ORIGINAL ARTICLE

Analysis of Observed and Perceived Climate Change and Variability in Gondar Zuria Woreda, Northwestern Ethiopia

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Abstract

Examining the spatiotemporal variability and trends of climate in the context of global climate changes particularly in countries like ours where rainfed agriculture is predominant is indispensable to suggest possible adaptation policies. Therefore, this study aimed at assessing the changes and variability of rainfall and temperature in Gonder Zuria Woreda, Northwestern Ethiopia. The study was conducted using quantitative research design. Climatic data which were collected from 1952 – 2016 were the data source of this study. Questionnaire was used to collect data from 100 local people about their perception on climate changes, and it was presented in frequency and percentage distributions. Coefficient of variation, anomaly index, Precipitation Concentration Index and Seasonality Index were used to analyze the variability of rainfall on annual and seasonal basis whereas Inverse distance weighting interpolation was used to show the spatial variability of rainfall. Furthermore, both non- Mann-Kendall tests and linear regression were used to detect the trends in time-series climatic data for the period of 1952-2016. The result revealed that there is intra-annual/seasonal and inter-annual variability of rainfall. Annual, summer and spring rainfall has decreased with a rate of 21.24, 7.2 and 1.85 mm per decade respectively. The minimum average and maximum rate of change of temperature was found to be 0.19, 0.25 and 0.3°C per decade respectively. The Mann-Kendall trend test result indicated that there is significant increasing trend for minimum, average and maximum temperatures. Most of the respondents (80%), perceived that temperature is increasing and rainfall is declining. Therefore, a sustainable climate risk management approach is recommended to adapt to the ongoing impacts of climate variability and climate change.

Keywords: Anomaly index, Climate change, Climate Variability, Mann-Kendall trend test, Perception, Precipitation concentration index

Introduction

There are different evidences and understanding that climate change is happening and it is considered as one of the greatest challenges of Ethiopia. Over the last century, atmospheric concentration of carbon dioxide has increased significantly which induced the average global temperature to increase by 0.74°C as compared with the preindustrial era (UNFCCC, 2007). Smallholder subsistence farmers are among those sections of the

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society who are victimed by the climate change harshly due to their low adaptive capacity, and due to their dependency on rain-fed agriculture which is very sensitive to climate variability (Speranza, 2010 and Easterling, 2011).

In Africa, especially in most parts of Sub-Saharan Africa, precipitation amounts are likely to decrease (SSA) while rainfall variability is expected to increase (IPCC, 2014). Many African countries are vulnerable to climate change since their economies are highly dependent on climate sensitive agricultural production (Mahmud et al., 2008). According to World Bank (2010) and Speranza (2010), Africa is expected to experience mainly negative climate change impacts in terms of an increase in temperatures, and a decrease in the largely erratic rainfall. UNDP (2014) stressed that the adverse impacts of climate change will be felt most acutely by the smallholder farmers in developing countries because they are by large dependent on natural systems for growing crops and raising live stocks.

In Ethiopia, like in many other sub-Saharan countries, there has been a warming trend of temperature increasing by about 0.37°C every ten years (Gebrehiwot & van der Veen, 2013). In Ethiopia, current climate variability is imposing a significant challenge by deterring the struggle to reduce poverty and sustainable development efforts (NMA, 2007). According to World Bank (2010) rank, Ethiopia is among the most vulnerable countries to the adverse effects of climate change in the world mainly due to its high dependency on rain fed agriculture, low adaptive capacity and a higher reliance on natural resources base for livelihood (EPCC, 2015).

Climate trend analysis studies which were conducted so far in Ethiopia were not conclusive, and some of them were conducted at macro scale (Gedefaw, et al., 2018; Asfaw et al., 2018; Alemu & Bawoke, 2018). Therefore, this study focused on the micro scale level at Gondar Zuria Woreda that has more or less similar agroecology. At the same time, this research tried to make trend analysis studies that conducted in Ethiopia at different spatio-temporal scales. Finally, it came up with some contrasting results. For example, Seleshi &Zanke (2014) identified no trend in the annual and seasonal rainfall in the northern and northwestern Ethiopia in the second half of the 20th century. Jury & Funk (2013) observed a declining trend in rainfall in southwestern Ethiopia in the periods 1948–2006. On the other hand, a study which was conducted by Mengistu et al. (2014) in the upper Blue Nile River basin (Ethiopia) showed statistically non-significant increasing trends in annual rainfall during the periods 1981–2010. In the same way, Gedefaw et al. (2018) used five representative meteorological stations in Amhara region to study variability of rainfall on monthly, seasonal, and annual time scales, and he reported a mix of significant positive and negative trends in the stations.

Moreover, most of the previous studies which were carried out in Ethiopia and in the Amhara region were focused on either the temporal trends and spatial climatic variability in large scale area or they tried to investigate the perceived climate change separately (Mengistu, 2014; Alemu & Bawoke, 2018; Asfaw et al., 2018; Gedefaw, et al., 2018 and Alemu & Dioha, 2020). Therefore, integrating the observed spatial-temporal climate trends and variabilities with perceived climate change is a better way of investigation. This study tried to investigate the temporal and spatial climatic changes that observed in Gonder, Zuria, and it also incorporated the perception of local community on climate change. The other rational is that there is a lack of scientific climate change and/variability information in Gondar Zuria woreda which triggers the researchers to focus the study area in Gondar Zuria Woreda. Therefore, because of the above-mentioned research gaps, the objective of this study was to investigate the observed and perceived climate changes and variability in Gondar Zuria woreda.

2. Materials and methods
2.1 Description of the Study Area

Location

The study area is found in Central Gondar Zone, Amhara Region, North west Ethiopia. Geographically, it lies between 12° 6' 45" N - 12° 38' 10" N latitude and 37° 15' 5" E - 37° 40' 10" E Longitude (Figure 1). Gondar Zuria woreda is bordered on the south by the Debub Gondar Zone, on the southwest by Lake Tana, on the west by East Dembiya, on the north by Lay Armachiho, on the northeast by Wegera and on the southeast by West Belessa. Towns which are found in Gondar zuria woreda include: Maksegnit, Degoma, Emfraz, and Teda.

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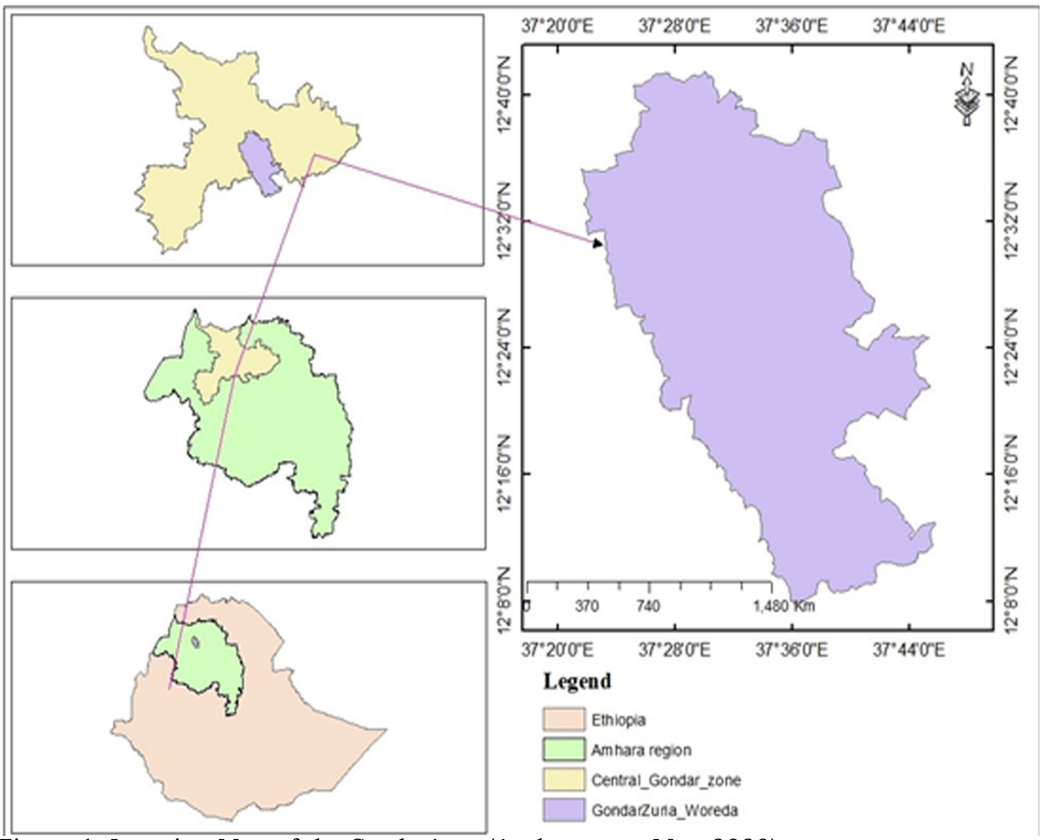


Figure 1. Location Map of the Study Area (Authors own Map,2020)

Local Climate and Agroecology

The agro ecology of the Woreda is mostly midland (Woyna Dega) agro ecology which is very suitable for different plant and animal diversity. Therefore, the farming system depends on the extent of the agro ecology. Mixed farming system (both different crop production and animal husbandry) is very common in the study area. The mean annual maximum temperature over the study periods was 25.11oC (Table 4). The minimum and maximum reading recorded from maximum temperature was 23.83oC and 26.29oC respectively (Table 4). Similarly, the mean annual minimum temperature of the study area during the study periods (1952-2016) was 12.67oC whereas the minimum and maximum reading from annual minimum temperature was 10.92oC (1962) and 14.30oC (2011) respectively (Table 4).

The study area is found under the unimodal rainfall regime where it receives high rainfall during summer (June to September). Summer rainfall is highly concentrated during July and August which alone covers more than half of the summer rainfall. The mean average rainfall concentration revealed the presence of high concentration of rainfall. Likewise, the rainfall anomaly also witnessed for the presence of inter-annual variability. On the other hand, mean annual and summer rainfall have decreased on average by 121.5 mm and 19.5 mm respectively in the past three decades as compared with the first three decades of the study period.

Socio-economic setting

The total population of Gondar Zuria Woreda was 264,920 in 2020 (Mulugeta, & Achenef, 2015). The livelihood of the Woreda is mainly dependent on climate sensitive rain feed agriculture (small holder crop and livestock production). However, small proportion of the population has engaged in off-farm activities (petty trade and so on). Crop production is the primary livelihoods for most of the population in the study area. Similarly, livestock production is important in the farming system of the woreda. The need for adopting draught power, source of food and income has made the mixed farming of animals with other agricultural activities inevitable (Mulugeta, & Achenef, 2015). The major land use categories of the Woreda are cultivated land, grazing land and settlement. Crops covered 56.5% of the area, grazing land or pasture covered 14.7% whereas forests and shrubs contains 10%, settlements 5.3% and the remaining 13.5% is a miscellaneous land use (Mulugeta, & Achenef, 2015).

2.2. Research design

Quantitative research design was used for this study. In this case, descriptive and correlational approaches of research were used since investigating the observed temporal trends and variability of climate needs a descriptive statistic (mean, minimum and maximum) and inferential statistics (t-test, mann-kendal trend test, linear regression).

2.3 Climatic Data Source

Monthly rainfall and temperature data for variability and for trend analysis were taken from National Meteorological Agency (NMSA) of Ethiopia. Four stations namely Gondar (1952-2016), Maksegnit (1987-2016), Robit (2001-2016) and Tikil-Dingay (2005-2016) which are found in and around the Woreda were considered for mainly interpolation (inverse distance waiting interpolation) to investigate the spatial variability of rainfall in the study area. Historical climatic data (temperature and rainfall) of Gondar meteorological station which were collected from the year 1952 up to 2016 was the main data source for temporal trend and variability analysis in this study because the other stations' data contained short period of time information. Finally, appropriate data processing, and filling missing data activities were done using the Normal ratio method.

2.4 Sampling techniques and data collection tool

Primary data for perceived climate change was collected using structured questionnaire. The questionnaire consists of perception of respondents about climate change. Selecting the respondents was done based on appropriate sampling technique which is systematic sampling technique. The sample size of the study was determined by Yemane (1967) formula:

$$n = \frac{N}{1+N(e)^2} = \frac{208{,}889}{1+208{,}889(0.1)^2} = 99.9 = 100 \qquad (1)$$

Where n is the sample size, N is population, e is an error assumed at 10%. Therefore, the sample size of this study is 100.

2.5 Data Analysis

Different data analysis methods were developed for this study. Climatic variability was computed using Coefficient of Variation, Standardized Rainfall Anomaly, Precipitation Concentration Index (PCI) and Seasonality Index. Furthermore, for trend analysis linear regression and Mann-Kendall trend test were used to detect the trend of rainfall and temperature with Sen's slope estimator. The perception of local community to climate trend was analyzed in descriptive statistics in terms of frequency and percent.

2.5.1 Analysis of temporal climate variabilities

CV (Coefficient of Variation) was calculated to evaluate the variability of the rainfall. A higher value of CV is the indicator of larger variability, and vice versa which is computed as:

$$CV = \sigma/\mu * 100 \qquad (2)$$

where CV is the coefficient of variation; σ is standard deviation and μ is the mean rainfall. According to Hare (2003), CV is used to classify the degree of variability of rainfall events as less ($CV < 20$), moderate ($20 < CV < 30$), and high ($CV > 30$).

PCI (Precipitation Concentration Index) is used to examine the variability (heterogeneity pattern) of rainfall at different scales (annual or seasonal). The PCI values were computed as given by Oliver (1980) and modified by De Luis et al. (2011) as:

$$PCI_{annual} = \frac{\sum_{i=1}^{12} P^2 i}{\left(\sum_{i=1}^{12} Pi\right)^2} \qquad (3)$$

where: Pi is the rainfall amount of the ith month.

According to Oliver (1980), PCI value which is less than 10 indicates uniform monthly distribution of rainfall (low precipitation concentration) whereas values which are between 11 and 15 denote moderate concentration, and values which are from 16 to 20 indicates high concentration, and values of 21 and above indicate very high concentration.

On the other hand, standardized anomalies of rainfall has been calculated to examine the nature of the trends which 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:

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

where, Z is standardized rainfall anomaly, Xi is the annual rainfall of a particular year, μi is long term mean annual rainfall over a periods of observation and 's' is the standard deviation of annual rainfall over the periods of observation.

Table 1 showed. Standardized Rainfall Anomaly Index value and classes (Agnew and Chappel, 1999)

SRAI	SRAI 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

According to Agnew and Chappel (1999) standardized rainfall anomaly index value and the classes are shown in Table 1.

2.5.2 Trend Analysis

Simple linear regression is a regression model that estimates the relationship between one independent variable and one dependent variable using a straight line. Both variables should be quantitative. Therefore, simple linear regression was used to make a graph for variables (temperature and rainfall) for the time periods of 1952-2016.

$$Y=aX+b \tag{5}$$

Y is dependent variable (either temperature or precipitation), X is considered as independent variable (years), a is the slope of regression line and b is constant.

Mann-Kendall (MK) test is widely used to detect trends of meteorological variables (Yilma and Zanke (2004); Mekonnen and Woldeamlak (2014); Tabari et al., 2015; Gebremedhin et al., 2016). MK test is a nonparametric test which tests for a trend in a time series without specifying whether the trend is linear or non-linear (Yue et al., 2002). Similarly, MK trend test is a non-parametric test commonly employed to detect monotonic trends in series of environmental data, climate data or hydrological data. In addition, MK test has been used to detect the presence of monotonic (increasing or decreasing) trends in the study area, and it is used to determine whether the trend is statistically significant or not. Since there are chances of outliers to be present in the dataset, the non-parametric MK test is useful because its statistic is based on the (+ or -) signs rather than the values of the random variable, and therefore, the trends determined are less affected by the outliers (Birsan et al., 2005).

The MK test statistic 'S' is calculated based on Mann (1945), Kendall (1975) and Yue et al. (2002) using the formula:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(Xj - Xi) \tag{6}$$

The application of trend test is done to a time series Xi that is ranked from i = 1, 2 … n-1 and Xj, which is ranked from j = i + 1, 2 …. n. Each of the data point Xi is taken as a reference point which is compared with the rest of the data point's Xj so that:

$$Sgn\ (X_j - X_i) = \begin{cases} +1\ if(X_j - X_i) > 0 \\ 0\ if(X_j - X_i) = 0 \\ -1\ if(X_j - X_i) < 0 \end{cases} \tag{7}$$

where Xi and Xj are the annual values in years i and j (j > i) respectively. It has been documented that when the number of observations is more than 10 ($n \geq 10$), the statistic 'S' is approximately normally distributed with the mean and E(S) becomes 0 (Kendall, 1975). In this case, the variance statistic is given as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{t=1}^{m} t1(t1-1)(2t1+5)}{18} \quad (8)$$

where n is the number of observation and ti are the ties of the sample time series. The test statistics Z is as follows:

$$Z = \begin{cases} \frac{S-1}{\sigma} \; if \; S > 0 \\ 0 \; if \; S = 0 \\ \frac{S+1}{\sigma} \; if \; S < 0 \end{cases} \quad (9)$$

Where Z follows a normal distribution, a positive Z and a negative Z which depict an upward and downwards trend for the periods respectively. Sen's Slope estimation test computes both the slope (i.e. the linear rate of change) and intercept according to Sen's method. The magnitude of the trend is predicted by Theil (1950) and Sen (1968) slope estimator methods. A positive value of β indicates an 'upward trend' (increasing values with time) while a negative value of β indicates a 'downward trend'. Here, the slope (Ti) of all data pairs is computed as (Sen, 1968).

2.5.3 Spatial rainfall Variability Analysis

To analyse the spatial rainfall variability, Inverse Distance Weighted (IDW) interpolation was used. Inverse Distance Weighted (IDW) is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. (ESRI, 2022). The closer a point is to the center of the cell being estimated, the more influence, or weight it has in the averaging process. The IDW is a mapping technique which is an exact convex interpolation method that fits only with the continuous model of spatial variation. The IDW derives the value of a variable at some new location using values obtained from known locations (ESRI, 2022). This is expressed mathematically in the equations given below (Tomislav, 2009):

$$Zj = \frac{\sum_i \frac{Zi}{d^n{}_{ij}}}{\sum_i \frac{1}{d^n{}_{ij}}} \quad (10)$$

Where, Zi is the value of known point, dij is distance to known point, Zj is the value of unknown point, n is a user selected exponent (often 1, 2 or 3). Any number of points may be used up to all points in the same typically 3 or more (Khouni, et al., 2021).

3. Results and Discussion

3.1 Observed and perceived Trend of Rainfall and Temperature

The descriptive statistics (like, minimum, maximum, mean, standard deviation (SD) and coefficient of variation (CV) and Mann-Kendall trend test for rainfall, minimum and Maximum temperatures is presented in Table 2, Table 3 and Table 4 respectively. The mean annual rainfall of the area during the study periods was 1119.4 mm with standard deviation of 191.40 mm and 17% CV (Table 2). The minimum and maximum ever recorded rainfalls were 719.9 mm (in 1982- the driest year) and 1831.9 mm (in 1964-the wettest year) respectively (Table 2). As depicted in Table 2, summer is the major rainy season in the study area which contributes about 68% of the total rainfall while the rest contributed only 32% rainfall.

Table 2. Descriptive statistics and Mann-Kendall trend test for monthly, seasonal and annual rainfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Min	22.82	25.90	18.72	25.51	24.64	23.07	18.15	19.61	22.70	24.30	24.92	25.20	23.83
Max	29.29	31.24	31.80	32.34	32.19	27.61	24.89	24.44	27.01	27.96	28.96	28.71	26.29
Mean	27.67	28.90	29.56	29.66	28.48	25.41	22.62	22.74	24.83	26.27	26.91	27.01	25.11
SD	0.98	1.16	1.80	1.20	1.34	0.95	1.05	0.87	0.79	0.90	0.91	0.76	0.63
CV	0.04	0.04	0.06	0.04	0.05	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.03
R	0.25	0.43	0.06	0.49	0.15	0.25	0.46	0.47	0.41	0.44	0.53	0.55	0.63
Mk test Z	3.097	3.533	2.599	5.033	1.183	2.106	4.659	4.456	3.555	3.318	4.637	4.416	5.588
Sig	**	***	**	***	Ns	*	***	***	***	***	***	***	***
Sen slope	0.018	0.030	0.019	0.037	0.011	0.014	0.029	0.023	0.019	0.021	0.029	0.022	0.024

***,**,* and ns is significant at 0.01, 0.05,0.1 levels and non-significant respectability

Table 3. Descriptive statistics and Mann-Kendall trend test for monthly and annual minimum temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Min	7.13	9.30	0.00	12.24	11.38	8.67	11.41	10.18	10.51	8.58	8.03	8.62	10.92
Max	13.43	15.32	17.00	17.79	19.75	16.60	15.80	14.56	14.25	16.65	13.74	16.23	14.30
Mean	11.10	12.64	14.25	15.39	15.23	13.95	13.43	13.12	12.69	12.44	11.84	11.11	12.67
SD	1.23	1.31	2.09	1.10	1.28	1.03	0.73	0.82	0.80	1.09	1.02	1.32	0.76
CV	0.11	0.10	0.15	0.07	0.08	0.07	0.05	0.06	0.06	0.09	0.09	0.12	0.06
r	0.61	0.66	0.15	0.53	0.51	0.55	0.44	0.53	0.44	0.53	0.59	0.60	0.70
Mk test Z	5.20	5.64	4.37	4.43	5.30	5.63	4.27	5.40	4.40	4.51	4.89	5.06	6.27
Sig	***	***	***	***	***	***	***	***	***	***	***	***	***
Sen slope	0.039	0.046	0.034	0.031	0.036	0.027	0.018	0.022	0.021	0.026	0.030	0.040	0.028

*** is significant at 0.01 level (own computation based on available data of Gondar meteorological station)

The results of Mann-Kendall test for monthly rainfall data also revealed that there was a statistically significant decreasing trend for the month of February, July, December at p<0.1 (Table 2). On the other hand, a statistically significant increasing trend was observed in rainfall for the month of January (P<0.05) 3).

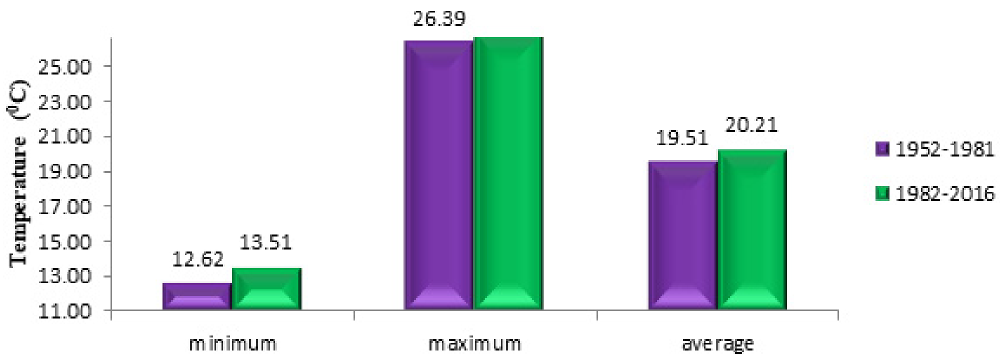


Figure 2: Annual minimum, maximum and average temperature in three decades (before and after 1981)

Table 4. Descriptive statistics and Mann-Kendall trend test for monthly and annual maximum temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Min	22.82	25.90	18.72	25.51	24.64	23.07	18.15	19.61	22.70	24.30	24.92	25.20	23.83
Max	29.29	31.24	31.80	32.34	32.19	27.61	24.89	24.44	27.01	27.96	28.96	28.71	26.29
Mean	27.67	28.90	29.56	29.66	28.48	25.41	22.62	22.74	24.83	26.27	26.91	27.01	25.11
SD	0.98	1.16	1.80	1.20	1.34	0.95	1.05	0.87	0.79	0.90	0.91	0.76	0.63
CV	0.04	0.04	0.06	0.04	0.05	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.03
R	0.25	0.43	0.06	0.49	0.15	0.25	0.46	0.47	0.41	0.44	0.53	0.55	0.63
Mk test Z	3.097	3.533	2.599	5.033	1.183	2.106	4.659	4.456	3.555	3.318	4.637	4.416	5.588
Sig	**	***	**	***	Ns	*	***	***	***	***	***	***	***
Sen slope	0.018	0.030	0.019	0.037	0.011	0.014	0.029	0.023	0.019	0.021	0.029	0.022	0.024

***,**,* and ns is significant at 0.01, 0.05,0.1 levels and non-significant respectability

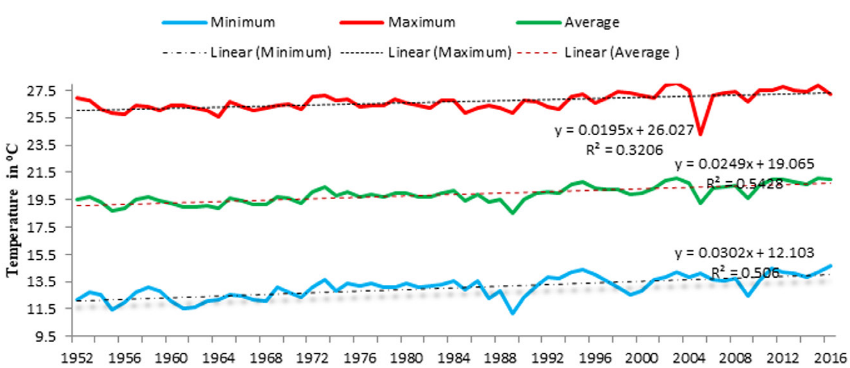


Figure 3. Trends of Annual Temperature (minimum, average and maximum) from 1952-2016

The coefficient of variations (CV) for monthly as well as annual minimum and maximum temperature ranges from 0.03-0.15 (3-15%) revealed a low variability in temperature. The linear regression model indicated that there was a rate of change of temperature by about 0.195, 0.249 and 0.302oC per decade for minimum, average and maximum respectively during the periods of 1952–2016. This result is in agreement with the farmers' perception which explained temperature is decreasing over the last three decades (Figure 4). This finding is very close to the average annual mean minimum temperature throughout the country which indicated an increase range of 0.15- 0.37 °C every decade (NMA, 2007, Mengistu et al., 2014). Generally, most studies concur on the existence of a warming trend in Ethiopia in both the maximum and minimum temperatures over the past few decades.

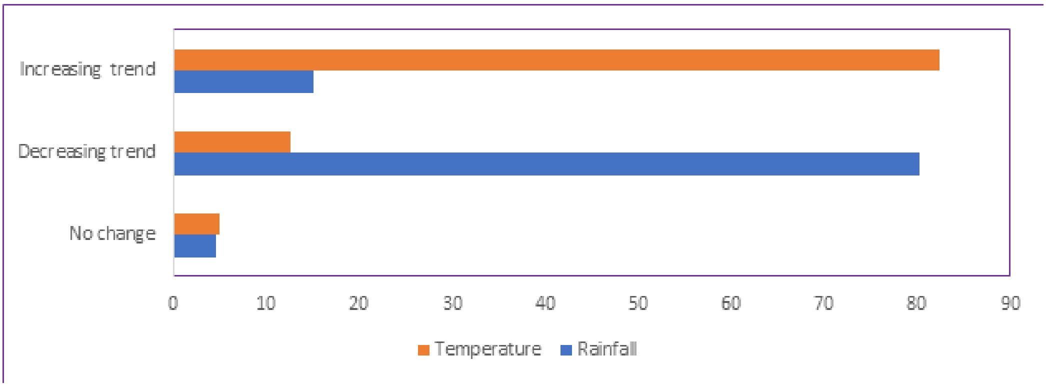


Figure 4: Local people's perception on the trend of temperature and rainfall for the last 30 years (Source: Own survey (2016).

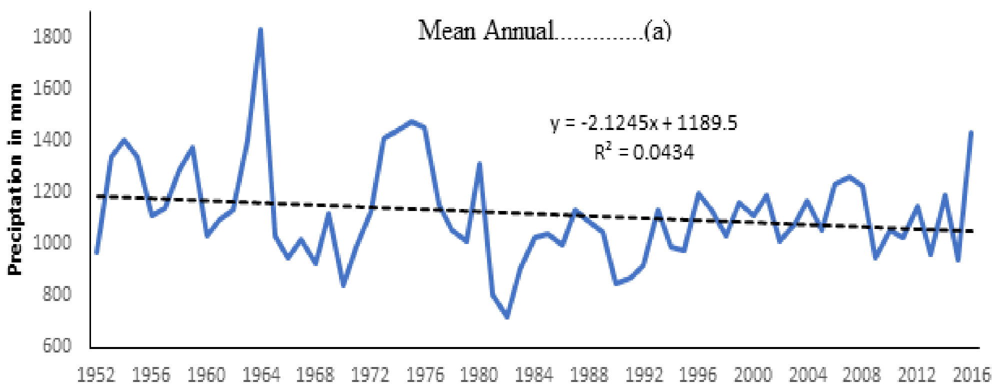
Mann-Kendall trend test for long-term monthly and annual minimum temperature revealed that there was statistically significant increasing trend for all months and year (Table 3). It is in agreement with the findings of Solomon et al (2015), Birhanu (2017), Mengistu et al. (2014) and Birhanu et al, (2017). Similarly, long-term trends of monthly and annual maximum temperature revealed that there was statistically significant increasing trend for all months and years except May (Table 3). This is also consistent with the findings of Birhanu (2017), Birhanu et al, (2017), Mengistu et al. (2014), Alemu and Dioha (2020) as well as Taye, et al. (2013).

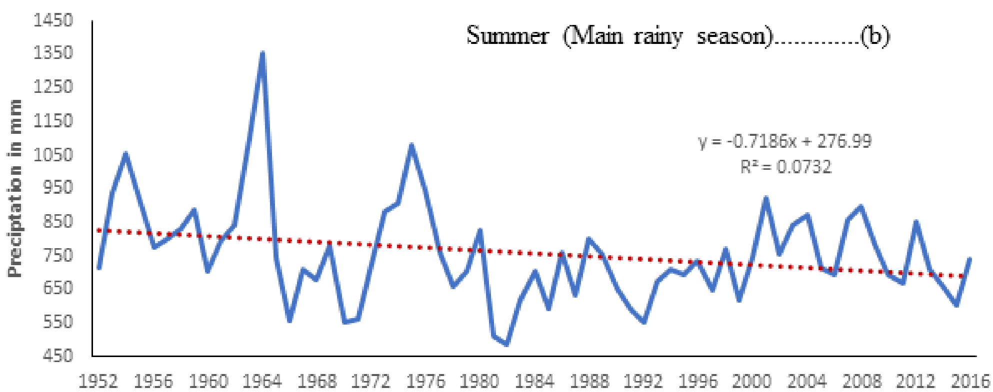
3.2 Spatio-temporal Variability and Change in Rainfall

The coefficient of variation (CV) for monthly and annual rainfall ranges from 0.17 to 1.37 which revealed low variability in temperature. Months of January (CV=1.56), February (CV=1.65) and December (CV=1.37) showed extremely high variability of rainfall. Moreover, as shown in Figure 5, the rate of change in rainfall which is determined by the slope of the regression line is about -2.1245mm/year, -0.7186mm/year and -0.1847mm/year for annual, summer and spring rainfall respectively during the periods of 1952–2016. The annual rate of reduction is higher which is caused by the reduction of the main (summer) rainfall season.

Very low values of rainfall anomaly corresponded to a severe drought period and the value in the study area ranges from +3.72 in 1947 to -2.08 in 1982. Historical droughts in Ethiopia had been linked with ENSO events in the past (Shanko and Camberlin, 1998; NMA, 2007; Daniel, 2011; Kassa, 2015). Recent documented droughts of Ethiopia in 1913–14,1920–21, 1932–331965, 1970, 1984, 1987, 1991–1992, 1993–94, 2002, 2009, 2012, 2015/16 were either coincide or follow El Nino events shortly.

As depicted in Figure 5, the rainfall anomaly for these drought years was found to be low. Similar output indicated that annual and summer rainfall had decreased by 21.2 and 7.2 mm/decade respectively. Table 5 revealed that 7.7%, 10.8% and 1.5% of the study years fall under moderate drought, severe drought and extreme drought respectively even though about 40 years (61.5%) is under near normal. Similarly, Girma et al (2016) reported that more than half of the study years have a negative anomaly. Precipitation concentration index generally uses for evaluating seasonal precipitation changes to investigate the heterogeneity of monthly rainfall data. It is a powerful indicator for temporal precipitation distribution. In this study, the precipitation concentration index (PCI) values were ranged from 15.85 to 29.02 as shown in Table 6. The precipitation concentration index (Table 6) revealed that there is high and very high concentration of rainfall. That means the precipitation in the study area is concentrated in short period of time mainly in two or three months of rainfall probably in summer season only. Thus, concentrated rainfall has impact on the agricultural production by reducing the availability of water for crop consumption.





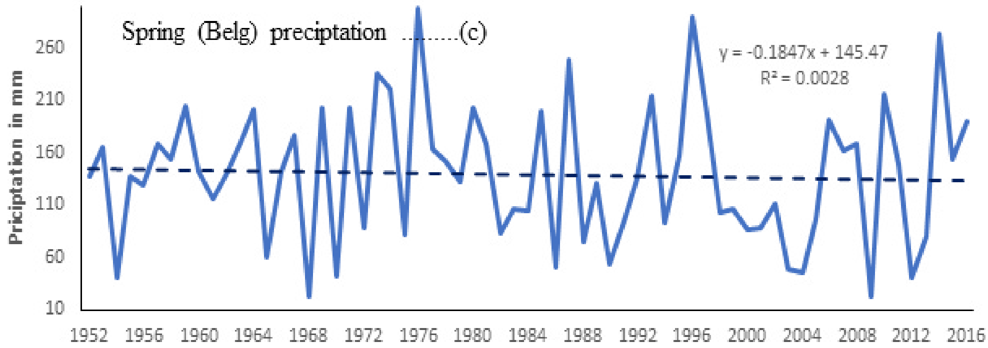


Figure 5. Trend of rainfall from 1952-2016 (a) mean annual, (b)summer and (c) spring

Table 5. Standardized Rainfall Anomaly Index

Drought Category	Rainfall Anomaly Index	Frequency	Percent
Extreme Drought	<-1.65	1	1.5
Severe Drought	-1.65 to -1.28	7	10.8
Moderate Drought	-1.28 to -0.84	5	7.7
Near Normal	-0.84 to 0.99	40	61.5
Moderate Wet	1.0 to 1.49	6	9.2
Very Wet	1.5 to 1.99	5	7.7
Extreme Wet	>2	1	1.5
Total		65	100.0

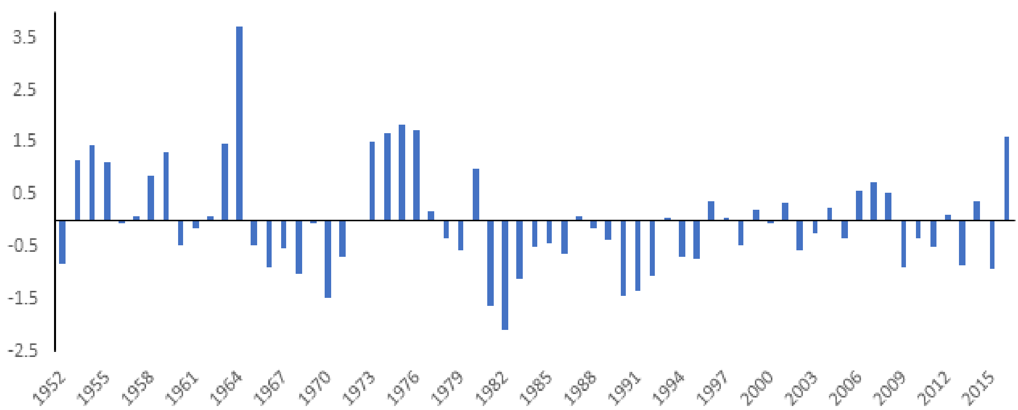


Figure 6. Standardized rainfall anomaly Index

In detail about 40 and 23 years were found to have high and very high concentration of rainfall respectively (Table 6). Arragaw and Woldeamlak reported similar high concentration of rainfall (2017) in central highlands of Ethiopia. Moreover, similar to this study Belay (2014) revealed that there is moderate to high precipitation concentration in Central Rift Valley in Ethiopia. Furthermore, Hagdu et al. (2013) reported that high and very high concentration of precipitation in Northern Ethiopia (Tigray). On the contrary, Ayalew et al. (2012) reported that moderate to high inter-annual rainfall concentration in Amhara region. The lowest value of PCI (<10) indicating the perfect uniformity in rainfall distribution or same amount of rainfall occurs in each month of the year.

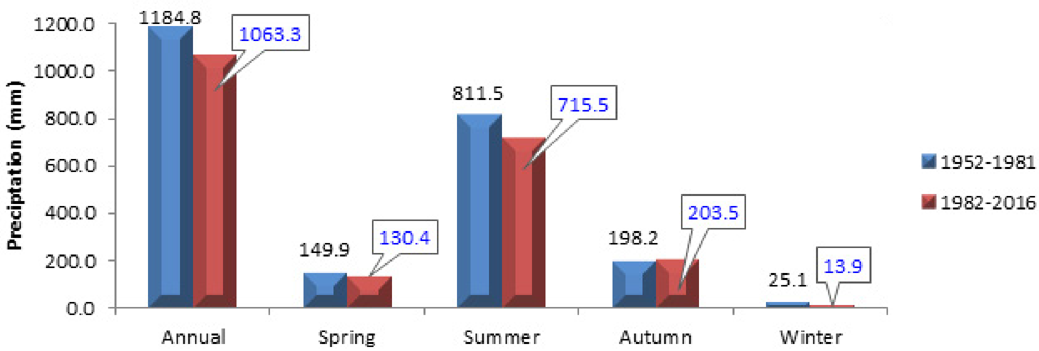


Figure 7. Average seasonal and annual rainfall in three decades (before and after 1981)

Table 6. Precipitation Concentration Index

Index	Description	Number of years (1952–2016)
<10	Low precipitation concentration (almost uniform)	0
11–15	Moderate concentration	2
16–20	High concentration	40
>21	Very high concentration	23
Mean PCI (1952–2016) = 19.91 (High concentration of precipitation)		

Figure 7 revealed that the annual rainfall of three decades (1952-1981) was 1184.8mm. However, after three decades (1981-2016), the annual rainfall became 1063.3mm. Except autumn, in the annual, spring and winter seasons the rainfall is reduced by 121.5mm, 19.5mm, 11.2mm respectively. Statistically, independent samples t-test was employed to compare the mean difference in annual rainfall between 1952-1981 and 1982-2016. Statistically significant mean difference was obtained (t (62) = - 2.46; p =0.017) at 95% level of significance. The mean annual rainfall for the periods 1952–1981 (mean =1184.8) was statistically higher than the mean annual rainfall of the Woreda for the periods of 1982-2016 (mean =1063.3). The result revealed that rainfall has been decreased after three decades. This is in agreement with the farmers' perception which indicated that rainfall is decreasing over the last three decades (Figure 4). Similar to this study Amogne et al. (2018) reported the empirical climatic result is in agreement with the farmers' perception.

Similar concept to the precipitation concentration index, seasonality index of precipitation is a method used to test the seasonality pattern of the precipitation. Therefore, Table 7 below depicted those 38 years from the total study time (65 years) are markedly seasonal with long drier season. Similarly, 22 years received most rain in three months or less. Generally, the rainfall of the study area ranges from seasonal to extremely seasonal (Table 7). This has an impact on rainfall dependent livelihood communities in the study area.

Table 7. Seasonality Index of Rainfall

Rainfall Regime	SI Class limits	Frequency
Very Equable	< 0.19	0
Equable but with a definite wetter season	0.20 - 0.39	0
Rather seasonal with a short drier season	0.4- 0.59	0
Seasonal	0.60- 0.79	3
Markedly seasonal with long drier season	0.80- 0.99	38
Most rain in 3 months or less	1.00- 1.19	22
Extreme, almost all rain in one-two months	≥1.2	2
Total		65

The spatial variability of rainfall is interpolated using meteorological stations climate data from four stations of Gondar, Maksegnit Tikil-Dengay and Robit. It is interpolated to the Woreda shapefile using inverse distance weighting (IDW) method. Figure 8 illustrated the spatial variability of the mean annual rainfall (mean annual rainfall of 12 years (2005-2016) were considered since the maximum available climate data of Tikil-Dengay station is 12 years) to the study Woreda. The interpolated data showed that rainfall ranges from 997.055 mm (lowest) to 1209.28 mm (highest). Most part of the central plains (part of Maksegnit, Teda, Degoma) received less rainfall than the Southeastern and Northwestern highlands in the study Woreda. Therefore, the different places which are found within short geographical distance in the Woreda received different amount of rainfall at the same time period. This may be due to differences in elevation, topography and agroecology.

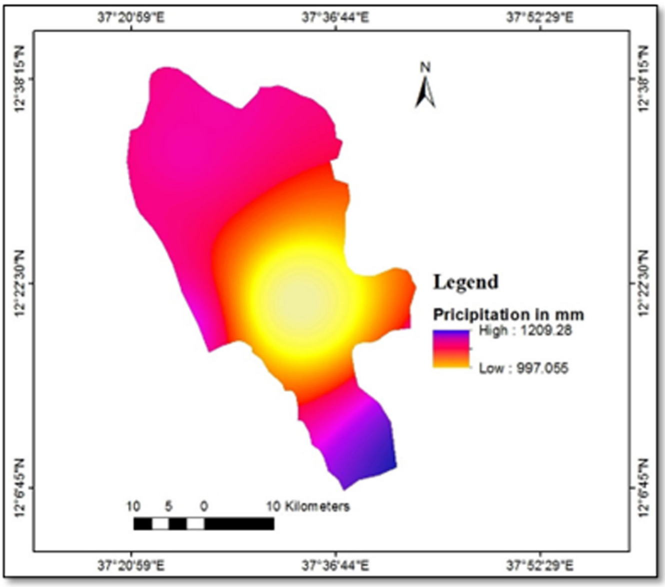


Figure 8; Special Variability of Rainfall in the Woreda (own computation, 2016)

Conclusion

Generally, the study area is characterized by increasing perceived and observed temperature, and decreasing perceived and observed rainfall with very high temporal and seasonal variability of rainfall. Moreover, changes in temperature and rainfall were occurred in the study area after the periods of 1980s. In terms of rainfall distribution, the rain begins late, and it quits relatively early which negatively affected particularly agricultural activity. A statistically significant increasing minimum and maximum temperature trend was observed in the study area. However, the annual and summer rainfall have revealed statistically insignificant, but the trend has been declining which is in line with the perception of local community. Moreover, rainfall in the study area is characterized by high coefficient of variation, erratic, unreliable and concentrated into two months. Therefore, this study suggested that climate-dependent sectors such as agriculture (both crop and livestock) and water resource developments are already highly exposed to current climate-related risks, and the future climate change will be another burden. Therefore, a sustainable climate risk management approach is recommended to adapt to the ongoing impacts of climate variability, and climate change in the study area. Finally, further study is recommended to investigate the future projected climate change interms of temporal and spatial basis.

Author Contributions

AM has made substantial contribution in: conception of the design, acquisition of data, interpretation of results and leading the overall activities of the research. He has contributed in designing, data analysis, interpretation, manuscript preparation and submission. He has given also the final approval of the version to be published. Similarly, GG has contributed in designing, data analysis, interpretation, manuscript preparation and submission. He has given also the final approval of the version to be published.

Conflict of interest

The authors declare there is no conflict of interest.

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