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Impacts of Climate Variability on Maize (*Zea mays* L.) Yield in Kurfa Chele District of East Hararghe Zone, Oromia, Ethiopia

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Abstract: Climate variability is among the principal source of variations in crop production in developing countries including Ethiopia that greatly relies on subsistence farming. This study assessed the impacts of climate variability on maize (Zea mays L.) yield in Kurfa Chele district, eastern Ethiopia. Climate data (1996-2016) and maize yield data (2001-2016) were acquired from the NMA of Ethiopia and KWANRO, respectively. Variability, trend and anomaly of climate variables were analyzed using INSTAT +3.37 and Mann-Kendall trend analysis. The mean start of rainy seasons, length of growing period and end of the rainy seasons in Kurfa Chele district were 31st March, 178 days and 25th September, respectively and belg onset was highly variable (CV=42%). Annual and kiremt rainfall amounts were found to increase by a factor of 2.45 and 1.64 mm/year, respectively and were insignificant at 5%. Conversely, the belg rainfall decreased by a factor of -0.8 and was insignificant. The maximum temperature showed increasing trend at annual, kiremt and belg periods by a factor of 0.046, 0.053 and 0.066°C/year, respectively. Similarly, annual, kiremt and belg minimum temperatures showed increasing trend and were significant at 5%. The correlation of maize yield with rainfall and temperature parameters revealed that belg rainy days and kiremt rainy days have strong relationships with maize yield. The result of multiple regression showed that an increase in kiremt end date (-0.04 Kg/ha) and kiremt mean temperature (-2.57 Kg/ha) caused decrease in maize yield. Coefficient of determination indicates that climate features predict 79% the variation in maize yield. Thus, it is essential to advance extension services to improve perception of climate variability and proper implementation of adaptation practices in the study area.

Keywords: Climate Variability, Impacts, Kurfa Chele, Maize Yield, Rainfall, Temperature

1. Introduction

Globally, climate variability and change accounts for a third of variation in crop production. Changes in surface temperature and erratic rainfall or prolonged drought threaten agricultural production especially in sub tropical regions [23]. Developing countries are more vulnerable to climate variability and change as small-scale farmers depend on rainfall for their production and other factors in the environment [22].

Africa is one of the most vulnerable continents to climate change and variability [16] which makes it most food insecure continent with the Sub-Saharan African (SSA) countries being the most affected by climate change and variability [43]. This is because of increase of stresses such as human population, water shortage, land degradation and food insecurity [22]. Agriculture in the SSA countries is dominated by smallholder farmers and it contributes the largest share of the economy. Smallholder farmers of this region are the most vulnerable due to limitation in adaptation capacities [1]. The maize mixed cropping system covers over a third of the area in the SSA region with the majority of production based on rainfall [3].

In large parts of SSA maize is the major staple crop, accounting for a total of nearly 27 million ha. Maize covers 30% of the total area under cereal production in this region: 19% in West Africa, 61% in Central Africa, 29% in Eastern Africa and 65% in Southern Africa [15, 36]. The importance of maize also can be explained as it covers more than 30% of the total calories and protein consumed in Africa [15]. Even though the significance of maize in SSA, yields remain low [38]. The dependency of farming systems on rainfall increases vulnerability of maize productions to climate variability and change. While farmers have a long record of adapting to the impacts of climate variability which represents a greater challenge because impacts are out of the range of farmers' previous experiences. Consequently, climate variability will harshly test farmers' resourcefulness and adaptation capacity [6].

The agriculture sector constitutes more than half of the nation's gross domestic product (GDP), generates more than 85% of the foreign exchange earnings, and employed about 80 percent of the working population in Ethiopia [12, 47]. Maize is one the most important cereal produced in Ethiopia as it ranks second after *teff* in area coverage, first in total national production and yield per hectare [10]. The national maize yield average is of 2.95 t/ha [9]. This is far below the world's average which is about 5.66 t/ha [46]. The estimated average yields of maize in the mid- and low-altitude areas are about 2.5 t/ha and 2.0 t/ha, respectively [8]. Thus, Ethiopia's dependence on agriculture makes the country for the most part vulnerable to the adverse impacts of climate variability on maize yield.

Climate variability and associated droughts have been major causes of food insecurity and famine in Ethiopia [42, 2]. For instance, the worst disaster in Ethiopia has experienced in 1983/84 failure of the main rainfall season, and resulted in reduction of the agricultural out puts by 21%, and GDP by 9.7% [22]. The same study also revealed that because of El Niño caused drought in 2015/2016, the average number of food insecure people in the country was more than 10 million.

In Ethiopia, the temperature has been increasing annually at the rate of 0.2°C over the past five decades [4]. This has already led to a decline in agricultural production. Cereal production in Ethiopia is expected to decline by 12% under moderate global warming [48]. Among the Ethiopian regional states, Oromia is already vulnerable to extremes of climatic variability; and climate variability is likely to increase the frequency and magnitude of some natural disasters and extreme weather events. These extreme events could be worsened by existing social and economic challenges in the region, particularly for those areas and communities dependent on resources that are sensitive to climate changes [35].

In Oromia Regional State, maize production is influenced by wide range of factors including climate variability, topography, and socio-economic diversity. Moreover, the majority of its population depends on subsistence agriculture. Kurfa Chele district in which this study was conducted is evidently the hardest hit by climate variability, which brings reductions of crop production.

Kurfa Chele district is one of the eastern parts of the country which is affected by climate variability and exposed to food insecurity problem area, thus taken by the government as a pilot district for the implementation of Productive Safety Net Program (PSNP) [44]. Even if researches were done on impacts of climate variability on maize crop, they focused on survey parts and this research incorporated characterization of climate variability with focusing on maize yield. Climate variability poses a huge threat to farmers in the district due to their high dependence on small-scale and rain fed crop production. Land degradation and water scarcities have become threatening problems. Agricultural production in Kurfa Chele is frequently affected by climate related shocks [25]. Farmers in the district have been reacting to climate variability through various adaptation strategies but face challenges to fully prevent yield loss as a result of climate variability. The dependency of agricultural production, which is frequently affected by variable climatic conditions, brings food security problem that is still recurrent in the district. Therefore, this study was undertaken with the aim of generating additional information that might help to deal with the impact of climate variability on maize yield**.**

The general objective of the study was to assess the impact of climate variability on maize yield in Kurfa Chele district, with the following specific objectives:-

1) To characterize climate variability of 1996-2016 years in the study area.
2) To evaluate the relationship between climate variability and maize yield in the study area.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location of the Study Area

This study was conducted in Kurfa Chele District, which is one of the 20 districts in East Hararghe Zone of Oromia National Regional State of Ethiopia. Geographically, the district is located between $8^0 58^{'} 0''$ N - $9^0 22' 0''$ N latitudes and $41^0 47^{'} 30''$ E – $42^0\ 1^{'} 0''$ E longitudes (Figure 1). The district is bordered on the south by Gurawa, on the west by Bedano, on the north by Kersa, on the east by Haramaya and Fadis districts. The administrative center of Kurfa Chele district is Kurfa; that is located at distance of about 56 km West of Harar and 540 km East of Addis Ababa. The district constitutes 20 *kebelle* administratives. Out of these, 2 are urban *kebelles* while the remaining 18 are rural *kebelles.* In each *kebelle* agricultural extension workers and health extension workers were assigned. According to the information obtained from the district Rural Road Authority in 2018, ten rural and two urban *kebelles* were accessible for all weather roads while the remaining 8 rural *kebelles* were accessible only by dry season road [41].

2.1.2. Topography

Kurfa Chele district covers about 259.69 km² (30,177 ha) and topographic lands lie between 1100 to 2600 meters above sea level; Gara Mulleta (Debal), Dedero and Gebiba are amongst the highest points respectively. Rivers include the Dawe, Gefra Gelana and Gefra Goga. Relief of the district is characterized by plateaus and rugged dissected mountains (to the West) deep valleys, gorges and plains (to the South and North). The West high lands being part of Hararghe plateau include dissected mountain peaks like Garamuleta (3404m) [25].

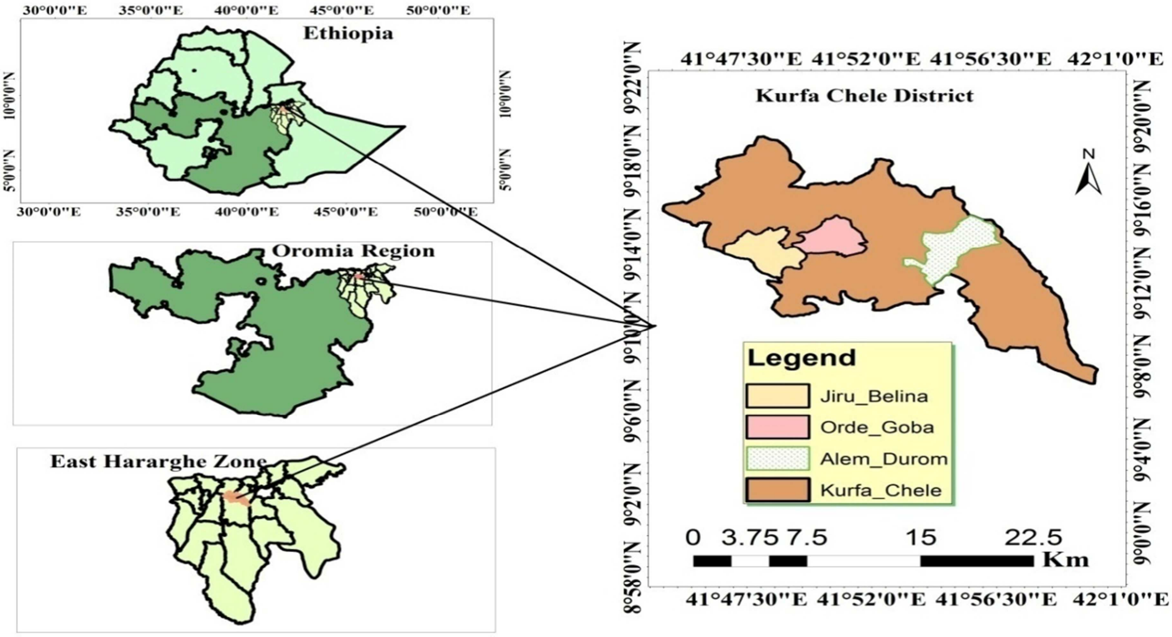

Figure 1. *Location map of the study area.*

2.1.3. Climate and Drainage

The climate of Kurfa Chele is characterized by a bimodal rainfall distribution, *belg* season (short rainy season) in the months of March to April and *kiremt* (the main rainfall season) extending from June to September. Its annual rainfall ranges from 500 mm to 1200 mm with annual average temperature varies between a maximum of 27°C and a minimum of 12°C. The district has three traditional agro-ecological zones *dega* (highland) *woinadega* (midland) and *kola* (lowland) agro climatic zones covering about 36%, 13% and 51% of the total area of the district, respectively [25].

The district is found within the Gobele drainage basin and accordingly drained by both perennial rivers and seasonal streams. The major perennial river is Dawe which has about 10km of length from Garamuleta to Gobele. Small seasonal streams are Gefra, Melka Kersa, and Gola Gaya. Finally these rivers after joining other rivers those originate from other neighboring districts drain into Gobele River [25].

2.1.4. Land Use and Agriculture

From the total coverage 11,097 ha (39.42%) is used for crop production, 6,746 ha (22.35%) is covered by forest, 3047 ha (10.09%) is used for grazing land, 2,905 ha (9.6%) is bush and shrub land, 3653 ha (12.1%) is used for social services and 1927.16 (6.4%) is rocky and hilly land used for other purposes [25]. But the size of farm land used for crop production is limited and their production system is mainly rain-fed. The mean land holding per farm household is 0.5ha in general and even less for high land and irrigable low land areas [41].

More than 98% of the Kurfa Chele District population makes its living on agricultural activities. In the district, crop production is largely rain-fed in the face of irregular rainfall and frequent drought. The major crops are cereals, mainly sorghum and maize, in small areas wheat, barley, oat, pulses and *teff*, cash crops *khat* and coffee in low lands, potatoes and onions in high lands and green pepper in some small low land areas. They are produced in large and little area coverage's by using rainfall and irrigation during rainy and dry seasons, respectively. Maize is a long-cycle crop which is planted during the small rainy season (*belg*) between March and April, and harvested between October and December [25].

Animal production is also considered as additional to the crop production activities. Cattle, goats, sheep, camels, donkeys and horses are among largely reared animals, respectively. The potential can be taped to the benefits of agriculture sector it's dependents and inter dependent and the national economy as a whole. The major constraints of the sectors are back ward production system, poor infrastructure development especially marketing infrastructure and poor veterinary services [25].

Although there were no disaggregated figures for the study district, most households encountered food shortage for four to six months every year [30]. As a result, Kurfa Chele district is one of the most foods insecure districts of Oromia Regional State in Eastern Ethiopia.

2.1.5. Population Characteristics

The district has a total population of 58,712 in 2007 based on 2007 population and housing census of Ethiopia, and it is projected to be 75,939 in 2016 given a 2.9% annual growth rate of Oromia Region. From this population 37,557 are females and 38,382 are males, 90.2% of the total population lives in the rural parts of the district and the remaining 9.8% of the population are urban dwellers [7].

2.2. Sources of Data

Secondary sources were used to acquire data in this study. Historical secondary data of climate (grid) and maize yield were obtained from National Meteorological Agency (NMA) of Ethiopia and Kurfa Chele Agriculture and Natural Resources Office (KWANRO), respectively.

A thirty years (1986 - 2016) daily rainfall and temperature grid data of the study area were obtained from the NMA of Ethiopia at Addis Ababa and captured in to Microsoft excel 2007 spreadsheet following the day of year (DOY) entry format. Historical maize yield data (2001-2016) were obtained from KWANRO and captured in to Microsoft excel 2007 spreadsheet.

2.3. Methods of Data Analysis

2.3.1. Analyses of Rainfall and Temperatures

The daily rainfall and temperature data (1986-2016) reorganized in a monthly, seasonal and annual time step in Microsoft excel 2007 spread sheet. Initially, in the study area, variability of seasonal rainfall was analyzed for its onset date, end date, LGP and the number of rainy days. The reorganized rainfall and temperature data were averaged over the thirty year and analyzed in order to examine the seasonal, monthly and annual variability.

Daily rainfall data was fitted to the simple Markov Chain model to determine the probability of dry spell lengths of 5, 7, 10 and 15 days within the growing season using INSTAT +3.37 software [40].

Monthly, seasonal and annual rainfall and temperature were assessed using CV and SD techniques. In addition for more information and detail analysis, first moments of variation (mean, minimum, maximum, quartile and standard deviation) was obtained using descriptive analysis. INSTAT +3.37 software was used for analyzing some rainfall characteristics and temperature.

The classification of monthly, seasonal and annual rainfall variability was based on Hare classification [18]. Therefore, CV was used to classify the degree of variability of rainfall actions as less, moderate and high. The equation is as follows:

$$CV = \frac{\sigma}{\mu} * 100 \tag{1}$$

Where CV is coefficient of variation, σ is standard deviation and μ is long term mean of rainfall/ temperature. When CV < 20% it is less variable, CV from 20% to 30% is moderately variable, and CV > 30% is highly variable.

2.3.2. Trends of Rainfall and Temperature

Rainfall trends are essential to optimize the spatial distribution and adaptability of different agricultural projects [31]. Mann-Kendall test was used to analyze trend of rainfall and temperature because of two reasons. First, it is a non-parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to unexpected breaks due to inhomogeneous time series [45]. Each data value is likened with all successive data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic *S* is increased by 1. In contrast, if the data value from a later time period is lower than a data value sampled earlier, *S* is decreased by 1. The net result of all such increasing and decreasing affects the final value of S. The Statistic (S) formula of Mann-Kendall is as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(Tj - Ti) \tag{2}$$

$$\text{sign}(Tj - Ti) = \begin{bmatrix} 1 & \text{if } Tj - Ti > & 0 \\ 0 & \text{if } Tj - Ti = & 0 \\ -1 & \text{if } Tj - Ti < & 0 \end{bmatrix}$$

Where; T_j and T_i are the monthly, seasonal and annual values in years j and i, j > i, respectively.

A positive value of S indicates a rising trend whereas a negative value indicates a declining trend in the data. At specific probability level H_0 is rejected in favor of H_1 if the absolute value of S equals or exceeds a specified value $S_{\alpha/2}$, where $S_{\alpha/2}$ is the smallest S which has the probability less than α/2 to appear in case of no trend. For n ≥ 10, the statistic *S* is approximately normally distributed.

Kendall's tau is another measure of correlation which determines the strength of relationship between the two variables [32]. Kendall's tau values range between -1 and +1, with a positive correlation showing that the ranks of both variables increase together whilst a negative correlation indicates that as the rank of one variable increases, the other decreases.

The magnitude of the trend in the seasonal and annual series was determined using a Sen's slope estimator which is nonparametric method [37] and calculated as:

$$Ti = \frac{xj - xk}{j - k} \tag{3}$$

Where Ti is Sen's estimator, xj and xk represent data values at time j and k, respectively.

2.3.3. Analysis of Rainfall Anomaly

The standardized rainfall anomalies (SRA) used to evaluate inter-annual variability with respect to the long term normal conditions for a specific time scale. Rainfall anomaly is used to observe the nature of rainfall over the period of observation and to decide dry and wet years in the record [27]. The SRA was calculated as the difference between the annual/seasonal totals of a particular year and the long term average rainfall records divided by the standard deviation of the long term data. The SRA was calculated using equation:

$$z = \left(\frac{x - \mu}{\sigma}\right) \tag{4}$$

Where, Z is standardized rainfall anomaly; x is the annual/seasonal rainfall total of a particular year; μ is mean annual/seasonal rainfall over a period of observation and σ is the standard deviation of annual/seasonal rainfall over the period of 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 ($Z > -0.84$) [27].

2.3.4. Correlation and Regression Analysis

Some major rainfall parameters and temperatures mechanisms were examined for better understanding the impact of climatic factors on maize yield. Similar to this, from the rainfall data collected, the following parameters were derived; *Belg* rainy days (day), *kiremt* rainy days (days), *kiremt* end date (DOY), length of growing period (days), *belg* rain fall total (mm), *kiremt* rainfall total (mm), *belg* mean temperature (°C) and *kiremt* mean temperature (°C). Likewise, from the temperature data, the following parameters were derived; *belg* and *kiremt* maximum temperature, *belg* and *kirmet* minimum temperature and *kiremt* mean temperatures in °C.

Correlation and multiple regression analysis are the statistical tools that were used to establish the relationship and impact of rainfall characteristics and temperature components on maize yield. The regression model for the study was computed as:

$$y = a + b1x1 + b2x2 + b3x3 \ldots\ldots\ldots bnxn + e \quad (5)$$

Where; Y is the value of the dependent variable (maize yield in quintal/ha); a is y-intercept and b1, b2, b3… bn are regression coefficients; x1, x2, x3,…xn are the independent variables (rainfall and temperature parameters) and *e* is error of estimate or residuals of regression. Coefficient of multiple determinations (R^2) was used to determine the percentage of climatic parameters impacts together.

Pearson correlation coefficient (r) analyze was used to analyze the correlation between maize yields (qt/ha) with rainfall characteristics and temperature components.

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum xi^2 - (\Sigma xi)^2][n\Sigma yi^2 - (\Sigma yi)^2}} \quad (6)$$

Where: coefficient (r) ranges from -1 to +1. A correlation coefficient (r) close to +1 indicates strong positive relationship, -1 indicates strong negative relationship and 0 indicates no relation.

3. Results and Discussion

3.1. Rainfall Variability and Trends

The result showed that, the district monthly rainfall was lowest for October, November, December, January, February and March (0 mm) followed by May (2.6 mm), July (3.1 mm), June (9.1 mm), April (9.6 mm), August (29.2 mm) and September (31.1 mm), whereas the highest monthly rainfall recorded in April (431.1mm), September (259.9 mm) and October (254.8 mm) respectively. Monthly SD of rainfall differs from 15.81 mm to 80.88mm and monthly CV varies from 39.8% to 224.6% as indicated in Table 2. From December to April the monthly rainfall revealed a decreasing trend; however positive trends were occurred from May to November. Therefore, rain-fed small holder farmers in the study area suffer from water shortage for crop production, livestock and for domestic consumptions in declining months. Monthly rainfall does not show statistical significance trend at *alpha* 0.05 significant levels in all months of the years except in February.

Belg rainfall amount ranged from 75.98mm to 540.6 mm. Conversely, Sen's Slope value showed that a decreasing *belg* rainfall trend by a factor of -0.81 mm/year in the district, but does not show statistically significant trend in the series. This is similar with the study which stated that spring (*belg*) rain in parts of Ethiopia has turned down by 15-20% since the mid-1970s [11, 17]. *Kiremt* rainfall amount ranged from 156.9 mm to 547.8mm. The *kiremt* rainfall showed an increasing trend by a factor of 1.64 mm/year. *Kiremt* rainfall probability value did not reveal statistical significance at 0.05.

The total annual rainfall amount for the study area ranged from 295.3mm to 996.9mm per year. The mean annual rainfall of the district was 632.4 mm in the period of observation (1986-2016). The district received the highest and lowest rainfall amount in 2006 (996.9mm) and 2015 (295.3mm), respectively. The rainfall also shows inter annual moderate variability as shown by the CV (27.4%) in Table 1. A study also showed that annual and *kiremt* rainfalls are less variable than *belg* rainfall [13]. The annual rainfall showed an increasing trend by a factor of 2.45 mm per year. Annual rainfall probability value showed that there is no significant trend at 0.05 significant levels. The positive trend over study area is not statistically significant, which might be connected to large inter annual variation. East Africa shows an increasing rainfall trend [19, 20].

Table 1. *Statistical description of total monthly, seasonal and annual rainfall at Kurfa Chele district (1986-2016).*

Variables	Mean	Min.	Max.	SD	25%	50%	75%	CV%
Jan	13.44	0	140.3	30.19	0	1.891	9.104	224.6
Feb	10.65	0	62.42	16.93	0	3.419	12.74	158.9
Mar	45.84	0	123.5	38.08	14.63	40.17	66.51	83.1
Apr	112.4	9.56	431.1	80.88	68.16	102.6	133.1	71.9
May	75.77	2.63	211.5	51.29	35.91	58.9	110.8	67.7
Jun	41.92	9.09	125.8	27.82	21.55	36.62	54.11	66.4
Jul	81.14	3.09	175.1	41.12	51.36	81.92	108	50.7
Aug	96.41	29.15	184.5	38.37	65.07	91.32	117.3	39.8
Sep	84.06	31.08	259.9	45.84	54.05	69.71	106.3	54.5
Oct	44.63	0	254.8	54.96	9.387	28.92	60.18	123.1

Variables	Mean	Min.	Max.	SD	25%	50%	75%	CV%
Nov	15.78	0	96.99	20.65	0	7.613	26.31	130.8
Dec	10.28	0	61.71	15.81	0	3.215	13.05	153.8
Belg	244.7	75.98	540.6	106.3	178.7	211.3	324.7	43.5
Kiremt	303.5	156.9	547.8	99.82	222.6	282.9	389.7	32.9
Annual	632.4	295.3	996.9	173	478.6	614.9	785	27.4

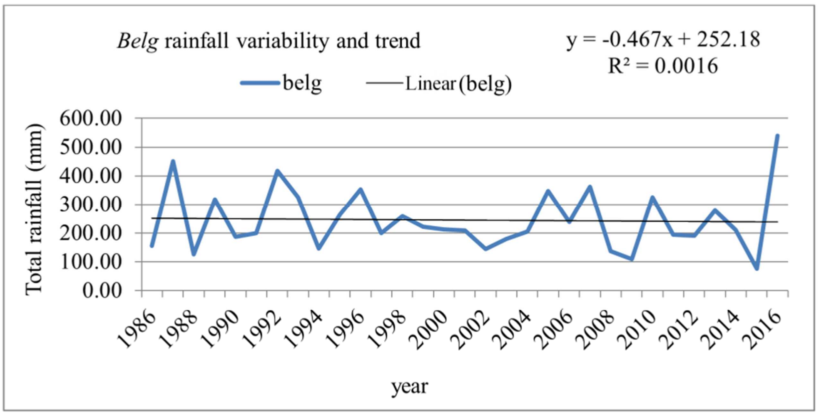

Figure 2. *Belg rainfall variability and trend at Kurfa Chele.*

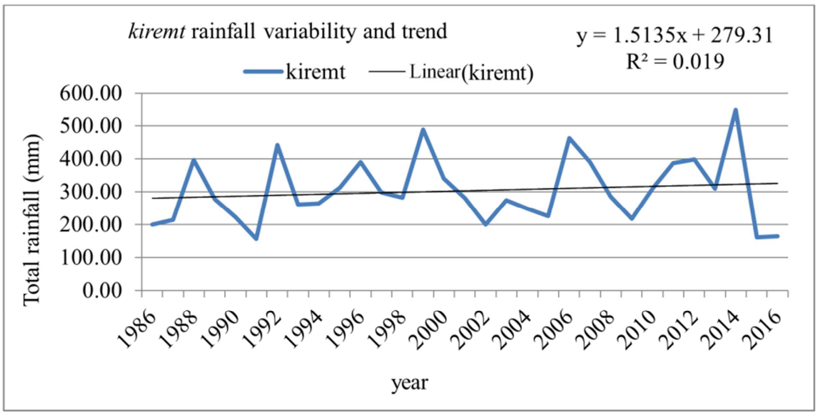

Figure 3. *Kiremt rainfall variability and trend at Kurfa Chele.*

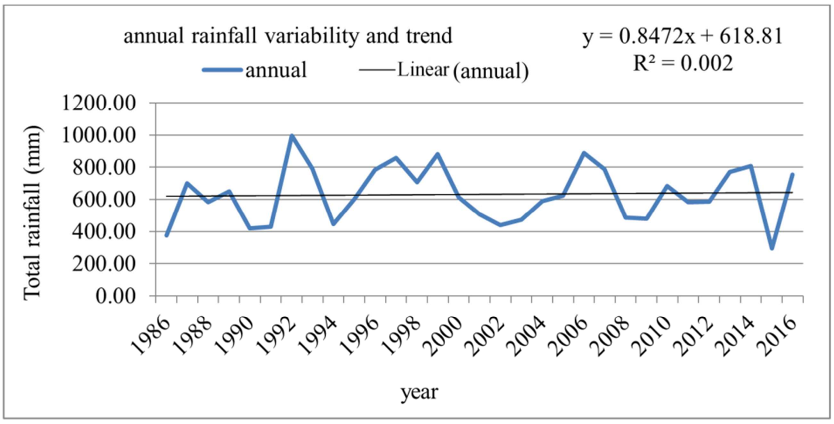

Figure 4. *Inter-annual rainfall variability and trend in Kurfa Chele.*

3.2. Rainfall Characteristics

3.2.1. Onset of Rainy Season

The analyzed historical rainfall data (1986-2016) outcomes showed that the mean, minimum and maximum and median (best sowing or planting date) start dates of rainy season (SOS) of *belg* at Kurfa Chele were 91 (March 31), 37 (February 6), 214 (August 2) and 80 (March 21) days of the year (DOY), respectively (Table 2). This align with the finding which stated that start of rainy season as rainfall total of 10 mm or more in 3 consecutive days or more with no dry spell length of 9 days or more in the next 30 days should occur with an earliest starting day first of February [28].

Inter annual and seasonal variability of SD and CV varied from season to season. The SD and CV of *belg* rainy season onset were 38 and 42% in the district, respectively. This enables to conclude that start of rainy season is highly variable and the district is vulnerable to drought as its CV is greater than 30% according to Hare [18] variability classification. This also affects maize crop at vegetative stage and ultimate yield. At Kurfa Chele station, the Lower Quartile (Q1=25%) of start of rainy season was 72 DOY (March 13) which means that the study area had the probability of getting onset on 13th March 1 year out of 4 years. Similarly, the Upper Quartile (Q3=75%) of start of rainy season was 103 DOY (April 12) which imply that the study area had the chance of receiving onset on 12th April 3 year out of 4 years in the study period.

3.2.2. End of the Rainy Season

The analysis of results showed that the mean, median, minimum and maximum end date of rainy season (EOS) of Kurfa Chele was 269 (September 25), 265 (September 21), 245 (September 1) and 320 (November 15) DOY, respectively. This finding is nearly related to the report of EPCC [14] on central and southern Ethiopia. Additionally, the time gap (late onset) between cessation of *belg* and onset of *kiremt* is very short (soil moisture not decline under 1 mm) and in many years merge with main rainy season and challenging harvesting of *belg* crops.

Upper quartile (Q3=75%) EOS of rainy season of the study years has value less than 283 at the district, While the lower quartile (Q1=25%) EOS value of rainy season was lower than 247. The EOS value of CV of rainy season showed variability of 9%, with SD of 23 days for the study area (Table 2). The CV and SD over the district prevailed that EOS is very serious problem during the study period.

3.2.3. Length of Growing Period

The mean, median, minimum and maximum length of growing period (LGP) of rainy season at the district was 178, 185, 31 and 239 days, respectively. In the same way, LGP value of rainy season revealed that upper quartile and lower quartile of Kurfa Chele were 203 and 154, respectively (Table 2). From this we understand that, LGP depends on start and end of rainfall and hence, late onset and early cessation of rainfall result in shorter LGP. Similarly, reported by [33] that the changes in start and end of rainfall affected the LGP, suggesting delayed onset of rainfall compensated by delayed cessation and vice versa. Length of growing period indicated high variability with CV for rainy season 25% for the study area with SD of 44 days. This corresponds to the study of EPCC [14].

Table 2. *Descriptive statistics of onset, end date and length of growing period of rainy season.*

Events	Mean	Min.	Max.	SD	25%	50%	75%	CV%
Belg onset (DOY)	91	37	214	38	72	80	103	42
End (DOY)	269	245	320	23	247	265	283	9
LGP (days)	178	31	239	44	154	185	203	25

3.3. Number of Rainy Days of Rainy Seasons

3.3.1. Belg Season Number of Rainy Days

The result of this study showed that during *belg* season the observed Number of Rainy Days (NRD) varied from 17 days at Kurfa to 57 days during 1986-2016 at Kurfa as illustrated in Table 3 below. The observed CV of *belg* season NRD also showed that there was less variable to very high inter annual variability in the NRD at Kurfa. Moreover, the present study has shown that the number of rainy days were more variable during the *belg rainy* (CV 33%) season than during *kiremt* (CV 17%) season as one can consider from their CV that the study area is highly vulnerable to drought. During *belg* rainy season of the study period, the SD and CV of Kurfa Chele were 11.06 days and 33% days respectively. This supported by the study of Misgina [29]. The rain of *belg* season was preceded by dry spells of 5 to 15 days. This dry spell usually resulted in numerous crop failures especially with late planted crops.

3.3.2. Kiremt Season Number of Rainy Days

The result showed that the *kiremt* NRD varied from 37 days to 71 days at the study area. During *kiremt* season of the last three decades, the SD and CV of Kurfa were 8.29 days and 17%, respectively. This indicates that the study area is less variable (CV 17%) during *kiremt* rainy season compared to *belg* season and it is optimal condition for maize crops as rainfall is stable. The above is align with the report of NMA [34] which state that farmers of Ethiopia relay on *kiremt* rainfall for their crop production and a small variation in the rainfall amount, intensity, duration, star of rainy season and cessation days, directly affects the activities of crop production.

Table 3. *Descriptive statistics of monthly, seasonal and annual number of rainy days, at Kurfa Chele district (1986-2016).*

Variables	Mean	Min.	Max.	SD	25%	50%	75%	CV%
January	2	0	9	2.52	0	1	2	137
February	3	0	14	3.41	0	1	4	134
March	7	0	18	4.92	3	7	10	68
April	13	5	20	4.33	9	13	15	35
May	11	2	20	5.16	7	11	15	47
June	8	2	21	4.41	5	7	11	55

Variables	Mean	Min.	Max.	SD	25%	50%	75%	CV%
July	13	1	20	4.03	11	12	16	32
August	15	7	20	3.58	12	16	18	25
September	14	7	22	3.84	12	14	16	28
October	6	0	18	4.64	3	5	9	73
November	2	0	12	2.61	0	1	4	114
December	2	0	8	2.06	0	1	3	123
Belg	33	17	57	11.06	24	34	41	33
kiremt	49	37	71	8.29	42	50	56	17
Annual	95	62	132	17.45	84	94	105	18

3.3.3. Length of Dry Spells and Probability of Occurrences

Knowing the dry spell lengths and probability of occurrence of rain enables meteorologist to give monthly and seasonal climate forecast. Similarly, information of dry spell lengths helps decision makers, local communities and NGOs to plan economic activities while reducing the harmful effects of drought, manage water resources and agricultural activities [24].

The analysis of the historical occurrence of dry spells is also important for planning time of minimum dry spell risks in the DOY. This study analyzed the probability of dry spells of 5, 7, 10 and 15 days length (1986-2016) in the study area (Figure 5). The probability of dry spells occurrence of *belg* season highly varies. At Kurfa Chele, the probability of dry spells occurrence longer than 5 days remained above 80% during *belg* and 50% at *keremt*. On the other hand, the probability of dry spell occurrence >7 days length was 50% at *belg* and 25% during *keremt*. Whereas, the probability of dry spell occurrence 10 was observed being 20% at *belg* and 5% at *kiremt* time. The probability of dry spell of 15 days was 5% at *belg* and 0% at *kiremt* time. This suggests that standing crops frequently exposed to moisture stress at critical stage of growth at the study area. This also indicates that dry spell of short period has high probability of occurrence compared to long dry spells.

Dry spells length probability curve converges to its minimum during the peak of rainy seasons (around April 2 and August 10 or 92 DOY and 222 DOY) and turn upward again around April 30 (120 DOY) during short rainy season and Sept 7 (250 DOY) indicating end of the rainy season in the study area. Dry spell of any length can occur at any stage of crop growth, but it is potentially damaging if it overlaps with flowering and grain filling stages [40]. Maize is more sensitive to dry spells throughout its growing period beginning in *belg* and until end of *kiremt* [5].

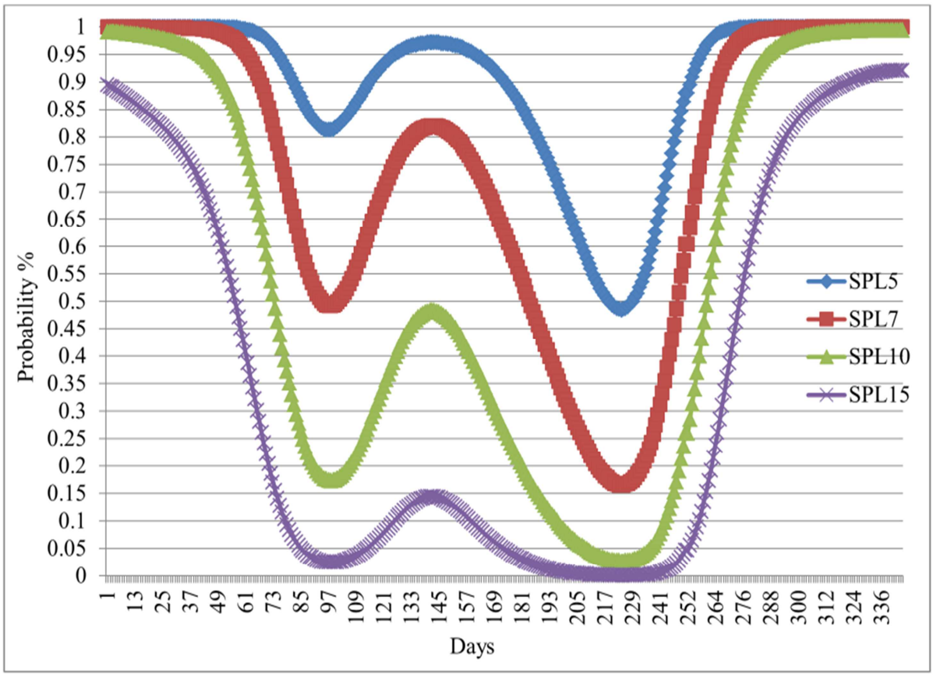

Figure 5. *Probability of dry spells length (5, 7, 10 and 15 days) at Kurfa Chele district.*

3.4. Seasonal and Annual Rainfall Anomalies

3.4.1. Belg Rainfall Anomaly

This study showed that both *belg* rainfall anomalies of the observation years were experiencing an amount lower than the long term mean. The present study implies that in Kurfa 1986, 1988, 1990, 1991, 1994, 1997, 2002, 2003, 2008, 2009, 2011, 2012 and 2015 years were characterized by *belg* rainfall total below the mean and could be classified as moderate to extreme drought years. Therefore, 1987, 1989, 1992, 1996, 2005, 2007, 2010 and 2016 were observed to have a *belg* rainfall above the long term mean (Figure 6).

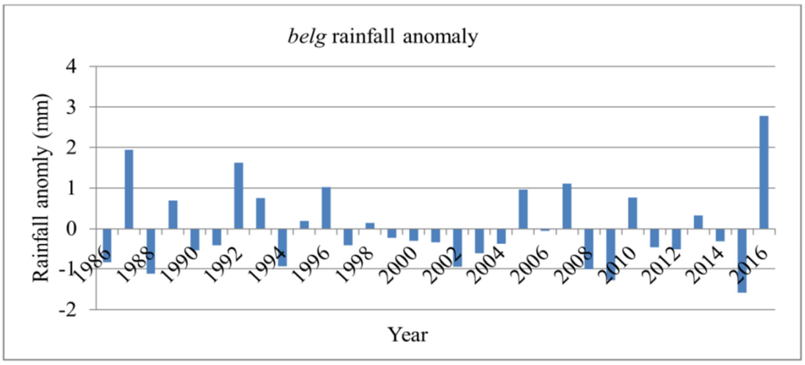

Figure 6. *Belg rainfall anomalies in mm at Kurfa Chele district.*

3.4.2. Kiremt Rainfall Anomaly

In Kurfa Chele district, the rainfall anomaly was characterized by dry and wet conditions (Figure 7). In addition to this, *kiremt* rainfall at the district during the study period (1986-2016) was below long term mean anomaly for 1986, 1987, 1990, 1991, 1993, 1994, 1998, 2002, 2003, 2004, 2005, 2009, 2015 and 2016 years. On other hand, years 1988, 1992, 1996, 1999, 2000, 2006, 2007, 2011, 2012 and 2014 received *kiremt* rainfall above long term mean anomaly for the study period. One can understand from this information that rain-fed crop production in Kurfa has been challenged by risk of dry years during the study period.

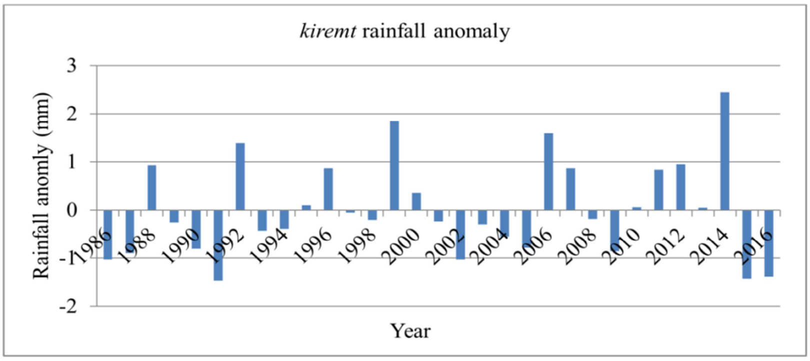

Figure 7. *Kiremt rainfall anomalies at Kurfa Chele district.*

3.4.3. Annual Rainfall Anomaly

The study area experiences both dryness (negative anomaly) and wetness (positive anomaly) in the last three decades. In connection to this, dryness in some years followed by wetness in other years and vice versa. Inter annual variation of rainfall is presented in terms of normalized rainfall anomaly index as shown in Figure 8. The study area experienced both wet and dry years between 1986 and 2015. Drought analysis, revealed that at Kurfa Chele 1992, 1993, 1996, 1997, 1999, 2006, 2007, 2013, 2014 and 2016 were moderately to highly wet years while; 1986, 1990, 1991, 2001, 2002, 2003, 2008, 2009 and 2015 were moderately to severely dry years respectively. At Kurfa Chele, 2006 and 2015 years were the wettest and the driest years in the study period, respectively (Figure 8).

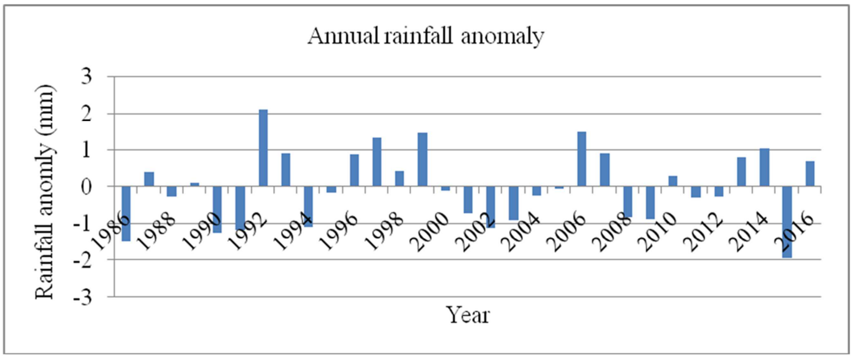

Figure 8. *Annual rainfall anomalies at Kurfa Chele district.*

3.5. Temperature Variability and Trend

3.5.1. Annual, Seasonal and Monthly Maximum Temperature Variability and Trend

According to monthly maximum temperature result, March was the most variable while September was the least variable as their CV indicated 5.8% and 3.3% of maximum temperature, respectively. Monthly SD of maximum temperature ranges from 0.91°C to 1.63°C. It was least for June (22.31°C), July (22.32°C), August (23.45°C) and December (23.65°C) months respectively. On other hand, highest monthly maximum temperature registered in the months of February (30.96°C), January (30.46°C), October (30.25°C), April (29.73°C) and November (29.6°C), respectively (Table 4). Sen's Slope value of monthly maximum temperature showed an increasing trend throughout the year. Maximum monthly temperature demonstrated significant trends for February, March, June, July and August and did not significant at 0.05 significant level in the remaining months.

The study area, *belg* maximum temperature ranges between 25.97°C and 29.46°C and its mean was 27.57°C. From the analysis SD and CV of *belg* maximum temperature were 0.98°C and 3.5%, respectively (Table 4). The *belg* maximum temperature showed an increasing trend by a factor of 0.066°C /year. The *belg* maximum temperature told statistically significant trend at 0.05.

In the district, maximum *kiremt* temperature fluctuated between 24.18 and 27.34°C and its mean was 25.55°C for the last three decades. The computed SD and CV of maximum *kiremt* temperature were 0.81°C and 3.2% respectively (Table 4). The analysis of Mann-Kendall test statistics value of Sen's Slope indicated that maximum *kiremt* temperature showed an increasing trend by a factor of 0.053°C /year in the district and it showed statistically significant trend at all significant levels during the study period.

At Kurfa Chele, the mean annual maximum temperature observed varies between 25.48°C and 28.41°C and mean annual average maximum temperature was 26.58°C. The SD and CV of annual maximum temperature were 0.68°C and 2.6%, respectively. In the study area, an increasing trend of annual maximum temperature experienced by a factor of 0.046°C /year. The positive value of Sen's Slope (0.046) is indication of an increasing trend in the annual maximum temperature, which might be related with global climate change and warming. The main reason for this temperature raise is carbon dioxide and other heat trapping "greenhouse" gases that human activities produce. The biggest source of carbon dioxide emission is from people burning coal, deforestation, factories and other fossil fuels [39]. The maximum annual temperature revealed statistically significant trend at all significance levels. Increase in temperature will poorly oppress crops and plants require more water to refill loss in the form of irrigation [21].

Table 4. *Statistical description of monthly, seasonal and annual maximum temperature at Kurfa Chele (1986-2016).*

Column	Mean	Min.	Max.	SD	25%	50%	75%	CV%
January	26.62	24.35	30.46	1.35	25.77	26.47	27.34	5.1
February	27.9	24.83	30.96	1.43	26.8	27.84	28.64	5.1
March	28.37	25.76	32	1.63	27	28.17	29.93	5.8
April	27.27	24.44	29.73	1.40	26.15	27.21	28.3	5.1
May	26.73	24.8	28.07	0.91	26.08	26.99	27.29	3.4
June	26.18	22.31	28.07	1.11	25.63	26.09	26.93	4.2
July	24.99	22.32	27.51	1.34	23.9	24.9	26.21	5.4
August	25.35	23.45	27.41	1.05	24.69	25.14	26.36	4.1
September	25.68	24.67	27.57	0.84	24.9	25.48	26.24	3.3
October	27.03	24.75	30.25	1.34	26.22	26.72	28.04	4.9
November	26.62	25	29.6	1.14	25.75	26.39	27.29	4.3
December	26.17	23.65	28.16	1.03	25.54	26.04	26.75	3.9
Belg	27.57	25.97	29.46	0.98	26.63	27.47	28.39	3.5
Kiremt	25.55	24.18	27.34	0.81	24.94	25.52	25.97	3.2
Annual	26.58	25.48	28.51	0.68	26.09	26.49	26.92	2.6

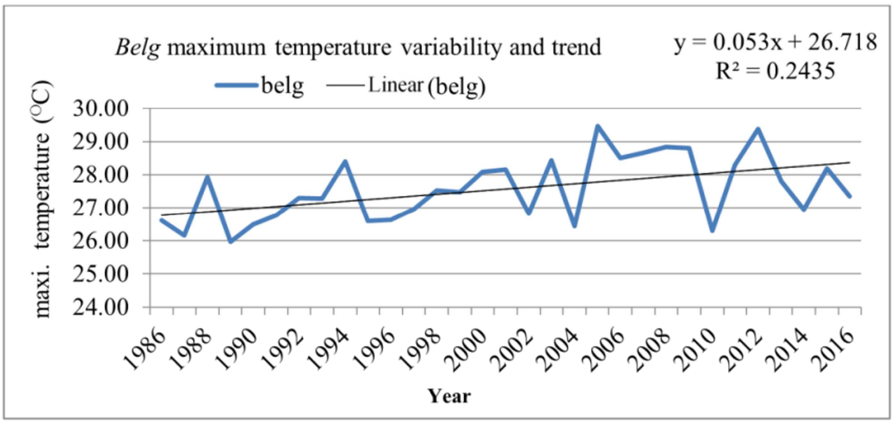

Figure 9. *Belg maximum temperature variability and trend at Kurfa Chele.*

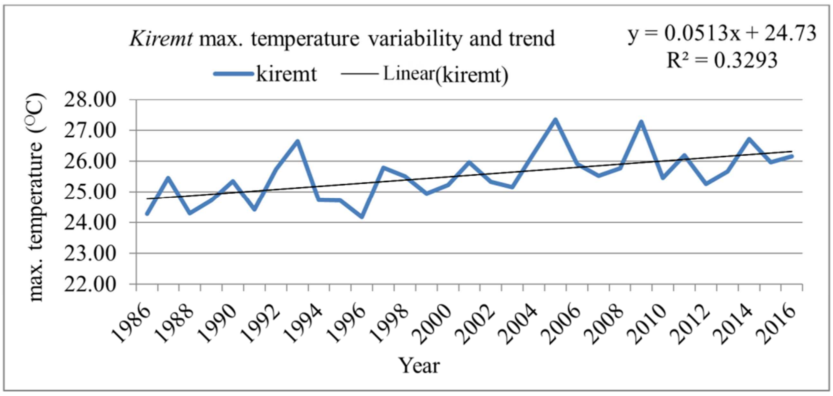

Figure 10. *Maximum kiremt temperature variability and trend at Kurfa Chele.*

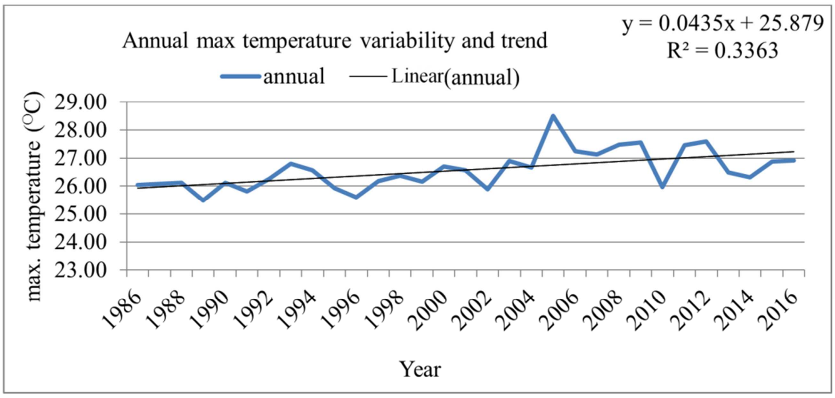

Figure 11. *Maximum annual temperature variability and trend at Kurfa Chele.*

3.5.2. Annual, Seasonal and Monthly Minimum Temperature Variability and Trend

Higher monthly minimum temperature values observed in June (16.38°C), March (16.38°C), May (16.38°C), July (16.38°C) and April (16.38°C). This rise in monthly minimum temperature indicates that increased heating leads to greater high evaporation and resulting surface dryness which affects maize crop. Monthly minimum temperature was least for the months of December (8.6°C), November (9.1°C), February (9.6°C) January (9.8°C) October (11.01°C) and September (11.01°C) as illustrated in Table 6. Mann-Kendall trend test revealed that monthly minimum temperature in the study area showed an increasing trend in the time series over the study period which agree with the finding of Dereje *et al.* [11]. The monthly minimum temperature showed statistically significant trend at 0.05 significant levels in all months except in December.

The *belg* minimum temperature extends from 11.6°C to 15.95°C and its mean minimum temperature is 13.77°C C. The calculated SD and CV of *belg* minimum temperature were 0.81°C and 5.9%, respectively. The proportion of variation in *belg* minimum temperature explained by the time was 35.4% (Figure 12). The *belg* minimum temperature trend was positive and it increased by 0.05°C /year. The *belg* minimum temperature *P*-value had statistically significant trend at 0.01 and 0.05 significant levels. This is supported by the investigation of Lemma *et al.* [26] which revealed that increasing trend for both maximum and minimum temperature in Adama district, Ethiopia.

In Kurfa Chele, the calculated *kiremt* minimum temperature diverged 12.41°C to 15.12°C and its mean minimum temperature was 13.76°C. The CV of *kiremt* rainy season minimum temperature was 4.2% and its SD was of 0.58°C. The proportion of variation in *kiremt* minimum temperature explicated by the year was 32.4% (Figure 13). Sen's slope statistic showed that an increasing trend in the time series data of minimum *kiremt* temperature and it was increased with a factor of 0.04°C per year. The trend of minimum *kiremt* temperature was statistically significant at 0.05 significance levels. In agreement to this, USAID [45] reported that temperature increase by a factor of 1.3°C.

The calculated SD and CV of annual minimum temperature were 0.62°C and 4.7% respectively for the last three decades. The annual minimum temperature for the district ranged from 12.04°C to 14.65°C and annual mean minimum temperature was 13.25°C during the study period (Table 5). The amount of variation in annual minimum temperature explained by the time was 51.2% (Figure 14). Mann-Kendall trend test showed that annual minimum temperature of the study area showed an increasing trend by 0.05°C /year for the past three decades. The annual minimum temperature trend was statistically significant at 0.1 and 0.05 significance levels, which align with an increasing trend of average annual mean temperature throughout the country NMA [34].

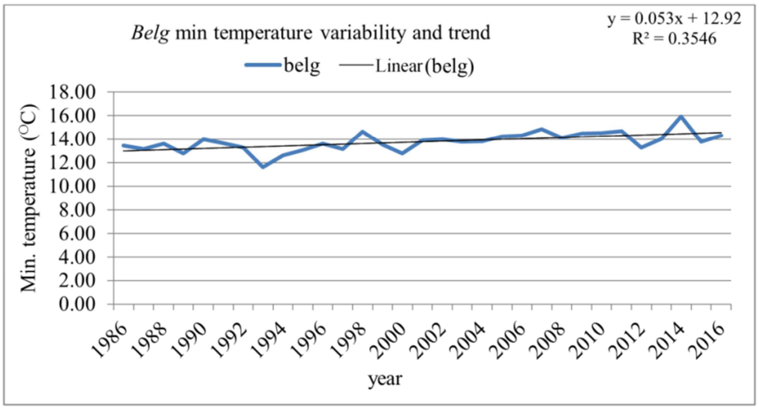

Figure 12. *Minimum belg temperature variability and trend at Kurfa Chele.*

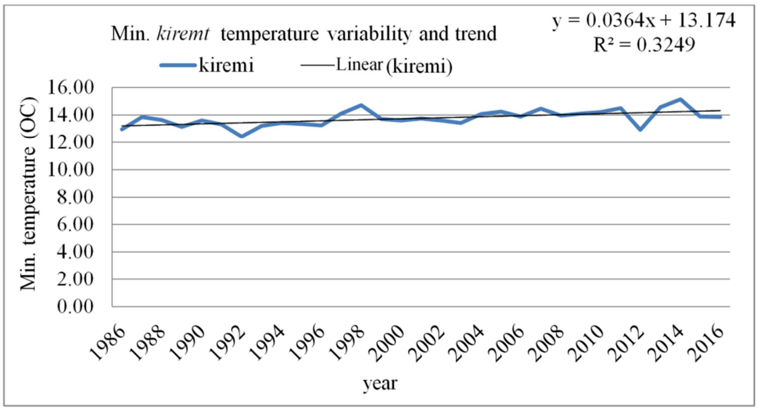

Figure 13. *Kiremt minimum temperature variability and trend at Kurfa Chele.*

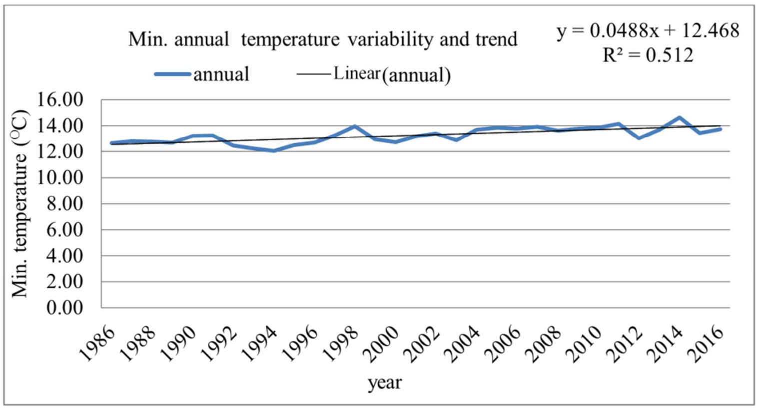

Figure 14. *Minimum annual temperature variability and trend at Kurfa Chele.*

Table 5. *Statistical description of monthly, seasonal and annual minimum temperature at Kurfa Chele (1986-2016).*

Variables	Mean	Min.	Max.	SD	25%	50%	75%	CV%
January	12.1	9.755	14.42	1.075	11.53	12.33	12.8	8.9
February	12.97	9.624	15.64	1.313	12.12	12.86	13.7	10.1
March	13.9	12.16	16.26	0.8819	13.49	13.92	14.51	6.3
April	14.12	12.35	15.81	0.7558	13.81	14.04	14.59	5.4
May	14.08	12.27	16.09	0.8316	13.53	14	14.74	5.9
June	14.06	12.66	16.38	0.729	13.67	13.94	14.31	5.2
July	13.78	12.59	15.99	0.7004	13.4	13.82	14.1	5.1
August	13.7	12.29	14.95	0.6424	13.31	13.72	14.11	4.7
September	13.49	11.87	14.83	0.6651	13.08	13.44	14.02	4.9
October	13.19	11.01	14.98	0.9996	12.65	13.3	13.83	7.6
November	12.08	9.097	13.8	1.106	11.39	12.23	12.9	9.2

Variables	Mean	Min.	Max.	SD	25%	50%	75%	CV%
December	11.52	8.643	13.45	0.9811	10.98	11.52	12.07	8.5
Belg	13.77	11.6	15.95	0.8096	13.27	13.78	14.3	5.9
Kiremt	13.76	12.41	15.12	0.5803	13.33	13.74	14.09	4.2
Annual	13.25	12.04	14.65	0.6198	12.72	13.23	13.76	4.7

3.6. Impacts of Climate Variability on Maize Yield

3.6.1. Correlation Analysis for Rain Fall, Temperature and Maize Yield

The triangular correlation results show that *belg* rainy days (r=0.60) and *kiremt* rainy days (r=0.61) had positive and strong relationships with maize yield. *Belg* onset (r= -0.10) showed weak negative relationship with maize yield whereas *kiremt* end date of rainfall (r=0.29) and length of growing periods (r=0.22) correlation results revealed weak positive relationship with maize yield. *Belg* rain fall total has moderate positive relationship (r=0.48) and *kiremt* rainfall total (r=0.12) has weak positive relationship with maize yield. While, *belg* mean temperature (r=-0.23) and *kiremt* mean temperature (r=-0.31) had weak and moderate negative relations with maize yield (Table 6). Consequently, *kiremt* rainy days, *kiremt* end date, length of growing periods and *kiremt* mean temperature have great impacts on annual maize yield in the district.

Table 6. *Pearson correlation of rainfall, temperature and maize yield at Kurfa Chele.*

BRD	1									
KRD	0.39	1								
BOS	-0.51*	-0.17	1							
KEND	0.49	0.64*	-0.28	1						
LGP	0.62*	0.43	-0.89	0.69*	1					
BRFT	0.64*	0.07	-0.45	0.11	0.39	1				
KRFT	0.22	0.56	-0.26	0.83*	0.59	-0.02	1			
BMT	-0.01	-0.13	0.07	0.20	0.04	0.01	0.33	1		
KMT	0.31	-0.21	-0.20	0.09	0.19	0.13	0.11	0.44	1	
YLD	0.60*	0.61*	-0.10	0.29	0.22	0.48	0.12	-0.23	-0.31	1
	BRD	KRD	BOS	KEND	LGP	BRFT	*KRFT*	BMT	*KMT*	YLD

*Correlation is significant at the 0.05 significant levels

Note: YLD = maize yield (Kg/ha), BRD= *Belg* Rainy Day (days), KRD= *Kiremt* Rainy Day (days), BOS= *Belg* onset (DOY), KEND= *Kiremt* End Date (DOY), LGP= Length of Growing Period (days), BRFT= *Belg* Rain Fall Total (mm), KRFT= *Kiremt* Rainfall Total (mm), BMT= *Belg* Mean Temperature (°C), KMT= *Kiremt* Mean Temperature (°C)

3.6.2. Regression Analysis for Rainfall, Temperature and Maize Yields

The estimated impact of climate parameters on maize yield variation at Kurfa Chele were *belg* rainy days (0.20 Kg/ha), *kiremt* rainy days (0.20 Kg/ha), *belg* mean temperature (0.13 Kg/ha), belg onset (0.02 Kg/ha), *belg* rainfall total (0.01 Kg/ha), *kiremt* end date (-0.04 Kg/ha) and *kiremt* mean temperature (-2.57 Kg/ha) regressed following the required steps (Table 7).

The analyzed coefficients of regression in the study area revealed that among the rainfall and temperature components BRD, KRD and BMT are the major variables that have positive impacts on maize yield in the study area. Therefore, maize yield has been increased when the above parameters are going up. Differently, the multiple regression model results show that *kiremt* end date (-0.04 Kg/ha) and *kiremt* mean temperature (-2.57 Kg/ha) have negative impacts on maize yield. Hence, the higher *kiremt* end date and *kiremt* mean temperature the lower maize yield in the district.

From the analyzed regression, the following model equation was developed:

$$Y=50.26+0.20BRD+0.20KRD+0.02BOS-0.04KEND+0.01BRFT+0.00KRFT+0.13BMT-2.57\ KMT$$

Where; Y= the predicted maize yield in Kg/ ha

Table 7. *Coefficients of regression analysis for rainfall and temperature at Kurfa Chele.*

Model		Unstandardized Coefficients		Standardized Coefficients	t-value	Sig.
		B	Std. Error	Beta		
	(Constant)	50.26	34.76		1.45	0.19
	BRD	0.20	0.10	0.68	2.07	0.07
	KRD	0.20	0.12	0.44	1.74	0.12
	BOS	0.02	0.02	0.27	1.33	0.22
1	KEND	-0.04	0.05	-0.31	-0.81	0.44
	BRFT	0.01	0.01	0.22	0.94	0.37
	KRFT	0.00	0.01	0.09	0.25	0.81
	BMT	0.13	1.36	0.02	0.10	0.92
	KMT	-2.57	1.42	-0.39	-1.82	0.11

a. Dependent Variable: maize yield

The calculated value of coefficient of multiple regressions (R^2) was 0.79 (Table 8). This indicates that 79% of the variations in maize yield per hectare occurred for the study 15 years (2001-2016) at Kurfa Chele district by the combination of *belg* rainy days, *kiremt* rainy days, *belg* mean temperature, belg onset, *belg* rainfall total, *kirem*t rainfall total, *kiremt* end date, *kiremt* mean temperature and the remaining 21% o f the variation in the maize yields could be by confounding variables; for instance it could be low fertility of soil, soil erosion, poor maize crop management, shortage of inputs and the likes. The Probability value obtained from the analysis of variance (ANOVA) show that the influence of climate features on the maize yield is statistically significant at 5% (Table 8).

Table 8. *Regression values for predictors (rainfall and temperature) at Kurfa Chele.*

Model	R	R^2	Change Statistics				
			R^2 Change	F Change	df1	df2	Sig. F Change
1	0.89[a]	0.79	0.79	3.72	8	8	0.04

a. Predictors: Constant, BRD, KRD, BOS, KEND, BRFT, KRFT, BMT, KMT

4. Summary, Conclusions and Recommendations

4.1. Summary and Conclusions

This study was conducted to assess the impacts of climate variability on maize (*Zeamays* L.) yield in Kurfa Chele district where climate variability is a threat to maize production. The result of the study showed that the mean start of rainy seasons, length of growing period and end of the rainy seasons in Kurfa Chele district were 31st March, 178 days and 25th September, respectively and *belg* onset was highly variable (CV=42%). The area habits the probability of dry spells lengths exceeding 5, 7, 10 and 15 days which of *belg* was highly variable. It was also observed that the lowest probabilities of occurrence of dry-spells of all durations were recorded in the month of April and August. However, there were high probabilities of dry-spells in other months which can affect crops especially during the start of *belg* season and end of the *kiremt* season.

The district receives maximum and minimum annual rainfall total amounts of 996.9 mm and 295.3 mm, respectively. Moreover, annual and *kiremt* rainfall amounts were found to increase by a factor of 2.45 and 1.64 mm/year, respectively and were not statistically significant at p=0.05. On the other hand, the *belg* rainfall amount decreased by a factor of -0.81 mm/year and it was not statistically significant at 5%. *Belg* rainfall had high variability (CV 33%) compared to *kiremt* (CV 17%). The annual and seasonal coefficients of variation of rainfall and temperatures varied moderately and highly over the district. High variability of number of rainy days, mean temperature, cessation, and length of growing period and dry spell of different lengths were identified as limitations of maize crop production in the study area. Changes in length of growing period of *belg* explained more by variability of onset (CV 42%), while *kiremt* season was influenced more by variability of cessation. Anomaly of rainfall indicated that 1992 was the wettest and 2015 was the driest year. The maximum temperature showed increasing trend at annual, *kiremt* and *belg* periods by a factor of 0.046, 0.053 and 0.066 °C/year, respectively. Similarly annual, *kiremt* and *belg* minimum temperatures showed an increasing trend by 0.05, 0.04 and 0.05 °C/years respectively and they were statistically significant at 1% and 5% levels.

The maize yield in the study area was highly correlated with number of rainy days of rainy seasons and mean temperature. Therefore, reduction in maize yield observed as a result of declining in *belg* rainy days, *kiremt* rainy days, *kiremt* mean temperature and *kiremt* end days overtime. The magnitudes of correlation of maize yield with rainfall and temperature parameters were *belg* rainy days (r=0.60) and *kiremt* rainy days (r=0.61) have strong relationships with maize yield, while the *belg* rainfall total (r=0.48), rainfall cessation (r=0.29), rainfall onset (r=-0.10), *kiremt* rainfall total (r=-0.12), *belg* mean temperature (r=-0.23) and *kiremt* mean temperature (r=-0.31) have also moderate and weak, positive and negative relationships with maizeyield by their expectative magnitudes correspondingly.

The regression results of inter-annual and seasonal variability of *kiremt* end date (-0.04) and *kiremt* mean temperature (-2.57) were the major causes of variation in maize yield in the district over the period of 2001 to 2016. The magnitudes of results of multiple regressions were an increase in *belg* rainy days (0.20Kg/ha), *kiremt* rainy days (0.20Kg/ha), *belg* mean temperature (0.13Kg/ha), *belg* onset (0.02Kg/ha) and *belg* rainfall total (0.01Kg/ha) caused an increase in maize yield. However, an increase in *kiremt* end date (-0.04Kg/ha) and *kiremt* mean temperature (-2.57Kg/ha) caused a decrease in maize yield. Coefficient of determination (R^2) found that climate characters affect maize yield by 79% extent jointly.

Identifying impacts of climate variability contributes in factoring and resolving challenges of food security in an area. Better understanding of climate systems and crop production risk and its management is very important to help farmers to make pre-informed and critical decisions about their crops to resist climate variability shocks. High variability of onset and *belg* rainy seasons makes the district vulnerable to crop failure. Besides, high probability of dry spells, decreasing of *belg* rainfall and increasing of temperatures may cause increasing of evapotranspiration which also impact on maize yield.

4.2. Recommendations

Based on the results obtained, the following recommendations are forwarded;

1) Farmers in Kurfa Chele district recommended to utilize properly available rainfall moisture during *belg* season because of high variability of *belg* with increasing of temperature and decreasing of rainfall.
2) Farmers in the district encouraged to adjust planting date by considering onset and end dates of rainy seasons.
3) Policy makers and NGOs are better to consider the decrease in *belg* rainfall and increase in temperatures during preparation of their plans and strategies in the study area.
4) Maize producing farmers advised to use new, drought tolerant and higher-yielding maize varieties as *belg* and *kiremt* rainy days and mean temperatures have effects on yield.
5) It is important for government and NGOs to invest more on rain water harvesting practices and digging out of ground water in order to reduce shortage of water for drinking and irrigation.
6) Relevant government institutions and local NGOs are recommended to give awareness of climate variability for farmers.
7) Further studies are necessary to assess the impacts of climate variability on crop production to address knowledge gaps in the district.

Acronyms and Abbreviations

CV	Coefficient of Variation
DOY	Days of the Year
EOS	End of Season
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IPCC	Inter-governmental Panel on Climate Change
KWANRO	Kurfa Chele *Woreda* Agriculture and Natural Resource Office
LGP	Length of Growth Period
NAAS	National Academy of Agricultural Science
NMA	National Metrological Agency
NRD	Number of Rainy Days
PSNP	Productive Safety Net Program
SD	Standard Deviation
SOS	Start of Season
SRA	Standardized Rainfall Anomaly
SSA	Sub-Saharan Africa
USAID	United States Agency for International Development
WMO	World Meteorological Organization

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Appendix

Table 9. *Mann-Kendall statistics result for monthly, seasonal and annual rainfall in Kurfa Chele district.*

Parameters	Kendall's tau	Statistic (S)	p-value	alpha	Sen's slope
Jan	-0.125	-53	0.357	0.05	0.00
Feb	-0.371	-162	0.005	0.05	-0.34
Mar	-0.162	-75	0.208	0.05	-0.86
Apr	-0.123	-57	0.345	0.05	-1.32
May	0.153	71	0.237	0.05	0.98
Jun	0.015	7	0.920	0.05	0.01
July	0.101	47	0.438	0.05	0.73
Aug	0.006	3	0.973	0.05	0.041
Sept	0.092	43	0.479	0.05	0.56
Oct	0.022	10	0.878	0.05	0.17

Parameters	Kendall's tau	Statistic (S)	p-value	alpha	Sen's slope
Nov	0.199	89	0.130	0.05	0.35
Dec	-0.229	-100	0.085	0.05	-0.12
Belg	-0.054	-25	0.686	0.05	-0.81
Kiremt	0.110	51	0.399	0.05	1.64
Annual	0.071	33	0.590	0.05	2.45

Table 10. *Anomalies of annual and seasonal rainfall in the study area.*

	Annual	*Belg*	*Kiremt*
1986	-1.4914	-0.84233	-1.03382
1987	0.393468	1.935701	-0.89332
1988	-0.27636	-1.11848	0.930194
1989	0.10974	0.695409	-0.25489
1990	-1.23925	-0.53936	-0.81044
1991	-1.17931	-0.42386	-1.4689
1992	2.107173	1.620771	1.390232
1993	0.911277	0.752408	-0.43062
1994	-1.07868	-0.93347	-0.38732
1995	-0.17187	0.192173	0.100912
1996	0.882064	1.0219	0.863795
1997	1.316988	-0.42012	-0.05109
1998	0.427636	0.141044	-0.20629
1999	1.447803	-0.22115	1.849018
2000	-0.10096	-0.29938	0.359978
2001	-0.72808	-0.34029	-0.22957
2002	-1.11351	-0.94303	-1.03169
2003	-0.91269	-0.62066	-0.29502
2004	-0.23803	-0.37627	-0.55449
2005	-0.04575	0.962041	-0.78621
2006	1.478803	-0.05031	1.594901
2007	0.898428	1.110922	0.867872
2008	-0.83383	-1.01027	-0.18332
2009	-0.88892	-1.27616	-0.85888
2010	0.294341	0.759003	0.057353
2011	-0.28949	-0.46751	0.839651
2012	-0.2571	-0.5152	0.946584
2013	0.796514	0.327996	0.055159
2014	1.025919	-0.31405	2.447465
2015	-1.94858	-1.58717	-1.43087
2016	0.697942	2.783321	-1.38909

Table 11. *Mann-Kendall statistics result for monthly, seasonal and annual maximum temperature at Kurfa Chele district.*

Parameters	Kendall's tau	Statistic (S)	p-value	alpha	Sen's slope
Jan	0.075	35	0.567	0.05	0.016
Feb	0.286	133	0.024	0.05	0.069
Mar	0.280	130	0.028	0.05	0.069
Apr	0.243	113	0.057	0.05	0.059
May	0.211	98	0.099	0.05	0.037
Jun	0.282	131	0.026	0.05	0.04
July	0.402	187	0.001	0.05	0.085
Aug	0.303	141	0.017	0.05	0.048
Sept	0.207	96	0.106	0.05	0.025
Oct	0.222	103	0.083	0.05	0.045
Nov	0.153	71	0.237	0.05	0.029
Dec	0.043	20	0.747	0.05	0.01
Belg	0.368	171	0.003	0.05	0.066
Kiremt	0.432	201	0.000	0.05	0.053
Annual	0.462	215	0.000	0.05	0.046

Table 12. *Mann-Kendall Statistics result for monthly, seasonal and annual minimum temperature at Kurfa Chele district.*

Parameters	Kendall's tau	Statistic (S)	p-value	alpha	Sen's slope
Jan	0.363	169	0.004	0.05	0.07
Feb	0.338	157	0.007	0.05	0.08
Mar	0.376	175	0.003	0.05	0.04
Apr	0.428	199	0.001	0.05	0.05
May	0.376	175	0.003	0.05	0.05

Parameters	Kendall's tau	Statistic (S)	p-value	alpha	Sen's slope
Jun	0.415	193	0.001	0.05	0.04
July	0.394	183	0.002	0.05	0.04
Aug	0.269	125	0.034	0.05	0.03
Sept	0.398	185	0.001	0.05	0.04
Oct	0.424	197	0.001	0.05	0.06
Nov	0.389	181	0.002	0.05	0.07
Dec	0.243	113	0.057	0.05	0.03
Belg	0.462	215	0.000	0.05	0.05
Kiremt	0.441	205	0.000	0.05	0.04
Annual	0.514	239	< 0.0001	0.05	0.05

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