Journal of Resources Development and Management
ISSN 2422-8397 An International Peer-reviewed Journal
Vol.90, 2023

Framers' Perception of Climate Change and Time-Series Trend Analysis of Rainfall and Temperature in North-Western Ethiopia

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Abstract
Smallholder farmers are the most vulnerable community to climate change in Ethiopia because they are highly dependent on subsistence rain–fed agricultural production system. The aims of this study were to identify the perceptions of farmers on climate change and time series trend analysis of rainfall and temperature in the Gondar Zuria district of northwestern Ethiopia that has been severely affected by climate change stresses. In Ethiopia, studying the time series trends of rainfall and temperature in the context of climate change is crucial. As a result, it is easy to identify and implement better climate change adaptation strategies. Primary data were collected from a randomly selected 121 sample households and purposefully selected ten key informants through questionnaires and interviews. The survey data was analyzed using SPSS software version 21, XLSTAT software and excel spreadsheet. The variability and trend analysis were conducted from downloaded Gridded monthly rainfall and temperature data from free online climate explorer Which is Global Precipitation and Climate Centre (GPCC V7) and the Climate Research Unit (CRU TS 3.23) with 0.5 by 0.5 resolution from 1980 to 2013 respectively. Climate variable data have analyzed by using a precipitation concentration index, anomaly index, coefficient of variation and simple linear regression. Furthermore, the Mann-Kendall test was used to detect the time series trend. The result revealed that the mean maximum temperature had an increasing trend through time significantly. But the trend for mean minimum temperature showed a non-significant increasing trend during the period of 1980–2013. Whereas, the rainfall showed a statistically insignificant decreasing trend in the main rain (summer) season. While there was an inter-annual variability in the amount of Belg season rainfall and it showed an increasing trend. The result revealed that farmers perceive changes in temperature and rainfall over the past 30 years. The Gondar Zuria district is characterized by a semi-arid climate and hence, received low and erratic rainfall during the summer season. Therefore, we recommend possible adaptation strategies designed for climate change particularly rain-fed agriculture economic dependent countries should give emphasis for 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
DOI: 10.7176/JRDM/90-02
Publication date: January 31st 2023

1. Introduction

Currently, climate change is documented as one of the greatest challenges of our world. It is projected to have adverse consequences for the world's ecosystems, economies, and societies. However, the severity of adverse effects varies across countries, regions, and socio-demographic groups, due to 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).

The most frequent and consistently happened challenges due to climate change in Africa include, frequent floods, droughts, and a shift in marginal agricultural systems (Collier and Conway, 2008). Agriculture is a backbone sector which contributes to more than 60% of employees from the active population and on average up to 40% of gross domestic product's (GDP) in Sub-Saharan countries. However, it is highly affected by the negative effect of climate change (Kandji et al., 2006). Like other Sub-Saharan countries; agriculture is the most important sector in Ethiopian. It employs accounting for half of GDP, 83.9% of exports, and 80% of total employment in Ethiopian according to the Central statistical agency of Ethiopia (CSA, 2016).

Ethiopia has ranked among the most vulnerable countries in the world to the adverse effects of climate change, because of its high dependence on rain-fed agriculture, low adaptive capacity and a higher reliance on natural resource base for livelihood (World Bank, 2010). The productivity and competitiveness of the agricultural sector are increasingly challenged by the temporal and spatial variation of climate (Weldlul, 2016). The negative impact of climate change on crop and livestock production has resulted in a nationwide food shortage and greatly hinder economic growth (Assefa et al., 2008). Droughts in Ethiopia can shrink household farm production by up to 90% of normal years' output and leading to the deaths of people and loss of assets. Additionally, rain-fed dependent crop production is the basis of all subsistence farming in most parts of Ethiopia. Though the rainfall is erratic and unreliable in much of the country, its variations and associated droughts have been historically major causes of food shortages and famines (Abiy et al., 2014). A 10% decrease in seasonal rainfall has resulted in a 4.4% decrease in the country's food production (Von, 1991). These problems are very serious in the arid and semi-arid areas of the country (Yohannes and Mebratu, 2009).

According to the World Bank (2003), Amhara region is one of the most vulnerable areas to climate change in Ethiopia. The increase in temperature along with a decrease in precipitation has become a serious problem that frequently affects the agricultural sector in the region. As a result, drought is the most dominant and frequently occurring climate-related shock in the region (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 (Gondar Zuria District agricultural development office report, 2017).

Climate variables such as temperature and precipitation are the two most important variables in the field of climate sciences and hydrology frequently used to show the extent and magnitude of climate change and variability (IPCC, 2007). Consequently, investigating the time series trend analysis of these climate variables is very crucial in order to provide input for policymakers and practitioners that help to make informed decisions for the management of drought, control of flood, planning of water harvesting technologies and recommend possible climate change adaptation strategies and climate-smart agricultural practices. Therefore, careful observation, recording, and analysis of temperature and precipitation data are very essential (Abeysingha, 2014; Tabari and Talaee, 2011).

Numerous studies have been undertaken about the trend analysis of temperature and rainfall with different time-series and objectives. The study in north-central Ethiopia showed a statistically significant increasing trend of mean maximum and minimum temperature and a general tendency of decreasing in rainfall (Prasada and Solomon, 2013). Furthermore, the study conducted by Betelhem (2014) stated that the average maximum and minimum temperature were increased by 0.8ºc and 0.03ºc, respectively, every decade from the period of 1984 to 2013 in Ethiopia. In addition, she found the rainfall coefficients of variations were 23%, 46% and 35% for annual, Belg and Summer, respectively. This implies that there was a high inter-annual variability of rainfall. The degree of variation in the amount of rainfall was higher for a Belg season than the Kiremt season. According to Seid (2014), the trend analysis between annual rainfall and time indicated that annual rainfall in Ethiopia decreases by about 46.75 mm per year. Besides, the study by Bewket (2010) revealed that statistically insignificant decreasing trend of rainfall. The rainfall in the region has low inter-annual variability as compared to studies done over another part of Ethiopia. Furthermore, Woldeamlak (2007) pointed out that though there were intra-annual and intra-regional differences in the amount and variability of rainfall in Amhara region (where the extent of variability is higher in the northwestern part of the region), no systematic pattern of change across the region regarding trends in annual and seasonal rainfall was obtained.

Time series trend analysis of rainfall and temperature is not new in Ethiopia. Though Gondar Zuria District is among the most drought-prone areas of the country, the time series temperature and rainfall, as well as the farmers' perception of climate change, are not thoroughly studied. But y. As a result, this study was aimed at temperature and rainfall trend analysis based on historical data from 1980–2013, and assessment of the perception of farmers on climate change. The finding could give a better picture of climate change and the trend of climate variables in the District. Hence, it can be used as baseline data for designing and implementing effective agricultural adaptation strategies to climate change. Besides, it can also be used to inform decision-makers that enhance farmers' capacity to adapt climate change in the study area.

2. Materials and methods

2.1. Description of the study area

The study was carried out in Gondar Zuria woreda (district) of Central Gondar Zone in Amhara Regional State, Northwest Ethiopia (Fig.1). The Central Gondar Zone consists of 11 districts, including Gondar Zuria District. Gondar Zuria District has 41 rural and 3 urban Kebeles (sub-districts). The total area of the district is 48,204.39 km^2. It is bordered with South Gondar Zone, Lake Tana, Dembiya district, Lay Armachiho district, Wegera, and Belessa districts in the south, southwest, west, north, northwest, and southeast, respectively (Gondar zuria district land administration and use office, 2017).

The District is characterized by a semi-arid climate with a low and erratic bimodal type of rainfall i.e. Belg, the season starts in February and ends in April/May and the summer, the season from June to September with the highest rainfall in July. In the district, the peak monthly average maximum and minimum temperatures were recorded during April with 29.96 °C and 15.72 °C respectively. The district is located at 1500-3200 a.m.s.l and falls into two agro-ecological zones called Weyna Dega (72%) and Dega (28 %) (Gondar Zuria agriculture office, 2017). It has two types of soils namely; Nitisols and Vertisols. The land use cover of the area includes; crop (56.5%), pasture (14.7 %), forests and shrubs (10%), settlements (5.3%) and miscellaneous land (13.5%). The tree vegetation of the study area is part of the evergreen dry Afromontane forest that dominates the highlands of Ethiopia (Gondar Zuria District Agriculture Office, 2017).

The district has 38,383 households, of which 30,325 male and 8,058 female-headed households. The total number of the population of the district is 230,033, of whom 118,107 males and 111,926 females. 201,880 and 28,153 of the populations live in rural and urban centers respectively. The area has an estimated population density of 205.9 people per square kilometer as compared to the zone average of 60.23 (Gondar Zuria District Finance and Economy Office, 2017). Mixed farming is predominant in the District i.e. crop production and livestock rearing (90%). Major crops that are produced in the area include wheat, sorghum, pea, teff, maize, and others. The livestock population in the district is equivalent to 207,000 tropical livestock units. In terms of irrigation potential, the district has suitable areas because relatively a small area of the district is adjacent to Lake Tana (Gondar zuria district agriculture office, 2017).

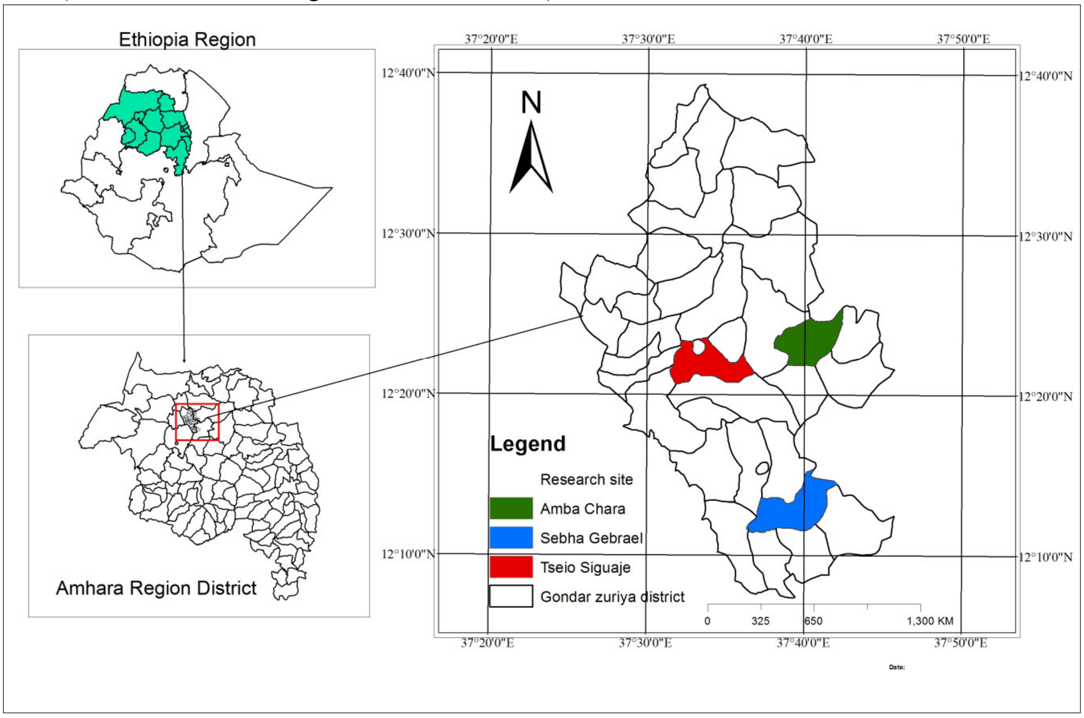

Fig. 1. Map of the study area

2.2. Research design

This study was employed mixed research design by combining quantitative (survey) and qualitative (case study) approaches. The rationale for choosing a mixed research design for this research is to generate deeper and broader insights; gain data about a wider range of interests and allow appropriate emphases at different stages of the research process. Moreover, the combination of qualitative and quantitative approaches provides a complete understanding of a research problem (Creswell, 2003). In this mixed research design, more weight was provided to quantitative than a qualitative one. The purpose of using qualitative data collected through key informant interviews and field observation in addition to quantitative data collected was to clarify the meaning or fully explaining the results. In terms of sequence, this study was employed concurrent type, in which both quantitative and qualitative data were collected at the same time.

2.3. Data type and source

Both primary and secondary sources were used to collect the data. The primary data was collected from the socio-economic, institutional and biophysical situation of the sample households' through a questionnaire. Gridded monthly precipitation data were obtained from Global Precipitation and Climate Centre (GPCC V7) and temperature data from the Climate Research Unit (CRU TS 3.23) with 0.5 by 0.5 resolution from 1980 to 2013 used for variability and trend analysis. Gridded monthly precipitation and temperature data are a reconstructed data series based on records of meteorological station and satellite observations. This gridded data set is very useful as weather stations are limited in number, unevenly distributed, have missing data and with a short period of observations. Meteorological station data were also obtained from Bahir Dar regional meteorological station from 1980 to 2013 used for validation analysis. Secondary data was collected from documents such as journal articles, annual reports, Intergovernmental Panel on Climate Change report and other related resources from different data sources.

2.4. Sampling procedure and sample size determination

There are about 11 rural districts in the Central Zone of Gondar administration. 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 because it is one of the semi-arid and drought-prone areas. Moreover, farmers' who live in the district depend on climate-sensitive agricultural productions, particularly livestock and crops which are the most vulnerable and affected ones with recurrent drought. The frequency and magnitude of drought have been increased from time to time and has affected their production. Second, Gondar Zuria District has 44 rural kebeles and out of these kebeles, the researcher has selected three Kebeles, Amba chara, Sabah Gebriale, and Tseion Siguaje Kebeles by lottery method. Third, from the selected three kebeles, sample households were selected from the total population of 16,779 and 3,290 households based on the proportionate to size rule. The sample size was calculated using the formula proposed by Watson (2001) cited in (Ayele, 2014).

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

Where; n: sample size required, N: number of households, A: degree of precision or the desired margin of error, expressed as a decimal: (i.e.0.08, for 8 %), Z: based on confidence level: 1.96 for 95% confidence, P: estimated variance in population as a decimal (0.5 for 5-50, 0.3 for 70-300) and R: estimated response rate, as a decimal, 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%.

In survey research, response rate, also known as completion rate, is usually expressed in the form of a percentage. For many years, a survey's response rate was viewed as an important indicator of survey quality. Many observers presumed that higher response rates assure more accurate survey results (Curtin et al., 2000). The sample size of the equation was found 121.4 households. Then the researcher has used the sample size of approximately 121, which is believed to be representative of the total population of 16,779 and 3,290 households.

Table 1. Sampled kebeles for study, numbers of 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

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

$$R = N/n \quad (2)$$

Where; R= the sampling interval, N= total number of households, n =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 n^{th} element is selected until the desired number is secured by R (i.e. R= 27) plus to the first selected random number. R = 3290/121 =27.19 approximated to 27.

2.5. Data collection instruments

Data were collected from the 121 households and 10 key informants through a questionnaire and a key informant interview. The researchers have been used field observation, household questionnaire, and a key informant interview as an instrument of data collection. Field observation was conducted throughout the whole courses of the research in order to ensure the validity of information obtained. The researcher selected key informants purposively. The interview was conducted with 10 key informants, including local leaders (three), model farmers (four) and Agriculture and Rural Development experts (three) table (2). Each key informant was asked the same set of question in a fixed order.

Table 2. Key informant 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

Two types of questionnaires (closed and open-end questions) were used. They were administered by trained data collectors who were university graduate students. The researcher played the role of supervisory. A brief orientation and training for four data collectors were given. The data were collected in the first three weeks of January 2017.

2.6. Data analysis

A statistical package for social science (SPSS) software version 21 was used to analyze the data. Percentages, frequencies, and means were used to represent farmers perceived long-term changes in temperature and rainfall and to explain the different socioeconomic characteristics of the sampled households. Different techniques were used for the analysis of rainfall and temperature, which generally grouping into variability and trend analysis categories. These analyses were undertaken using XLSTAT software and excel spreadsheet. The following analysis techniques of rainfall and temperatures were used;

2.6.1. Simple Linear Regression

Simple linear regression was used to detect and characterize the long-term trend and variability of temperature and rainfall values at an annual time scale. This test considers the simple linear regression of the random variable Y on time X. The regression coefficient is the regression line slope coefficient computed from the data. It describes the trend whether positive or negative. The simple linear regression line was calculated using equation (3);

$$Y = \beta X + c \qquad (3)$$

Where, Y = changes in rainfall and temperature during the period; β = slope of the regression equation; x = number of years from 1980 to 2013; c = regression constant.

2.6.2. The coefficient of variation (CV)

In comparing different years of rainfall with different means and evaluating the variability of rainfall in the study area, we have used the coefficient of variation (CV). It is used to classify the degree of variability of rainfall events. According to Hare (2003) classification, the value of CV has low (CV< 20), moderate (20 < CV <30), and high (CV >30). A lower value of CV is the indicator of smaller variability, and vice versa. The CV was calculated using equation (4);

$$CV = \sigma/\mu \times 100\% \qquad (4)$$

Where; σ is a standard deviation and μ is the mean precipitation.

2.6.3. Precipitation Concentration Index (PCI)

As indicated in Oliver (1980), the values of PCI have the following classifications; low precipitation concentration (<10) which indicate a uniform monthly distribution of rainfall, moderate concentrations (11-5), 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;

$$PCI\ Annual = \sum_{i=1}^{12} Pi\,2/\ (\sum_{i=1}^{12} Pi)\,2 \qquad (5)$$

Where; Pi is the rainfall amount of the ith month, $\sum =$ Summation over the 12 months.

2.6.4. Standardized anomalies of rainfall

Different studies have been used standardized anomalies of rainfall to examine the nature of the trends, to determine the dry and wet years in the record, and to assess frequency and severity of droughts in their studies (for example, Agnew and Chappel,1999; Woldeamlak and Conway, 2007; Taye et al., 2013; Getachew and Tesfaye, 2014). According to Agnew and Chappel (1999), drought severity classes were classified based on the value of standardized rainfall anomaly to show the drought severity of an area. According to the authors, the drought severity classes are extreme drought *Z < -1.65 severe drought (-1.28 > Z > -1.65), moderate drought (-0.84 > Z > -1.28), and no drought (Z > -0.84). The standardized anomalies of rainfall were calculated using the following equation;

$$Z = (Xi - \mu)\ /S \qquad (6)$$

Where; Z is standardized rainfall anomaly; Xi is the annual rainfall of a particular year; μ is long term mean annual rainfall over a period of observation and 's' is the standard deviation of annual rainfall over the period of observation.

2.6.5. Mann-Kendall Test (MK test)

The Mann-Kendall (MK) trend test is a non-parametric approach that has been widely used for the detection of a trend in different fields of research, including hydrology and climatology (Ampitiyawatta and Guo, 2009). Its statistics are based on the + or -signs, rather than the values of the random variable. Therefore, the trend is determined by the MK test which is not affected by outliers (Birsan et al., 2005). The MK test was used to detect the presence of increasing or decreasing trends of rainfall and temperature and its significance level. The MK test analysis has been carried out on annual and monthly based for the Belg and summer seasons. According to Mann (1945); Kendall (1975) and Yue et al. (2002), the initial value, S, is assumed to be 0 (no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. If the data value of the later time period is lower than a data value from an earlier time period, S is decremented by 1. The net result of all such increments and decrements yield the final value of S. MK test statistic 'S' was calculated using the following equation (7);

$$S = \sum_{i=}^{n-1} \sum_{j=i+1}^{n} sgn(xj - xi) \qquad (7)$$

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 points Xi is taken as a reference point which is compared to the rest of the data points Xj so that;

$$Sgn\,(Xj - Xi) = \begin{cases} +1 if\,(xj - xi) > 0 \\ 0\ if\ (xj - xi) = 0 \\ -1\ if\ (xj - xi) < 0 \end{cases} \qquad (8)$$

Where Xi and Xj are the annual values in years i and j (j > i) respectively.

It has been known that when the number of observations is more than 10 (n ≥10), the statistic 'S' is approximately normally distributed (Kendall, 1975). Furthermore, the variance statistic was computed as;

$$Var\,(S) = N(N-1)\,(2N+5) - \sum_{k=1}^{n} tk(tk-1)(2k+5)/18 \qquad (9)$$

Where N is the number of observations and tk is the tied number of the sample time series. According to Theil (1950) and Sen (1968) Sen's Slope estimation test was computed both the slope (i.e. the linear rate of change) and intercepts. It is used to show the magnitude of the trend. A negative value of β indicates a 'downward trend', whereas a positive value of β indicates an 'upward trend' (increasing values with time) Here, the slope (Ti) of all data pairs. Sen's Slope was calculated using equation (10);

$$Ti = Xj - Xi/j\text{–}I \qquad (10)$$

Where Xj and X k are considered as data values at time j and k (j > i) correspondingly.

3. Results and discussions

3.1. Socioeconomic characteristics of sample households

Out of the total sample households surveyed, 67.8 and 32.2 % were male-headed and female-headed households respectively. As shown in table 3 more than half of (62%) of the household heads were illiterate with no formal education of any kind and thus are unable to read and write. Only 32 % of the respondents were literate and are able to read and write. Regarding marital status, 71.3 % of the respondents were married, while 3.3 % of them were single, 14% of them were divorced and 10.7 % of the respondents were widowed.

Table 3. Socioeconomic characteristics of sample households

Characteristics of the respondents		Frequency	Respondents (%)
Gender of HHs	Female	39	32.2
	Male	82	67.8
Educational of HHs	Illiterate	75	62.0
	Literate	46	38.0
Marital status of HHs	Married	87	71.3
	Single	4	3.3
	Divorced	17	14
	Widowed	13	10.7
Total		121	100

As summarized in table 4 the age distribution of the respondents ranges from 30-75 years with an average age of 50 years. The total land size of sampled households ranges from zero (landless) to six hectares with an average size of 1.95 hectares. Although the average family size of the respondents is seven, the absolute size of the respondents ranges from two to 13 members. The average farming experience of the household heads was 27.64 years with the maximum being 58 and the minimum experience being four years. Regarding household income, it was difficult to establish because the respondents could hardly tell sincerely their household annual farm income.

Table 4. Descriptive statistics of the sample households

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Age of HHH in years	121	30.00	75.00	50.33	12.04
Total land size of HHH in hector	121	0.00	6.00	1.95	1.36
Family size of HHHH in number	121	2.00	13.00	6.74	2.67
Farming experience of the HHH in years	121	4.00	58.00	27.64	12.42
Annual total farm income of HHH in Ethiopian Birr	121	1,075.00	85, 000	31,023.64	24,072.69
Number of livestock in TLU	121	0.00	18.00	7.62	5.47

However, an attempt had been made to know their income by asking the amount of crop production per year and converting it to Ethiopian Birr based on the current market price. Accordingly, the income distribution of the respondents ranges from 1,075-85,000 Ethiopian Birr with an average income of 31,023.64 Birr per year. Farmers in the study area are engaged in mixed farming activities, including food crop production (such as teff, sorghum, maize, barley, wheat, and soybean) and rearing of domestic animals such as cows, oxen, goats, sheep's and donkey. Moreover, the survey results revealed that the mean livestock holding of the sampled households in terms of tropical livestock unit (TLU) was 7.62, the maximum and minimum are 18 and zero TLU, respectively.

3.2. Farmers' perception of climate change

In order to get essential information and insight into farmers' adaptation to climate change, looking at their perception of each parameter/indicator is quite important. Hence, knowledge about farmers' perception of climate change attributes in the study area is an appropriate issue to be discussed. For this purpose, two known climate attributes: temperature and precipitation have been used.

3.2.1. Perception of temperature changes

As shown in Fig. 2, About 81% of the respondents perceived that the temperature in the area is increasing. This implies that the majorities of the farmers in the study area are aware of climate change and perceives an increased temperature. Whereas 9.1% of the respondents had noticed no changes in the temperature, 6.6% of the farmers noticed a decrease in temperature and 3.3% of the farmers perceived there was an irregular pattern in temperature, over the past 30 years. Similarly, most of the key informants were explained that temperature has increased over the past 30 years in the study area. This study is in line with the study of Bryan et al. (2009) and Dereje (2014), who found that most of the respondents had reported that there was an increasing temperature in Ethiopia. Moreover, most farmers (82%) perceived an increase in temperature over the past 10 years in Ghana (Ndamani and Watanabe, 2015). Therefore, about 81 % of the respondents were reported that there is an increasing temperature over the past 30 years in this research study site.

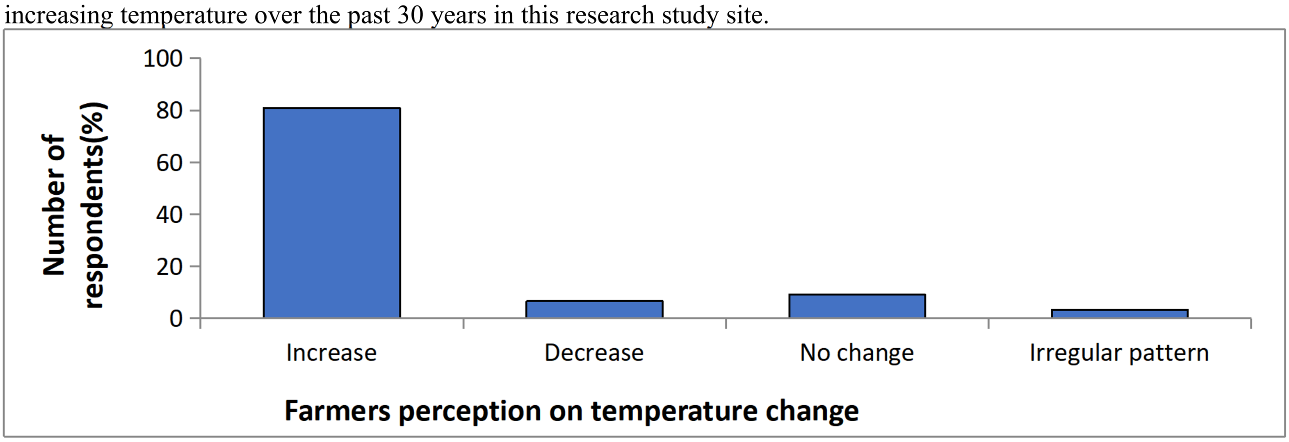

Fig. 2. Farmers' perception on temperature change

3.2.2. Perception of precipitation changes

About 78% of the respondents reported that the changes in rainfall patterns and a decrease in its amount over the past 30 years (Table 5). 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 decreasing of rainfall. About 9.1% of the respondents perceived that there was an irregular pattern of precipitation.

Table 5. Farmers' perception on 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

Nearly 8% of the respondents noticed that 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. This was confirmed by most of the key informants reporting that precipitation decreased from time to time in the Gondar Zuria District. This study is supported by Dereje (2014) who found 75% of the investors were perceived a decrease in precipitation in Ethiopia. Misgina and Simhadri (2015) were also reported that an average of 75% and 81% of respondents observed the trend of declining rainfall and increasing temperature respectively in Ethiopia. About 81 % of the respondents perceived that the temperature has been increased and about 78 % of the respondents reported that changes in rainfall patterns and decrease its amount over the past 30 years in the study area. It has been concluded that the analysis of farmers' perception of precipitation and temperature change revealed that there was climate change over the past 30 years in the Gondar Zuria District.

3.3. Rainfall and temperature variability trend analysis

The variability and trend analysis of rainfall and temperature data validation was performed. The results of the validation analysis revealed that Global Precipitation and Climate Centre (GPCC) based rainfall data has been strongly correlated with the meteorological station data than the Climate Research Unit (CRU) data. The meteorological station rainfall data of the Gondar Zuria District were found to be highly correlated with GPCC ($r = 0.580$; $P < 0.001$). However, the correlation coefficient of meteorological station rainfall data with CRU data was low and non-significant ($r = 0.197$, $P = 0.265$). The Kolmogorov- Smirnov test to compare whether the data from meteorological station and satellite follow the same distribution or not were performed. Hence, the analysis revealed that the meteorological station data and GPCC V7 data follow the same distribution, because the p-value was not statistically significant ($P = 0.085$). The gridded precipitation data obtained from GPCC V7 and the reference meteorological station rainfall data were strongly in agreement. Because the result for CRU was significant ($P = 0.000$) and the distribution of the two samples are different. Consequently, better compatibility of the meteorological station data with GPCC V7 than CRU data.

3.3.1. Rainfall variability

The monthly rainfall distribution in the Gondar Zuria District was found to be variable. The monthly coefficient of variation (CV) lies between 14.14 up to173.01. It was found to be highest during February (173.01) and January (168.16), and lowest during August (14.14) and July (15.83). The mean annual rainfall was found to be 1272.68 mm and with 12.73% CV. As indicated in table 6, summer is the major rainy season, which contributes about 79.40% of the total rainfall (where approximately 51% comes only in two months: July and August, while September and June contributed 13.9 and 14.8% of the summer rainfall, respectively). Belg is the shortest rainy season which lasts from February to April/May. It contributes a significant amount of rainfall (around 12.0% of the total).

Not only the monthly rainfall distribution but also the seasonal rainfall distribution was variable in the Gondar Zuria District. The coefficient of variation (CV) for this area during annual, Belg, and summer seasons were found to be 13, 44.3, and 12%, respectively (Table 8). Therefore, the CV is found to be high during Belg season (44.3%) and low (12.1 and 12.7%) during the summer season and annual, respectively, as indicated in Hare (2003). Hence, the degree of variation in the amount of rainfall was higher for a Belg season than annual and summer season in the Gondar Zuria District. This implies that there is more interannual variability of Belg season rainfall than the Summer season. The current finding was similar to the reports by Aklilu (2006) and Viste et al. (2013), who found that more variability in Belg rainfall than the summer rainfall in most parts of Ethiopia. Woldeamlak and Conway (2007) also reported that more rainfall variability in Gondar in a Belg season with the CV value of 48% than annual and Summer with 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 seasons, respectively. As opposed to the long rains, the short rains have been recording a strong interannual variability over the last four decades in equatorial East Africa (Philippon et al., 2002).

Table 6. 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

The precipitation concentration index in table 7 disclosed that the presence of a high and very high concentration of rainfall from 1980 to 2013 years in Gondar Zuria District. Similarly, a high concentration of rainfall was reported by (Woldeamlak and Conway, 2007; Amogne et al., 2018) in the central highlands of Ethiopia. Based on Oliver (1980), PCI values classification of the Gondar Zuria District is 27 and 6 the number of years PCI values lies 16-20 and ≥21 respectively. There was a presence of a very high concentration of rainfall in the year 1981, 1983, 1986, 1990, 2003, and 2009. The only moderate concentration of rainfall has been also recorded in the year 1997 over the period from 1980 to 2013 in the Gondar Zuria District. This implies that there was not a uniform distribution of rainfall in the 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 years.

Table 7. Precipitation Concentration Index (PCI)

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

According to Agnew and Chappel, (1999), drought severity classes were very low values of rainfall anomaly correspond to severe drought periods. The values of rainfall anomaly of Gondar Zuria district range from +1.8 in 1980 to -2.7 in 2009. As indicated in (fig. 3), 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 in 2010 with the rainfall anomaly value of -0.9 (i.e. $-0.84 > Z > -1.28$). The severe drought years were 1982, and 1984, with rainfall anomaly values of -1.6 (i.e. $-1.28 > Z > -1.65$) in the Gondar Zuria district.

This result is in line with the findings of Webb and Braun (1992) who noted that when a severe drought hit Ethiopia in 1984, the famine was already underway, as a result of dry episodes during the previous years. Ellen et al. (2012) also found that the year 2009 was the only year from 1972 to 2011 when extreme drought occurred on the annual scale in all parts of Ethiopia. In the year 2010, there was also a moderate drought in the southern part of Ethiopia. The recent severe drought occurred in 1982 and 1984 years in all parts of Ethiopia. Generally, in this study 1982 and 1984 were the most severe drought periods in the study area from the periods of 1980 to 2013.

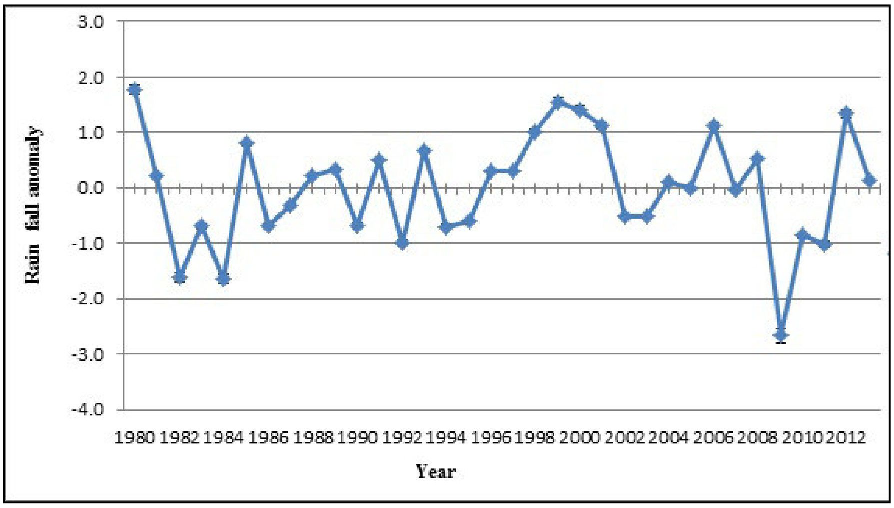

Fig. 3. Rainfall anomalies of Gondar Zuria District

3.3.2. Linear regression analysis of rainfall and temperatures

Fig. 4 showed 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 Belg season. Rainfall of Belg season has shown an increasing trend from 1980 to 2013 (fig. 4). 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.

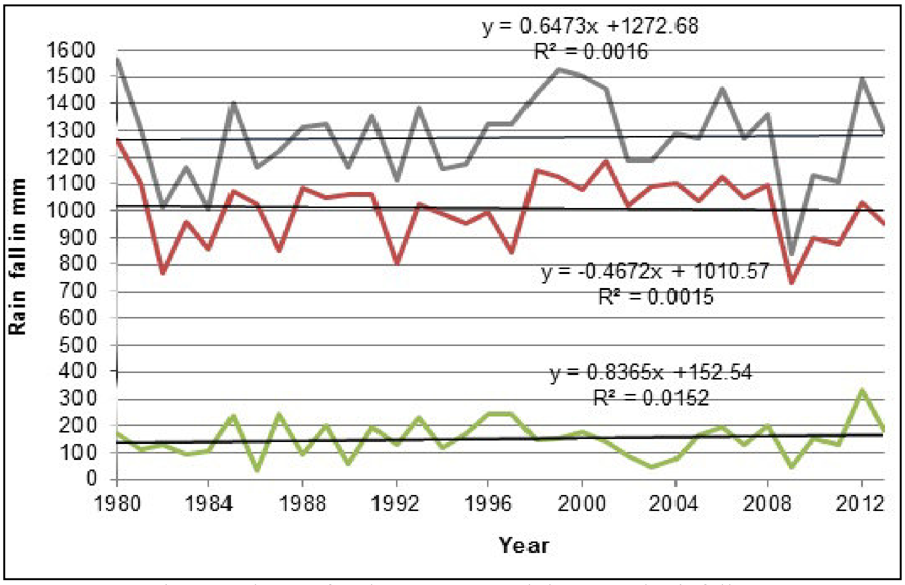

Fig. 4. Regression trend test of Belg, summer and the annual rainfall

As it is shown in table 8, 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 than the summer season in the study area. The mean temperature in the study area ranges from 13.8 °C (minimum) to 28.1 °C (maximum). According to the National Meteorological Agency (2001), the annual maximum temperature in the country has increased by 0.1 °C per decade. Moreover, the annual minimum temperature of the country has increased by 0.37 °C per decade (NMA, 2007).

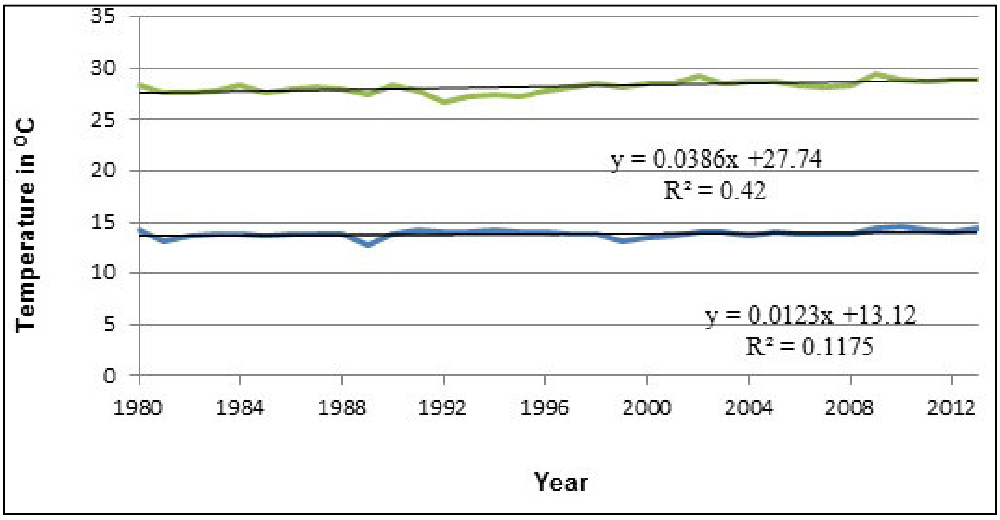

Fig. 5. Simple regression trend test of annual maximum and minimum temperatures

Both annual mean maximum and minimum temperatures increased and there was a change of temperature from one year to the other (Fig. 5). Using a linear regression model, the rate of change is defined by the slope of the regression line. The average maximum and minimum temperature were increased by 0.04 °C and 0.01 °C, respectively, every decade from the period 1980 to 2013. The regression analysis also revealed that both annual mean maximum (p= 0.000, R^2 = 0.420) and minimum (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 %) towards temperature change. This is supported by Henock (2014) who found an increasing trend with a rate of 0.045 °C /year of annual mean maximum temperatures in Ethiopia. Therefore, annual mean maximum and minimum temperatures revealed that an increasing trend with 0.04 °C, and 0.01 °C per year respectively in the study area. This implies that there was climate change in the Gondar Zuria district over the past 34 years.

Table 8. Linear regression trend result of Belg, summer and an annual rainfall

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

Note: NS not statistically significant at the 0.05 alpha level

3.3.3. Rainfall and temperature Mann-Kendall trend analysis

The monthly rainfall trend analysis of September and February showed a decreasing trend and they were found statistically significant (both at $P<0.05$). Summer season rainfall trend result also showed a decreasing trend, but it was found statistically insignificant (Table 9). However, the Mann Kendall trend test demonstrated that there was an increasing trend of annual and Belg season rainfall even though it was statistically insignificant. This is similar to the study by Ambun et al. (2013) which reported a decreasing trend of monthly rainfall during September and February. Besides, the study in the north-central part of Ethiopia by Amogne et al. (2018), reported that the rainfall trend has shown a decreasing trend in the summer season.

Table 9. 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	Increase
Feb	-5.000	-0.009	0.036*	-0.142	Decrease
Mar	-11.000	-0.020	0.883	-0.014	Decrease
Apr	45.000	0.080	0.517	0.361	Increase
May	-41.000	-0.073	0.556	-0.34	Decrease
June	33.000	0.059	0.638	0.531	Increase
July	-31.000	-0.055	0.659	-0.416	Decrease
Aug	-23.000	-0.041	0.746	-0.307	Decrease
Sept	-13.000	-0.023	0.024*	-0.162	Decrease
Oct	-3.000	-0.005	0.977	-0.044	Decrease
Nov	-1.000	-0.002	1.000	-0.001	Decrease
Dec	42.000	0.075	0.543	0.022	Increase
Belg	29.000	0.052	0.681	0.586	Increase
Summer	-9.000	-0.016	0.906	-0.197	Decrease
Annual	39.000	0.070	0.576	1.731	Increase

Note: *statistically significant at 0.05 alpha level

In this study, a positive significant trend was found for maximum temperature data on an annual and monthly basis. The Mann Kendall trend test result revealed that a statistically significant increasing trend in annual maximum temperature data was observed for the periods from 1980-2013, except for the months of June, July, August, September, and October (Table 10). The result was found in agreement with the report by Birhanu et al. (2017). In general, the mean annual maximum temperature trend showed a statistically significant warming trend. The observed increase in the mean annual maximum temperature in the study area is caused by an increase in mean monthly temperatures.

Table 10. Mann-Kendall trend test of the monthly and annual maximum temperature of the study area (1980-2013)

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

Note: *, **, *** statistically significant at 0.1, 0.05 and 0.01 alpha levels

The Mann Kendall and Sen's Slope estimation test analysis of mean minimum temperature revealed that a negative statistically insignificant decreasing trend in October and June. on the other hand, a statistically significant increasing trend was found in April (table 11). As shown in table 11, except the months of June and October, all months showed an increasing trend of mean annual minimum temperature. This suggests that the annual minimum temperature was showed an increasing trend. Therefore, there were an increasing temperature and decreasing rainfall in the district which suggests the existence of climate change in the Gondar Zuria district over the past 34 years.

Table 11. Mann-Kendall trend test of monthly and annual minimum 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	Increase
Feb	12.140	122.000	0.218	0.073	0.024	Increase
Mar	14.644	11.000	0.020	0.882	0.002	Increase
Apr	16.155	141.000	0.252	0.038*	0.029	Increase
May	16.515	80.000	0.143	0.241	0.016	Increase
June	15.430	-6.000	-0.011	0.941	-0.001	Decrease
July	14.905	83.000	0.148	0.224	0.011	Increase
Aug	14.587	26.000	0.046	0.711	0.002	Increase
Sept	14.083	66.000	0.118	0.335	0.008	Increase
Oct	13.741	-35.000	-0.062	0.617	-0.005	Decrease
Nov	12.643	125.000	0.223	0.066	0.026	Increase
Dec	10.827	27.000	0.048	0.702	0.005	Increase
Annual	13.857	105.000	0.187	0.124	0.01	Increase

Note: *, statistically significant at the 0.05 alpha level

4. Conclusions

This study was undertaken in Gondar Zuria district in northwestern Ethiopia with the aim of assessing Framers' perception of climate change and time-series trend analysis of rainfall and temperature. Most of the respondents were perceived as a long-term change in rainfall amount and distribution and an increasing trend of temperature. Farmers' perception of climate change is in line with the climatic records except for Belg season and annual rainfall amount. More than half of the summer season rainfall is highly concentrated in July and August. The time series trend analysis also showed that there was a decreasing trend of 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 maximum and minimum temperature showed an increasing trend. Due to increasing temperature and erratic rainfall, the area becomes prone to drought and experienced several drought years. Therefore, Gondar Zuria district is characterized by a semi-arid climate and hence, received low and erratic rainfall during the summer season. As a result of changing of current climate patterns such as decreasing summer season rainfall amount, more frequent droughts, increasing temperatures, and shortening of rainy seasons, vegetation growth and crop production were challenged in the study area.

As a recommendation, the rural household should involve in conferences, seminar and panel discussions about climate change issues to raise their awareness. In order to improve the coverage and quality of climatic data, developing climate forecasts and make climate information available to local households, and early warning of climatic hazards as early as possible, the number of meteorological stations should be increased. 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 be conducted on climate change trend analysis and its relationship with the crop. Generally, future agricultural policy should focus on facilitating access to climate change information and enhancing research on drought resistance crop varieties that are more suited to drier conditions.

Acknowledgements
The authors would like to thank Ministry of education for financial support.

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