. The daily rainfall data for a time period of 1983-2012 for nine stations in the study area is collected. The meteorological/rainfall data of 30 years has been collected from NMSA. Regarding climate model the Hadcm3 Model, for A2 and B2 emission scenarios for the base line data (1983-2012).

Table 2 Geographical locations and altitudes of the nine meteorological stations used in the study.

Stations	Latitudes(East)	Longitudes(North)	Elevation(m)
Alaba	7^0 23' N	38^0 39'E	1781
Angacha	7^0 3' N	38^0 29' E	2191
Butajira	8^0 7' N	38^0 22'E	2131
Durame	7^0 14' N	37^0 55' E	2101
Fonko	8^0 27' 33"N	38^0 36'13"E	2380
Hossana	7^0 33' N	37^0 51'6" E	2157
Shone	7^0 53'40" N	38^0 29'55" E	1980
Wolkite	8^0 17' N	37^0 47' E	1910
Wulberag	8^0 33' 19" N	40^0 19'35" E	2001

Household Survey Data: Farmers perception towards rainfall variability has been addressed through focus group discussions (FGDs), key informant interviews (KIIs), household surveys, and direct field observations. Likewise, semi-structured and open-ended questionnaires developed have been used to administer the household survey.

The strategy used to select the households to collect relevant information is first, the five districts, which are characterized most probably by Dega (highland) and Woina Dega (midland) agro-ecology according to the traditional climatic zone classification system are purposefully selected in the area. Then after, two kebeles from each district, are selected randomly using lottery system. Secondly, the appropriate sample size for the household survey is estimated by Cochran's formula (Cochran; 1963). However, due to limited resources during data collection 16 samples from each district with a total sample size of 80 households are considered for present analysis. Finally, the primary data obtained from the sample households will be subjected to statistical analysis.

In the present study the monthly, seasonal and annual rainfall variability was analyzed using various indices. Observed monthly, seasonal and annual rainfall variability has been investigated using normalized rainfall anomalies index (AI), precipitation concentration index (PCI) and rainfall trend Analysis.

Normalized Rainfall Anomaly Index (AI): The Normalized Anomaly Index (NRAI) can be expressed as:

$$AI = \frac{(X_i - \overline{X})}{S_x}$$

where X_i represent individual observations in the dataset; $\overline{X}, S_x$ are the mean and standard deviation of the observations. AI falls in the range of -1 and +1 for normally distributed data sets. If AI is large positive, then the rainfall is positively deviating from the mean and vice versa, whereas, if AI is zero, then there is no rainfall variability (Ketema, 2006).

Precipitation Concentration Index (PCI): The Precipitation Concentration Index (PCI) was proposed by Oliver (1980) to define temporal aspects of the rainfall distribution within a year. It is expressed as:

$$PCI_{annual} = \frac{\sum_{i=1}^{12} P_i^2}{\left(\sum_{i=1}^{12} P_i\right)^2} * 100$$

and PCI seasonal is given by

$$PCI_{seasonal} = \frac{\sum_{i=1}^{3} P_i^2}{\left(\sum_{i=1}^{3} P_i\right)^2} * 25$$

where, P_i = Monthly precipitation (mm)

The PCI permits grouping of data sets according to the derived value, with PCI magnitudes less than 10 represents uniform whereas values greater than 10 shows moderately to strongly irregular temporal rainfall distribution.

Possible trends in annual rainfall pattern during the analysis window has been detected by Mann-Kendall (Mann 1945; Kendall, 1975) tend analysis at prescribed significance level.

4. Results and Discussions

Rainfall variability: The normalized anomaly index (AI) has been computed on seasonal basis during the study period (1982-2012) for all the nine stations. The years of occurrence of the maximum and minimum AI values in any particular season are not uniform for all the stations during the analysis window. This shows that there is high spatial rainfall variability during the study period. The frequency of the minimum AI values is more in Kiremt (June, July, August, September) and Belg (February, March, April, May) season, whereas, maximum AI values are more palpable in Bega (October, November, December, January) season. This suggests that the chances of failure of rains in the study area is more pronounced during Bega season than Kiremt and Belg season. Table 3 presents the AI for rainfall stations accounted in this study. The annual rainfall anomaly index follows similar pattern in Alaba Kulito, Fonko, Wulbareg, Butajira and Wolkite stations and with small deviation at Angacha, all other station share similar annual anomalies (Fig. 2).

Table 3. Maximum and minimum seasonal AI values of selected stations during 1982-2012.

Stations	Seasons					
	Kiremt (JJAS)		Bega (ONDJ)		Belg (FMAM)	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Alaba	2.69 (2011)	-1.43 (1990)	3.31 (1997)	-1.28 (1994)	3.13 (2009)	-1.56 (1999)
Angacha	1.85 (2002)	-2.04 (1984)	2.55 (1997)	-1.58 (2012)	1.77(2012)	-1.41 (1994)
Butajira	2.43 (2005)	-1.99 (2010)	2.42 (1982)	-1.40 (2001)	2.34 (1990)	-1.32 (2008)
Durame	2.55 (2007)	-1.82 (1993)	2.30 (1982)	-1.60 (1994)	2.78 (2005)	-1.55 (2010)
Fonko	3.41 (2012)	-1.18 (1990)	4.02 (1997)	-1.31 (1992)	2.24 (1987)	-1.80 (1983)
Hossana	2.20 (2003)	-1.84 (1984)	3.18 (1982)	-1.24 (1994)	2.87 (1986)	-1.30 (1983)
Shone	2.37 (2009)	-1.44 (1995)	2.83 (1997)	-1.50 (1994)	1.77 (1993)	-1.73 (2008)
Wolkite	2.22 (1988)	-2.17 (2005)	2.84 (1987)	-1.19 (2010)	2.50 (1987)	-1.37 (2000)
Wulberag	3.06 (2011)	-1.51 (2005)	2.71 (1997)	-1.28 (1984)	3.03 (1987)	-1.98 (2008)

Precipitation Concentration Index (PCI): The annual PCI for all the stations, in general, is highly variable over the analysis window which is characteristic feature of year to year non-uniform rainfall concentration over the stations. Even though the highest and lowest PCI magnitudes are observed during Bega and kiremet seasons respectively, these values are not statistical significant for stations considered. However, the Kiremet season PCI magnitudes show significant variability for Durame, Butajira, Fonko, Hossana and wulbareg stations (Fig. 3).

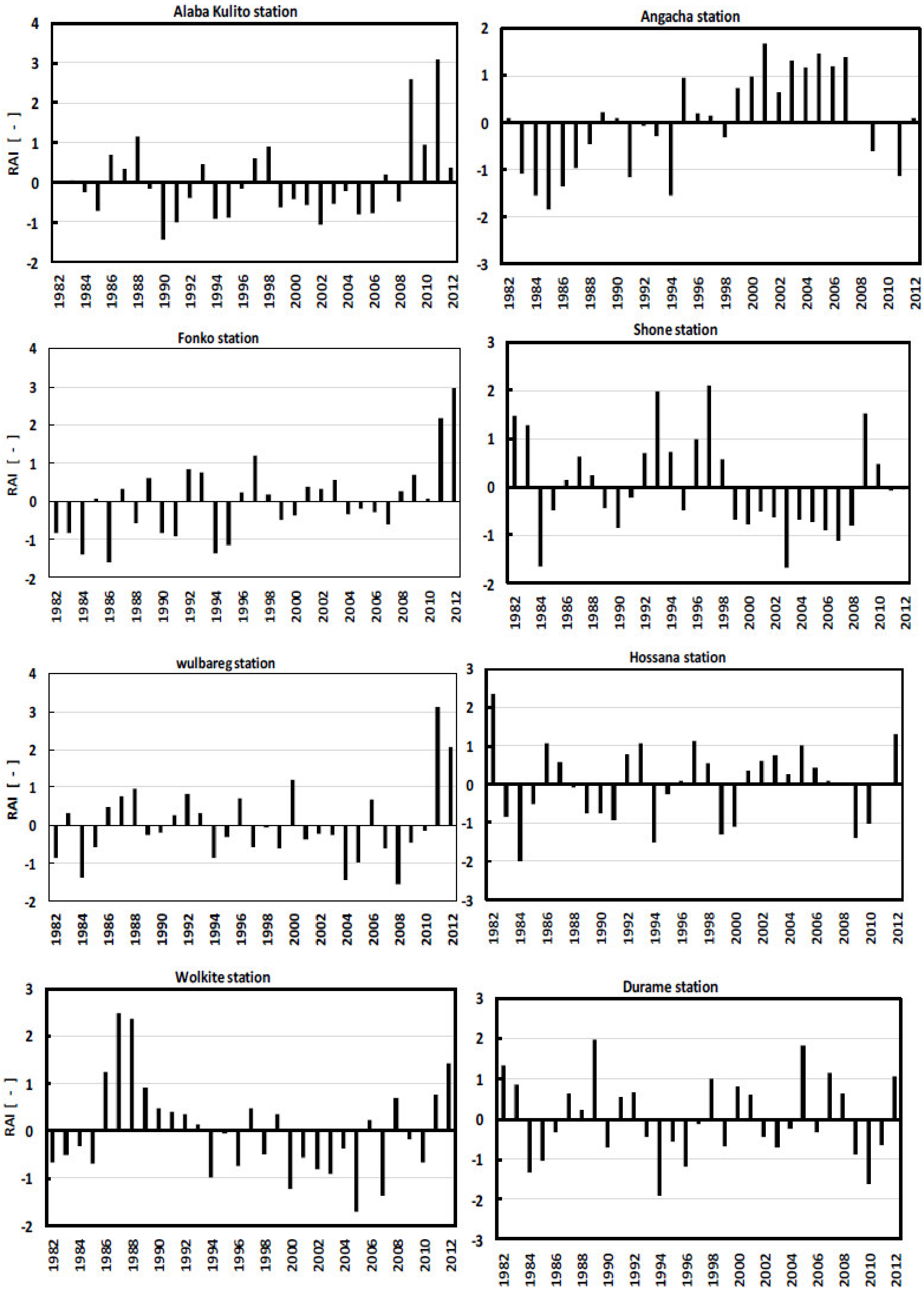

Fig. 2 Annual Rainfall anomaly Indices for selected stations.

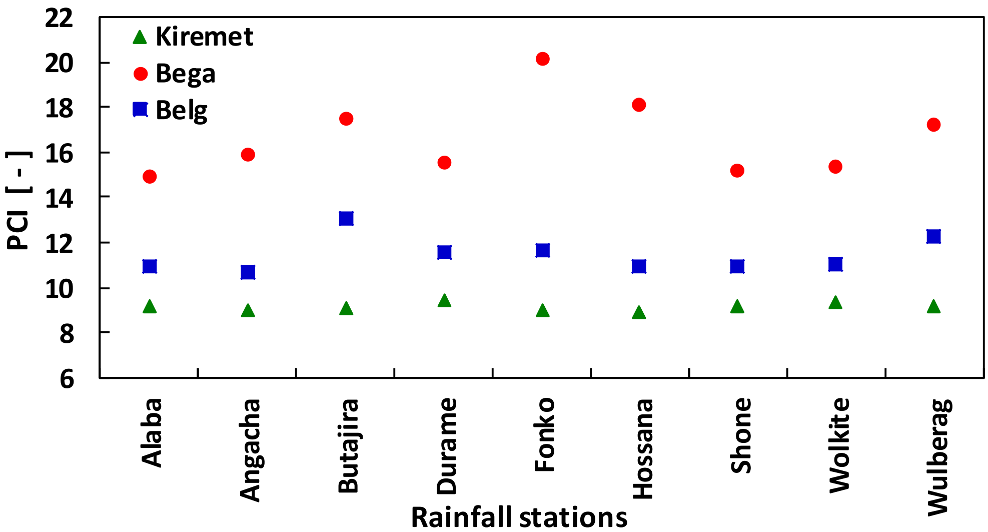

Fig. 3 Average seasonal Precipitation Concentration Index values for selected stations

Annual and Seasonal Rainfall Trend Analysis: Annual rainfall series at Alaba, Angacha, Fonko, Hossana and Wulberag stations show an increasing trend over the study period at 10%, 5 % and 1 % significance level. However, for all other seven stations the annual rainfall no statistically significant trend is detected (Table 4). Regarding seasonal rainfall variability, Alaba, Angacha, Butajira, Durame, Fonko, Hossana and Wulberag show an increasing trend in the Kiremt seasonal rainfall, while the other two stations (Shone and Wolkite) have shown a decreasing trend (Table 5). The Bega season rainfall pattern shows increasing trend for Alaba, Butajira, Fonko and Wulbareg station while all other stations exhibit decreasing trend. During Belg season, only three stations (Alaba, Fonko and Wolkite) show an increasing trend while the other six stations show a decreasing trend.

Table 4. Mann-Kendall Trend Test Statistics for annual rainfall series

Stations	Test statistics (z-test)	Critical values (statistical table)			Significance
		α	α	α	
Alaba	0.714	1.645	1.96	2.576	NS
Angacha	**2.719**	1.645	1.96	2.576	**S (.01)**
Butajira	-0.442	1.645	1.96	2.576	NS
Durame	-0.136	1.645	1.96	2.576	NS
Fonko	**2.651**	1.645	1.96	2.576	**S (0.01)**
Hossana	0.17	1.645	1.96	2.576	NS
Shone	-1.564	1.645	1.96	2.576	NS
Wolkite	-1.054	1.645	1.96	2.576	NS
Wulberag	0.000	1.645	1.96	2.576	NS

S= significant , NS = Not Significant

Table 5. Mann-Kendall Test Statistics (Z-test) for seasonal rainfall series

Stations	Mann-Kendall Test Statistics(Z-test) at α=5%		
	Kiremt	Bega	Belg
Alaba	0.816	0.986	1.156
Angacha	**2.583***	-0.646	-1.530
Butajira	0.408	**2.006***	-1.394
Durame	1.700	-0.238	**-2.278***
Fonko	**2.074***	**2.617***	1.428
Hossana	1.836	-0.204	-0.340
Shone	-0.034	-0.476	-1.802
Wolkite	-1.326	-0.476	0.136
Wulberag	1.156	0.578	-0.884

* indicates the significances of rainfall in that season

Farmers' perception towards rainfall variability: The socio-economic profile of households, their perception towards rainfall variability, adaptation strategies applied and associated constraints while combating against the variability will be analyzed for 80 households sampled in the study area. To make the sample representative both male headed household (67%) and female headed household (33%) farmers are accounted in the sampling. The field survey sampling also engages communal farmers (83%), and limited number of small scale commercial farmers (17%). Diverse categories in terms of age (20-80 yrs.), household size (1-14) and land owned (0.4 ha - 33 ha) is observed. About 50 % the interviewee attended primary schools and are aware of reading and writing. Very few (5%) have attended adult education and the remaining majority completed secondary school to college level studies. 63 % of the household are monogamously married and 25 % are widowed. The majority of family members (55%) are categorized under active labor force age range (15-65) while 41% of the household members are under 15.

About 84% of the respondent agreed that they are earning income from agricultural product sale while 16 % opined as no income has been generated from their farm field except covering house level food cost. Generating household income from off-farm such as carpentry, brick molding, thatching and building, getting hired as daily labourer in local construction industries activities is a common trend in the study are. Accordingly only 15.7 % the population under the sampling earn household incomes from off-farm engagements.

Farmers' perceptions and understanding of rainfall variability has significant importance in their livelihoods adjustments and adaptations to varying rainfall patterns. Cognizant to this, farmers were requested whether they perceived long term changes in precipitation (rainfall amount and distribution) over the past 20 years or not. On average 80 % the respondents agreed that there were rainfall variability in magnitude and frequency, while 11 % perceived as no change in rainfall pattern and 4 % opined as they do not know the existence of such changes. Regarding annual and seasonal rainfall variability is considered, majority of Hadiya, Silte and Gurage districts described a declining and Alaba and Kembata-Temabro district perceived an increasing annual and seasonal rainfall pattern over the past 20 years. This variation could be evolved due to the fact that rainfall amount received during the recent years was below the long term average. Although most farmers in the region perceived change in annual and seasonal rainfall totals, there was considerable difference among the stations. Most of the respondents (80%) agree that the observed change in rainfall variability is due to natural and man-induced impacts (Fig. 4)

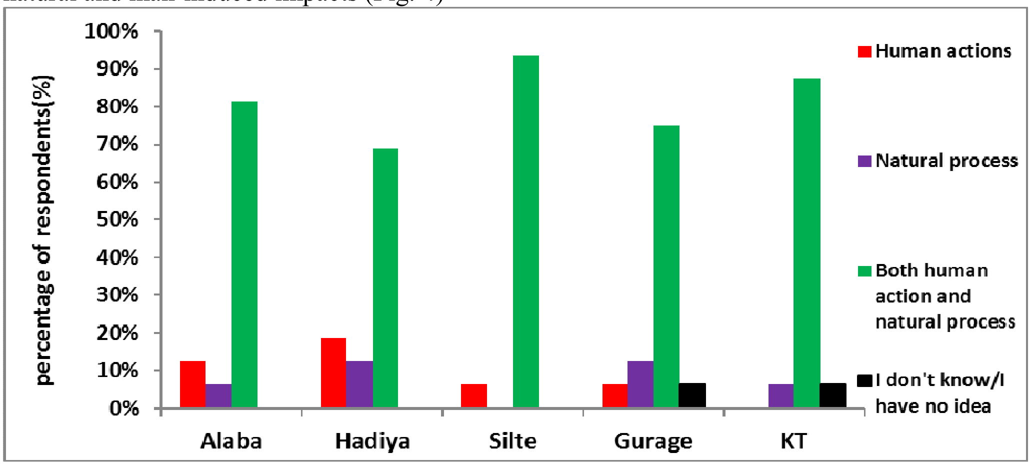

Fig. 4 Farmer's perception on the causes of rainfall variability in five districts in the study area

Hence, larger number of respondents (92.5%) agreed that they are taking adaptation measures/options in response to changing rainfall patterns. Therefore, farmers are trying to develop their own strategies to cope with negative effects of rainfall variability in the study area. Diverse category of adaptation options were undertaken to minimize the risk imposed by disrupted rainfall. Implementing soil and water conservation practices, application of irrigation, use of groundwater as sources of irrigation water are among the major adaptation mechanisms. Perceived barriers of using various adaptation options have also been assessed from the empirical data. Limited support from various institutions, land scarcity, water meager and lack of credit & saving facility negatively affected the adaptation mechanisms than others (Table 6).

Table 6. Farmers' adaptation mechanisms and barriers to adaptation regarding rainfall variability.

Adaptation Mechanisms of rainfall variability by local farmers	**% respondents**	**Major Barriers and Constraints to Adaptations Identified by local farmers**	**% respondents**
Using different crop varieties	7.5	Limited institutional support	12.5
Implementing soil and water conservation	11.3	Lower educational status	3.75
Diversifying crop and animal	3.8	Absence of land to be owned	3.8
Digging water wells	10	Disclosure to mass media	3.8
Changing use of chemicals/Fertilizers	2.5	Lack of awareness/information	3.8
Using irrigation	11.3	Labor shortage	10
Changing crop	7.5	Water scarcity	11.3
Changing planting date	7.5	Lack of health service	8.8
Planting trees on farm	8.8	Lack of knowledge	7.5
Engaging in off-farm activities	7.5	Lack of credit/saving service	11.3
Reducing the number of livestock	5	Lack of agricultural technologies	6.3
Changing quantity of land under cultivation	3.8	Others	2.5
Adjusting crop management	6.3	-----	-----
Diversify from farming to non-farming	5	------	------
No adaptation mechanism	2.5	-----	-----

5. Conclusions

There is an indication of greater climate variability characterized by extreme weather events such as drought and flood, shifts in the onset and cessation time of seasonal rainfall that ultimately affected agricultural production and endangered the livelihood of the farmers and the economy of many Sub-Saharan nations. Rainfall variability has historically been a major cause of food insecurity and famines in Ethiopia. Obtaining scientific evidence regarding the annular and seasonal rainfall variability and associating information to farmers' perceptions in the region provides a credible information to decision makers and the end users. Joint application of statistical rainfall variability analysis tools and farmers' perception towards rainfall variability provides a concise summary of the prevailing rainfall pattern in the region. In general, the contiguous regions analyzed for rainfall variability experiences temporal (year to year) and spatial (station to station) rainfall variability in terms of precipitation concentration index, rainfall anomaly index and trend analysis. Majority of the farmer respondent do agree with the perceived erratic and unpredictable rainfall in terms of intensity and frequency during the analysis window and they have been applying different adaptive strategies. The present study may provide essential information to the decision makers and agricultural community while enhancing their notions towards rainfall variability searching for better adaptive mechanisms. Future studies should rely on longer years of rainfall data with wider geographical coverage to deal with rainfall variability in the region.

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