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Impact of Climate Variability on Maize (Zea mays L.) Yield and Farmers' Adaptation Strategies in Hawassa Zuria District, Sidama Region, Ethiopia

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Abstract: Climate variability has been adversely affecting agricultural activities and production in many developing countries including Ethiopia. The purpose of this study was to analyze the impact of climate variability on maize yield and assess farmers' adaptation strategies in Hawassa Zuria district, Sidama Region, Ethiopia. Historical climate data of rainfall and temperature for the period of 1989 to 2019 were obtained from the National Meteorological Agency (NMA) of Ethiopia and long term maize yield data was acquired from agricultural office of the district. Moreover, data on farmers adaptation practice was collected from a total of 290 household heads through survey questionnaire, interviews and focus group discussions. Data quality control, onset date, cessation of the rainy season, length of the growing season, dry spell length and number of rainy days were analyzed. Mann–Kendall trend test and Sen's slope estimator were used to detect the magnitude and statistical significance of changes in rainfall and temperature. The onset of rainy season and length of growing period were highly variable, while the annual rainfall amount showed a statistically non-significant increasing trend by a factor of 4.34 mm/year in the study area. The annual mean maximum and mean minimum temperature significantly increased by a factor of 0.294°C and 0.64°C per decade, respectively. There was a negative correlation between maize yield and rainfall and temperature features. Climatic factors accounted for approximately 94% of maize yield variation observed in the study area. Coping and adaptation strategies implemented to combat challenges of climate variability. Due to a program run by agricultural extension services from the local government and NGOs, the majority of households adopted crop diversification. During the prolonged dry years, the additional tree planting was primarily for the purpose of providing natural shade for their cattle and crops on the farm. The study concludes that climate variability is apparent and seriously affects maize yield in the study area. Therefore, depending on the finding of the study, the following recommendations are forwarded are: Take special care and attention to the start of the growing season, the end date, and the length of the growing season in the study area; farmers should have access to supplemental irrigation systems from Hawassa Lake or boreholes, especially they live near the lake; and farmers should be warned about the increasing severity of climate variability in the area.

Keywords: Adaptation, Climate Variability, Dryspell, Hawassa Zuria, Maize

1. Introduction

Climate variability is the major environmental challenge of the twenty-first century [14]. The effects of increased temperature and changes in rainfall patterns are likely to reduce agricultural production and put further pressure on marginal land. Climate variability has a detrimental impact on agricultural productivity because it causes soil moisture loss, faster depletion of soil organic matter, premature grain drying, and greater heat stress [20].

Maize (*Zea mays* L.) is one of the most important cereals worldwide and cultivated globally leading in total yield and the third most important food crop after wheat and rice [25]. Only 3% of maize yield may be consumed directly by humans in developed countries whereas, in SSA, more than 80% is used as a food and also provides at least 30% of the total calorie intake of people [46, 50]. Maize is one of the major cereal crops that serve as food source in Ethiopia. According to [17], maize stands second in terms of production area (over 2.05 million ha) and supports about 10 million households in the country. This rainfed and subsistence agriculture system, account for about 34% of the country's GDP and 68% of population employment [64].

Ethiopia is among the countries in SSA that experience variation in the rainfall and temperature in east Africa. For instance, a 0.2°C to 0.28°C rise per decade in the average annual maximum temperature between1960 and 2006 was reported in recent studies whereas, a 0.37°C/ decade increase in minimum temperature was observed between 1951 and 2006 [22]. In the countries like Ethiopia, where agriculture is entirely dependent on rainfall, an increase in temperature coupled with rainfall variability makes agriculture the most susceptible to climate change. This rainfed and subsistence agriculture system, account for about 34% of the country's GDP and 68% of population employment [64].

In southern regional state of Ethiopia, maize is produced predominantly by smallholder farmers and it can grow at higher temperatures compared to many other cereals, which are most vulnerable to rainfall variation and heat stress [1, 17, 53]. The issue of climate variability, characterized by irregular rainfall patterns, rising temperatures, dry spells, and premature rain cessation during crucial crop phases, poses a great threat to agricultural production. Consequently, farmers need reliable information on the seasonal climate patterns to enable them to adjust their farming practices accordingly [24]. In Hawassa Zuria, maize remains the major staple food crop relative to others. The majority of small farms are covered with maize crop in the district; as the source of income, animal fodder, and household consumption [65]. Since smallholders in the district are highly dependent on rainfall, recent variation in rainfall, temperature, recurring drought and heat stress had adversely reduced maize production and farmers' livelihoods [35]. This could mean modifying the sowing dates, choosing different cultivars, adjusting input use rates and overall farm management techniques. Previous studies on the impact of climate variability in Ethiopia were conducted at a broader scale [18, 63], who found that the western Ethiopian highlands showed higher rainfall on an annual basis while the part of the watershed that belongs to the Ethiopian rift valley showed lower rainfall.

Adaptation options are key things that farmers in Hawassa Zuria District individually or collectively undertake to respond to climate variability hazards (e. g., tree planting, soil conservation, migration, and planting early maturing crops) [11]. Generally, farmer's perspective increasing time to time towards to adaptation options including, choosing heat and drought stress-tolerant varieties, intensification, diversification, expansion, increased off-farm income, exit from agriculture, adjusting cropping calendar, in-situ moisture conservation, [7, 33, 34, 52, 55].

Owing to this challenge, maize production in Hawassa zuria Woreda is suffering significant yield losses as it affects important stages like anthesis and maturities, which ultimately determine the final grain yield. Therefore, this study is important to increase the understanding of the actual rainfall and temperature variability impact on maize productivity at Hwassa zuria and other similar agro-climatic areas. Moreover, the study explores farmers' efforts to counter the effects of climate variability in maize production. The overall objective of this study was to analyze the impact of rainfall and temperature variability on maize yield and explore farmers' adaptation strategies in Hawassa zuria district of Sidama Region, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Hawassa Zuria district, which is located about 22 km from Hawassa town in Sidama Reginal State of Ethiopia (Figure 1). Geographically, the study area is located between 07°01′ 54″ to 07°50′ 36″ N and 38°15′39″ to 38°25′43″E. The altitude of the study area ranges between 1680 to 2090 m. a. s. l. The area is bordered by Tula town to the east, Lake Hawassa to the north, Oromia region to the west, and Boricha district to the south. This district has 23 *kebeles* with total population of 135,618 of whom 68,395 are men and 67,223 women [54].

The annual mean maximum and minimum temperatures are 30°C and 17°C, respectively, and mean annual rainfall for the district ranges from 800 to 1200 mm. Hawassa zuria district has 23 *kebeles*, from this 18 are categorized as *kola* and the rest 5 categorized into *woina dega* agro-ecological zone. The main rainy season (*kiremt*) starts in June/July and continues up to the end of September, which accounts for 48% of the total annual rainfall, and the short rainy season (*belg*) occurring from early March to the beginning of June and accounting for 39% of the total annual rainfall. The remaining 13% falls during the dry spell months this result is in line with report of [29].

Maize is the major crop grown in the Hawassa zuria district *kebeles* others include potato, red and white haricot bean, maize, sweet potato and *enset* (*Ensete ventricosum*). The only water resource available is Lake Hawassa, one of the biggest lakes within the rift valley. *Eutric Fluvisols* and *Molic Andisols* are the dominant soils in the district, excessively drained, very porous, and deep to very deep, sandy - loam, medium and course textured vitric Andosols are also developed on flat to gently undulating topography and rolling plain [49, 60].

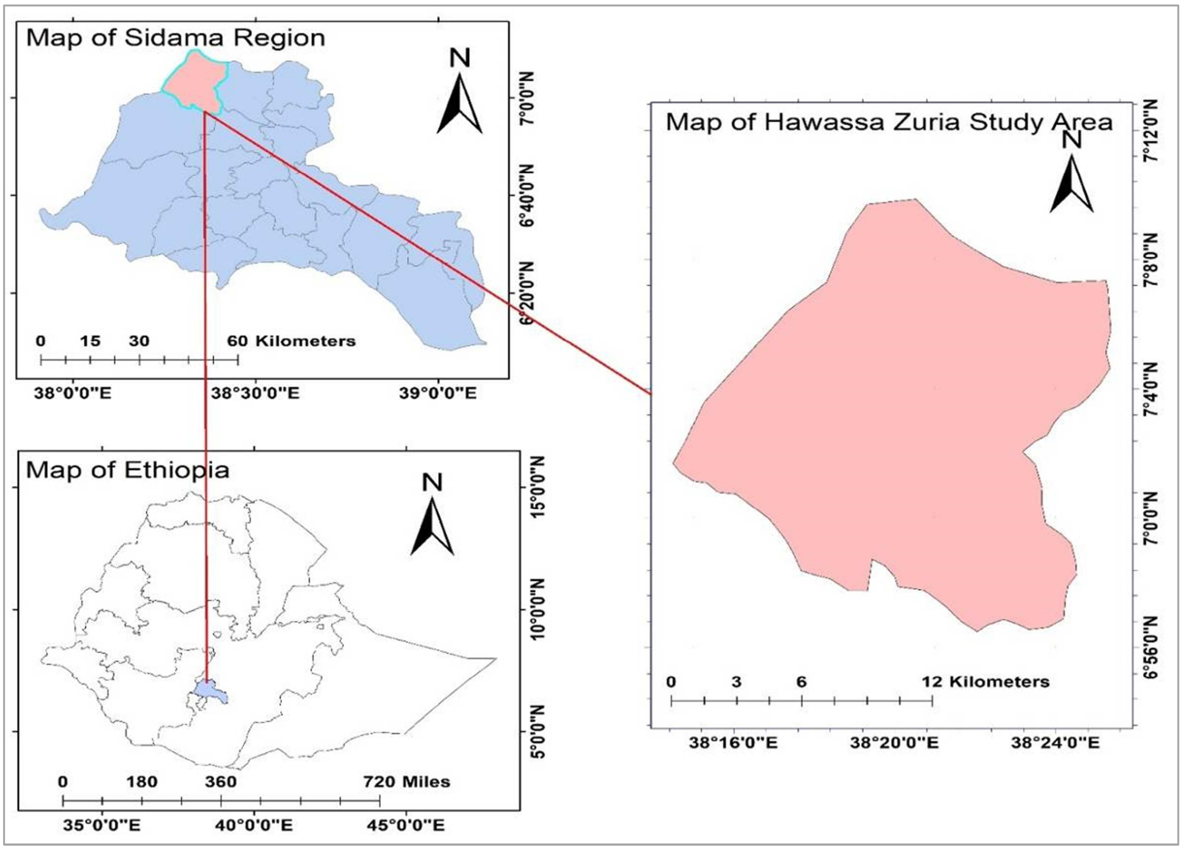

Figure 1. *Map of the study area.*

2.2. Sampling Technique and Sample Size

Due to its potential for maize production, experience with farmers' tribulations with climate concerns, and familiarity with the location, the Hawassa Zuria district was purposively selected. From the 23 maize production *kebeles* of the district, three *kebeles* (Dore Bafano, Hawassa irsha limat, and Rukesa suke) were selected randomly. Households were also selected randomly from the three *kebeles* for survey data collection. A total of 290 maize producer households were selected for this study using a simplified formula of [66]

$$n = \frac{N}{1+N(e)^2}, = \frac{1056}{1+1056(0.05)^2} = 290$$

Where n is the sample size, N is the population size, and e is the level of precision or the sampling error.

Table 1. *Distribution of sample maize producer households.*

Kebeles of maize producer	Number of HHs	Sample of HHs	Sample size in percentage (%)
Dore bafano	410	120	41
Hawassa irshalimat	360	94	33
Rukesa suke	286	76	26
Total	1056	290 100	

2.3. Data Sources and Data Collection Methods

This study employed both primary and secondary data collection methods. The primary data at community level were collected through a structured questionnaires, key informant interviews, focus group discussions (FGD), and field observations. For focus group discussion six individual were chosen for each *kebele* based on the criteria of age groups above 18 years, sex, and ethnicity (male and female). For three *kebele*s, structured open-ended and closed-ended questionnaires were constructed to acquire information on climate variability, particularly the impact of rainfall variability and temperature fluctuations on maize yield and management methods. Secondary data, such as daily rainfall and temperature, were obtained from the Ethiopian National Meteorological Agency (NMA), various published research papers and reports, and documents in the district's agricultural offices.

2.4. Data Quality Control

Maintaining the quality of the primary data involved making certain that all questions were answered, appropriate codes were used, the right individuals were interviewed, and the responses given were in line with the questions they followed. Prior to analysis, the study area's climatic data, like daily rainfall and temperature, and crop yield data were plotted against time (day of year format) and subjected to visual examination for the presence of discontinuities and special codes for missing values. The proportion of missing values was calculated, and stations with missing values of less than 10% of the entire data series were used in this study. The RclimDex 1.0 software's process was used to discover data quality issues such as keying errors, irregular rainfall and temperature values, and outliers. Daily rainfall amounts less than 1mm (if any) are erased because less than 1mm of rainfall value has almost no effect on the growth of crops, and daily maximum and minimum temperatures are set to a missing number or if the daily maximum temperature is less than the daily minimum temperature, respectively. To fill up the missing data values, the Decision System Support for Agro-technology Transfer (DSSAT) software was employed.

2.5. Data Analysis Methods

To analyze the climate variability impact on maize yield, the weather parameters such as annual rainfall, the temperature of minimum and maximum were computed using descriptive statistics such as means, percentages, the standard deviation of the series. Microsoft excel was used to generate frequency tables, cross tabulation, bar graphs and to facilitate easy understanding and interpretation. Mann-Kendall tests were computed to test the magnitude of the trends of the climate variables. The INSTAT plus (v3.37) software [2, 19, 26, 56-58] were used to compute and summarized the daily rainfall data in terms of monthly, seasonal and annual total (mm), onset of rainy season, end of rainy season, length of dry spell, length of growing period, coefficient of variation and rainfall anomaly.

Qualitative data generated from the questionnaire were analyzed by using SPSS data analysis tool. Thus, frequencies, percentiles, means, standard deviations, and tables were used to summarize and present the result. Correlation and multiple regression methods were computed to establish the relation, case and effects of rainfall and temperature on maize yields. The model's R-squared value has been used to determine how much of the yield reduction is explained by rainfall and temperature.

2.5.1. Coefficient of Variation (CV)

The impact of climate variability on variables such as rainfall and temperature was studied using descriptive statistical approaches such as coefficient of variation (CV), standard deviation (SD), mean, and median. The coefficient of variation computed as the following formula: $\text{CV}\ (\%) = \left(\frac{SD}{\overline{X}}\right) \times 100$ Where x and δ are the average and standard deviation of rainfall, respectively over the given period. According to Hare (1983), CV (%) values are classified as follows: <20% as less variable, 20-30% as moderately variable, and >30% as highly variable.

2.5.2. Standard Anomaly Index (SAI)

Rainfall anomaly was computed to examine the nature of rainfall throughout observation and to determine dry and wet years in the record. This was calculated as:

$Z = \frac{(X-\mu)}{\delta}$ Where, x is the seasonal total rainfall of a particular year; μ is the mean of the observation and δ is the standard deviation of the observation. Based on Z values, drought severity classes are given as 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) [9, 42].

2.5.3. Mann-Kendall (MK)

One of the most widely used approaches for detecting climatic trend in time series data is the MK trend test. It is one of the most extensively used non-parametric tests for detecting a trend in climatic data time series [44]. This non-parametric test is also less susceptible to outliers and can detect a trend in a time series without stating whether it is linear or non-linear [47]. The MK test compares a data value's relative magnitude to all subsequent data values in an ordered time series. The Z value was used to determine whether or not there was a statistically significant trend. A positive Z value shows both upward and downward movement. Correlation and multiple regression methods were computed for this study to establish the relation, case and effects of rainfall and temperature on maize yields.

3. Results and Discussion

3.1. Annual and Seasonal Rainfall

The annual rainfall of Hawassa Zuria district in the years 1989-2019, ranged from 702.1 mm in 2015 (the driest year) to 1256 mm in 2006 (the wettest year) (Table 2). This annual rainfall range result is close to the annual rainfall reported by [38] for the study period of 1987-2017 in Hawassa Zuria and Hula districts of Sidama Region, Southern Ethiopia. The mean annual rainfall, standard deviation, and coefficient of variation (CV) were 1019 mm, 150.7mm, and 15%, respectively. The recorded annual rainfall amount was recorded below average in the years of 1990, 1991, 1993, 1994, 1999, 2000, 2003, 2004, 2008, 2009, 2011, 2012, 2015 and 2016 in Figure 2. Approximately half of the study years had annual average rainfall below long-term average, which indicates that the district had rainfall deficit in the last three decades.

Mann-Kendall trend analysis indicated that the annual rainfall amount in the study area showed a statistically non-significant increasing trend by a factor of 4.34 mm/year during the study period. This finding is in agreement with the findings of [43, 51] who reported increasing trend in annual rainfall in the Central Rift Valley escarpment of Ethiopia. Similarly, [38] reported an increasing trend in annual rainfall in Hawassa Zuria and Hula districts of Sidama Region, Southern Ethiopia.

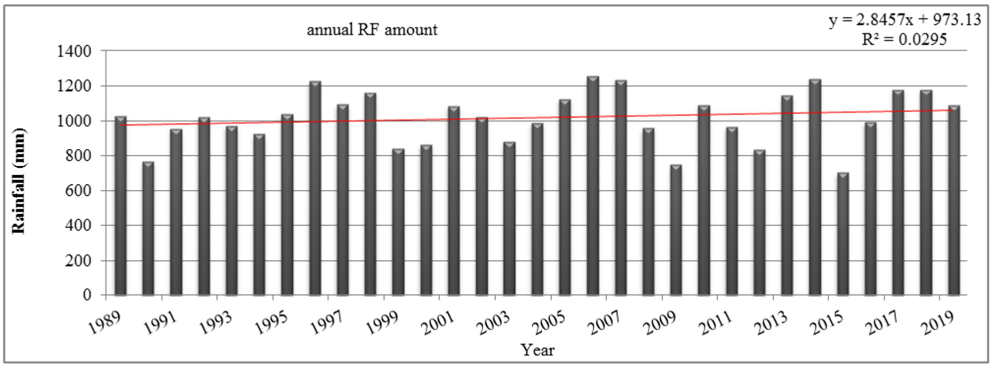

Figure 2. *Time series of annual rainfall total for data year of 1989-2019.*

Seasonal rainfall analysis showed moderate variability during *kiremt* season (CV = 22%), *belg* season (CV =26%) whereas *bega* season had high variability (CV =42%). Based on [32], the annual, *kiremt,* and *belg* rainfall totals were less to moderately variable whereas, *bega* rainfall was highly variable in the study area. *Kiremt* rainfall contributed 48% of the annual rainfall while *belg* (36%) and *bega* (16%) rainfall contribute smaller proportions. The result of the present study is in line with the report of [40, 41]. The Mann-Kendall trend analysis showed that there was a statically significant increasing trend for the *kiremt* rainfall, whereas the *belg* seasonal rainfall showed a non-significant increasing trend (Table 2). [26] Observed a declining trend in annual and seasonal rainfall levels in northern Ethiopia, but this result contradicts these findings. However, the trend analysis of *bega* season rainfall revealed that a statically non-significant decreasing trend in the study area. This result is in line with the study of [38] who reported an increasing trend in *kiremt* rainy season in Hawassa Zuria districts of Sidama Region, Southern Ethiopia.

Table 2. *Descriptive statistics and Mann-Kendall trend test for annual and seasonal rainfall in Hawassa Zuria district based on data year (1989-2019).*

Variable	Mean	SD	Minimum	Maximum	CV	Z_{MK}	Q
Annual	1019	150.7	702.1	1256	15%	1.19	4.34
Belg	362.6	93.7	134.1	512.2	26%	0.68	1.63
Kiremt	491.4	108.7	300.9	743.3	22%	1.73^{+}	2.98
Bega	164.6	69.3	51.5	343.4	42%	-0.51	-0.64

Where, CV= Coefficient of variation, SD= Standard deviation, Max. =maximum temperature, Min. =minimum temperature, ZMK= Mann-Kendall trend test, Q= Sen's slope estimation '+' significant at 0.1 significance level.

3.1.1. Analysis of Monthly Rainfall

The computed descriptive statistics of rainfall including mean, coefficient of variation (CV) and standard deviation (SD) of rainfall distribution over the study area for the period 1989–2019 were presented in Table 3. In the study area, the rainfall condition was highly variable for all months, which indicated unpredictability and vulnerable to drought condition. The three months with highest maximum monthly rainfall were May (128.5 mm), July (129 mm) and August (129.6 mm) which contributed 12.6% and 12.7% and 12.7% to the annual rainfall. These findings contradict those of [12] who studied Southern Ethiopia from 1983 to 2016. The shortest rainy season (*bega*), which runs from November to January, got the least amount of rain, accounting for 8.8% of the total rainfall. Rainfall is particularly important for maize cultivars in the study area from May to September.

The Mann-Kendall trend analysis showed that there was a statistically significant increasing trend for the month of May at *P* =0.05 levels in (Table 3). However, the observed decreasing trend in the month of December was significant at *P* 0.1 significance level. There was no significant increase in rainfall trend that were observed in April, June, July, August, September and November whereas no significant decreasing trend was observed in January, February, March and October. These findings contradict those of [12] who studied Southern Ethiopia from 1983 to 2016.

Table 3. *Descriptive statistics and Mann-Kendall trend tests for monthly rainfall.*

Parameters	Mean (mm)	SD (mm)	CV (%)	ZMK	Q	Contribution (%)	Trends
Jan	28.0	30.7	109	-1.6	-0.5	2.8	D
Feb	37.1	41.1	111	-1.1	-0.7	3.6	D
Mar	78.9	42.4	54	-0.2	-0.2	7.8	D
Apr	118.0	51.9	44	0.3	0.4	11.6	I
May	128.5	57.9	45	2.0^{*}	2.2	12.6	I
Jun	109.7	52.3	48	0.0	0.1	10.8	I
Jul	129.0	45.2	35	0.9	1.2	12.7	I
Aug	129.6	43.6	34	1.4	1.6	12.7	I

Parameters	Mean (mm)	SD (mm)	CV (%)	ZMK	Q	Contribution (%)	Trends
Sep	123.3	44.0	36	0.7	0.7	12.1	I
Oct	74.9	47.2	63	-0.1	-0.2	7.4	D
Nov	39.9	39.9	100	1.1	0.4	3.9	I
Dec	21.8	24.8	114	-1.8^{+}	-0.4	2.1	D
Annual	1019	150.7	15	1.2	4.3	100	I

Where, D= decrease, I= increase, * and += indicates significance at 0.05 and 0.1 level respectively

3.1.2. Onset, Cessation and Length of Growing Season

Analysis of long term (1989-2019) rainfall data revealed that the onset of rainy season (SOS) was less variable (CV=14%) and highly stable (SD=17days) in the study area. From the present study, earliest onset of rainy season was during the 2nd decade of April (106 DOY) and also, the late onset date occurred during the 2nd decade of June (169 DOY). These findings contradict those of [36], who found that in Ethiopia's Baro-Akobo basin, early onset happened in the third decade of May while late onset occurred in the third decade of September. The rainy season begins on 19 April (110 DOY) once every four years (25 percent), but the (SOS) occurs twice every four years (50 percent) on 24 April (115 DOY) and three times every four years (75 percent) on 4 May (125 DOY) (Table 4). The research area's onset date trend analysis revealed a statistically non-significant increasing trends; the positive sign indicates that rainfall duration is mostly determined by the onset date.

The earliest date of EOS was 30 September (274 DOY) and the latest cessation date was on 13 Nov (318 DOY). The end date had a CV of 5%, SD 14 days, which means that rainfall cessation in the area was less variable and high stable during the study period. The main rainy season ends three out of four years (75%) in the second week of October (292 DOY) and twice in four years (50%) in the first week of October, although the (EOS) occurs once every four years (25%) in September (274 DOY). This finding is in line with the finding of [19] that showed the main rainy season terminates during second week of October three out of four years in the central rift valley of Ethiopia.

The season of growing period is most of the time influenced by onset and end date of rainfall. However for present study growing season (LGS) indicated that significantly relate with onset date. In the study area growing season ranged between 113 to 211 days, with mean of 163 days. According to the current research, LGS begins on June 1st (154 DOY) once every four years, however LGS can occur three times every four years on June 23rd (175 DOY). The LGS showed a statistically non-significant upward trend, indicating that it has an impact on agricultural yield in the research area. During the study period, the LGS was less variable (CV= 14%) and moderately stable (SD=22 days). Furthermore, the LGS showed a similar variability with respect to onset date (Table 4). Which implies; that the length of the growing season was more dependent on the study area's onset date. Generally, the rainfall onset and cessation dates critically affect the amount of rainfall received over an area and the length of growing period.

Table 4. *Descriptive statistics of seasonal rainfall for Hawassa Zuria district.*

Season	Mean	SD	Min.	Quartile 1 (25%)	Median (50)	Quartile 3 (75%)	Max.	CV (%)	ZMK	Q
SOS	122	17	106	110	115	125	169	14%	0.24	0.06
EOS	285	14	274	274	279	292	318	5%	0.9	0.08
LGS	163	22	113	154	165	175	211	14%	1.04	0.45

Where, SOS = start of season, EOS = end of season, LGS = length of growing season, DOY = day of year, Min.= minimum temperature, Max.= maximum temperature, SD= standard deviation, CV= coefficient of variation ZMK= Mann-Kendall test, Q= Sens's slope estimations.

3.1.3. Number of Rainy Days

In the *kiremt* season, the number of rainy days ranged from 50 to 75 days, with a mean of 62.7 days, an SD of 5.9 days, and a CV of 9% (Table 5). [3] Found slightly shorter *kiremt* rainy days (40-68) with a mean of 61 days over central throughout the study period of 1985-2018. The observed CV values imply that the number of rainy days throughout the research period were less variable. The lowest and highest number of rainy days (NRD) recorded in *kiremt* in 1995 and 2007 were 50 and 75 days, respectively. The number of rainy days for *belg* season ranged from 28-64 days with a mean value of 46.8 day and a CV of 20%. Similarly, the number of rainy days from *bega* season ranged from 10-42, with average value of 22.8 day and CV of 33%. As a result, the measured CV of *kiremt* and *belg* rainy days revealed that inter-annual variability was higher. As a result, the number of rainy days in the research area is less reliable when it comes to planning agricultural activities. This finding is in line with report of [38] who reported inter-annual variability between *kiremt* and *belg* rainfall in Sidama Region, Ethiopia.

During the study period, rainy days were less than 59 days for JJAS, 42 days for FMAM, and 18 days for ONDJ once every four years (25 percent probability). Furthermore, the number of rainy days for JJAS, FMAM, and ONDJ three times in four years (75 percent) would be less than 68, 55, and 26 days, respectively. On the other side, JJAS, FMAM, and ONDJ each had less than 63, 46, and 23 days twice in four years (50 percent). Rainy days in the study area indicated statistically significant increasing trends at *P* 0.05 levels. The numbers of rainy days is mostly determined by the start and end of the season, which implies that, the number of rainy days increase when rain begins early and ends late.

Table 5. *Descriptive statistics and trend analysis of number of rainy day for study area.*

Season	Min.	Quar. 1 (25%)	Median (50%)	Quar. 3 (75%)	NRD Max.	Mean	SD	CV (%)	ZMK	Q
Kiremt	50.0	59	63.0	68	75.0	62.7	5.92	9%	2.2*	0.3
Belg	28.0	42	46.0	55	64.0	46.8	9.26	20%	-1.0	-0.2
Bega	10	18	23	26	42	22.8	7.5	33%	-1.45	-0.2

Note, NRD= number of rainy day, JJAS= June, July, August, September, FMAM= February, March, April, May, ONDJ= October, November, December, January *= indicates significance at 0.05

3.1.4. Probability of Dry Spell

The probability of dry spells exceeding 5, 7, 10 and 15 days length in Hawassa Zuria district during 1989-2019 is depicted in Figure 3. The probability of a dry spell lasting 7, 10 and 15 days was less than 20% from the second decade of July (196 DOY) to the first decade of September (253 DOY), the third decade of March (88 DOY) to the third decade of September (268 DOY), and the first decade of March (64 DOY) to the first decade of October (283 DOY). The probability of dry spells longer than 5 days in kiremt and belg seasons is greater than 20%.

The graph below shows that all dry day drops from 100 percent to *belg* and *kiremt* months rising area, whereas the probability of a 15-day dry spell decreases from 90 percent. In July and August, the probability of a 7, 10 and 15-day dry period was zero; however, the probability of a 5-day dry spell was more than 20% in the study area throughout the main rainy season (*kiremt*) (Figure 3). This finding is consistent with [3] findings on central Ethiopia. This means that decision-makers had an easier time predicting the occurrence of dry spells lasting longer than seven days. Within the growing seasons, the chance of dry spells increases as the length of the dry spell threshold shortens, and the probability of dry spells reduces as the length of the dry spell threshold lengthens. All the dry spell length probability curves converge to their minimum only during the peak rainy period (July and August or DOY 180-244) and turn upward again around the first decade of September (245 DOY), signaling the end of the growing season.

According to [59], dry spell analysis is important for on-farm agricultural decisions such as crop or cultivar choice and crop management practice (supplementary irrigation, fertilizer). This information is very important for farmer decisions on the crop to be cultivated and planting sowing date as a function of observed from cessation date. Generally the risk of dry spell length for longer dry spells like, 7, 10, and 15 days observed a declining pattern for kiremt and *belg* seasons, which indicated that the persistence of lower risk for drought-resistant crop production [2].

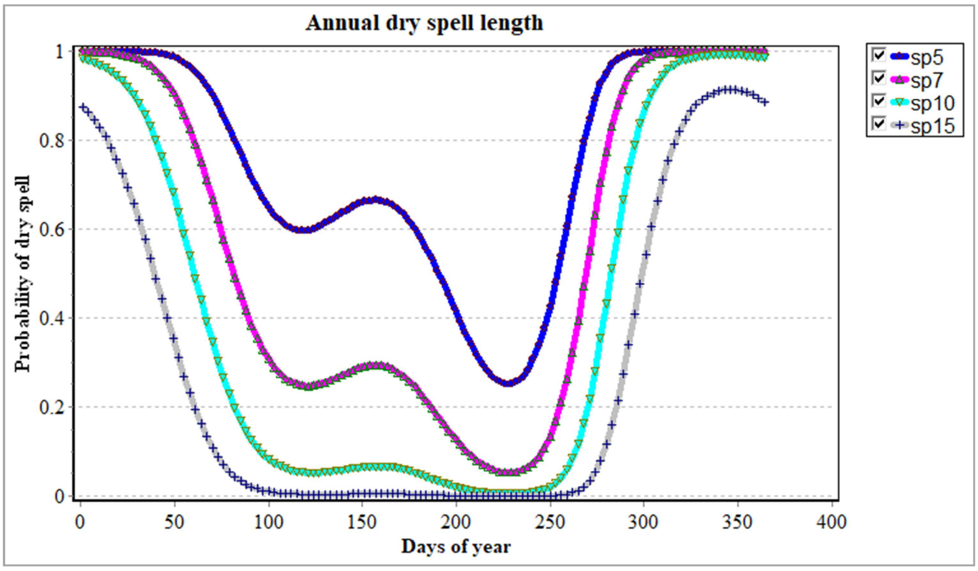

Figure 3. *Probability of dry spell length exceeding 5, 7, 10, and 15 days at Hawassa Zuria district 1989-2019.*

3.1.5. Anomaly of Annual and Seasonal Rainfall

Annual and seasonal rainfall anomalies of the study period were depicted in Figures 4-6. The figure show that the annual and seasonal rainfall anomalies in the study area were below the long-term average in 15 to 19 years over the study period. Based on the Standardized Precipitation Index (SPI) [39] there were moderately wet (1 to +1.49), very wet (1.5 to +1.99) and extremely wet (+2 and above) as well as moderately dry (-1 to -1.49), severely dry (-1.5 to -1.99) and extremely dry (-2 and below) periods for both annual and seasonal rainfall during the study period (1989-2019).

Furthermore, the yearly rainfall anomaly suggested that the years 1999, 2000, and 2012 were moderately dry. In the research area, the years 1990 and 2009 were severely dry; whereas 2015 was extremely dry (Figure 4). On the other hand, the years 1996, 2007, 2017, and 2018 were moderately wet years with rainfall above the long-term normal, and 2006 and 2014 were very wet years for annual rainfall anomaly throughout the research period.

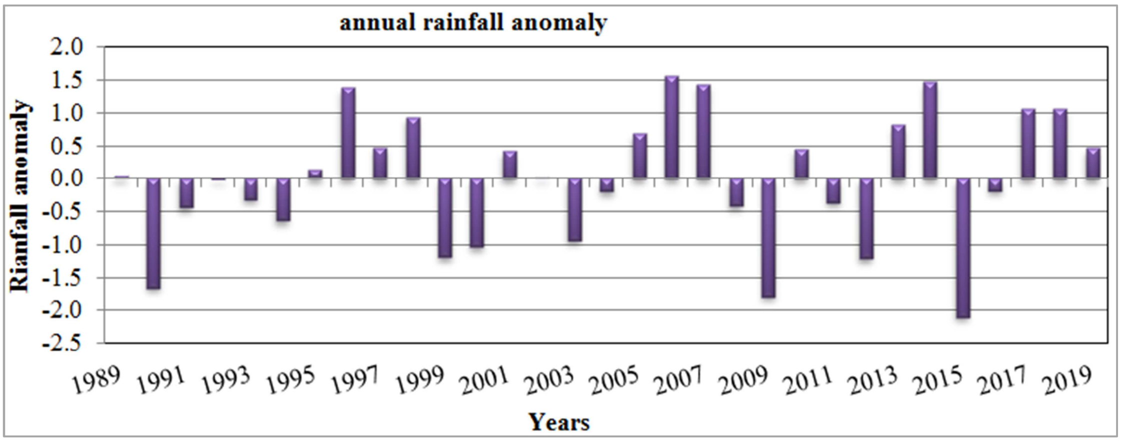

Figure 4. *Observed rainfall anomalies for annual rainfall for the period of 1989-2019.*

According to the *kiremt* rainfall anomaly, around 61 percent of observation years had rainfall below the long-term mean. The years 1990, 1993, 2009, and 2016 were moderate to severe drought years in the research area, with *kiremt* rainfall below the study period's average (Figure 5). On the other side, rainfall has been above the long-term average of the research period in 39 percent of the years. These findings contradict those of [3], who said that over central Ethiopia, 47 percent of the *kiremt* season showed a weak to significant negative departure from the long-term mean rainfall, while 53 percent recorded rainfall above the long-term mean. During the study period, however, the years 1995, 1996, 2006, 2013, 2014, and 2019 were classified as moderately wet (1 to +1.49) to extremely wet (1.5 to +1.99) while 2007 was an extremely wet year. Rainfall with a similar high concentration was observed by [5] in central highlands of Ethiopia.

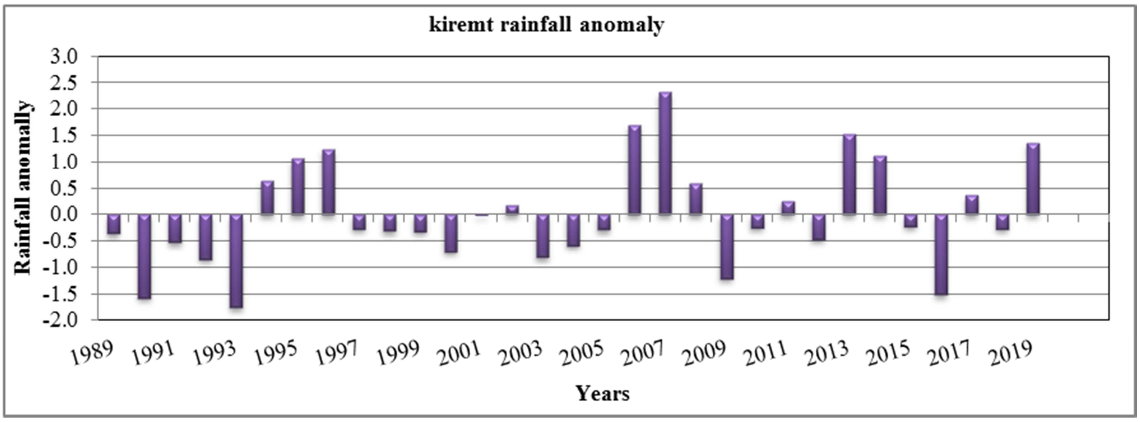

Figure 5. *Observed kiremt rainfall anomaly in the study area during 1989-2019.*

According to the analysis of the *belg* rainfall anomaly, 52 percent of the years in the studied period (1989-2019) had rainfall below the average (Figure 6). However, during the study period, the years 1999, 2008, and 2009 were moderately to severely dry, but 2015 was an extremely dry year. According to [27], the year 2015 observed the highest negative anomaly explained by the presence of El Niño, which impacted the major livelihood of rural people in many parts of Ethiopia. On the other side, rainfall has been above the research period's long-term average in nearly half of the years. Furthermore, *belg* rainfall amounts were found to be above the research period's average in the years 1989, 1990, 1991, 1993, 1996, 1998, 2001, 2005, 2006, 2007, 2010, 2014, 2016, 2017 and 2018. This finding is not in agreement with report of [41] in Sidama region and by [10] in southern Ethiopia.

The rainfall anomaly, which is characterized by inter-annual variability and a trend of being below the long-term average, has been more pronounced in the study area during the last three decades; which influenced maize productivity. In the past, droughts in Ethiopia have been linked to ENSO episodes [8]. El Niño episodes in Ethiopia in 1987, 1991, 2001, 2009, and 2015 coincided with an extended drought from April to November, covering the country's major agricultural season [30].

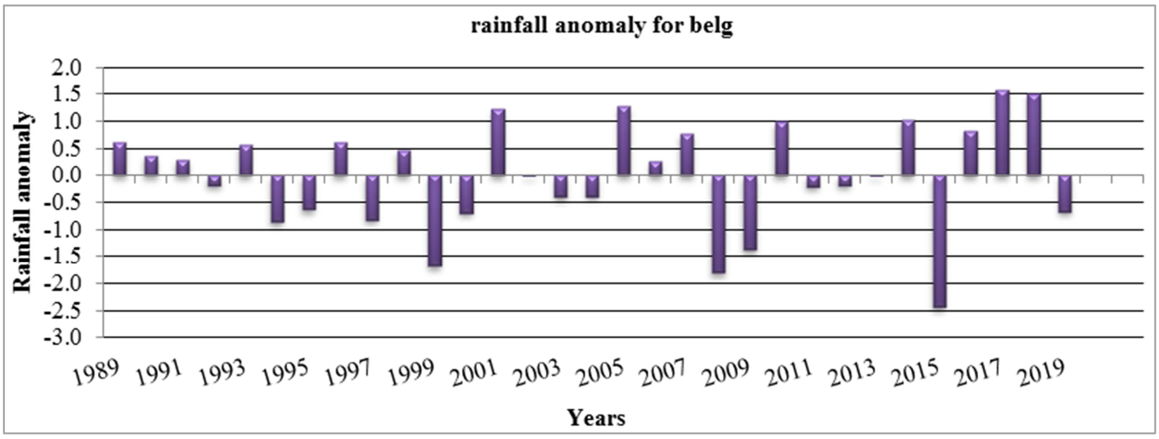

Figure 6. *Belg rainfall anomaly for the study period of 1989-2019.*

3.1.6. Analysis of Temperature Variability and Trends in the Study Area

During the study period, maximum and minimum temperatures in the study area were 29°C and 15°C, respectively (1989-2019). In the research area, the annual mean maximum temperature ranged from 26.5°C to 28.5°C, with a mean of 27.5°C (Table 6). Overall, annual mean maximum temperature showed a statistically significant increasing trend having the rate of change of 0.294°C per decade (Figure 7). This result in agreement with the report of [37, 23], who reported increasing annual average maximum temperature by a factor of 0.292°C per decade over the period 1960 to 2006 in Ethiopia. Similarly, this result is very close with finding of [38] in Hawassa zuria in Sidama region Ethiopia and [12] in Southern Ethiopia.

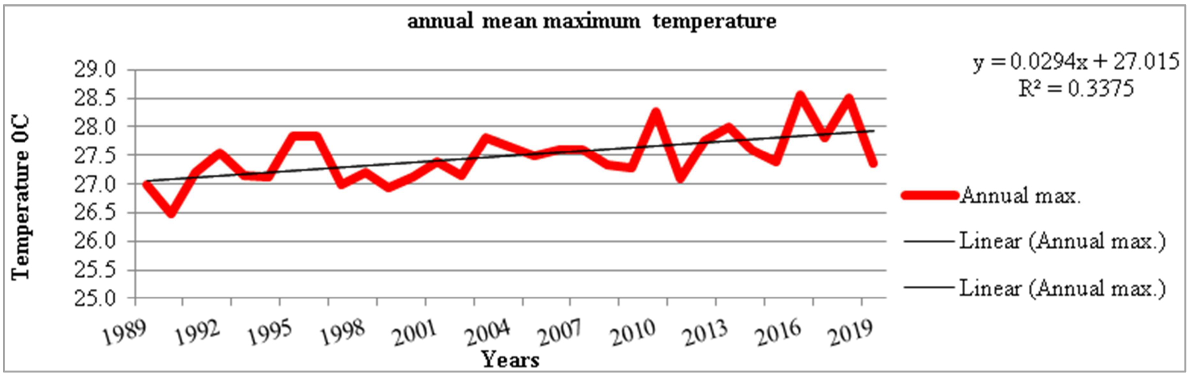

Figure 7. *Trends of annual mean maximum temperature during the study period of 1989-2019.*

According to the current analysis, the average maximum temperature recorded in the last thirty years was practically comparable in 2016 and 2018 (Figure 7). On the other hand main season maximum temperature ranged between 24.1°C to 26.7°C with mean 25.3°C, whereas short season maximum temperature ranged between 27.5°C to 30.5°C in the study area (Table 6).

During the research period, the annual average minimum temperature ranged from 12.2°C to 13.3°C, with a mean of 13.1°C. The annual minimum temperature in the study area was increasing at a rate of 0.64°C per decade (Figure 8). This result is corroborates with report of [28] who reported annual mean minimum temperature increased significantly in southern Ethiopia. Minimum temperature of *kiremt* season ranged from 13.3°C to 15.7°C with mean of 14.4°C (Table 6) in the study area. Minimum temperature of *belg* season ranged between 12.4°C and 15.8°C with mean of 13.6°C during the study period. In the study area, minimum temperature of *belg* season changed by the rate of 0.45°C per decade.

In the study area the main season average maximum temperature observed 25°C once in four years (25% probability), 25.2°C twice in four years (50% probability) and 25.5°C three times in four years (75% probability). In the research area, however, the main season average low temperature was 13.9°C once every four years, 14.4°C twice every four years, and 14.8°C three times every four years. However, short season mean maximum temperature observed 28.7°C once in four years. Whereas, 29°C twice in four years' time and 29.5°C in three out of four years in the study area. During the study period, the mean minimum temperature was 13°C once every four years, 13.5°C twice a year, and 13.7°C three times a year (Table 6).

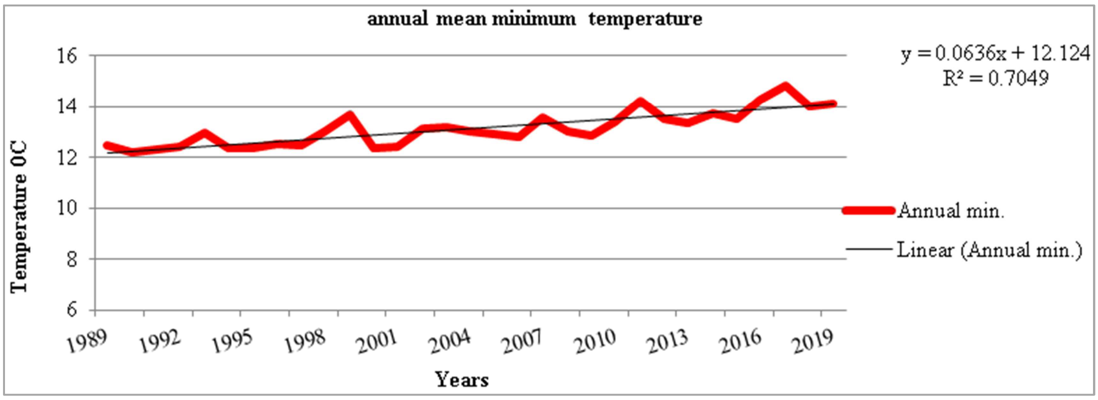

Figure 8. *Trend analysis of annual minimum temperature in the study area.*

Table 6. *Descriptive analysis of annual and seasonal temperature in the study area during study period of (1989-2019).*

Temperature features	Mean	Min.	LQ (25%)	Median	UQ (75%)	Max.
Annual Max. temp	27.5	26.5	27.2	27.5	27.8	28.5
Annual Min. temp	13.1	12.2	12.5	13.0	13.6	14.8
Kiremt Max. temp	25.3	24.1	25.0	25.2	25.5	26.7
Kiremt Min. temp	14.4	13.3	13.9	14.4	14.8	15.7
Belg max. temp	29.0	27.5	28.7	29.0	29.5	30.5
Belg min. temp	13.6	12.4	13.0	13.5	13.7	15.8

Max. = maximum temperature, Min. = minimum temperature, LQ= lower quartile, UQ= upper quartile

The graph of main and short rainy season maximum temperature revealed that increasing trends observed in both cases in the study area (Figure 9). Annual minimum temperature is increasing faster than the annual maximum temperature during the study period. This finding is in line with others from the Central Rift Valley Region of Ethiopia by [41, 43, 45] in Sidama, whose research found minimum annual temperature to increase faster than the maximum.

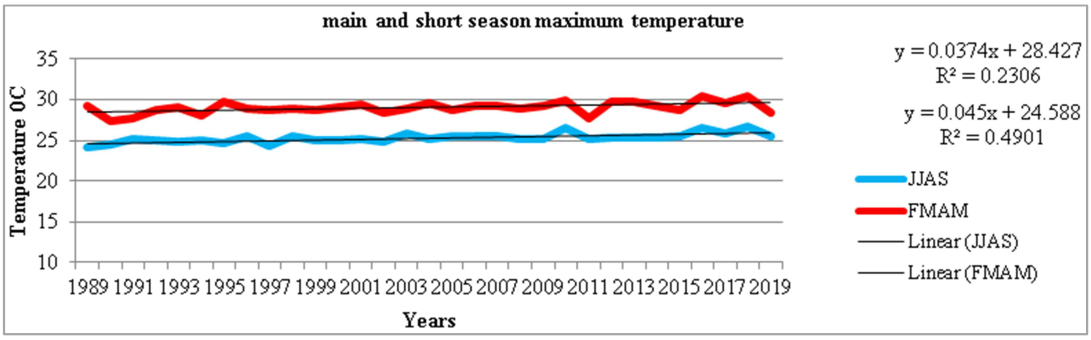

Figure 9. *Trends observed maximum temperature in main and short rainy season during periods of 1989-2019.*

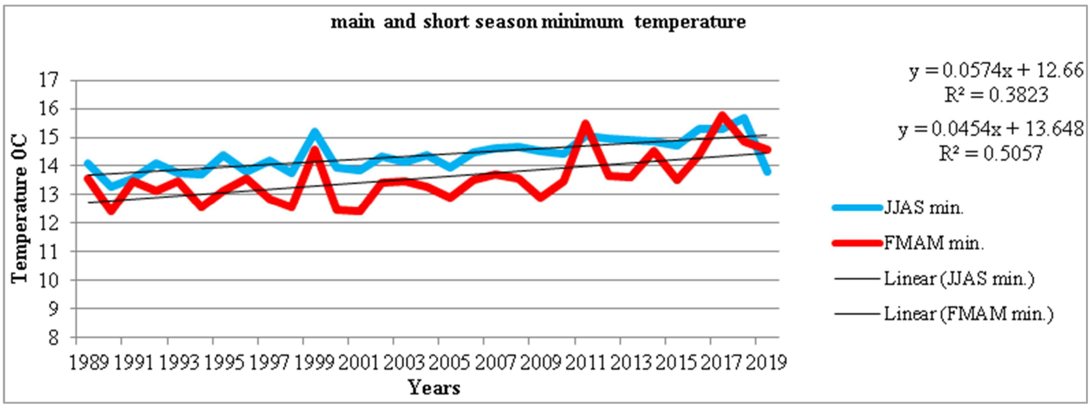

Figure 10. *Observed average minimum temperature trends in main and short rainy season.*

During the study period, the highest *kiremt* minimum temperatures were reported in 1999 with 15.1°C and in 2018 with 15.7°C in the study area, while the lowest *belg* season minimum temperatures were recorded in 1999 with 14.6°C, 2011 with 15.5°C, and 2017 with 15.8°C (Figure 10). However, throughout the study period from 2015 to 2018, the main and short season low temperatures both increased rapidly, owing to ElNio years. During these years, maize output in the research area revealed a 0.6 qt/h decrease in yield. This data is consistent with [61], who found a 20% yield drop in maize in Sub-Saharan Africa between 1961 and 2017.

Monthly maximum temperatures in the study area increased from the first week of January to the second week of March, then increased again from the third week of September to December. During the study period, however, decreasing tendencies were found from the third decade of March to the second decade of September (Figure 11). Maize is planted under a single-cropping method in April, when the appropriate soil temperature is reached for germination. May, June and July corresponds to the key-growing season in Hawassa zuria district. This finding is consistent with [21] analysis, which found that the months of March to September are the most productive in the Halaba zone of southern Ethiopia. This suggested that rising temperatures have steadily pushed the sowing period in the research area from the third week of March to the last week of April, and occasionally the first week of May, when the soil moisture levels are optimal for maize germination and growth. Maize yield has decreased by 0.6 qt/ha over the last 12 years.

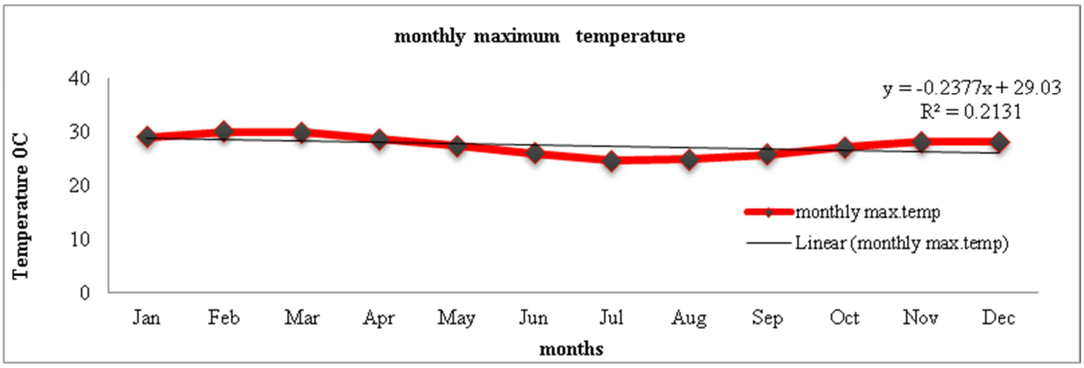

Figure 11. *Study area mean monthly maximum temperature during period of 1989-2019.*

Increases in temperature between March and May, as well as precipitation between June and August, were found to have a negative impact on maize productivity. The graph of mean monthly maximum temperature revealed that February and March were the warmest months in the research area (Figure 11). However, based on mean monthly minimum temperatures, the coldest months in the research site were November and December (Figure 12) during the study period.

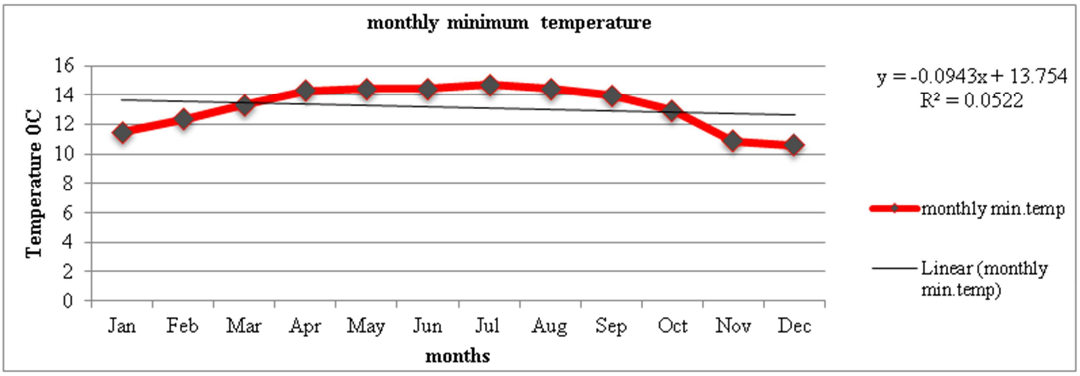

Figure 12. *Mean monthly minimum temperature in the study area during period of 1989-2019.*

3.2. Demographic Characteristics of the Respondents

Table 7 shows the socioeconomic characteristics of the household head. Dore Bafano *kebele* provided 90 (75%) male and 30 (25%) female household heads out of a total of 290 HHHs. In the population sample, 48 (63.2%) male and 28 (36.8%) female household heads were from Rukessa Suke, and 80 (85.1%) male and 14 (14.9%) female household heads were from Hawassa Irshalimat *kebele.* From survey data the sex sample proportion of the three *kebeles,* male-headed households share the largest proportion in the study area. The composition of age groups categorized between 25-30, 30-45 and >50 and for each *kebele* the largest age shares founded between 30-45 age groups covered 71%, 47.4% and 56.4% Dore Bafano, Rukessa Suke, and Hawassa Irshalimat respectively. According to the survey result the age group greater than 50 years shared the smallest proportion in the study area.

The age group of 30-45 holds the largest share in a sample of the population, which indicated that the respondents were very active and well-informed to current climate-related challenges on agriculture and other socio-economic activity in the study area. Regards to family size composition large size family numbers found between 3 and 5 members accounted for 55.8%, 61.8%, and 68.1 for Dore Bafano, Rukessa Suke, and Hawassa Irshalimat respectively *kebele*s. In the research area, respondents' education status was classified as primary, capable of reading and writing, secondary, illiterate, and above 12 for a sample of the population, with primary education accounting for the highest percentage of education levels. This is because education status is a very important tool to easily understand the information of climate variability to adjust and to empower the adaptive capacity to climate variability. The education status of capable to read and write secondly held the largest proportion from a sample population in the survey of household heads, which covered 33 HHHs (27.5%) Dore Bafano, 11 HHHs (14.5%) Rukessa Suke, and 21 HHHs (22.3%) Hawassa Irshalimat. From the survey result, the secondary education level covered 10.8%, 11.8%, and 10.6% for each *kebele* respectively. Despite the great importance of literacy on adaptation to climate variability, the survey data in Table 7 shows the respondents achieved primary and secondary level education from the sample population. The remaining household head grouped illiterate and above twelve education levels, which accounted for 20%, 32.9%, 30.9% and 2.5%, 5.3%, 1.1%for each *kebele* respectively.

Farmland size has a positive and negative role on farmers' livelihood to coping climate variability if it is efficiently and effectively used farmland for productive things. The survey of household results revealed that the farmland size of 0.5 to 1 hectares hold large share from the sample of the respondent in the study area, which covered 48.3%, 56.5%, 50.9% Dore Bafano, Rukessa Suke and Hawassa Irshalimat respectively. Another large share of farmland size categorized 0.13 to 0.25 hectare in the study area, which accounted for 48.3%, 43.4%, and 49% for each kebele respectively. Due to the findings of the HHH survey, practically all farmers in the sample survey have less than one hectare of farmland. During the survey, respondents stated that this makes them sensitive to climate variability-related challenges.

Table 7. *Socio-economic characteristics for selected kebeles in the study area.*

Variable		Dorebafano		Rukessasuke		Hawassa irishalimat	
		N	%	n	%	n	%
Sex	Male	90	75	48	63.2	80	85.1
	Female	30	25	28	36.8	14	14.9
	Total	120	100	76	100	94	100
	25-30	36	30	19	25	13	13.8
Age	30-45	71	59.2	36	47.4	53	56.4
	>50	13	10.8	21	27.6	28	29.8
	Total	120	100	76	100	94	100
	<3	22	18.3	19	25	13	13.8
Family Size	3 to 5	67	55.8	47	61.8	64	68.1
	>5	31	25.8	10	13.2	17	18.1
	Total	120	100	76	100	94	100
	Illiterate	24	20	25	32.9	29	30.9
	capable to read and write	33	27.5	11	14.5	21	22.3
Education level	primary school	47	39.3	27	35.5	33	35.1
	secondary school	13	10.8	9	11.8	10	10.6
	>12 grade	3	2.5	4	5.3	1	1.1
	Total	120	100	76	100	96	100
Farm land size	0.13-0.25 ha	58	48.3	33	43.4	43	49
	0.3-0.35 ha	4	3.3	0	0	0	0
	0.5-1 ha	58	48.3	43	56.5	48	50.9
	Total	120	100	76	100	94	100
	Petty trade	9	7.5	4	5.3	8	8.5
	Daily laborer	15	12.5	6	7.9	16	17
Source of income	Remittance	5	4.2	0	0	0	0
	Others	90	75	66	86.8	70	74.5
	Total	120	100	76	100	94	100

During the survey period, respondents were given the option of earning money from sources other than agriculture, such as petty trade, working as a daily worker, remittance, and other sources; of these, majority HHHs from each *kebele* earned money from agriculture and received safety net aid (Table 7). Second, some respondents use minor trade and working as daily laborers as sources of income, in the study area. During the interview, the respondent stated that agriculture provided practically all of our revenue, and that as a result, we are now facing climate variability-related concerns.

Farmer's Adaptation Strategies to Climate Variability

One of the proposed objectives of this study was to assess some of adaptation and coping methods being practiced by farmers along with community based adaptation strategies in response to negative effects of climate variability. In the study area Household head respondent identified different adaptation option and coping strategies during interviewed period. Accordingly major adaption option respondent were practiced in locality such as using new varieties of crops, diversification of crops and livestock, planting grass cover, migration and use of early maturing crops (Table 8). However, majority of household head practiced 38.3% diversification of crops and livestock, 26.6% use of early maturing crops and 19.7% using new varieties of crops as adaptation option in the study area. Migration is another adaptation option, during migration most time based on livestock pasture short term movement to the highland areas is common reserving some crops until the coming season.

Table 8. *Adaptation option to climate variability in the study area.*

	Frequency	Percent
Using new varieties of crops	57	19.7
Diversification of crops and Livestock	111	38.3
Planting grass cover	8	2.8
Migration	10	3.4
Use of early maturing crops	77	26.6
Receiving aid from safety net	90	31
Inter-cropping system	150	51.7
Wise storage of crops (saving)	50	17.2
Planting trees	120	41.4
Building flood protection features	79	27.2
(ditches)	60	20.7
Protecting water reservoirs	31	10.7
Constructing roads		
Total	290	100

Coping strategies are actual responses to crises on livelihood systems in the face of unwelcome situation; therefore they are termed as short term responses, [13, 31]. Regards to coping strategies household head uses different mechanisms like, receiving aid from safety net, inter-cropping system and wise storage of crops (saving) (Table 8). Majority of household heads uses as strategies 51.7% inter-cropping system in the study area. As inter-cropping system in the study area maize crop and inter-cropped with haricot bean, potato and cabbage most time.

Communities have always adapted to climate variability by making preparations supported on their resources and knowledge accumulated through experience of past weather pattern. During conversation between focus group, development agent and elders about community based adaptation options, they identified common works in locality. Majority of household respondent practiced planting trees (41.4%), as community adaptation strategies in the study area (Table 8). However, the study of [16] revealed that using new crop varieties, planting trees and soil conservation, are the most common adaptation options in Ethiopia. Community organizing for adaptation to climate variability in itself also increases resilience to climate risks by strengthening and expanding social networks and links with supporting institutions [15].

3.3. Correlation of Maize Yields with Rainfall and Temperature

The correlation coefficient computed between maize yield, rainfall features, maximum and minimum temperature is shown in Table 9. In the study area there was negative correlation between maize yield and rainfall and temperature features. The correlation of maize yield with onset date was statistically non-significant and weak negative correlation (r=-0.479). On other hand the cessation date has moderate strong negative and statistically non-significant correlation with maize yields (r= -0.521).

During the study period, maize yield had a non-significant and very weak negative connection with LGS (r= -0.047) (Table 9). There are non-significant, weak negative correlations (r= -0.444) between the number of rainy days and maize yield, as well as non-significant, moderately strong negative correlations (r =- 0.528) between the *kiremt* rainy season (JJAS) and maize yield.

Table 9. *Pearson's correlation matrix of maize yield and rainfall and temperature features in the study area.*

	Maize Yield	SOS	EOS	LGS	NRD	JJAS	FMAM	TMAX	TMIN
Maize Yield	1								
SOS	-.479	1							
EOS	-.521	-.199	1						
LGS	-.047	-.758**	.790**	1					
NRD	-.444	-.245	.589*	.545	1				
JJAS	-.528	-.185	.758**	.620*	.479	1			
FMAM	.292	-.624*	.320	.603*	.228	.008	1		
TMAX	.319	-.458	.020	.300	.315	-.274	.750**	1	
TMIN	-.496	.014	.397	.255	.268	.005	.399	.225	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Belg season (FMAM) revealed weak positive relationships with maize yield (r= 0.292) as well as maximum temperature (r = 0.319). This result is in agreement with the study of [48] Rainfall characteristics and Maize Yield in Kwara State and [4] effect of Variability in Rainfall Characteristics on Maize Yield in Gboko. Generally end of season and *kiremt* rainfall mainly impact the annual maize yields in the study area.

For this study, explanatory variables such as the start of the season, end of the season, number of rainy days, *kiremt* (JJAS), *belg* season (FMAM), maximum and minimum temperature are used in the regression analysis. The model was created using the dependent variable of maize yield and an independent variable to predict the impact of the explanatory variable on maize yield or the dependent variable.

The result of regression coefficient analysis showed that different rainfall and temperature features impact the maize yield in different changing values. The season of onset date changes maize yields negatively (-0.181 qt/ha). This means the late starting of the season in the study area challenges the yield of maize production than early onset. Late onset triggers late plantings which favor disease; as result yield decrease. This finding is supported by [21] who reported that the declining trend of maize yield (productivity) due to onset date in Halaba zone, Southern Ethiopia. Others, end of season and *belg* season were important features in this data for maize yield positively revealed.

Table 10. *Coefficient of regression for rainfall and temperature features in the study area.*

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	219.149	71.922		3.047	.038
SOS	-.181	.073	-.448	-2.497	.067
EOS	.040	.101	.106	.399	.710
NRD	-.119	.128	-.181	-.927	.407
JJAS	-.038	.015	-.650	-2.550	.063
FMAM	.019	.014	.388	1.363	.245
TMAX	-1.557	2.445	-.166	-.637	.559
TMIN	-5.887	1.654	-.598	-3.559	.024

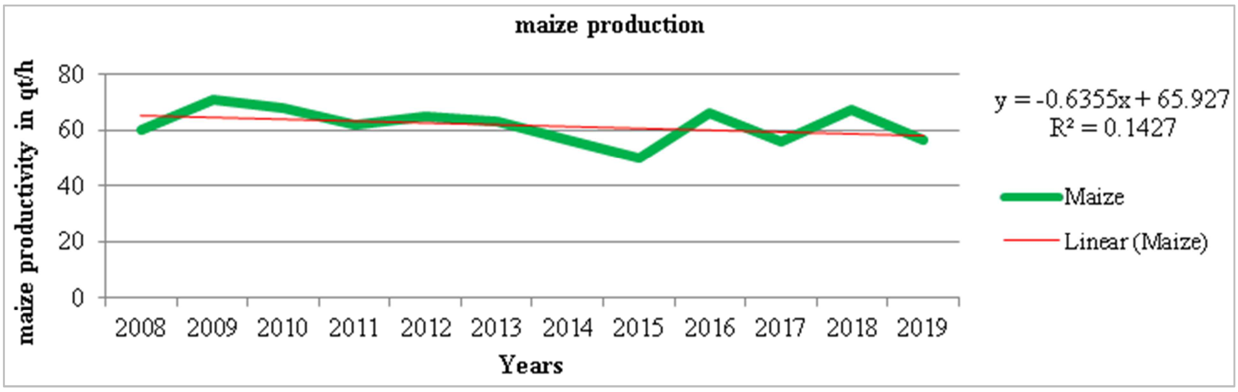

Figure 13. *Maize production trends in the study area.*

a. Dependent Variable: Maize yield

In the study area maximum and minimum temperature highly a negative impact on maize yields (-1.557 qt/ha) and (-5.887 qt/ha) respectively. This result is not agree with report of [62] who stated that, maize yield increases with increasing temperatures are favorable in an environment, on separate and combined effects of temperature and precipitation change on maize yields in sub Saharan Africa for mid to late 21st century.

The computed value for the coefficient of determination (R^2) is 0.94 during the study period. This indicates that 94% of the variance on maize yield per hectare in the study area last twelve years. This maximum value of variation on maize yield was the combination of the start of the season, end of the season, number of rainy days, *kiremt* and *belg* rainy season, maximum and minimum temperature with others the rest 6% non-climatic factors in the study area.

The maize production was reduced by 0.6 quintals per hectare per year (Figure 13). In order to determine evidence of changes in maize production, a regression line was constructed; it showed a 14.27 percent decline in productivity in the interim. The Hawassa zuria districts decreasing maize production (productivity) is mostly caused by unpredictable onset and seasonal rainfall, rising warmth, and high potential evaporation.

4. Conclusion and Recommendation

Annual and seasonal rainfall revealed statistically non-significant increasing trends from 1989 to 2019, however seasonal rainfall being more variable than annual rainfall. Annual mean maximum and minimum temperatures in the study area have shown statistically significant increases over the last three decades. The maize production decline reported in the research area is due to this, particularly the impact of increasing mean minimum temperature years. On the other hand, in this study, mean monthly rainfall exhibited statistically significant declining trends during the study period. Rainfall features such as onset season (SOS) and end of season (ES) are less variable and have high stability in the study area, according to the analyzed daily rainfall data. The duration of the growing season (LGS) exhibits similar variability as EOS and is in a generally stable state. The growing season ranged from 113 to 211 days, with a mean of 163 days and a 14 percent coefficient of variation. The length of a dry spell's chance of occurrence is crucial in rain-fed agriculture. During the study period, the length of dry spells was assessed for various months. At 7, 10, and 15 days from the first decade of August (217 DOY) to the second decade of August (235 DOY), second decade of April (103 DOY) to second decade of September (259 DOY), and second decade of March (76 DOY) to first decade of October (277 DOY), respectively, the probability of a dry spell was observed to be zero (0 percent).

When maize yield was correlated with rainfall and temperature, it was shown that the start of the season (LGS) (r=-0.479) showed a weak negative association with maize yield. However, maize yield demonstrated a moderately negative and non-significant relationship with end of season (EOS) (r= -0.521). The length of season (LGS) revealed a weak negative correlation with maize yield (r= -0.444). The negative effects of the onset date, number of rainy days, and *kiremt* rainy season reduced maize yields in the study periods, according to the results of multiple regression models. Furthermore, in this study, the maximum and minimum temperature effects had a significant negative impact on maize yield reduction. During survey time, Mr. Nemaro Danga and Abera Soressa, selected key informants, stated several coping and adaptation techniques to combat climate variability. They advised employing early-maturing crops, diversifying crops and livestock, planting trees, and constructing flood protection features as adaptation options. The findings reveal that the lower the rainfall variability, the fewer the maize yield production reduction, and hence the more dependable the rain is for maize cultivation and other agricultural activities in the research area that need special attention. Based on these results, it is recommended to Farmers and the district agricultural sector should take care and attention on start of season, cessation date and length of growing season, Supplementary irrigation system from Hawassa Lake should be access for farmers especially they live near to this lake and this research can be used as an input; however, more research is needed to analyze both short and long-term climate variability in maize and other crops in the study area.

Availability of Data and Materials

All the data used in this study are available from the corresponding author up on reasonable request.

Authors' Contributions

All authors equally contribute in design, review and writing the manuscript. They all read and approved the paper. All authors read and approved the final manuscript.

Competing Interests

The Authors declare that there are no competing financial or non-financial interests regarding the publication of this manuscript.

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