ACADEMIC INN INTERNATIONAL

ISSN NO : 2523-1189

Journal of AGRICULTURAL AND RURAL RESEARCH

open access

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To cite the article: Addisu Kebede, Diriba Korecha & Eyale Bayable (2019), Impacts of climate change and variability on major crop production in Ankesha Guagusa district of Awi zone, North Western Ethiopia. *Journal of Agricultural and Rural Research*, 3(4): 158-171.

Link to this article:
http://aiipub.com/journals/jarr-190921-010081/

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IMPACTS OF CLIMATE CHANGE AND VARIABILITY ON MAJOR CROP PRODUCTION IN ANKESHA GUAGUSA DISTRICT OF AWI ZONE, NORTH WESTERN ETHIOPIA

Addisu Kebede[1]*, Diriba Korecha[2] & Eyale Bayable[3]

[1]*Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia
[2]Famine and Early Warning Systems Network – Ethiopia, Addis Ababa, Ethiopia
[3]Center for Environmental Science, Addis Ababa University, Addis Ababa, Ethiopia
Email: *addisukebede2016@gmail.com/addisuk@eefri.gov.et

ARTICLE INFO

Article Type: Research
Received: 07, Sep. 2019.
Accepted: 27, Dec. 2019.
Published: 28, Dec. 2019.

***Keywords**:*
Climate Change and variability, impacts, major food crops, Mann-Kendall trend test, Ankesha Guagusa district

ABSTRACT

Ethiopia is one of the developing countries in which agriculture is the primary source of its economy. Being dependent mainly on rainfall, this sector has been adversely affected by climate change and variability. But the change in all parts of the country is not equal and the scientific knowledge on the magnitude of local climate change and variability and its impact on crop production is lacking. Therefore, this study was conducted to generate research-based knowledge on the trend of climate change and variability and its impacts on major crop production in Ankesha Guagusa district. The required data for this study was generated from different sources. Mainly, the climatic data; monthly rainfall and temperature data of the study area was obtained from the National Meteorological Agency and crop production data with cultivated area was obtained from district's Agricultural Office. It relied on both qualitative and quantitative methods of data collection and analysis. The result of temperature and rainfall data analysis indicated that inter-annual and seasonal rainfall variability is high while temperature has been significantly increasing over time. As a result crop production is frequently declined in different years. Rainfall variability and crop production correlation also shows high correlations and this suggests that, crops are highly sensitive to the impacts of climate change and variability. Thus, there needs identifying the local adaptation mechanisms of the rural communities and the adaptive capacity of the local people needs to be improved to overcome the adverse impacts of climate change and variability on crop production.

1. INTRODUCTION

Climate change and associated weather extremes have continued posing severe challenges to our planet. Despite the fact that significant debates remain over the extent to which humans have induced climate change (WMO, 2007). In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC, 2013) concluded that climate change is already happening with its multi-faceted effects on human society and the environment. The United Nations Environment Programme (UNEP) report has also shown that many of the continental regions have experienced a sharp seasonal and annual rainfall and temperature variations including extreme events; such as flood, storms and drought. According to (Collier et al, 2008), the effects of climate change are manifested in terms of increased variability, higher frequency of extreme weather events and decreased predictability. This increased weather variability as a result of climate change results in potentially sudden and irreversible disruptions to life and livelihood-sustaining natural systems.

Africa in general and the sub-Saharan region, in particular, is commonly identified as a region profoundly affected by climate change and variability. This is mainly because it is the only continent which has its significant areal spread within the tropics and is full of uncertainties of climatic attributes. In addition to this, the presence of the social, economic, and political constraints also determine the capacity of human systems to cope with climate change and variability (Pearce, 2009). Observable trends of ongoing climate change and current projections indicate increasingly severe negative impacts of climate change on the majority of countries, with the most severe impacts disproportionately affecting developing countries.

In Ethiopia, rain-fed agriculture is a major source of income and subsistence for the nation and it plays a great role in economic growth and development. This shows how much the country is vulnerable to the impacts of climate change and variability (MOFED). Variability in climatic elements; especially rainfall and temperature adversely affect crop production as they influence soil fertility and the length of growing season and causes crop damage, lower yields, income lose, harvesting difficulties, increased pest and diseases. As crop production is the main livelihood of Ankesha Guagusa district; farmers face socio-economic problems due to the impacts of climate change and variability. To reduce such effects; there is a need for research-based knowledge on the extent of climate change and variability and its impacts on crop production. Therefore, this study was aimed to fulfil this research gap and to address the trends of climate change and variability and its impacts on major crop production.

2. RESEARCH METHODS

2.1 Description of the study area

The study was conducted in Ankesha Guagusa district of Agew Awi Zone which is located in the North-Western part of Ethiopia, which is 448 km north-west of Addis Ababa; the capital city of Ethiopia, 137 Km south-west of Bahir Dar; the capital city of Amhara Regional State. The administrative centre of Ankesha Guagusa district is Agew Gimjabet town which is located at a distance of 17 km South-West of Injibara; the administrative town of Awi Zone. Geographically its location extends between the coordinates of 36° 36' 1 8" and 36° 59'33" East longitude and 10° 31'46" and 10 ° 41'32" North latitude (Figure 1). Ankesha is bordered on the south by Mirab Gojjam Zone (Wonberma district), on the west by Guangua district, on the north by Banja shekudad district and on the east by Guagusa Shekudad district.

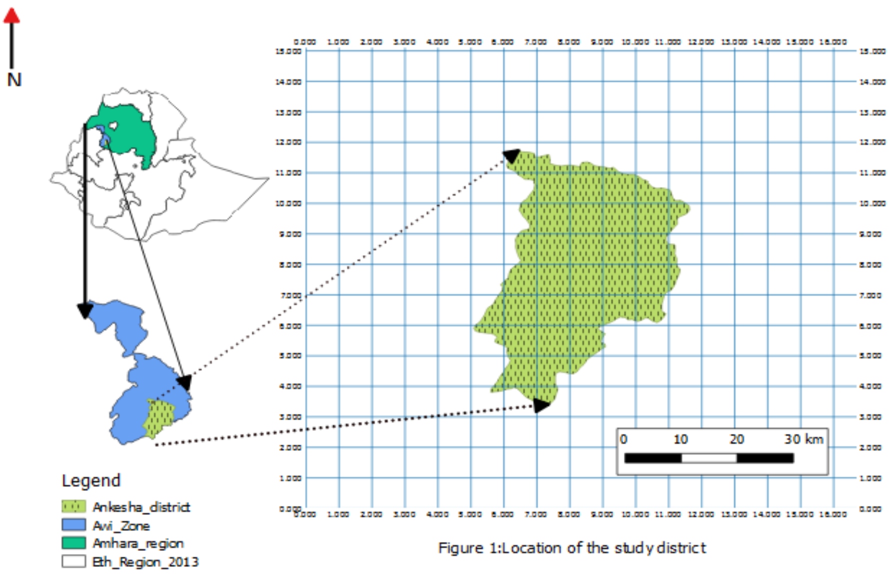

Figure 1:Location of the study district

The area has an elevation varying from 1500-2800 m.a.s.l and it has three agro-climatic zones; dega (high land), woina dega (mid land) and kola (low land). This diverse climatic pattern is favourable for agriculture, animal rearing and afforestation and most of its forest areas are covered by dense natural forests. In general, it receives most of its rainfall during a period that generally lasts from May to mid-September. The major cereal crops grown in the area include; wheat, barley, teff, maize and sorghum. As a result, Ankesha Guagusa district is recognized as one of the productive areas in Amhara Region.

2.2 Data sources and collection methods

The input data for this study was generated from different sources. The climatic data; monthly rainfall and temperature data of the study area were obtained from the National Meteorological Services Agency (NMSA) and 15 years annual crop production data for the major cereals which are identified in terms of area cultivated as well as total production were obtained from district's Agriculture and Rural Development Office (ARDO). Additionally, valuable secondary data were used from various sources. As stated in Devereux, et al. (2003), using both qualitative and quantitative techniques together yield more than the sum of two approaches used independently. Hence, both quantitative and qualitative data were collected through household survey, focus group discussion and field observation to match with climatic data and establish the pattern of local climate based on past temperature and rainfall records.

2.3 Methods of data analysis

Various methods of data analysis were employed in this study. Crop production and meteorological data were analyzed using descriptive statistical methods and presented in tables and graphs. The coefficient of variation, Precipitation Concentration Index (PCI) and Standardized rainfall anomaly was used as statistical descriptors of rainfall variability. The distribution of annual and seasonal rainfall was evaluated by using a modified version of Oliver's (1980) Precipitation Concentration Index (De Luı´s et al., 1999) was used. This index is described as:

$$\text{Annual PCI} = 100*[\Sigma Pi^2/(\Sigma Pi)^2], \qquad \text{Seasonal PCI} = 25*[\Sigma Pi^2/(\Sigma Pi)^2]$$

Where: Pi = the rainfall amount of the i^{th} month

Σ = summation over the 12 months for annual and 3 months for seasonal rainfall.

According to Oliver (1980), PCI values of less than 10 indicate the uniform monthly distribution of rainfall, values between 11 and 20 indicate high concentration, and values of 21 and above indicate very high concentration. Further, as in Agnew and Chappel (1999), the standardized anomalies of rainfall were calculated and used to assess the frequency and severity of drought and described as:

$$S = (Pt - Pm)/\sigma$$

Where S = standardized rainfall anomaly, Pt = annual rainfall in year t, Pm = is long-term mean annual rainfall over a period of observation and σ = standard deviation of annual rainfall over the period of observation. The drought severity classes are extreme drought ($S < -1.65$), severe drought ($-1.28 > S > -1.65$), moderate drought ($-0.84 > S > -1.28$), and no drought ($S > -0.84$) were assessed and graphically presented to evaluate the inter-annual fluctuations of rainfall. Correlation analysis was also used to examine the relationship between rainfall variability and crop production as well as the relationship among seasonal rainfall amounts to gain a better insight into rainfall-crop production relationships in the district.

2.3.1 Trend analysis and significance test

Several tests are available for the detection and estimation of climatic trends. In this particular study, the Mann-Kendall trend test was used. Addinsoft's XLSTAT 2015 software was used to analyze the trend analysis and Mann-Kendall trend test was used to see whether there is a trend or not in a given time series as in Leta (2011). Mann Kendall trend test is a statistical test widely used for the analysis of trends in climatic variables. There are two advantages to using this test. First, it is a non-parametric test and does not require the data to be normally distributed; secondly, it is less sensitive to outliers or extraordinary high values within the time series data. In this test, a score of +1 is awarded if the value in a time series is larger, or a score of -1 is awarded if it is smaller. The total score for the time-series data is the Mann-Kendall statistics, which is then compared to a critical value, to test whether the trend in rainfall is increasing, decreasing or no trend in rainfall can be determined. A positive value is an indicator of increasing (upward) trend and a negative value is an indicator of decreasing (downward) trend. The trend obtained by Mann-Kendall trend test was tested for significance and normalized test statistics (Z- score) was used to check the statistical significance of the increasing or decreasing trend of temperature and rainfall values and tested using Mann-Kendall trend significance test with the significance level of 0.05 ($Z\alpha/2 = \pm 1.96$).

Hypothesis testing: H0: $\mu = \mu o$ (there is no significant trend/stable trend in the data)

HA: $\mu \neq \mu o$ (there is a significant trend/ unstable trend in the data)

If $-Z1\text{-}\alpha/2 \leq Z \leq Z1\text{-}\alpha/2$ accepts the hypothesis or else rejects H0.

The absence or presence of a statistically significant trend was evaluated using the Z value. In a two-tailed test for trend, the null hypothesis H0 should be accepted if $|Z| < Z1\text{-}\alpha/2$ at a given level of significance.

3. RESULTS AND DISCUSSION

As indicated by different researchers; Ethiopian climate is changing. Still, the rate of change differs within localities and it is difficult to conclude the change is equal in all parts of Ethiopia. Climate change and variability of Ankesha Guagusa district was briefly assessed based on perceived changes by the local people combined with meteorological evidences.

3.1 Rainfall Variability and Trend

3.1.1 Annual Rainfall Variability and Trend

Mann Kendall trend analysis based on the recorded data of rainfall from 1983-2014 shows an increasing trend of rainfall with inter-annual variability. But the trend significance test shows there is no statistically significant trend. The annual rainfall of Ankesha Guagusa ranges between 1109.7 mm in the driest year to 1507 mm in the wettest year and the mean annual rainfall over those years is about 1302 with standard deviation of 110.4 mm and 8.5% coefficient of variation, which is lower than the coefficient of variation of the region (10.4%) studied by Woldeamlak (2009). Annual rainfall has experienced inter-annual variability over the past 32 years and there seems two to three consecutive occurrence of low and high rainfall. This shows that the rainfall is highly variable and erratic on annual time scale.

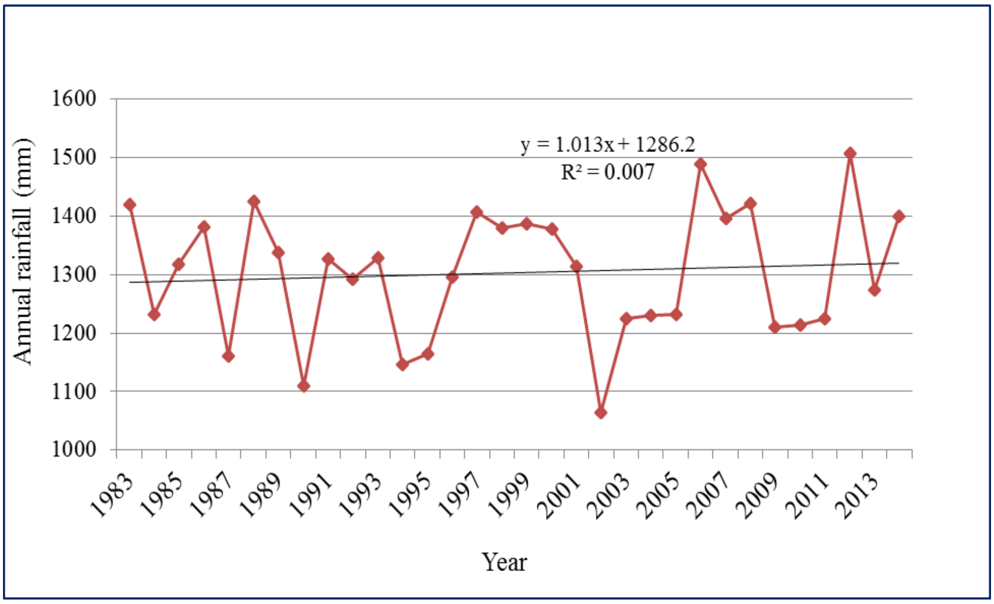

Figure 2 Annual rainfall variability and trend in Ankesha Guagusa district (1983-2014)

As shown in figure 2 above; the annual rainfall of the study area shows an increasing trend which is consistent with the analysis of annual rainfall for Simada woreda covering the period 1987-2008 who reported an increasing trend of rainfall (Marye, 2011).

3.1.2 Seasonal Rainfall Variability and Trend

The impacts of rainfall on crop production can be related to its total seasonal amount or its intraseasonal distribution. Hence, for a better insight of impacts on crop production, analysis of seasonal variation is very decisive since variation in all seasons of the year is not equally important from a crop production point of view. Like; most parts of Ethiopia, the area has two cropping seasons and experiences a bimodal rainfall (Type-1) pattern receiving small spring rains from February/March to May known as Belg; short rainy season and big rains from June to September; known as Kiremet; the main rainy season (NMSA, 1996; NMSA, 2001). Kiremet is generally the main cropping season that accounts for the overwhelming proportion of the total area cultivated and annual crop production.

Table 1. Coefficient of variation for belg, kiremet and total seasonal rainfall

Season	N	Minimum	Maximum	Mean	STD	Variance	CV (%)	Trend
Belg	32	66.8	297.6	197.2	65.74	4322.4	33	0.848
Kiremet	32	768.6	1140.6	958.76	92.6	8573.7	9.6	-2.084
Total seasonal RF	32	936.7	1296.1	1155.9	96.9	9389.6	8.3	-1.23

As shown in Table 1 above, Belg rainfall shows 33 % coefficient of variation, kiremet rainfall shows 9.6 % coefficient of variation and seasonal rainfall shows 8.3 % coefficient of variation indicating that there is high inter-seasonal variability of rainfall. The scale of variation in rainfall amount appears more for belg than kiremet season. This is also consistent with the conclusion made by Leta (2011); which reveals belg rainfall is more variable than kiremet rainfall. He stated that, belg rainfall is more favourable for crop production as there is no aeration problem and cloud cover. But its variability affects production by hindering agricultural activities such as; land preparation and sowing time, crop physiology such as germination and growth of seedlings.

Moreover, the seasonal variability of rainfall is strongly associated with late-onset and early offset of the rainy season. Analysis of belg rainfall has shown an increasing trend by about 0.84 mm/year. On the other hand, kiremet rainfall has shown a decreasing trend by 2.08 mm per year during the past couple of decades. The amount of total seasonal rainfall has also decreased by about 1.23 mm every year. This reduction in amount and variability of seasonal rainfall makes the prediction of the situation difficult affecting farming activities of farmers especially those whose livelihoods depend on rain-fed agriculture.

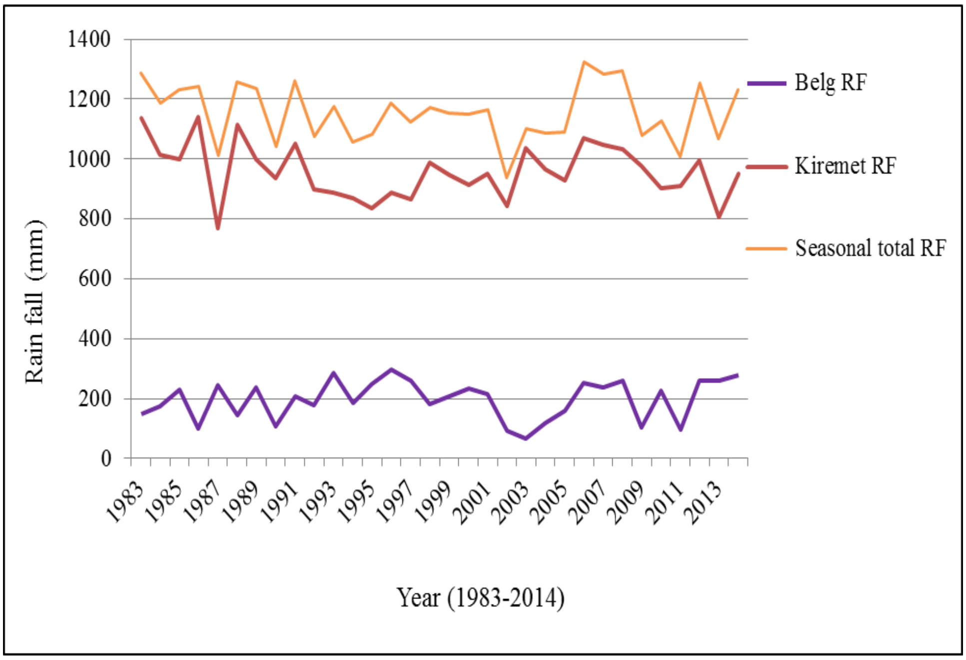

Figure 3 Seasonal rainfall variability and trend

3.1.3 Intra-seasonal Rainfall Variability and Trend

In addition to the seasonal rainfall and their season to season variability, the distribution of the rainfall within a season is very critical to agriculture. Intra-seasonal rainfall analysis indicates that what has happened within the season; like fluctuations in the peak rainfall time. The peak rainfall time does not occur at the same month each year; altering from year to year which also affects crop production.

With extreme cases of drought; with very low total seasonal amounts, crop production suffers the most. But more subtle intra-seasonal variations in rainfall pattern during crop growing periods, without a change in total seasonal amount causes a substantial reduction in crop yield. This means that the number of rainy days during the growing period is as important, if not more, like that of the seasonal total rainfall (Woldeamlak, 2006 cited in Woldemlak, 2009).

Table 2. Average rainfall and coefficient of variation for kiremet and belg months

Season	Months	Minimum	Maximum	Mean	STD	Variance	CV (%)
Belg	March	1.4	61.2	25.6	17.69	312.9	69
	April	10.2	114.1	48.9	27.7	767.3	56
	May	20.2	183	122.6	54.3	2948.5	44
Kiremet	June	27.3	290.4	188.6	55.6	3091.3	29
	July	180.5	409.8	286.5	64.6	4173.1	22
	August	215.6	396.8	283.9	42.2	1780.8	14
	Septem.	140.4	243.4	197.2	44.9	2016	22

belg month's rainfall is more variable than that of Kiremet month's rainfall and shows an increasing trend (Figure 4). The onset of rain for the growing season is March and this is important for agricultural operations such as land preparation and sowing time. This contributes to increased soil moisture availability. Hence, the occurrence of adequate rainfall in the early periods of belg season is critically important for the production of sorghum and maize, which are long-cycle crops sown early from the kiremet rains.

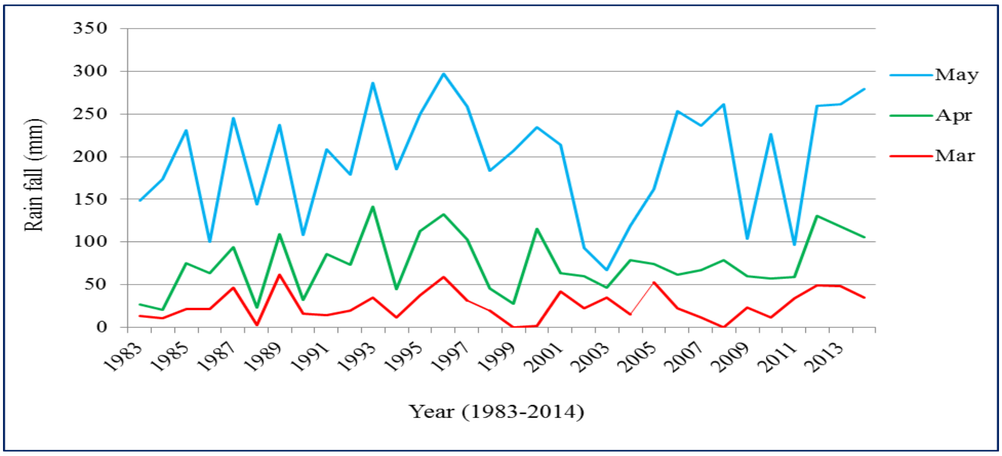

Figure 4 Average monthly rainfall trends for belg months

By the beginning of the belg (short rainy season), which follows bega (long dry season), soil moisture is virtually nil. But the soil moisture reserved during belg season is sufficient to support plant growth during dry spells; even though, the occurrence of kiremet rainfall is likely to become more common. From kiremet months; the pronounced reduction is seen in June, July and August months and shows a decreasing trend except September (Figure 5). The observed decrease in rainfall of June, July and August are detrimental as it further shortens the potential crop growing period of the area posing challenges to pasture and crop growing. This means that the potential plant growing period is decreasing which requires farmers to think over the crop types that fit the existing length of growing period and to switch to short maturing crops which gives yield in this narrow rainy season. Rainfall in September is very important for long maturing crops at their final stage of maturity and strongly determines the productivity of crops like; maize and sorghum.

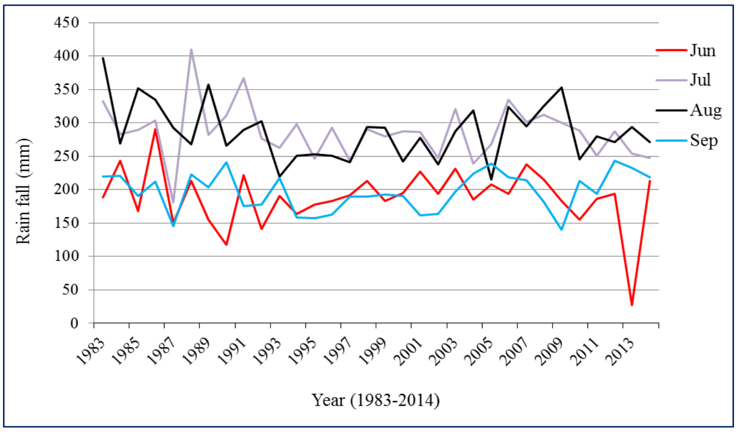

Figure 5 Average monthly rainfall trends for Kiremet months

The decreasing rainfall of June has an implication on cropping practice and crop yields which are highly sensitive to variation in the timing of the growing season. More than decreasing of monthly rainfall, the pronounced problem is the high variability of rainfall in the main rainy season. This indicates that within the summer or main rainy season, the rainfall is becoming heavy in some months leading to flooding which damages crops and in other months it becomes very little which ones again leading to the failure of crop production. This becomes very frequent phenomena especially in the lowland areas of Ankesha Guagusa. In general, the observed and perceived variation in rainfall onset and offset has an implication for crop yield reduction and risk of food security.

3.2 Temperature Variability and Trend

The Mann Kendall trend analysis for average temperature also shows a statistically significant increasing trend of temperature. According to NMA (2007), the average annual minimum temperature over the country has increased by about $0.37^{o}{}_{C}$ and the average annual maximum temperature has increased by about $0.1^{o}{}_{C}$, whereas, the average annual temperature has increased by $0.23^{o}{}_{C}$ every decade. Similarly, the data shows that the minimum temperature is increasing by $0.24^{o}{}_{C}$ and the maximum temperature is increasing by $0.3^{o}{}_{C}$. The average annual temperature is also increasing by $0.27^{o}{}_{C}$ every decade which is higher than the national average. This finding is consistent with studies of Bewket (2010); in which he showed an increasing trend of temperature by about $0.25^{o}{}_{C}$ per decade in Choke Mountain. The general trend of both annual maximum and minimum temperature of the study area is increasing with inter-annual variability during the last three decades. The mean annual maximum temperature of the study area is $25.8^{o}{}_{C}$ and the mean annual minimum temperature of the study area is $11.7^{o}{}_{C}$.

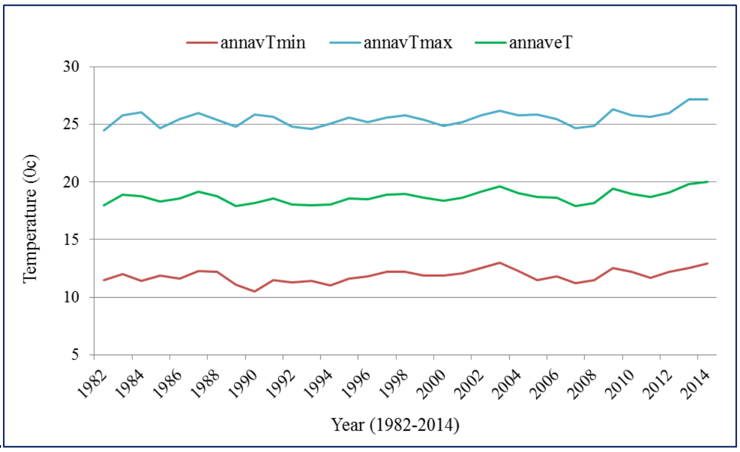

Figure 6 Trend and variability of average annual temperature at Ankesha Guagusa district

To show the deviation of annual maximum and minimum temperature from their long term mean value; the maximum and minimum temperature anomalies were calculated. A positive temperature anomaly indicates that the observed temperature was warmer than the reference value, while a negative anomaly indicates that, the observed temperature was cooler than the reference value. Accordingly, the deviation of annual maximum and minimum temperature of the study area from the mean maximum and minimum temperature was calculated and presented (Figure 7).

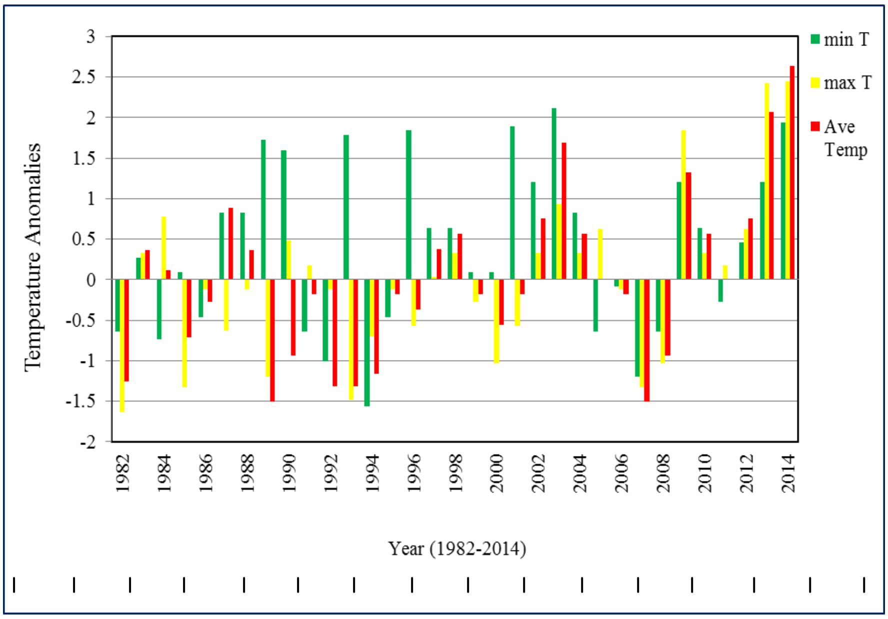

Figure 7. Maximum and minimum temperature Anomalies of Ankesha Guagusa district

The above Figure (7) shows that the minimum and maximum temperature of the study area is deviating from the mean temperature. As compared to the maximum temperature deviation, the minimum temperature shows high inter-annual fluctuation from the long term mean value. This is consistent with the studies of Abebe (2013); in which the minimum temperature shows high inter-annual variability than maximum temperature and he stated that, if the temperature extremely deviates from the long-term mean temperature (towards the positive or negative side); it has negative impacts on crop production.

3.3 Climate caused extremes

The statistical analysis shows that rainfall and temperature values have shown significant variations and weather-related shocks have been increasing which affects crop production of the area. This is also supported by survey conducted on 150 households and the data obtained from the ARDO. Though the degree differs, the occurrence of weather events is consistent with that of Ethiopia; farmers already suffer from extremes of climate, manifested in the form of frequent drought that occurred in 1965, 1972, 1973, 1978, 1984, 1991, 1994, 1999 and 2002 and recent flooding which caused loss of life and property occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 (NMA, 2006). Meteorological drought years were used as evidence to show the years that drought occurred. As in Agnew and Chappel (1999); the standardized rainfall anomalies of the study area between 1983 and 2014 were calculated and used to assess the frequency and severity of drought as follows (Figure 8).

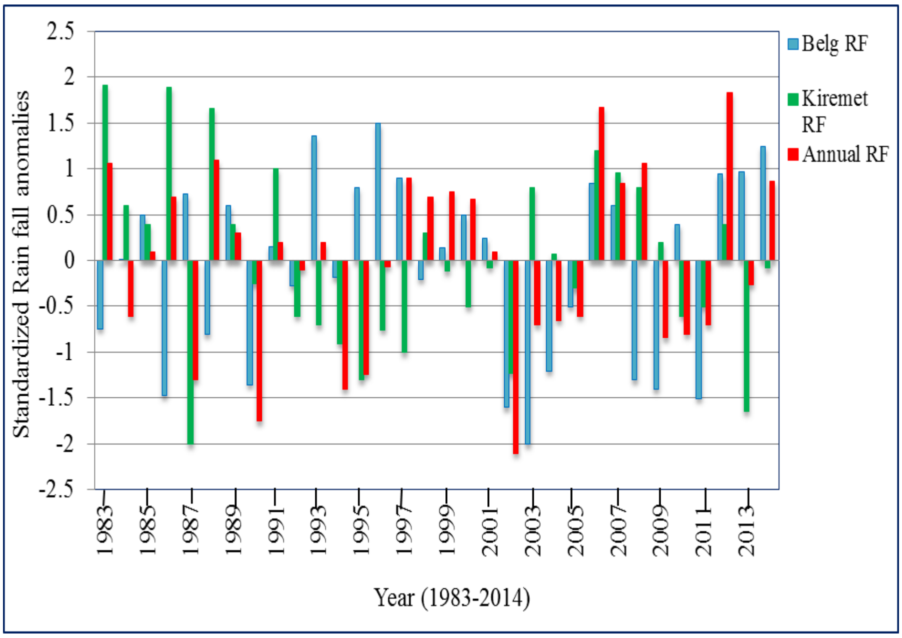

Figure 8. Standardized Rainfall Anomaly of Ankesha Guagusa district

The result of standardized anomalies of rainfall in Figure 8 above shows that the area has experienced a significant number of drought years. From these, extreme drought occurred in 1990 and 2002; severe drought occurred in 1987, 1994 and 1995. This is consistent with the studies of Rediat (2011); in which he showed, the increased frequency of drought in Ebinat Woreda. The survey also indicated that heavy rainfall occurred in 1986 and 1988 resulted in flooding which caused damage on life and property; especially in low land areas of Ankesha Guagusa. The frequently experienced climatic shocks identified by the respondents that have a significant impact on crop production are prolonged drought including late onset/early offset of rain, flood, frost and unseasonal rainfall. Therefore, the survey conducted from the respondents was supported by meteorological data.

3.4 Impacts of climate change and variability on crop production

As crop production in the study area is totally dependent on the onset of the rainy season, any changes in the amount and temporal distribution of rainfall and other climatic factors affect crop production. The late onset of the rainfall hinders agricultural operations such as land preparation and sowing time while early offset of the rain when most of the crops are at flowering stage also directly affects fruit setting of crops. The shortening of rainy seasons together with temperature variability poses major challenges on crop production. The discussion made with households in focus group discussion indicated that the pattern of rainfall is showing greater variability during the last decades. Sometimes it rains with high intensity resulting in heavy flood and sometimes become so scarce resulting in water shortage. Even within main rainy season, the distribution of rainfall shows high variability which affects crop production. This is consistent with the finding of (Pankhurst and Johnson, 1988 cited in Woldeamlak, 2009) which is stated as rainfall in much of the country is often erratic and unreliable; and rainfall variability and associated droughts have historically been major causes of food shortages and famines.

According to the survey, the occurrence of drought and flood become more frequent in Ankesha Guagusa district. During the drought and late-onset of rain, land becomes dry and difficult to plough, lack/insufficient amount of precipitation hinders germination of seeds. Even a week delay in the onset of rain is found to have significant impact on crop yield. The situation has also created a good opportunity for weeds to stay in the cropping land so that it latter emerges and out-compete with crops. The high surface temperature linked with reduced number of rainy days is causing shortage of soil moisture in cropping seasons which leads to poor seedling and slow growth resulted in low productivity of crops. In addition to drought and flood, unseasonal rainfall also results in seed drop, ripened crop germination, harvested crop spoilage. All these impacts cause delayed seeding, increased pest and resulted in reduced crop yield and deprives farmer's livelihood.

In Ankesha Guagusa district, a prolonged drought occurred in the year 2001/2002 has resulted in significant loss of production. According to the data obtained from Ankesha Guagusa district agricultural office, 29,186 hectares of land was cultivated and 673, 522 quintals of production obtained during the main growing season. The loss in 2001/2002 is estimated to be 163,310 quintals compared to the previous year (2000/2001) following the lowest seasonal rainfall over the period of record and as mentioned by FGD members, the rain for the main growing season started late in mid-May and ended up earlier than usual. This is consistent with (NMA, 2006) that indicates the period of frequent drought and the research conducted by Leta (2011) which showed 362,034 quintals of crop loss in Bako Tibe woreda in 2001/2002. In the same way, in 2008/09 from 30,108 hectares of land cultivated 762,395 quintals of crop production was obtained. The loss is estimated to be 118,595 quintals compared with the previous year.

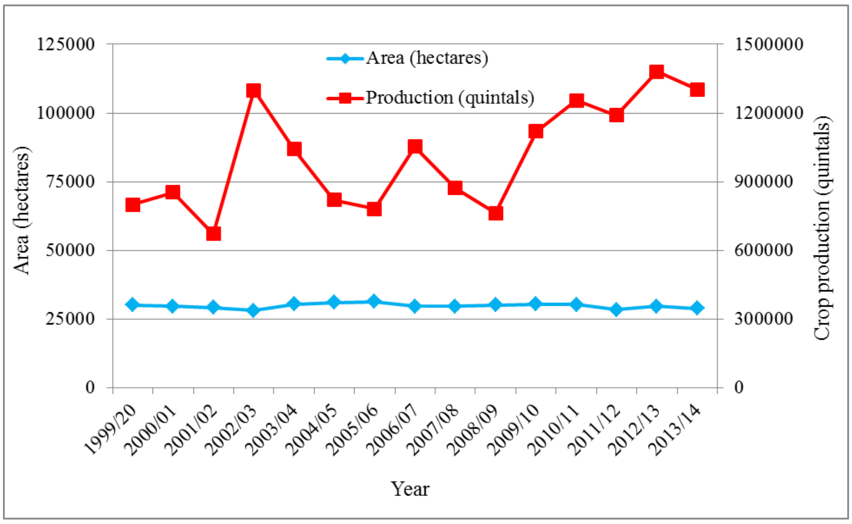

Figure 9. The trend of Agricultural crop production of main growing season of Ankesha Guagusa district (Source: Ankesha Guagusa district ARDO)

As we can see from Figure 9 above, the production decline in 2002, 2006 and 2009 at Ankesha Guagusa district is mainly attributed due to climatic shocks such as prolonged drought, delay in the onset of rainfall and early cessation of rain before crop maturity. The total production for major crops shows an increasing trend following the increasing trend of seasonal rainfall after the year in which the crop production data was available. This might be also due to increased use of improved and drought-resistant seed varieties which attributed to increased crop production.

3.5 Rainfall Variability and crop production correlation

Rainfall in terms of seasonal total amounts and seasonal distribution is the most important climatic element in the predominantly rain-fed smallholder agricultural systems and its impact on crop production can be related to its total seasonal amount or intra-seasonal distribution.

Table 3. Correlations between cereal crop production and seasonal rainfall

Pearson's Correlation between cereal production and kiremet rainfall (N=15)			
Season	Wheat Production	Barley Production	Teff Production
Kiremet Rainfall	0.61	0.57	0.63

Pearson's Correlation of Maize and sorghum production with seasonal totals (N=15)		
Season	Maize Production	Sorghum Production
Belg Rainfall	0.27	0.59
Kiremet Rainfall	0.31	0.3

From Table 3 above, the production of teff, barley and wheat show stronger correlations with kiremet rainfall while sorghum production is more strongly correlated with belg rainfall. Maize shows a considerable positive correlation with belg and kiremet seasons. This is consistent with Woldeamlak (2009) and he stated that productions of cereals showed statistically significant correlations with each other, suggesting rainfall is the common yield-limiting factor as use of chemical fertilizers and other agricultural inputs is limited and farmers are vulnerable to food insecurity due to rainfall variability and there is a need for water resources development including household level rainwater harvesting for crop production.

CONCLUSION

This study investigated the impacts of climate change and variability on major crop production in Ankesha Guagusa district. Analysis of historical climate data showed that, temperature and rainfall are characterized by general trends of increase and higher inter annual variability. This high inter-annual and seasonal rainfall variability and frequent drought affected the livelihood of the local people which is highly dependent on rain-fed agriculture. Due to high correlations between crop production and rainfall, small changes in amount and distribution of seasonal rainfall caused significant negative impacts on crop production. As a result of climate change and variability, a number of climatic hazards occurred in the study area such as shifting in the timing of rainfall and a shortened period of rainy season, increased frequency of drought and flood, frost, unseasonal rainfall, pests and diseases. The occurrence and increased intensity of these climatic hazards resulted in frequent loss of crop production and reduced the capacity of the local people to cope with the impacts of climate change and variability. Hence, institutional support is vital in developing locally appropriate coping and adaptation strategies to the impacts of climate change and variability on crop production.

ACKNOWLEDGEMENTS

We would like to thank Ethiopian National Meteorological Services Agency and Ankesha Guagusa district agricultural office for kindly providing the necessary data. our sincere thanks also go to those who participated in reviewing this paper.

Competing interests: The authors declare that, they have no competing interests.

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