Environment, Development and Sustainability (2021) 23:12904–12924
https://doi.org/10.1007/s10668-020-01192-0

Time-series trend analysis and farmer perceptions of rainfall and temperature in northwestern Ethiopia

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Received: 8 December 2019 / Accepted: 21 December 2020 / Published online: 29 January 2021

Abstract
Smallholder farmers are the most vulnerable community to climate change in Ethiopia since they rely heavily on the subsistence rain-fed farming system. Thus, better climate change adaptation strategies need to be identified and implemented. This study aimed at identifying the farmers' perceptions of climate change and time series trend analysis of precipitation and temperature in northern Gondar Zuria District, Ethiopia. Data were gathered using a questionnaire from the institutional, socio-economic, and bio-physical situation of the 121 sample households. The survey data were analyzed using SPSS software version 21, XLSTAT software, and excel spreadsheets. The climate change trend analysis was conducted using monthly precipitation, which has been downloaded from free online resources such as Global Precipitation. The temperature data were collected using the Climate Centre and Climate Research Unit with 0.5 by 0.5 degree resolutions from 1980 to 2013. The climate variable data have been analyzed using a precipitation concentration index, anomaly index, coefficient of variation, simple linear regression, and Mann–Kendall test. The result revealed that for the main rain season (summer), a statistically insignificant decreasing trend was obtained. In the Belg season, there was a growing trend of precipitation. The max monthly and annual temperatures have increased significantly over time. However, the min temperature trend shows a non-significant increasing trend over the 1980–2013 periods. The recorded monthly precipitation and temperature data trend analysis were similar to the farmers' perceptions of changes in temperature and rainfall over the past 30 years. Therefore, we recommend possible adaptation strategies designed for climate change. Particularly, countries whose economy is dependent on rain-fed agriculture should pay attention to the increasing trend of temperature and the decreasing and unreliable nature of rainfall.

Keywords Climate change · Mann–Kendall test · Rainfall · Temperature · Farmers' perception · Gondar Zuria District

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1 Introduction

Currently, climate change is documented as one of the greatest challenges of our world. It has adverse effects on the world's ecosystems, economies, and societies. However, the severity of adverse effects varies across countries, regions, and socio-demographic groups because of their differences in exposure, sensitivity, and adaptive capacity (IPCC 2014). Mostly, developing countries are the most adversely affected by the negative effects of climate change because of their low level of adaptation (Abid et al. 2015; Mobeen et al. 2017). Climate is one of the fundamental elements of the earth system. In a general view, climate is the statistical explanation of the mean and variability of the respective quantities over a span of several decades (Panda and Sahu 2019). Climate change is characterized as one of the planet Earth's most fundamental and inevitable environmental issues. Although climate change has already been perceived through temperature and rainfall changes in Ethiopia, its extent is poorly examined at a regional level (Ayalew et al. 2012). Globally, the variability of rainfall over time and space influences all aspects of human life, especially agricultural economies and social activities. It is essential to identify accurately patterns in seasonal rainfall due to the high dependence on rain-fed farming in Ethiopia. The key reason for this is to establish seasonally predictive models on a large scale in Ethiopia, as they will bring many benefits for the growth and achievement of environmental sectors that meet the demand for food and water of their people (Alhamshry et al. 2020).

Agriculture employs more than 60% of employees from the active population and, on average, up to 40% of gross domestic products (GDP) in Sub-Saharan countries (Kandji et al. 2006; FAO 2016). However, it is affected considerably by the negative effect of climate change (Kandji et al. 2006). Like other Sub-Saharan countries, agriculture is the most important sector in Ethiopia. Ethiopia is among the most vulnerable countries to the negative impacts of climate change because of its high dependence on rain-fed farming (World Bank 2010). Agricultural production is highly constrained by temporal and spatial variations of climate in the country (Assefa et al. 2008; Weldlul 2016). World Bank (2003) recorded that droughts could decrease households' farm production by up to 90% of normal output over the years and could lead to the death of livestock and human beings in Ethiopia. The precipitation is unpredictable and ineffective in most parts of the country, so its associated droughts have historically been the main cause of food scarcity and famines (Abiy et al. 2014). According to Von (1991), a decrease of 10% over the long-term average in seasonal rainfall typically leads to a 4.4 percent decline in the country's food production. In the arid and semiarid areas of Ethiopia, historically, a large number of people have been affected recurrently by drought and/or flooding in the recent decade, which led to the death of people and loss of assets (Yohannes and Mebratu 2009).

According to the World Bank (2003, 2018) report, the Amhara region is among the most climate sensitive areas in Ethiopia. The rise in temperature and the decrease in precipitation have become serious problems that often affect farming in the region. Consequently, drought is the region's most prevalent climatic shock (Misganaw et al. 2014). The Gondar Zuria District in Central Gondar Zone has suffered from climate extremes, manifested in the form of low rainfall and flood. The district is highly affected by climate change, and agricultural production is declining from time to time (CSA 2016).

Temperature and precipitation are the two most significant factors that are frequently used to demonstrate the magnitude and extent of climate change in climate science (Sklenicka 2002; IPCC 2007). Therefore, the analysis of these climate variables using time series trends is very important. It helps to provide input for decision-makers for the management of drought, control of flood, and planning of water harvesting technologies. It is also important to recommend possible climate change adaptation strategies. Therefore, it is essential to carefully observe, record, and analyze temperature and precipitation data (Abeysingha 2014; Tabari and Talaee 2011).

Numerous studies have been carried out on pattern analysis of temperature and rainfall in other areas of Ethiopia, with various time series analysis and variety of objectives. Kozan (2020) claimed that the spatial and temporal rainfall variability needs to be understood in order to understand the effect of drought on local ecosystems. According to the study by Alhamshry et al. (2020), precipitation is Ethiopia's largest meteorological parameter, as approximately 80% of Ethiopia's labor is working in rain-fed farming which is very dependent on low or high availability of rainfall. In the analysis of rainfall patterns and the results of meteorological stations, Cochrane et al. (2020) have found that many aspects are convergent as well as divergent. In the light of further climate change, it will become increasingly important to pass on meteorological information to the farmers and their livelihood. The results of the studies conducted by Prasada and Solomon (2013) and Betelhem (2014) revealed that there has been a statistically significant increasing trend of monthly mean max and min temperature and a general tendency toward decreasing rainfall in Ethiopia. The degree of variation in the amount of rainfall was higher for the Belg season than the Kiremt season. According to Seid's study (2014), the trend analysis indicated that annual rainfall in Ethiopia decreases by about 46.75 mm per year. Moreover, the study findings by Bewket (2010) revealed the statistically insignificant decreasing trend of rainfall. Woldeamlak (2007) indicated that the amount of rainfall and variability in the northwestern region of the Amhara area differ between intra-annual and intra-regional rainfall levels.

There is a strong awareness that Africa's vulnerability to climate change is higher than in most other areas. Owing to the physical changes expected in the environment and the need to adapt to those changes, this vulnerability can be divided into exposure. The high proportion of vulnerability in Africa stands in stark contrast to its exposure to global greenhouse gas emissions. The relationship between climate and humanitarian disaster has concentrated more on Ethiopia than almost any other country in Africa, partly due to a number of drought events that have resulted in famines requiring humanitarian intervention (Dyer et al. 2019). The rainfall and temperatures are the most critical physical parameters in the atmosphere. This determines the environmental status of the region, which affects agricultural productivity. There was no extensive study in Gondar Zuria District. However, the country is located in the most drought-prone areas. Therefore, the novelty of this study is threefold: (i) detecting climate variables (i.e., rainfall and temperature) trends carefully in Gondar Zuria District, Northwest Ethiopia, (ii) providing a better picture of climate change and climate change trends in Gondar Zuria District, and (iii) applying a trend analysis on the basis of historical data for annual, total, summer and Belg rainfall from 1980 to 2013 using descriptive and statistical tests that have not been investigated before. Hence, this study can be used as baseline data for designing and implementing effective agricultural adaptation strategies to climate change. In addition, it can be used to inform decision-makers, which in turn enhances farmers' capacity to adapt to climate change in the study area.

2 Materials and method

2.1 Description of the study area

Gondar Zuria woreda (District) is located in Central Gondar Zone, Amhara Regional State, Northwest Ethiopia (Fig. 1). The zone consists of 11 Districts, including Gondar Zuria District. Gondar Zuria District consists of 41 rural and 3 urban Kebeles (subdistricts) (Digafe et al. 2015). The study area has a semiarid climate with low and irregular bimodal rainfall types like Belg and summer. The Belg season is mostly from February to April/May, and the summer lasts for four months from June to September with the max rainfall in July. The mean min and max monthly temperatures of the district were recorded as 29.96 °C and 15.72 °C, respectively, during April. The District is situated at 1500–3200 a.m.s.l. (above the mean sea level) and falls into two agro-ecological zones called Weyna Dega (72%) and Dega (28%). It develops two soil types namely Nitisols and Vertisols. The District has a total of 38,383 households which comprises 30,325 males, and 8058 females. The District's total population is 230,033: 118,107 are males; 111,926 are females, and 201,880 and 28,153 people live in rural and urban centers, respectively.

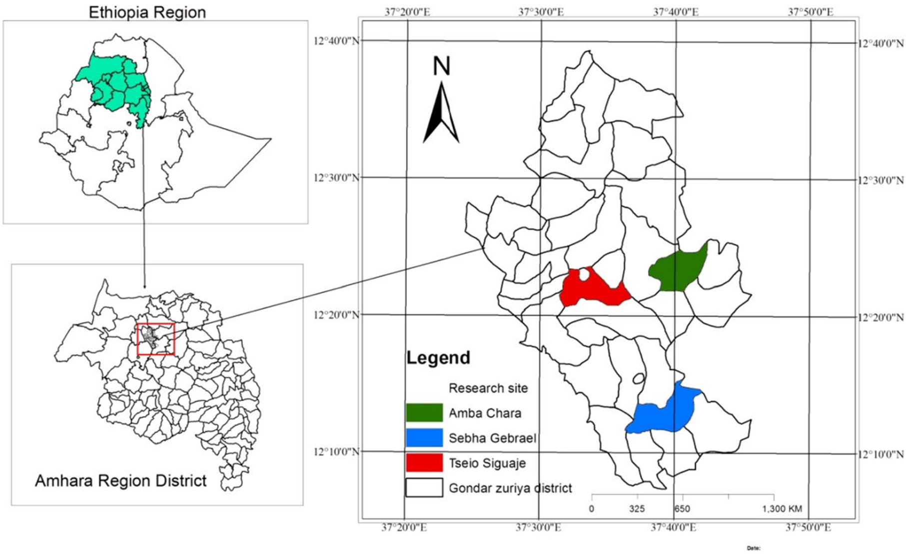

Fig. 1 Map of the study area

3 Research design

This study employed a mixed research design by combining quantitative (survey) and qualitative (case study) approaches. In this mixed research design, more weight was provided for the quantitative approach, rather than the qualitative one. In addition to the quantitative data obtained from key informant interviews and field observations, qualitative data were used for clarifying the interpretation or describing the findings in greater detail. With regard to the sequence of the analysis, both quantitative and qualitative data were simultaneously obtained from a concurrent sample.

3.1 Data type and source

Both primary and secondary sources had been used in this study. The primary data were obtained using a questionnaire on the social, institutional, and biophysical aspects of the sample households. Monthly precipitation and temperature data were obtained from a free online climate explorer called KNMI Climate change atlas.[1] Full monthly precipitation data were collected from the Global Precipitation and Climate Centre (GPCC V7),[2] and data on temperature were obtained from the Climate Research Unit (CRU TS 3.23)[3] with 0.5 by 0.5 degree resolutions from 1980 to 2013. GPCC's data are the most comprehensive gridded rainfall dataset available which is based on measurements from over 80,000 stations worldwide. In this study, the precipitation dataset covered a period ranging from 1980 to 2013. The GPCC rainfall data set for the adopted resolution is known to provide reasonable estimates in Ethiopia (Amogne et al. 2018). The CRU Climate Dataset produced by the Climate Research Unit is also gridded at a resolution of 0.5 degrees at the time of this study, with data available at a monthly time-step from 1980 to 2013. The CRU data set is again based on long-term observations from several thousand stations worldwide. The CRU data set has also been used in various climate change studies and is known to provide reasonable estimates of temperature. In addition, climate change analysis requires a min of 30 years of precipitation and recorded temperature data. Such adequate recorded precipitation and temperature data were therefore obtained from GPCC and CRU as well as other free online satellite data sources such as Cent Trends.

In this study, datasets were used for climate change analysis, and data validation and homogeneity tests were conducted. The satellite grided data collection is very useful when the weather station is small in size, scattered unevenly and there are a short observation time. Data validation was conducted on the basis of Bahir Dar Regional Meteorological Station records from 1980 to 2013 along with GPCC/CRU satellite data on precipitation and temperature. The findings showed that the rainfall data collected from the GPCC were closely correlated with the gauge station data as compared with the CRU data. Gondar Zuria District rainfall data at the gauge station were noted to be strongly correlated with GPCC (i.e., $r = 0.580$, $p < 0.001$). A nonparametric Kolmogorov–Smirnov test was also determined to check if the data from the gauge station and the satellite followed the same

[1] https://climexp.knmi.nl/plot_atlas_form.py.

[2] http://www.cgd.ucar.edu/cas/catalog/surface/precip/gpcc.html.

[3] https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_3.23/.

pattern. As the findings for CRU ($p<0.001$) were significant and the two samples were distributed differently, there was an exceptionally strong consensus between the GPCC V7 grids of precipitation and the rainfall data from the gauge station. In this study, the related literature and secondary data have been obtained from journal articles (downloaded from Google Scholar, Science Direct, and Web of Science), annuals, and Intergovernmental Panel on Climate Change reports.

3.2 Sampling procedure and sample size determination

The multistage sampling procedure was used to select the sample respondents and obtain adequate representation for this study. First, out of the 11 rural districts, the Gondar Zuria District was selected purposively as it is among the drought-prone areas. Moreover, farmers who live in the district are dependent on climate-sensitive agricultural productions, particularly livestock and crops which are the most vulnerable and affected ones by recurrent drought. The frequency and magnitude of droughts have increased from time to time and have affected their production. Second, Gondar Zuria District has 44 rural kebeles and out of these kebeles, the researcher has selected three kebeles, i.e., Amba Chara, Sabah Gebriale, and Tseion Siguaje Kebeles by lottery method. Third, of the selected three kebeles, the sample of households from the total population of 16,779 and 3,290 households was selected on the basis of the proportion of the size rule. The sample size was calculated using the formula proposed by Watson (2001):

$$n = \frac{\left[\frac{p\times(1-p)}{(A^2/Z^2)+P\frac{\times(1-P)}{N}}\right]}{R} \tag{1}$$

where n is the required sample size, N is the number of households, A is the degree of precision level (8%), Z is the value of 1.96 (based on confidence level), P is the estimated variance in a population as a decimal (0.5 for 5–50, 0.3 for 70–300), and R is the estimated response rate. Therefore, $N=3290$, $A=$desired margin of error 0.08, $Z=$value 1.96, $P=$estimated variance 0.3, and $R=$assuming the response rate is 100%.

For survey research, the response rate is typically expressed in the form of a percentage, also known as the completion rate. According to Curtin et al. (2000), the response rate of an inquiry was seen as a significant measure of the quality of the survey. The sample size calculated from the equation was 121.4 households. Then, the researcher has used the sample size of approximately 121, which is believed to be representative of the study (Annex 1).

Finally, using a systematic sampling method, households were selected from each of the three Kebeles. In this case, the lists of the households were first collected from the manager of each Kebele and health extension experts. Moreover, the researcher generated a random number table from the Microsoft excel sheet and provided a rank for table numbers. This means that there are N units (i.e., 3290 households) in the sample of kebeles and n units (121 households) in the sample of selected households. Then, the sampling interval was determined using the following equation:

$$R = N/n \tag{2}$$

where R is the sampling interval, N is the total number of households, and n is the desired sample size.

The first number is selected at random from a random number table before providing a rank for table numbers, and then, every nth element is selected until the desired number is secured by R (i.e., $R = 27$) plus the first selected random number.

3.3 Data collection methods

A semi-structured questionnaire, field observation, and a main informant interview gathered data from 121 sample selected households and 10 main informants. Skilled data collectors who were university students are responsible for them. The main role of the researchers was acting as supervisors. Four data collectors were given a short orientation and preparation. In the first 3 weeks of January 2017, the data were collected. Over the course of the study, field monitoring has been carried out to ensure the quality of the information gathered. The researchers have carefully selected main informants. The interview was conducted with 10 key informants, including three local leaders, four model farmers, and three experts from the agriculture and rural development office of the area (Annex 2).

3.4 Data analysis

The data were evaluated using the Statistical Package for Social Science (SPSS) version 21, XLSTAT software, and excel spreadsheets. The percentages, frequencies, and means were used to reflect farmers who experience long-term temperature and rainfall changes and to illustrate the different socioeconomic characteristics of the households being sampled. In climate change trend analysis, the following techniques were used.

3.4.1 Simple linear regression

The long-term trend and temperature variability and precipitation values at an annual time scale were identified and characterized by a simple linear regression. The linear regression demonstrates whether the trend is positive or negative. The simple linear regression line was calculated using Eq. (3).

$$Y = \beta X + c \tag{3}$$

where Y is the rainfall and temperature change during the period, β is the slope of the regression equation, X is the number of years from 1980 to 2013, and $c =$ constant regression.

3.4.2 The coefficient of variation (CV, %)

The (CV) was used in order to evaluate the variability of the rainfall by comparing different years of rainfall with different means. CV demonstrates the extent of data variability in the sample relative to the mean population. It is a unitless variation measure and is defined as the standard deviation divided by the mean, multiplied by 100% (Canchola et al. 2017). The coefficient of variation was calculated using Eq. (4).

$$CV = \sigma/\mu \times 100\% \tag{4}$$

where σ is a standard deviation, and μ is the mean precipitation.

3.4.3 Precipitation concentration index (PCI)

The PCI is used to analyze the rainfall variation at various (annual or seasonal) scales. PCI was used to estimate the monthly heterogeneity of rainfall (Olive 1980). As indicated by Oliver (1980), the values of PCI have the following classifications: low precipitation concentration (<10) which indicates a uniform monthly distribution of rainfall, moderate concentration (11–15), high concentration (16–20), and very high concentration (>21). In determining the variability of rainfall at different scales (i.e., annual or seasonal), PCI was calculated using the following equation:

$$\mathrm{PCI}_{\mathrm{Annual}} = \frac{\sum_{i=1}^{12} P_{\mathrm{i}}^{2}}{\left(\sum_{i=1}^{12} P_{\mathrm{i}}\right)^{2}} \times 100 \tag{5}$$

where P_{i} stands for the rainfall amount of the ith month, and Σ stands for annual summation.

3.4.4 Standardized anomalies of rainfall

The standardized anomalies of rainfall have been used in previous studies (e.g., Taye et al. 2013; Getachew and Tesfaye 2014) to (a) determine the dry and wet years, (b) evaluate the nature of the trends, and (c) assess the frequency and severity of droughts in their studies. According to Agnew and Chappel (1999), they were classified based on the value of a standardized rainfall anomaly to show the drought severity of an area. The standardized anomalies of rainfall were calculated using the following equation:

$$Z = \left(X_i - \mu\right)/S \tag{6}$$

where Z is the anomaly of standardized rainfall, X_i is the rainfall in one year, μ is the long-term average mean rainfall over the observation period, and S is the standard deviation of the average rainfall over the observation period.

3.4.5 Mann–Kendall test (MK test)

Ampitiyawatta and Guo (2009) reported that the Mann–Kendall (MK) trend test is a very common nonparametric test to detect a pattern in various research fields. The results of the MK test are based on the signs (+ or −), rather than the random variable values. The MK check shows therefore that the outliers do not impact the pattern (Birsan et al. 2005). The nonparametric Mann–Kendall test was used in this analysis to detect the existence of increasing or decreasing rainfall and temperature patterns, and whether or not the trend is statistically significant in the analysis field. The study of climate change pattern tests was carried out in the Belg and summer seasons both annually and monthly. The initial value ‘S’ is assumed to be 0 (no trend) (Kendall 1975; Yue et al. 2002). If a later data value is greater than an earlier data value, then S is increased by 1. However, S is decremented by 1 if the later data value for the period of time is less than the previous data value. The net product of increases, as well as decreases, yields the final value of S. MK test statistic ’S ’is computed using Eq. (7).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(X_j - X_i\right) \tag{7}$$

The trend test is applied to X_i which is the time series ranked as i = 1, 2, …, n-1, and X_j which is the time series ranked as j = i + 1, 2, …, n. Each of the X_i data points is taken as a basis of comparison for the rest of the X_j data points.

4 Results

4.1 The perception of farmers of climate change

It is very important to look at their understanding of each parameter/indicator to gain crucial knowledge and insight into farmers’ adaptation to climate change. Awareness of farmers’ understanding of the characteristics of climate change in the study region is, therefore, an important topic to be discussed. Two recognized climate attributes have been used for this reason, namely temperature and precipitation.

4.1.1 Perception of temperature changes

As shown in Fig. 2, about 81% of the respondents perceived that the temperature is increasing in the area. This means that the large number of farmers in the study region is aware of climate change and expect a higher temperature. Although 9.1% of respondents did not note any temperature shifts, 6.6% of farmers observed a decrease in temperature, and 3.3% of farmers considered an unusual temperature trend over the past 30 years.

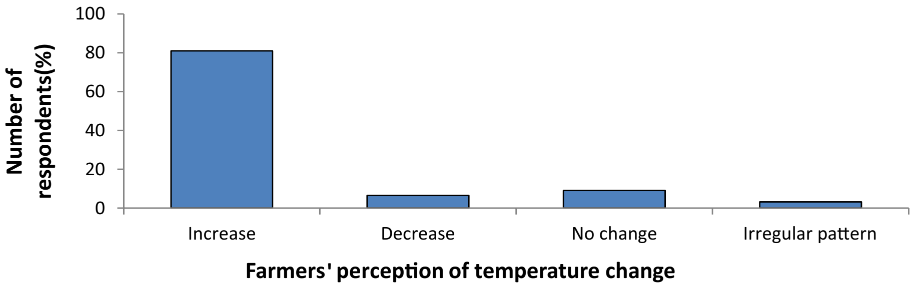

Fig. 2 Farmers’ perception of temperature change

4.1.2 Perception of precipitation changes

About 78% of the respondents reported changes in rainfall patterns and a decrease in rainfall amount over the past 30 years (Table 1). This may imply that the farmers of the study area are aware of the main indicators of climate change in terms of fluctuation of the rainy period and a decrease in rainfall. About 9.1% of the respondents perceived that there was an irregular pattern of precipitation.

Nearly 8% of the respondents noticed no change in the amount of rainfall. About 5% of the respondents noticed an increase in the total amount of rainfall over the past 30 years.

Table 1 Farmers' perception of precipitation change

Precipitation	Frequency	Percent
Increase	6	5.0
Decrease	94	77.7
Remain the same	10	8.3
Irregular pattern	11	9.1
Total	121	100.0

4.2 Rainfall and temperature variability trend analysis

In this study, before analyzing climate changes, data validation was performed for trend analysis of rainfall and temperature. The result revealed that the meteorological station precipitation data of Gondar Zuria District were highly correlated with those of Global Precipitation and Climate Centre (GPCC) (i.e., $r = 0.580$, $p < 0.001$). However, the weather station's correlation coefficient of precipitation with the climate research unit (CRU) was low and insignificant (i.e., $r = 0.197$, $p = 0.265$). In addition, a nonparametric Kolmogorov–Smirnov check was conducted to see whether the meteorological station and satellite data followed the same distribution or not. p-value was not statistically significant ($p = 0.085$) and was greater than the required threshold ($p = 0.05$). It shows that the GPCC V7 data and meteorological station data follow the same distribution. However, the CRU rainfall data and station data are different because the p-value was statistically significant ($p = 0.000$). As a result, the compatibility of station data with GPCC V7 is better than the CRU data.

4.2.1 Rainfall variability

The monthly rainfall distribution in Gondar Zuria District was found to be variable. The monthly coefficient of variation (CV) lies between 14.14 and 173.01%. It was found to be the highest during February (173.01%) and January (168.16%), and the lowest during August (14.14%) and July (15.83%). The mean annual rainfall was found to be 1272.68 mm, which was equal to 12.73% of the CV. As shown in Table 2, summer is the main rainy season, leading to about 79.40% of the total rainfall (where about 51% falls in just two months: July and August, while September and June contribute to 13.9% and 14.8% of the summer rainfall, respectively). Belg is the shortest rainy season from February to April/May. It contributes to a significant amount of rainfall (around 12.0% of the total amount).

Table 2 Statistical properties of monthly, seasonal, and annual rainfall

Month	*N*	Min	Max	Mean	SD	CV (%)	%
Jan	34	0.02	13.45	2.01	3.38	168.16	0.16
Feb	34	0.00	27.53	2.89	5.00	173.01	0.23
Mar	34	0.48	72.11	16.50	18.85	114.24	1.30
Apr	34	2.68	214.21	40.20	39.68	98.71	3.16
May	34	13.38	205.08	92.95	44.37	47.74	7.30
Jun	34	75.11	296.54	188.85	51.02	27.02	14.84
Jul	34	229.22	468.97	331.84	52.52	15.83	26.07
Aug	34	204.79	431.94	312.84	44.22	14.14	24.58
Sep	34	91.21	242.99	177.04	35.86	20.26	13.91
Oct	34	20.81	210.23	86.14	46.49	53.97	6.77
Nov	34	0.71	52.99	16.95	12.51	73.81	1.33
Dec	34	0.10	17.55	4.48	5.04	112.5	0.35
Belg(FMAM)	34	36.71	335.85	152.54	67.60	44.32	11.99
Summer (JJAS)	34	732.13	1266.36	1010.57	121.86	12.06	79.40
Annual mean	34	841.03	1560.57	1272.68	162.00	12.73	100

Table 3 Precipitation concentration index (PCI)

Index	Precipitation concentration	Number of years
< 10	Low (almost uniform)	0
11–15	Moderate	1
16–20	High	27
≥ 21	Very	6
Mean PCI (1980–2013) = **18.92** (High concentration)		

Not only the monthly rainfall distribution but also the seasonal rainfall distribution was variable in Gondar Zuria District. The coefficients of variation (CVs) for this area during a year, Belg, and summer seasons were found to be 13, 44.3, and 12%, respectively. Therefore, the CV is found to be high during Belg season (44.3%) and low (12.1 and 12.7%) during the summer and the whole year, respectively, as indicated by Hare (2003).

Table 3 shows that a high and very high concentration of precipitation was present in Gondar Zuria District between 1980 and 2013. Similarly, Amogne et al. (2018) recorded high concentrations of rainfall in the central highlands of Ethiopia. On the basis of a study by Oliver (1980), the PCI values for Gondar Zuria District are 27 and 6 for the years 16–20 and ≥ 21, respectively.

4.2.2 Linear regression analysis of rainfall and temperatures

Figure 3 shows that there was an increasing trend of annual rainfall by 0.647 mm per year over the last 34 years. The annual distribution of rainfall showed that annual mean amounts were below the average (1272.68 mm) for 16 years (1982, 1983, 1984, 1986, 1987, 1990, 1992, 1994, 1995, 2002, 2003, 2005, 2007, 2009, 2010, and 2011). There was high rainfall variability in the Belg season which has shown an increasing trend from 1980 to 2013

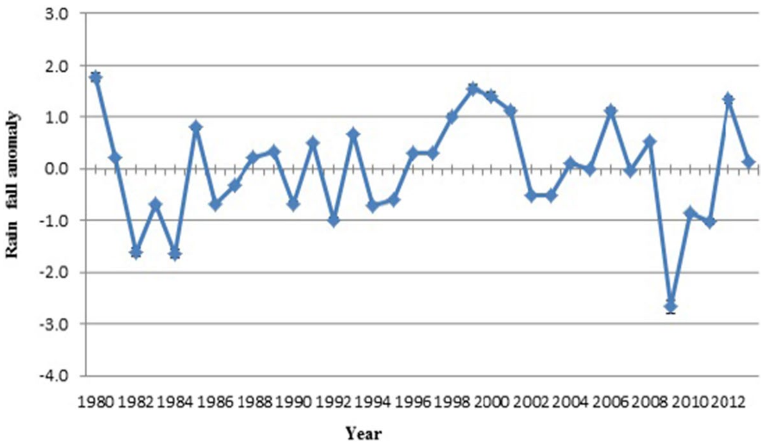

Fig. 3 Regression trend test of Belg, summer, and annual rainfall in mm

(Fig. 3). It has increased by 0.84 mm per year over the past three decades. On the other hand, summer rain has shown a decreasing trend; its amount decreased by 0.47 mm per year in the period from 1980 to 2013.

As it is shown in Table 4, the coefficients of variations were 12.7%, 44.3%, and 12.1% of annual, Belg, and summer rainfall, respectively. It indicates that there was a higher variability of rainfall in the Belg season between 1980 and 2013 compared with the summer season in the study area. The mean temperature in the study area ranges from 13.8 °C (min) to 28.1 °C (max).

Both annual mean max and min temperatures increased, and there was a change in temperature from one year to another (Fig. 4 and Table 4).

Table 4 Linear regression trend of Belg, summer, and an annual rainfall

Season	Change in rainfall (mm/year)	*p*-value	R^2
Belg	0.836	0.823 ^{ns}	0.015
Summer	– 0.467	0.830 ^{ns}	0.002
Annual	0.647	0.487 ^{ns}	0.002

^{ns}Not statistically significant at 0.05 alpha level

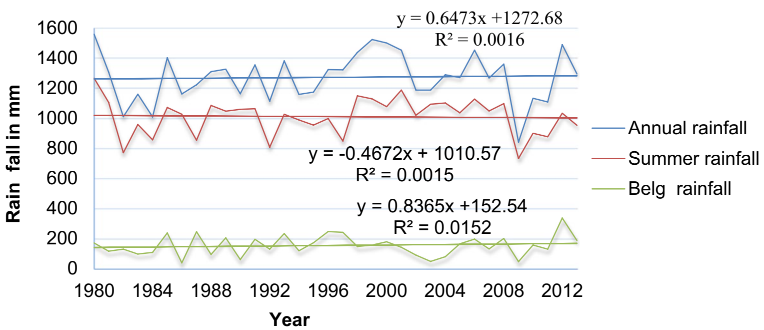

Fig. 4 Simple regression trend test of annual max and min temperatures

4.2.3 Rainfall and temperature Mann–Kendall trend analysis

A decreasing trend was found in the monthly rainfall trend analysis in September and February (both at $p<0.05$) which was statistically significant. There was a decrease in the summer wet season, but it was statistically insignificant (Table 5).

Table 5 Mann–Kendall trend test of monthly, seasonal, and annual rainfall

Month	MK (S)	Kendall's tau	*p*-value	Sen's slope	Trend
Jan	55.000	0.098	0.427	0.009	I
Feb	−5.000	−0.009	0.036*	−0.142	D
Mar	−11.000	−0.020	0.883	−0.014	D
Apr	45.000	0.080	0.517	0.361	I
May	−41.000	−0.073	0.556	−0.34	D
June	33.000	0.059	0.638	0.531	I
July	−31.000	−0.055	0.659	−0.416	D
Aug	−23.000	−0.041	0.746	−0.307	D
Sept	−13.000	−0.023	0.024*	−0.162	D
Oct	−3.000	−0.005	0.977	−0.044	D
Nov	−1.000	−0.002	1.000	−0.001	D
Dec	42.000	0.075	0.543	0.022	I
Belg	29.000	0.052	0.681	0.586	I
Summer	−9.000	−0.016	0.906	−0.197	D
Annual	39.000	0.070	0.576	1.731	I

I, increase; *D*, decrease

*Statistically significant at 0.05 alpha level

Table 6 Mann–Kendall trend test of the monthly and annual max temperature of the study area from 1980 to 2013

Month	Mean	MK (S)	Kendall's tau	*p*-value	Sen's slope	Trend
Jan	28.345	199.000	0.355	0.003**	0.040	I
Feb	29.923	237.000	0.422	0.000***	0.085	I
Mar	31.044	201.000	0.358	0.003**	0.050	I
Apr	31.596	237.000	0.422	0.000***	0.073	I
May	30.208	203.000	0.362	0.002**	0.056	I
June	27.415	106.000	0.189	0.120	0.026	I
July	24.878	61.000	0.109	0.374	0.017	I
Aug	24.575	2.000	0.004	0.988	0.000	I
Sept	26.092	91.000	0.163	0.182	0.018	I
Oct	27.644	113.000	0.202	0.097	0.020	I
Nov	28.290	162.000	0.289	0.017*	0.031	I
Dec	27.919	147.000	0.262	0.030**	0.034	I
Annual	28.345	275.000	0.490	0.000***	0.085	I

I, increase; *D*, decrease

*, **, ***Statistically significant at 0.1, 0.05, and 0.01 alpha levels

A positive, significant trend was found in this study on an annual and monthly basis for max temperature data. The Mann Kendall pattern test showed that, except for June, July, August, September, and October, a statistically significant rise in annual max temperature data was observed for the period from 1980 to 2013 (Table 6).

The negative statistically insignificant decreasing pattern in October and June was exposed by the Mann Kendall and Sen's Slope estimation test study of mean min temperature. In April, however, a statistically important upward trend was noticed (Table 7). As shown in Table 5, all months, except June and October, showed a growing trend in mean min annual temperature. This indicates that a growing increase has been expressed in the annual min temperature. As a result, the area has experienced rising temperatures and declining rainfall, indicating the presence of climate change in the area of Gondar Zuria District over the past 34 years.

5 Discussion

5.1 Perception of temperature and precipitation changes

Based on the results, most key informants explained that temperature has increased over the past 30 years in the study area. This study is in line with the studies of Rakib and Anwar (2016), Bryan et al. (2009), and Dereje (2014), who found that most respondents had reported that there was an increasing temperature in Ethiopia. In addition, more than 80% of farmers in Gondar Zuria District believe that the temperatures in the Gondar district were higher, and over 90% thought that the rainfall had changed, leading to a higher drought rate. It is useful to know what kinds of farmers are expected to see climate change — a major issue to understand how coping strategies are implemented.

The findings were confirmed by most of the key informants reporting that precipitation decreased from time to time in Gondar Zuria District. This study is supported by

Table 7 Mann–Kendall trend test of monthly and annual min temperature

Month	Mean	MK (S)	Kendall's tau	*p*-value	Sen's slope	Trend
Jan	10.617	71.000	0.127	0.302	0.012	I
Feb	12.140	122.000	0.218	0.073	0.024	I
Mar	14.644	11.000	0.020	0.882	0.002	I
Apr	16.155	141.000	0.252	0.038*	0.029	I
May	16.515	80.000	0.143	0.241	0.016	I
June	15.430	−6.000	−0.011	0.941	−0.001	D
July	14.905	83.000	0.148	0.224	0.011	I
Aug	14.587	26.000	0.046	0.711	0.002	I
Sept	14.083	66.000	0.118	0.335	0.008	I
Oct	13.741	−35.000	−0.062	0.617	−0.005	D
Nov	12.643	125.000	0.223	0.066	0.026	I
Dec	10.827	27.000	0.048	0.702	0.005	I
Annual	13.857	105.000	0.187	0.124	0.01	I

I, increase; *D*, decrease

*Statistically significant at 0.05 alpha level

Dereje (2014) who found that 75% of the investors perceived a decrease in precipitation in Ethiopia. Misgina and Simhadri (2015) also reported that, on average, 75% and 81% of the respondents observed the trend of declining rainfall and increasing temperature in Ethiopia, respectively. About 81% of the respondents perceived that the temperature has increased, and about 78% of the respondents reported changes in rainfall patterns and a decrease in their amount over the past 30 years in the study area. It has been concluded that the analysis of farmers' perception of precipitation and temperature changes revealed that there was a climate change over the past 30 years in Gondar Zuria District.

5.2 Rainfall and temperature variability

The degree of variation in the amount of rainfall was higher for Belg season compared with annual and summer rainfalls in Gondar Zuria District. This implies that compared with the summer season, there is more interannual variability in Belg season's rainfall. The current finding was similar to the reports by Aklilu (2006) and Viste et al. (2013) who found more variability in Belg rainfall compared with the summer rainfall in most parts of Ethiopia. Woldeamlak and Conway (2007) also reported more rainfall variability in Gondar in Belg season with the CV value of 48% compared with annual and summer rainfalls with the CV values of 17% and 22%, respectively. Furthermore, according to the study by Betelhem (2014), the coefficients of variations of rainfall were reported as 23%, 46%, and 35% for annual, Belg, and summer rainfalls, respectively.

There was a very high concentration of rainfall in the years 1981, 1983, 1986, 1990, 2003, and 2009. The only moderate concentration of rainfall has been recorded in the year 1997 over the period from 1980 to 2013 in Gondar Zuria District. This implies that there was no uniform distribution of rainfall in Gondar Zuria District over the past 34 years. It has been concluded that the distribution of rainfall was not uniform in the study area from 1980 to 2013. According to Agnew and Chappel (1999), drought severity classes were equal to very low values of rainfall anomaly that corresponded to severe drought periods. The values of rainfall anomaly in Gondar Zuria District range from +1.8mm in 1980 to +2.7mm in 2009. As indicated in Fig. 5, an extreme drought year occurred in 2009 with the rainfall anomaly value of -2.7 (i.e., $Z<-1.65$), and the moderate drought year was 2010 with the rainfall anomaly value of -0.9 (i.e., $+0.84>Z>-1.28$). The severe drought years were 1982

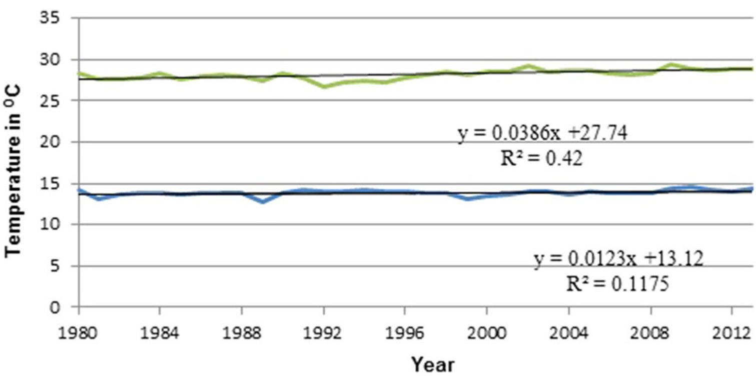

Fig. 5 Rainfall anomalies in Gondar Zuria District

and 1984, with rainfall anomaly values of -1.6 (i.e., $-1.28 > Z > -1.65$) in Gondar Zuria District.

This finding is consistent with the results of Webb et al. (1992) who stated that when a major drought hit Ethiopia in 1984 as a result of previous dry episodes, famine was already underway. Ellen et al. (2012) also found that 2009 was the only year between 1972 and 2011 in which extreme droughts occurred in all parts of Ethiopia. In the year 2010, there was also a moderate drought in the southern part of Ethiopia. The most severe droughts occurred in 1982 and 1984 in all parts of Ethiopia in the period from 1980 to 2013.

The regression analysis also revealed that both annual mean max ($p=0.000$, $R_2=0.420$) and min ($p=0.047$, $R_2=0.12$) temperatures were statistically significant at 0.01 and 0.05 alpha levels, respectively. This is similar to the perception of most farmers (81%) toward temperature changes. This is supported by Henock (2014) who found an increasing trend with a rate of 0.045 °C/year in annual mean max temperatures in Ethiopia. Therefore, annual mean max and min temperatures revealed an increasing trend with 0.04 °C and 0.01 °C per year, respectively. This implies that there was climate change in Gondar Zuria District over the past 34 years.

The Mann Kendall trend study, however, showed that there was an increasing increase in annual and Belg season rainfall although it was statistically insignificant. This is similar to the result of a study by Ambun et al. (2013), who recorded a decreasing trend in monthly rainfall in September and February. In addition, an investigation by Amogne et al. (2018) in Northern Ethiopia confirmed that rainfall in the summer season showed a declining trend. The Mann Kendall pattern test showed that, except for the months of June, July, August, September, and October, a statistically significant rise in annual max temperature data was observed for the period from 1980 to 2013 (Table 6). The outcome was in line with the result of the study by Birhanu et al. (2017). The mean annual average temperature increase generally showed a statistically significant rise in the temperature. A rise in mean monthly temperatures is causing the observed rise in the mean annual max temperature in the study region. Except for June and October, all months showed an increasing trend of mean annual min temperature. This suggests that the annual min temperature showed an increasing trend. Therefore, these results show the existence of climate change in Gondar Zuria District over the past 34 years.

6 Conclusions

In this study, most respondents perceived an increasing trend in temperature as well as a long-term change in rainfall amount and distribution. The time series trend analysis showed that there was a decreasing trend in summer season rainfall. There was inter-annual variability in the amount of Belg season rainfall, but it showed an increasing trend. In addition, both the average max and min temperatures showed an increasing trend. Due to increasing temperature and erratic rainfall, the area became prone to drought and experienced several drought years. As a result of changes in current climate patterns, such as the decrease in the amount of summer season rainfall, more frequent droughts, increasing temperatures, and shortening of rainy seasons, vegetation growth and crop production were observed in the study area.

Globally, rainfall variability affects every aspect of human life, especially farming and social activities, over time and space. Furthermore, rainfall is the most important weather parameter in Ethiopia, since about 80% of Ethiopian laborers are employed in rain-fed agriculture that depends heavily on low or high availability of precipitation, which is critical for precipitation agriculture. Changes in climate are likely to affect rainfall characteristics in various sites, including quantity, seasonality, variability, and spatial patterns. For rural farmers in the developed countries, this presents challenges as their livelihood depends largely on rain-fed practices. The findings identified certain aspects of convergence and divergence in farmers' interpretation of precipitation patterns and result from meteorological stations. Given further climate change, weather information specific to farmers and their agricultural livelihoods will be increasingly important.

Rainfall and temperature variations have been a major concern to climatologists, economists, agricultural policymakers, and even non-professionals, due to their impact on natural and social systems. This study included a trend analysis based on historical data for annual, total, and summer rainfall from 1980 to 2013 using descriptive and statistical tests. This provides a better picture of climate change and climate change trends in Gondar Zuria District, Northwest Ethiopia. Therefore, this research can be used as benchmark data for the design and implementation of successful agricultural adaptation and climate change strategies. It can also be used to educate decision-makers, which in turn improves the capacity of the farmers to respond in the study area to climate change. The study findings support water resource management, drought prevention, socio-economic growth, and regionally sustainable agricultural planning. In addition, it is suggested that experts identify and introduce effective and relevant adaptation strategies considering the projected trends and patterns for rainfall and temperature status in Gondar Zuria District, Northwest Ethiopia. Government policies should be implemented to increase household access to extension services and access to credit and information, which would boost and diversify the awareness and understanding of farmers about climate change and thus increase their coping strategies. Improving the incentives for households to produce off-farm income may provide an additional strategy for addressing negative shocks. Political capital is essential to the perceptions of farmers which demonstrates the importance of information diversification and dissemination. There are some tips for improving the quality of climate data, including developing climate forecasting, making climate information available to local households, and warning of climate hazards. The number of weather stations should also be increased. Generally, future agricultural policy should focus on facilitating access to information on climate change and enhancing research on drought-resistant crop varieties that are more suited to dryer conditions. Due to the absence of adequate long-term crop yield data, it was difficult to identify the relationship between crop yield and time series trend analysis of precipitation and temperature in this study. Therefore, further research should investigate (a) climate change trend analysis and its relationship with the crops, (b) demographic and socio-economic variables (such as age, land size, etc.) in the study area, and (c) evapotranspiration effect of temperature.

Acknowledgment This work was supported in part by the German DFG Clusters of Excellence CliSAP and CLICCS.

Funding This work did not receive any specific grants from funding agencies in the public, commercial, and profit sectors.

Appendix

See Annex 1 and 2

Annex 1 Data on sampled kebeles, households and sample size

No	Name of kebeles	Household size	Sample size
1	Tseion Siguaje	1425	52
2	Sabah Gebriale	1097	41
3	Amba Chara	768	28
Total		3290	121

Annex 2 Key informants interview sample size

No	Key informants	Sample size
1	Local leaders	3
2	Model farmers	4
3	Agriculture and rural development experts	3
Total		10

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