Climate Change and Variability Effects on Maize (Zea Mays L) Production, and Farmers Perception in Halaba zone, Southern Ethiopia

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Abstract
This study was conducted to investigate the impacts of climate change and variability on maize production, and perception of farmers to climatic trends Halaba zone, southern Ethiopia. Multi-stage sampling technique was used to select study sample. Primary data were collected using key informant interviews, group discussions and household surveys with 156 households. Descriptive statistics were used to analyze the collected data. According to the results, about (88.2%) of the respondents have indicated that the rain fall amount has decreased, similarly recorded rainfall data confirm that the annual rainfall was declined by the rate of 8.463 mm annually over the past 29 years. Coefficient of Variation of rainfall was 49.3%, which is highly variable based on degree of variability. Similarly, 89.5 % of interviewed farmers said that temperature showed an increasing trend, and the recorded data indicated that the mean average temperature was increasing by 0.139ºC per annum. Season rainfall was highly and significantly correlated with maize production. The production of maize recorded positive anomalies in fifteen (15) out of the twenty nine (29) years, and fourteen negative anomalies out of 29 production years. The overall analysis lead to conclude that despite the presence of awareness on climate change and its likely effects on livelihoods of the farmer, development intervention at local level were not systematically designed to address the problems of the resource poor farmers and environmental challenges. In the immediate future there is an urgent need to work on strengthening awareness, development package and disseminate successful climate change adaptation interventions to farmers.
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1. INTRODUCTION

Back ground of the study

Climate change is a global issue because it affects all countries in the world (Winsemius et.al, 2018, Vona, 2019). The most distressful event by posing tremendous negative impact on several sectors of the world is climate change (IPCC, 2014). Annual global temperature has increased by 0.4◦C since 1980, with even larger changes observed in several regions. Available evidence shows that the most adverse effects of climate change will be felt mainly by developing countries, especially those in Africa, due to their low level of coping capabilities (IPCC 2014a)

Rainfall and temperature have posed tremendous impact on crop yields of the agrarian communities of the developing countries like Ethiopia where agriculture is rain-fed and essential for the daily subsistence (FAO, 2016). Agriculture is the main source of livelihood for about 85% of Ethiopia‘s population, contributes 50% of the GDP and generates more than 80% of the foreign exchange earnings (Deressa and Hassan, 2009).

It is dominated by small scale crop-livestock mixed farming systems and cereals are the most important food crops occupying about 77% of the total cultivated area. Halaba zone is inherently vulnerable to climate related extreme events (drought, flood and dry winds) for many years. Agricultural output in the study area is highly dependent on erratic, unevenly distributed and difficult to forecast rainfall intensity and distribution. Consequently, climate change is imposed a significant impact on crop production and bearing profound effects on the livelihood of the communities. For the study area as a whole, a decline in rainfall is likely to lead to a decline in the yield of maize crop at every season.

Maize (*Zea Mays L)* is the most important cereal grain crop cultivated in the study area and it has a significant role in the livelihoods for instance: food, feed and income of smallholder farmers. Few studies conducted in the zone to specifically assess the impact of climate change on agriculture have revealed reductions and increased variability in crop productivity, but failed to correlate climate change with maize production. Given the background of the large population and progressive aging issues, future food self-sufficiency in Halaba zone is considered to be unsustainable and risky, leading to volatile local market conditions. Maize yields will reduce as a result of climate change for the semi-arid areas of Ethiopia by 2080s by up to 46%, but could result an increase by up to 59% result in sub humid/ humid areas (Faostat, 2017)

Therefore, putting the above issue into consideration, this study attempted to inquire the impact of climate change on maize production and portray/explanation how adaptation strategies can enhance maize production at Halaba zone of SNNP Region.

Objectives of the study

The overall objective of this study was to investigate the impact of climate change on maize production and assess its adaptation strategies in Halaba zone, SNNPR**.**

Specific objectives

- ✓ To evaluate climatic trends (Temperature and Rain fall) for the last 30 years
- ✓ To investigate the impacts of climate trends on the production of maize

2. METHODOLOGY

Research Design:-The study used a cross sectional survey design with the use of qualitative and quantitative approaches. In this research mixed methods were used because it helps to have better understanding of the situation in the villages than what could have been made with the use of one method.

Sampling techniques

Multi stage sampling technique was used, in the first stage study area Halaba zone was selected purposively since it is one of drought prone areas in the region and it has two distinct agro-ecological zones; namely 65% kola (700-1500 masl) and 35% woyna dega (1800-2300 masl). Then, potential maize producing kebele administrations were identified based on information from the zones' agricultural offices. And then from these potential maize growers of the zone, five kebele administrations were selected purposively based on their agro ecological settings(two kebeles from woyna dega and three kebeles from kola agro ecological zone were selected (Table 2) with the assumption that smallholder farmers within each agro-ecological system may have differences in their traditional knowledge and skills, and that this may result in different adaptive capacities in the communities which describes the study area.

By using systematic sampling technique (156 households) were determined from each kebele administrations using probability proportional to size (PPS) method to make equal representation of households in each kebele (Israel, 1992). The sample households were drawn for each kebele (KA) from the list of names after a certain sampling interval (K) that was determined by dividing the total number of households by the predetermined sample size of each kebele (Woldamelak 2009);

$$K = \frac{NHH}{n} = \frac{2489}{156} = 16 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1),$$

Where *NHH* is total households from each kebele,

n is sample size of the selected kebeles and

K is the sampling interval at which the sample is drawn next, a number was selected between one and the sampling interval (K) which is called the random start using lottery method and was used as the first number included in the sample. Then, every Kth household head after that first random start was taken until reaching the desired sample size for each ().

Table: 2 Sample household size and selected Kebeles for the study

Sample Kebeles	Agro ecology zone	Total no of HH	Sample HHs
			n=NHHs/K
Gadba	Kola	544	544/16=34
Gerama	Kola	515	515/16=32
Wanja/woldia	Woyna Dega	450	450/16=28
Huletegna Choroko	Kola	505	505/16=32
Amatai	Woyna Dega	475	475/16=30
Total		2489	156

Data Collection Methods

This study used a survey design in order to assess the impacts of climate change on maize (*Zea Mays L)* crop yield in Halaba zone of SNNPR. Quantitative data were collected by using household questionnaire while monthly rainfall records were obtained from Meteorological Agency stations (NMA) whereas qualitative data were collected through interviews and focus group discussions (FGD).

Methods of data analysis

Descriptive statistical techniques such as mean, standard deviation, coefficient of variation, percentages, frequency, table and figure (line graphs, Clustered one and Pie chart) were used to analyze the collected data dealing with farmer's perception on climate change, and meteorological data. STATA version 14 was used to analyze descriptive results. Moreover, Microsoft excel sheet used to present patterns and trends of rainfall and temperature data.

Standardized precipitation index (SPI): The SPI was used to identify drought during the period under consideration using annual rainfall data. The SPI is a statistical measure to detect unusual weather events and then to determine how often droughts of certain strength are likely to occur. The practical implication of SPI-defined drought, as the deviation from the normal amount of precipitation, would vary from one year to another, it can be calculated as:

$$\mathrm{SPI} = \frac{\mathrm{Xi} - \overline{\mathrm{X}}}{\sigma} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2),$$

Where; SPI refers to rainfall anomaly (irregularity) on multiple time scales; x represents annual rainfall in the year t; x "represents the long-term mean rainfall; and σ represents the standard deviation over the period of observation (Kurukulasuriya and Mendelsohn. 2006a). Hence, the drought severity classes are: extremely dry (SPI<- 2); moderately dry (-1 > SPI > -1); severe drought (-2 > SPI > -1.5); near normal -1<SPI > 1; moderately wet (1 < SPI < 1.5); very wet (1.5 <SPI < 2) and extremely wet (SPI > 2). Intra seasonal rainfall Variability was analyzed using the coefficient of variation (CV). According to Hare (1983), CV (%) values are classified as follows:

- < 20% as less variable,
- 20- 30% as moderately variable,
- And > 30% as highly variable.

$$\mathrm{CV} = \frac{\mathrm{SD}}{\overline{\mathrm{X}}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where CV is Coefficient of Variation, SD is Standard Deviation and $\overline{X}$ is mean

3 .RESULTS AND DISCUSION

As depicted in Table 2, the mean age of the respondents was 49.96 years with the standard deviation of 15.3. On the other hand, the educational status of respondents showed that on average enrollments of 2.16 which is very low status. On average, household size is about 5 person and the land ownership of 1.64 hectare. Regarding the farming experience, on average the households have 19.6 years of experience. Relatively, in the area was known by livestock ownership and households owned on average of 3.05 tropical livestock units.

Institutional parameters have also a significant roles in supporting farmers to adapt to a climate change. With this regards, 74% of respondents had an agricultural extension services. 16% of the respondents had access to a credit services and 73% had informed about a climate change information from a different sources.

Table 2. The summary statistics for household and institutional characteristics

Definition of independent variable	**Description**	**Summary of statistics**			
		Mean	**SD**	**Min**	**Max**
Age of the household head	Continuous (Years)	49.96	15.31	23	82
Education status of HH heads	Continuous(Years)	2.16	0.84	0	11
Family size of household	Continuous (Number)	4.73	1.59	2	9
Farm size	Continuous (Hectares)	1.64	0.49	0.5	2
Farming experience	Continuous (Years)	19.6	6.92	10	44
Livestock ownership	Continuous (TLU)	3.05	1.89	1	7.25
Access to extension service	Dummy, 1 if yes and 0, otherwise	0.26	0.44	0	1
Access to credit service	Dummy , 1 if yes and 0 otherwise	0.16	0.38	0	1
Access to climate information	Dummy , 1 if yes and 0 otherwise	0.17	0.37	0	1

Source; Based on literature review (2018)

Inter annual variation trend of rainfall: The results of the current study showed that, average annual rain fall of study area in the years 1989-2017, ranged from 417.4 mm to 1261.4 mm. The analysis also showed that, the mean annual rain fall of those years is about 954.68 mm. The coefficient of variation (CV) and standard deviation (SD) of the study area were 49.3 mm and 470.6379 mm respectively. The mean annual rainfall of the study area was decreased by 8.463 mm yearly (Figure 3). The driest year was 2017, which contains the minimum rain fall i.e. (417.4 mm) and the wettest year was 1993 which contains 1261.4 mm. Annual rain fall is below average in the years 1991, 1994, 1999-2003, 2005, 2006, 2008, 2009, 2012, 2014, 2015 and 2017. Findings from national and regional level rainfall trends analysis reported decreasing trend in Ethiopia (Belay, 2014; Kebede and Solomon, 2013; and Wing et.al, 2008)

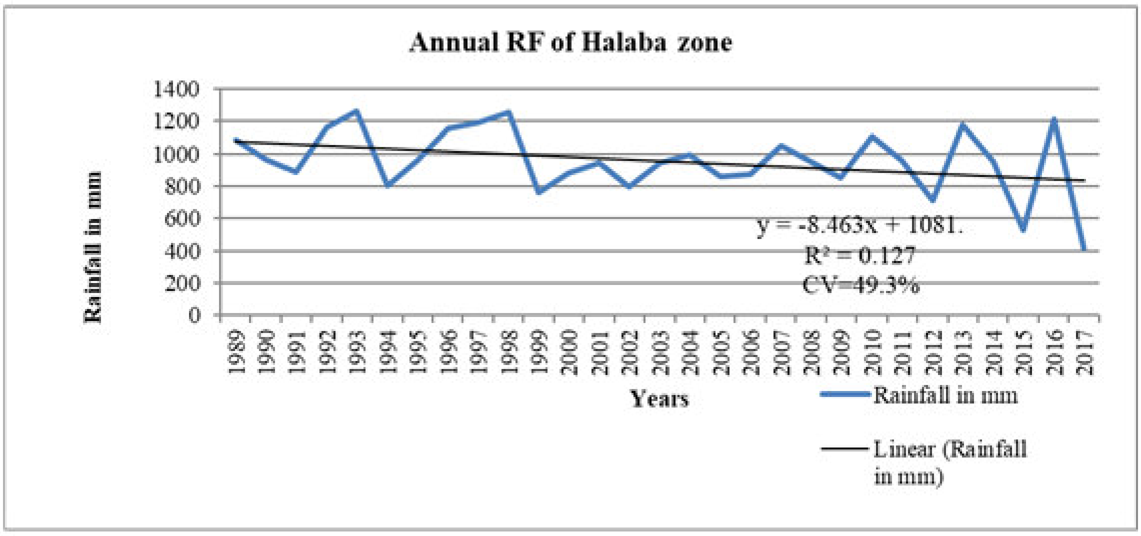

Figure 3 Inter-annual rainfall variations of the study area for the period 1989-2017
Source: Done by the researcher using data from NMA (2018)

Seasonal variability of rainfall. For the studied periods (1989-2017) the study area received bimodal rainfall i.e. main season, which starts from (June to September) and short season, which starts from (March to May) and the mean short season rainfall is 346.92 mm and mean of main season rainfall is 425.38 mm. The coefficient of variation (CV) of the short and main seasonal rainfall in the study area showed 55.4 % high variability and 17.5% less variability respectively based on degree of variability between the years 1989-2017. In line with other studies in Ethiopia, (2014) (Hadgu, 2013; Kassie et.al, 2013) reported that high coefficient variation in main rainy season. The short season rainfall showed a decreasing trend at a rate of 2.45 mm per a year while the main season rainfall also showed a decreasing trend at a rate of 0.44 mm.

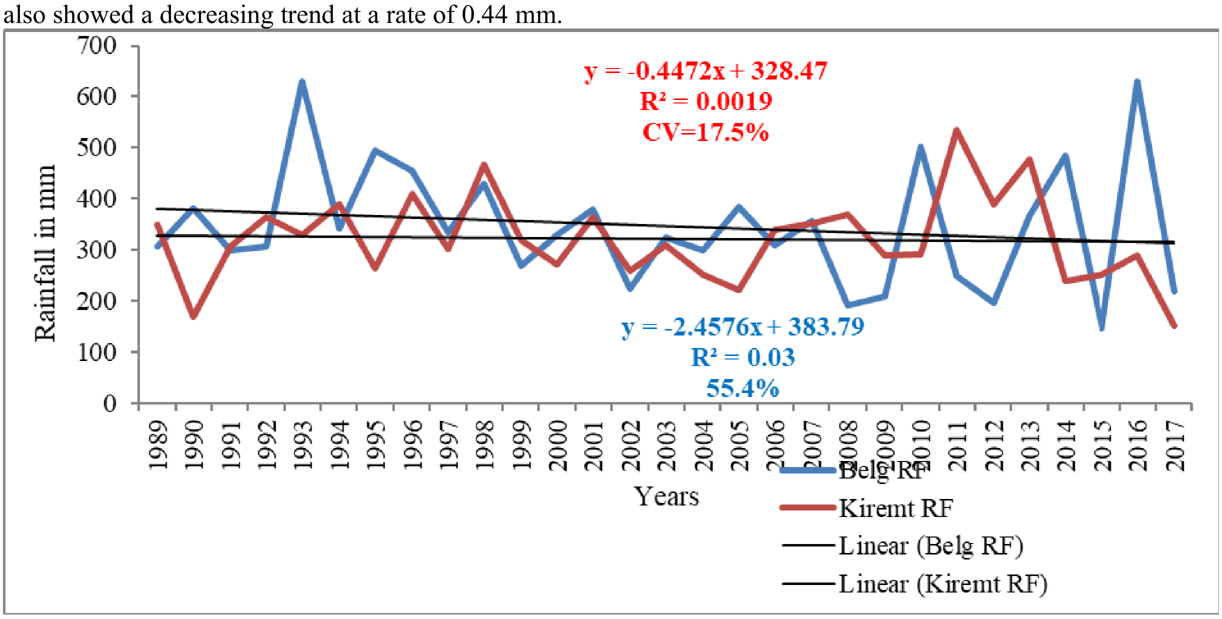

Figure 4 Short season and main season rainfall in study area for the period from 1989-2017
Source: Done by author using data from NMA (2018)

Temperature trend of the study area

The result of the current study showed that, the average yearly maximum temperature of the Halaba zone was 27.22^{0}C, while the average minimum temperature was 12.84^{0}C. The average maximum temperature of the study area over the past 29 years increased by about 0.083^{0}C annually, while average minimum temperature was increased by 0.196^{0}C. The present result was in line with that of NMA (2007) wherein the climate of Central Rift Valley of Ethiopia will get warmer in the coming decades and the increase in minimum temperature will be higher than the maximum temperature, particularly under the emission scenarios. The temperature across the country is predicted to rise from 0.5 to 3.6 ^{0}C by 2080 (Lobell, 2011).

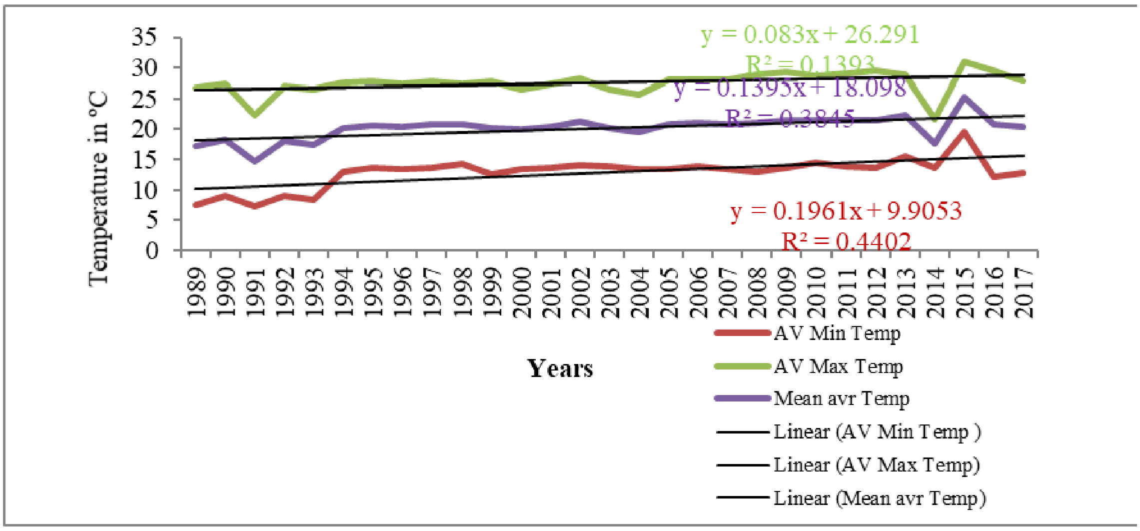

Figure 5 The yearly max, min and average temperature in study area for the period 1989-2017
Source: Done by the researcher using data from National Meteorological Agency (2018)

Annual and Seasonal Standard Precipitation Index as a Measure of Drought

Annual standard precipitations anomality (departure) for the past 29 years (1989-2017 in terms of drought frequency revealed that the study area experienced moderate drought with its SPI of -0.89 and -1.14 in 2014 and 2017 years respectively, while the rest of years were relatively moist (Figure 6).

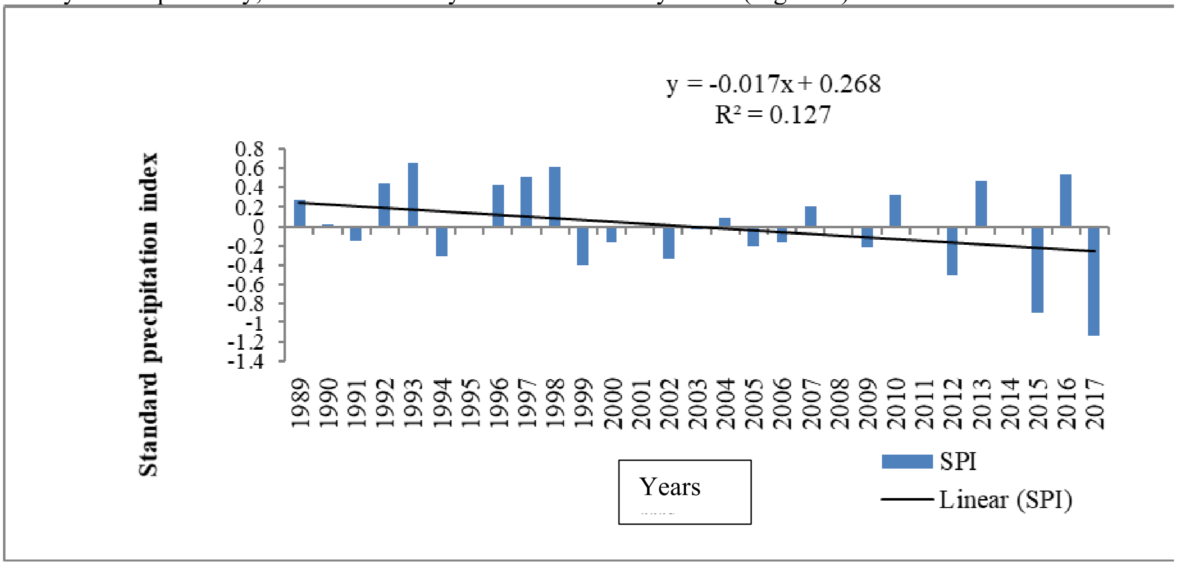

Figure 6 Annual SPI of Halaba zone
Source: Analyzed based on NMA (2018)

Maize Production and Trend of Productivity in Halaba zone

Maize production

The maize yield was decreased by the rate of 0.2qt/ha per annum. Regression line was fitted to determine evidence of trends in maize production; it depicted by 12.15% decrease in productivity in the meantime. The declining trend of maize yield (productivity) in the Halaba zone is mainly due to variable onset and seasonal rainfall increased warming, and high potential evaporation ("Effects of climate on maize yield").

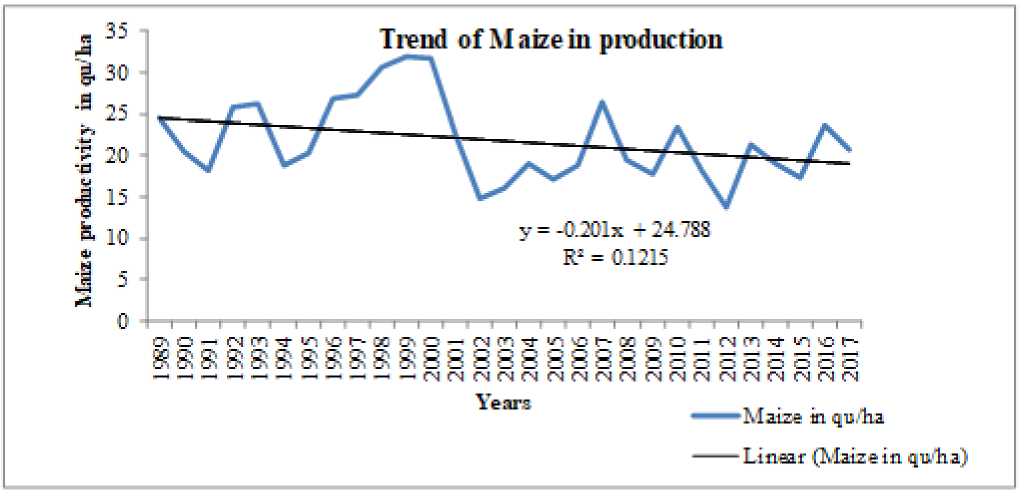

Figure 7 Trend of maize production in Halaba zone (1989-2017)
Source: Done by the researcher using CSA data (2018)

Climatic data and maize productivity

Rainfall-Maize Production Relationships

The patterns of inter-annual rainfall variability and fluctuations in maize production are presente graphically (Figure 9) to gain a better insight into rainfall-maize production relationships in the zone

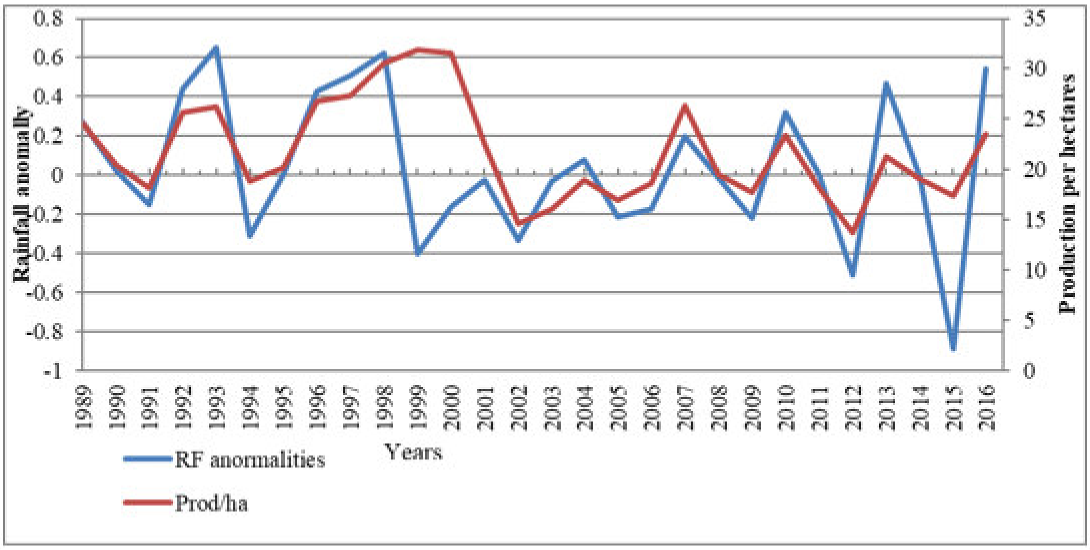

Fig 9 Standardized anomalies of production of maize and seasonal and annual RF amounts in the Halaba zone (1989-2017)
Source: - Done by the researcher using CSA and NMA data (2018)

The production of maize recorded fifteen positive anomalies and fourteen negative anomalies out of 29 production years (1989-2017). The production of maize was below the mean 21.774 Quintal per hectare in 2002 and 2012,.i.e 13.8 and 14.7 Quintal per hectare respectively were at their lowest levels on record for the period 1989-2017. The low maize production in 2002 and 2012 was apparently due to the below-average short season rainfall as well as main season rainfall.

Temperature-maize production relationships

Maize is planted under a single-cropping system in April, when the optimal soil temperature is reached for germination. May, June and July correspond to the key-growing season in Halaba zone. This indicated that the increasing temperatures have gradually shifted the sowing period from the historical third week of March to the last week of April and sometimes the first week of May which receive minimum optimal soil moisture amounts necessary for maize germination and growth in study area**.** The overall decrease of maize yield for the past 29 years was 0.2qt/ha. Increase in March-May temperature and June–August precipitation was found to have an adverse impact on maize production while increase in March-May precipitation was found to have a positive impact. As such, with the use of crop production data and climatic records, a 6 °C increase in temperature during the grain filling period resulted in a 10% yield loss in the US Corn Belt .

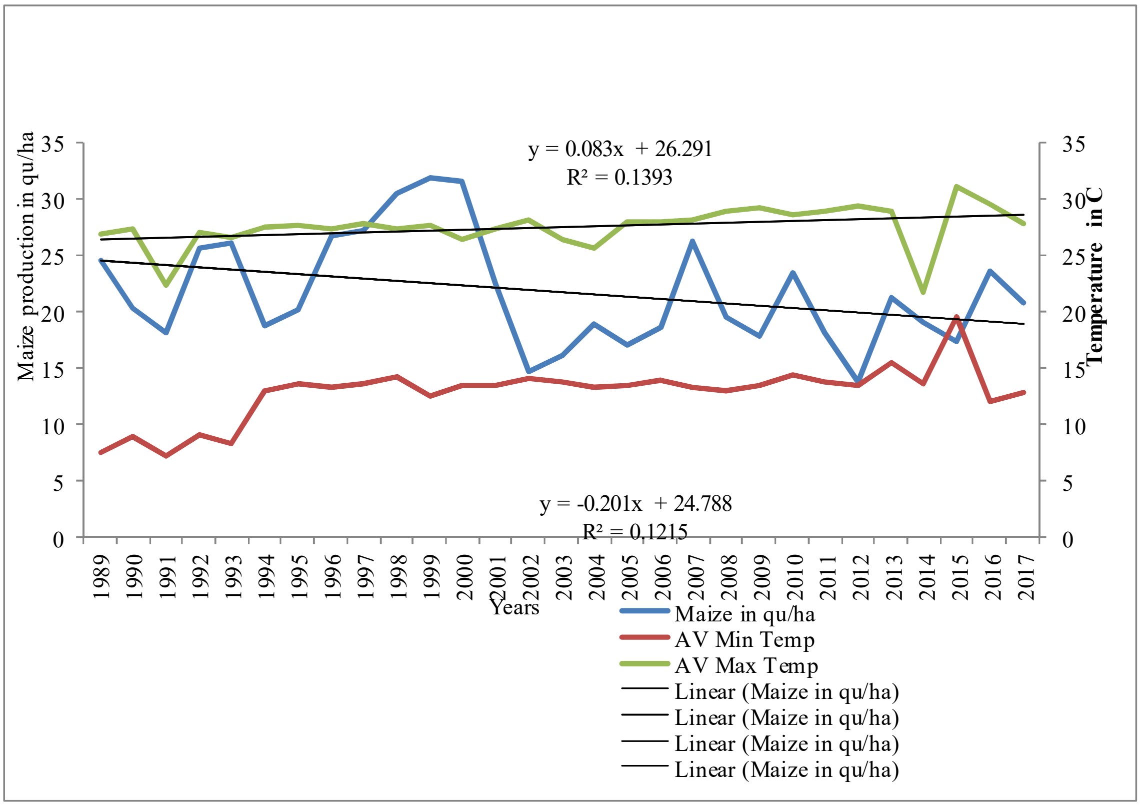

Figure 10 Relationship between maize yield, Min and Max Temperature in the study area
Source; Analyzed by the researcher using data obtained from CSA and NMA (2018)

This revealed that mean maximum temperature considerably related with the maize yield by 84.7 % at 10% significance level. Minimum temperature had the weak correlation values with maize yields in study area with the correlation value of 0.296 %.

Table 5 Correlations between production of maize and temperature in the Halaba zone

Temperature	Maize production	
	Pearson correlation(rho)	P-value
Min Temp	0.296	0.512
Max Temp	0.847	0.056*

*NB: Asterisk *Significant at the 10% level*
Source; Analyzed using data obtained from CSA and NMA (2018)

Climate change indicators were assessed up on the respondents.

Table 7 Farmers perception on climate change indicators

perceived climate change indicators	Response of farmers	
	Yes %	No%
Loss of some plant and animal species	86	14
Increased droughty condition	76	24
Decline of crop yield and livestock productivity	89	11
Incidence of crop and livestock pests and diseases	96	4
Water availability reduced	87	13
Number of observations=156		

Source: Own field survey (2018) in the study area for the period (1989-2017)

Discussion

This study attempted to investigate the impact of climate change and variability on maize production, climatic trends and farmer's perception and adaptation strategy in Halaba Zone. The meteorological data confirmed that the rainfall of the study area is characterized by greater inter-annual and seasonal variability in line with several empirical research findings conducted in Ethiopia. The rainfall is also described by alteration of wet and dry years in a periodic pattern over the past 29 years (1989-2017). Annual temperature in the study area showed increasing trend for the last three decades (1989 - 2017).The study has confirmed that Halaba zone found to be increasingly vulnerable to the risks of climate change and associated extreme weather events like drought and flood.

Conclusion

Maize production on the study area depends immensely on natural precipitation and rainfall variability affects its production. The results have shown that the less the rainfall variability, the less maize yield anomalies, thus the more reliable the rain is needed for the maize production in the study area. Maize production showed considerably very high and significant correlations with the short season rainfall, whereas it showed a weak and non-significant correlation with the main season rainfall even if it showed positive correlation. Mean maximum temperature had the strongest (significant) positive correlation value with maize yield, rather than mean minimum temperature in the study area. Based on the results, it is recommended that invest more in education because educated households are more alert than non-educated and yield increasing technology packages that increase farm income in rural areas should be underlined as policy options to reduce the negative impacts of climate change, install the meteorological station in the woreda to full fill the information gap on climate/weather variability and monitoring of crop-climate relationship in the area in order to achieve improved maize yield, encourage the farmers with improved agricultural inputs and draft power to insure rainfall risks, especially for smallholder farmers as they adopt improved agricultural production technologies to benefit from potentially unusual increased and decreased rainfall;

Significance of the Study

The study investigated impact of climate change and variability on maize production in relation to rainfall and temperature, farmer's perception on climate change and assessed farmer's adaptation strategies that they have adopted. The study could provide site information that helps them to adopt the best adaptation practices that would lead to sustainable maize production; boost up productivity contributes to build existing indigenous knowledge on climate change adaptation strategies and helps to generate ideas for further research.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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