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VARIABILITY AND TIME SERIES TREND ANALYSIS OF CLIMATE AND SMALL HOLDER FARMERS PERCEPTION: THE CASE OF JANAMORA WOREDA, NORTHWESTERN ETHIOPIA

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Abstract

This study analyzed variability and time series trend analysis of climate and small holder farmers' perception in the case of Janamora Woreda, Northwestern Ethiopia. For this study primary data was collected through questionnaire from 138 respondents selected through multi-stage sampling technique based on agro-ecology. Secondary data was collected from meteorological stations. Mann-Kendall and Chi-square tests were employed to test observed and perceived climate change and variability by using XLSTAT 2016 and SPSS version 23 respectively. Standardized rainfall anomaly index was used to determine the dry and wet years and the nature of trends. The results revealed significant increasing trend in annual average temperature in local stations except Debark and gridded temperature data. The rainfall revealed insignificant trend and high variability. About half of the study period revealed a negative rainfall anomaly. Similarly, 69.6 and 80.4% of the interviewed farmers were aware of an increase in temperature and a decrease in rainfall respectively. Moreover, χ^2 test showed that a significant variation (significant at $P<0.05$) in perception to temperature and rainfall between agro-ecology, gender and education status. Therefore, it is essential to design planned climate change adaptation strategies to enhance the adaptive capacity and resilience of rainfed dependent smallholder and further studies should be conducted in the future.

Key Words: *Trend Analysis, Temperature, Rainfall, Mann-kendall trend test, Perception, Janamora*

Introduction

Climate variability and change is the significant environmental and global threat of the current century (Edame *et al.,* 2011). The world's climate is continuing to change at rates that are projected to be new in recent human history (ILRI, 2006). The IPCC (2001) report showed that, the global mean surface temperature has been increased by 0.6°C (0.4°C to 0.8°C) over the last 100 years. This increasing global mean surface temperature is lead to changes in precipitation and atmospheric moisture (IPCC, 2001). Evidences indicated that the natural climatic variability in combination with climate change will adversely affect millions of livelihoods around the world (IPCC, 2007). In Africa, mean temperature levels have increased whereas precipitation levels have declined (IPCC, 2001). Temperature increases between 3°C and 4°C in Africa by the end of the 21st Century (Bryan *et al*., 2010).

Africa as a continent is most vulnerable to climatic changes and climate variabilities (Challinor *et al*., 2007). Most of the nations in Africa are vulnerable to climatic changes since the economies of these countries are reliant on climate sensitive crop and livestock production (Mahmud *et al*., 2008). Like other sub-Saharan countries, in Ethiopia, there is increasing temperature trend by about $0.37°C$ every ten years at alarming rate (NMA, 2007). Farmers and pastoralists in Ethiopia challenged through climatic changes and variabilities (MOARD, 2010). These challenges are due to poverty as well as lack of adaptive capacities (Temesgen *et al.,* 2008; Kaur *et al*., 2010).

Ethiopia will be vulnerable at a large scale to future climatic changes and variabilities from lists of African nations (Conway and Schipper, 2011). Agricultural, health and hydrological sectors are the most vulnerable to climatic change and variabilities as well as in livelihood approach pastoralists and smallholder rain-fed farmers were the most vulnerable groups (NMA, 2007; Kaur *et al*., 2010). Ethiopia had an experience of 11and 10 dry and wet years within the last 55 years respectively. The precipitation of the country was also revealed strongest inter annual variabilities (NMA, 2007).

Even though there are intra-regional and intra-annual variations in the amount and variabilities of precipitation in the Amhara regional state (Woldeamlak, 2007). Moreover, the extent of variabilities is the highest mostly on the east part of the regional state. In terms of trends in seasonal as well as annual precipitation, any patterns of change were not revealed. After data analysis for long periods of time in Tigray and Wollo, Conway (2000), had concluded absence of evidence for changes in the annual precipitation except a slight rise in spring (*Belig*) precipitation (1980s-1996) as well as the summer (*kiremit*) rain was reduced very slightly before the mid of 1980s at Kombolcha. Similarly, insignificant and decreasing trends were observed in annual rainfall of almost all of the meteorological station of upper Blue Nile (Tabari *et al*., 2015).

Mountain areas of Ethiopia are the most vulnerable to climatic change impacts and vulnerabilities (Belay *et al*., 2014). Particularly *Janamora* Woreda is mountainous and often-rugged landscape dominated by the great Semien mountains block (specifically Chennek and Bwahit mountains) with prevailing and highly variable climate conditions. But most studies were generalized as well as their outcomes were aggregated mostly at national level. Therefore, these studies might not reflect Janamora district's local conditions. This is why local issues needs knowledges skills and experiences which are very site specific (IPCC 2007). Because of the highest projections of significant future climatic variabilities and changes particularly in Ethiopia in next decades (Belay *et al*., 2014); aggregated national outcomes may not capture the local level. Due to this reason crop and livestock production becomes threatened. This concept is practicable for Janamora district with variable topographical region with variable climatic condition with the occurrence of droughts negatively affect the livelihoods. Therefore, the objective of this study is to analyze the variability and time series trend analysis of climate and small holder farmers perception in Janamora Woreda, Northwestern Ethiopia.

Materials and Methods

Study Area

The study was conducted in Janamora Woreda North Gondar Zone of Amhara Regional State, Ethiopia. Astronomically, it is located between 12° 44′ 21.2″ N - 13° 21′ 19.3″ N and 38° 0′ 0.3″ E - 38° 22′ 40.5″ E (Figure 1). Elevation of the Woreda ranges from 1238- 4512 m a.s.l. The woreda is part of the Simien mountains national park. About 104 Km^2 area of the park is under *Janamora* woreda and about 9 *kebeles* of the Woreda is found in and around the park. The Woreda is characterized by unimodal (one rainy season) type of rainfall. Monthly rainfall and monthly minimum and maximum temperature is illustrated in Figure 2. *Janamora Woreda* is characterized by steeply dissected and variable topography. It is found between 1238 – 4512 m a.s.l.

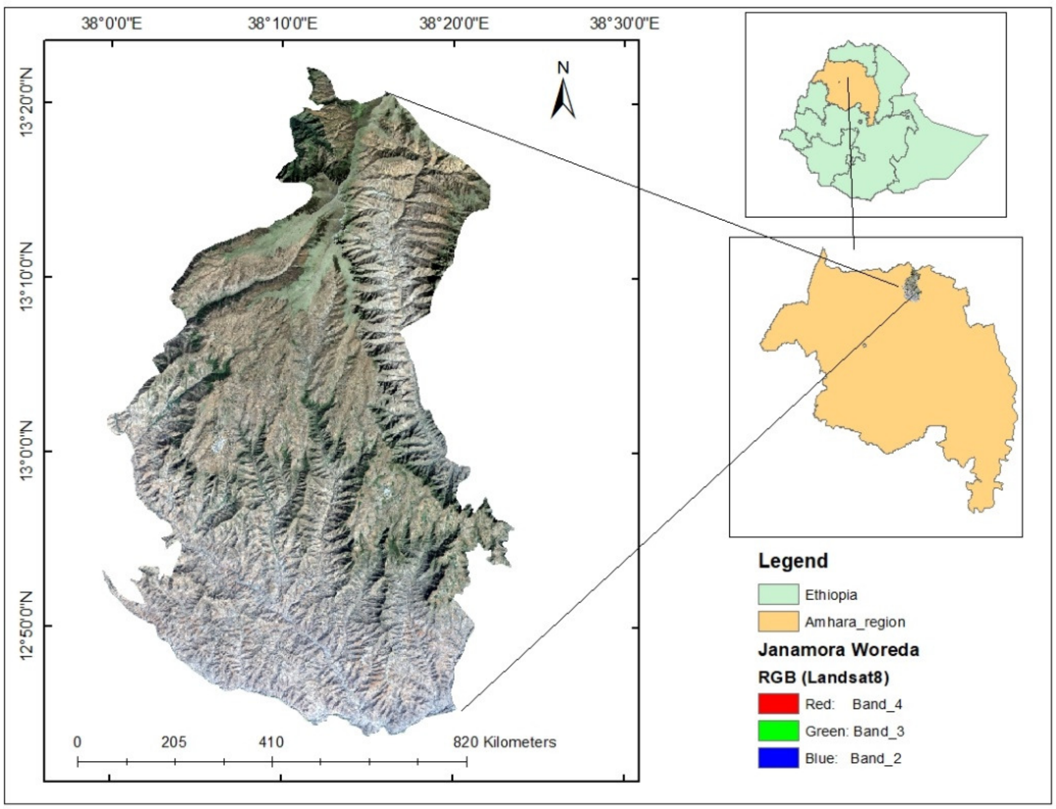

Fig. 1: Location map of the study Woreda

Most area of the woreda is very steep slope ranges from 0 - 250% of gradient. Based on traditional agroecological zones of Ethiopia (Ministry of Agriculture, 2000), the woreda is classified in to three major agro-ecological zones of *Dega* (highland), *Woyna Dega* (midland) and *Kolla* (lowland). The entire population of *Janamora* Woreda is 208719 in 2017. From this 49% were male and 51% were female. The socioeconomic characteristics includes agriculture, small scale trade, micro and small enterprise. However, above 90% of the people livelihood is mixed farming which is a subsistence form of agricultural production.

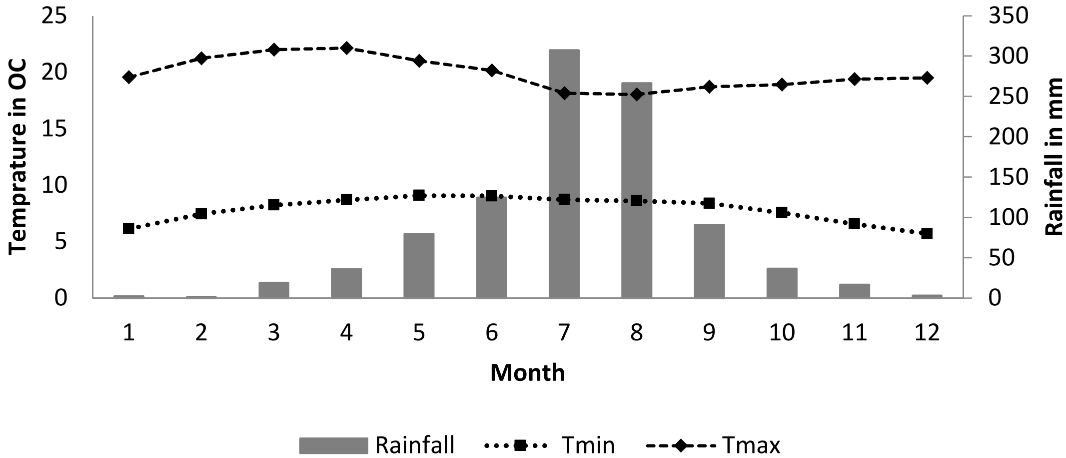

Fig. 2: Monthly total rainfall and average temperature for the study area (2004 – 2016)

Method of data collection, Sampling Design and Sample Size

Multi stage Sampling was used because the population characteristics within the woreda is heterogonous in agroecology. In the first stage stratified random sampling was carried out by considering *Kolla* (lowland), *Woyna Dega* (midland) and *Dega* (highland). In the second stage two *kebeles* were randomly selected from each agro-ecological zone and randomly selecting households from the six sampled *kebeles* using probability proportional to size (PPS). The sample size for household interview was calculated based on Cochran (1977) formula.

$$n = \frac{z^2pq}{d^2} \quad (1)$$

Where n = required sample size (when population is >10,000), Z = 95% confident limit (1.96), p = proportion of population to be included in the sample which is 10% of the total population, q = 1-P = 1-0.1 = 0.9, N = total number of population and d = margin of error (5%). Then $n =$ $(1.96)^2$*0.1 * 0.9 / $(0.05)^2$ = 138. Therefore, the sample size for this study was 138. After determining the sample size, the next step was determining the number of households for each sampled kebeles using probability proportional to size method. So, a total of 138 households (*Dega* = 46, *Woyna Dega* = 46 and *Kolla* =46) were selected. The primary data for this study was collected using standard questionnaires prepared for the survey in July 2017. Secondary data were obtained from Bahir Dar meteorological service agency proxy stations of Chennek or Siemen Mountains (13.27° N and 38.18° E) Debark (13.16° N and 37.89° E), Guhala (12.77° N and 38.8° E) and Amba-Giorgis (12.77° N and 37.62°E). To verify the quantitative data, qualitative data were collected through focused group discussion (FGD) and key informants' interview.

Method of Data Analysis

All the statistical data were entered and analyzed using SPSS version 23 and Spreadsheet 2016. Coefficient of variations (CV) was used to analyse the variabilities in climate. Mann Kendall test was applied to climatic elements (temperature and precipitation) to test any increasing or decreasing trends. Mann Kendall test is a non parametric trend test applicable to measure trends of particularly climatic data over time (Karpouzos *et al*., 2010). Negative results revealed reduction trend, while positive values showed a rise trend over time. This test revealed whether there is a monotonic decrease or increases with time on the dependent variable. All trend significant test with the level of significance 0.05 ($Z\_\alpha/2 = \pm 1.96$). Mann-Kendall trend test was analyzed through XLSTAT 2016. Mann Kendall test statistic 'S' was calculated based on Kendall (1975), Mann (1945), as well as Yue *et al*. (2002) through the following equation 2:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(Xj - Xi) \qquad (2)$$

Trend test have been applied to time series X_i and X_j. While X_i was ranked from i = 1, 2 … n-1 but X_j was ranked from j = i + 1, 2 …. n. In this regard X_i was considered as a reference point which is compared with the remaining data point's X_j Therefore:

$$Z = \frac{S-1}{\sigma} \text{ if } S>0;\ Z = 0 \text{ if } S>0 \text{ and } Z = \frac{S+1}{\sigma} \text{ if } S<0 \qquad (3)$$

where Z is normally distributed, when Z is negative, it depicts towards down but when Z is positive upward trends were shown for the period.

In one hand, standardized anomalies of rainfall have been calculated to examine the nature of the trends, enables the determination of the dry and wet years in the record and used to assess frequency and severity of droughts (Agnew and Chappel, 1999; Woldeamlak and Conway, 2007) as:

$$Z = \frac{(Xi-\mu i)}{s} * 100 \qquad (4)$$

where, Z is standardized rainfall anomaly; X_i is the annual rainfall of a particular year; 's' is the standard deviation of annual precipitation over the observation periods and μi is long term mean annual rainfall over a period of observation. According to Agnew and Chappel (1999) standardized rainfall anomaly index value and the classes are shown in Table 1.

Table 1: Standardized rainfall anomaly index value and classes

Rainfall anomaly index (RAI)	RAI value Category/class
>2.0	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.84 to 0.99	Near normal
-0.84 to -1.28	Moderate drought
-1.28 to -1.65	Severe drought
< -1.65	Extreme drought

Results and Discussion

The female headed household accounts 19.6% in Dega, 19.6% in Woyna Dega and 15.2% in Kolla agroecological zones. The mean age of the respondents was 47.4 years (Dega), 42 years (Woyna Dega) and 42.7 years (Kolla). The mean household size of the respondent was 6.065 (Dega), 5.826 (Woyna Dega) and 5.804 (Kolla). Which was greater than the national average household size (5.1 in rural and 3.9 in small town) of Ethiopia (CSA 2013; World Bank, 2013). About 78.3%, 76.1% and 71.7% sampled household heads in Dega, Woyna Dega and Kolla agroecologies were illiterate.

Analysis of Temperature change and Variability

Table 2: Annual temperature timeseries trends and variabilities

Station	Temp.	N	Min	Max	Mean	SD	CV	Trend °C/year	Kendall's tau	P-value
Janamora[+]	T ave.	38	13.1	27.2	19.8	0.58	0.028	0.0007	0.723	0.000*
Chennek	Tmin.	13	2.80	7.74	4.231	1.396	0.33	0.0024	0.788	0.000*
	Tmax.	13	12.1	15.7	14.04	0.993	0.071	0.0014	0.272	0.121
	T ave.	13	7.41	11.5	9.13	1.015	0.111	0.0018	0.727	0.000*
Debark	Tmin.	13	7.80	9.27	8.588	0.393	0.046	0.0026	0.303	0.096
	Tmax.	13	18.2	21.1	19.78	0.802	0.041	0.0028	0.212	0.186
	T ave.	13	12.9	15.2	14.18	0.559	0.039	0.0027	0.182	0.225
Amba-Giorgis	Tmin.	15	6.23	9.75	8.32	0.851	0.102	0.0033	0.154	0.251
	Tmax.	15	18.6	22.4	20.1	1.13	0.056	0.0141	0.670	0.000*
	T ave.	15	12.4	15.7	14.21	0.883	0.062	0.0087	0.473	0.010*
Guhala	Tmin.	30	4.39	15.9	10.38	3.027	0.292	0.0095	0.609	0.000*
	Tmax.	30	22.9	31.6	25.7	2.475	0.096	0.0075	0.513	0.000*
	T ave.	30	14.2	23.4	18.11	2.611	0.144	0.0085	0.655	0.000*

*is significant trend at P<0.05 level, SD = Standard Deviation, CV =Coefficient of Variance (Source: [+] is climate data downloaded from NASA website).

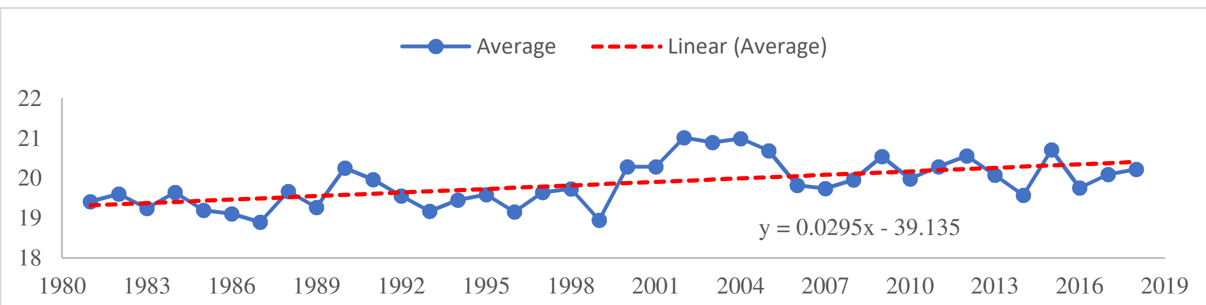

Fig. 3: Trends of annual average temperature for Janamora
(Source: NASA Power data access viewer)

The Mann-Kendall trend test for annual minimum temperature revealed statistically significant increasing trend for *Chennek* and *Guhala* stations Similar to Birhanu (2017). However, annual minimum temperature showed an increasing trend in all stations (Table 2). Moreover, annual maximum temperature showed statistically significant increasing trend for *Amba-Giorgis* and *Guhala* stations (Table 2). Annual maximum temperature showed an increasing trend in all stations. Similarly, Chennek, Amba-Giorgis, and Guhala stations as well as the gridded regional climate data for Janamora showed statistically significant increasing trend for annual average temperature (Table 2).

However, annual average temperature of *Debark* station was statistically insignificant but an increasing trend. Moreover, in Figure 3 *Guhala* station showed a positive slope that revealed an increasing trend of average temperature. Generally, statistically significant increasing trend was observed on annual average temperature for local stations and downloaded grid data. This is in accordance with the current national temperature increment (increased by

0.03℃ per year) of Ethiopia (Jury and Funk, 2012).

Small holder Farmers' perception to Temperature change and Variability

Most of the respondents from each agro-ecologies (73.78% from *Dega*, 56.42% from *Woyna Dega* and 78.12% from *Kolla*) perceived that temperature is increased (Table 3). The change in temperature occurred in all agro-ecologies and it was felt more or less equal by every farming community in the Woreda.

Table 3: Perceived temperature change and variability

	Perception on temperature (% of respondents)				χ^2	P-value
Agro-ecology	I don't know	Decreased	Increased	No Change		
Dega	2.17	19.53	73.78	4.34		
Woyna Dega	10.85	28.21	56.42	4.34	10.21^{ns}	0.116
Kolla	10.85	10.85	78.12	0		
Gender	Perception on temperature (% of respondents)					
	I don't know	Decreased	Increased	No Change		
male	5.07	17.4	59.4	1.5	20.15*	0.000
female	5.07	5.07	5.07	1.5		
Educational Status	Perception on temperature (% of Respondents)					
	I don't know	Decreased	Increased	No Change		
Illiterate	12	22.2	63	2.8	9.93*	0.019
Literate	0	6.9	93.1	0		

^{ns} and* is non-significant and significant at 0.05 level respectively

There was a significant difference in perception of male and female to temperature change (χ^2 =20.15) (Table 3). This difference in perception between gender is a reflection of the roles that the two sexes play in the society and the limited opportunities available to woman in terms of climate related information. Marther *et al.* (2016) and Alem *et al.* (2016) found significant difference perception between male and female. Chi-square shows significant variation among the different educational status ($\chi2$ =9.93, P=0.019) (Table 3). The implication is that educated peoples are keener in noting changes in temperature more than uneducated people; they become very conscious about their environment.

Analysis of Rainfall Trend and Variability

All the months in *Amba-Giorgis* station varied from 33.2 % - 318.6% CV showing very high variability of precipitation (Hare, 2003). The annual variability of rainfall as indicated in Table 4, is moderately variable for *Amba-Giorgis* (CV = 28.33%) and *Chennek* (CV = 20.77%) stations. Whereas, *Debark* and *Guhala* stations were less variable. The Mann-Kendall trend test for annual rainfall revealed statistically insignificant trend for all stations and the reginal gridded downloaded data (Janamora). However, a decreasing trend was seen in *Debark* and *Guhala* stations (Table 4). Similarly, Birhan Getachew (2017) found insignificant trend in annual rainfall.

Table 4: Annual rainfall trends and variabilities

Stations	N	Min.	Max.	Mean	SD	CV	Trend mm/year	Kendall's tau	p-value
Janamora+	38	598.6	1650.2	908.8	283.3	0.31	-0.22	-0.052	0.359ns
Chennek	13	666.6	1610.4	1071.7	222.6	0.21	0.392	0.061	0.418 ns
Debark	13	811.9	1615.1	1127.8	208.2	0.19	-0.086	-0.12	0.684 ns
Amba- Giorgis	28	527.3	1701.7	1002.3	283.	0.28	0.462	0.154	0.251 ns
Guhala	13	569.3	939	733.7	110	0.15	-0.919	0.048	0.369 ns

ns is non-significant trend at 5% level, SD = Standard Deviation, CV =Coefficient of Variance and MK = Mann-Kendall (Source: + is climate data downloaded from NASA website).

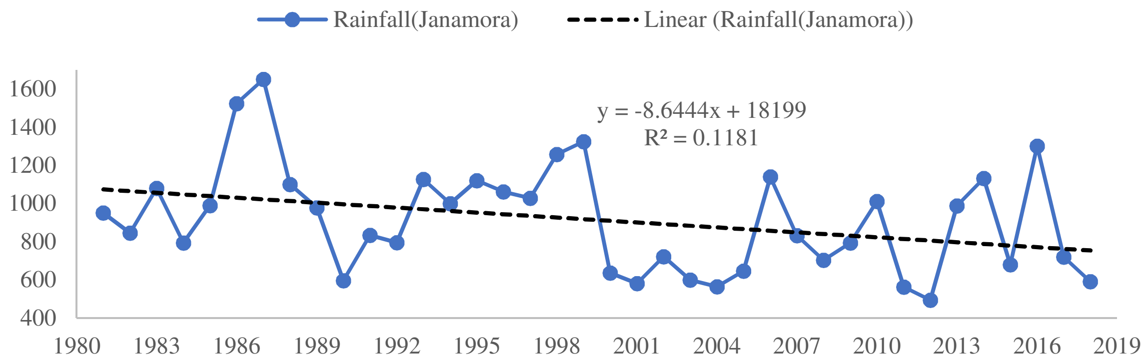

Fig. 4: Annual rainfall trend of gridded data for Janamora Woreda (1981-2018) (Source: NASA Power data access viewer)

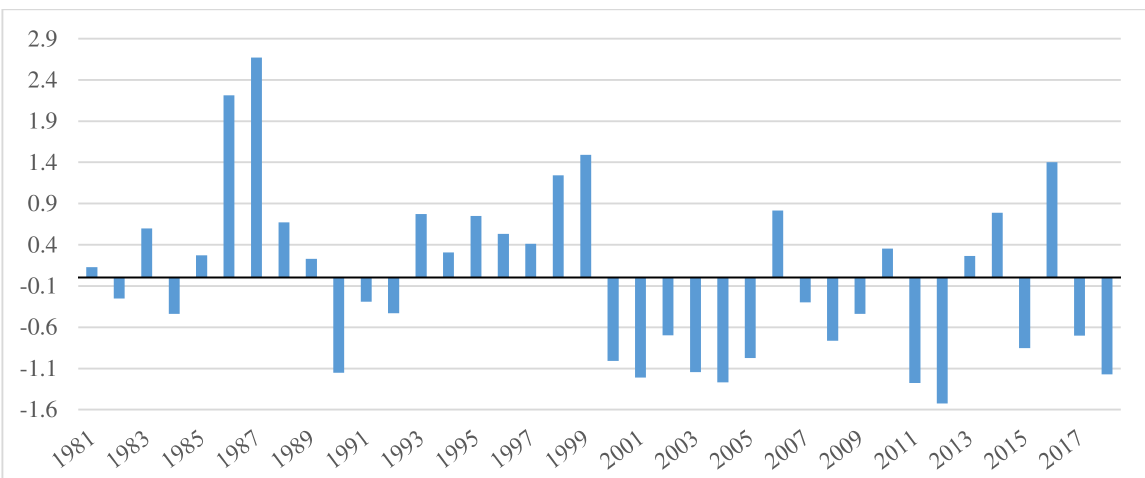

Fig. 5: Rainfall anomaly index (1981-2018)

In figure 4 the rate of change in rainfall which is determined by the gradient of the regression line is about -8.644mm/year, for annual rainfall during the period of 1981–2018. The annual rate of reduction is higher which is caused by the reduction of the main (summer) rainfall season.

Negative rainfall anomalies are a manifestation of severe to extreme drought periods. The standardized rainfall anomalies of this study vary from +2.67

(1987 i. e the wettest year) to -1.52 (2012 i.e the driest year (Table 5). As depicted in Figure 5; about half of the timeseries (1981-2018) showed negative anomalies. Table 5 revealed that 5.26% and 21.05% of the study year fallen under severe drought and moderate drought respectively. Even though, about 23 years (60.53%) is under near normal. Similarly, Girma *et al.* (2016) reported that above half of the study years have a negative anomaly.

Table 5: Rainfall anomaly Index

Drought category	Rainfall anomaly index	Frequency	Percent
Extreme Drought	<-1.65	0	0
Severe Drought	-1.65 to -1.28	2	5.26
Moderate Drought	-1.28 to -0.84	8	21.05
Near Normal	-0.84 to 0.99	23	60.53
Moderate Wet	1.0 to 1.49	3	7.90
Very Wet	1.5 to 1.99	0	0
Extreme Wet	>2	2	5.26
Total		38	100

Small holder Farmers Perception to Rainfall Change and Variability

There was statistically significant variation of perception in rainfall by gender (χ^2 = 18.36) (Table 6). Similarly, Marther *et al*. (2016), ATPS (2013) and Alem *et al.* (2016) also revealed that significant difference perception between male and female to climate change. Moreover, the statistical analysis for perception of rainfall change showed significant variation among the different educational status (χ^2 = 13.45) (Table 6). About 60.9%, 78.3% and 84.8% of respondents from *Dega*, *Woyna Dega* and *Kolla* agro-ecologies were well recognized the existence of drought in their local area respectively.

Table 6. Farmers' perception on rainfall change and variability

	Perception on temperature (% of respondents)				χ^2	P-value
Agro-ecology	I don't know	Decreased	Increased	No Change		
Dega	8.68	32.55	54.25	4.34		
Woyna Dega	10.85	6.51	78.12	4.34	22.19*	0.001
Kolla	6.51	2.17	86.8	4.34		
Gender	Perception on temperature (% of respondents)					
	I don't know	Decreased	Increased	No Change		
male	3.6	5.8	71.02	2.9	18.36*	0.000
female	5.07	0.73	9.42	1.5		
Educational Status	Perception on temperature (% of Respondents)					
	I don't know	Decreased	Increased	No Change		
Illiterate	9.2	21.1	66.1	3.7	13.45*	0.004
Literate	0	3.5	95.5	0		

ns and* is non-significant and significant at 0.05 level respectively.

In general, very high variability and insignificant trend of rainfall was observed. This implies that agricultural activities in the Woreda are challenged by such high variabilities and a decreasing trend of rainfall. Most of the respondents (80.4%) believed a decrease in the amount of rainfall, and the remaining and 28.7% of the respondents did not give enough attention about the trend of the rainfall. Similarly, through Focus group discussion (FGD), farmers of the woreda generally concurred that the main problem in terms of rainfall distribution is the timing (late onset and early cessation) and falling in intense episodes in very short duration. Statistical analysis showed significant variation of perception across different agro-ecological zones (χ^2 =22.19) (Table 6).

Similar to ATPS (2013) study. This is probably because in *Kolla* agro-ecology, water is already very scarce, and a little change in the amount of rainfall could have high impact.

Conclusion and Recommendations

Generally, very high variability of rainfall was observed in the study area. Significant increasing trend was observed on annual average temperature for all stations except *Debark*. Similarly, farmers' perception was in line with the observed climatic data that means an increasing trend in temperature. On the other hand, insignificant trend was observed on rainfall of all local stations as well as gridded rainfall data. But *Debark* and *Guhala* stations showed a decreasing trend. About half of the study periods revealed a negative rainfall anomaly. In line with the meteorological data analysis the local farmers perceived a decreasing trend in rainfall in the last three decades. Therefore, it is essential to adjust the agriculture activity with the variability situation and design planned climate change adaptation strategies so as to enhance the adaptive capacity and resilience of rainfed dependent smallholder farmers. Further study should be conducted in regard to future climate analysis.

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