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Characterization of Rainfall and Temperature Variability to Guide Wheat (*Triticum Aestivum*) and Barley (*Horduem Vulgare*) Production in Enderta *District*, Southeastern Tigray, Ethiopia

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Abstract: *Rainfall coupled with temperature is the most important climatic elements that determine crop growth in semiarid regions like Ethiopia. This study was conducted to characterize past rainfall and temperature variability and their effects on wheat and barley production in Enderta district. Daily and dekadal rainfall and temperature climate data covering: (1984-2014) were obtained from the National Oceanic and Atmospheric Administration and National Meteorological Agency respectively. Rainfall data was subjected to compute rainfall indicator indices such as rainfall totals, start of rain, and end of rain, length of growing period and length of dry spells using INSTAT climate guide. On the other hand, seasonal and annual temperature variability was assessed using the standardize anomaly Index. The analysis of observed data revealed that seasonal (Kiremt and belg) and annual rainfall variability was 25%; 55% and 24% respectively. Minimum and maximum temperatures showed an increasing trend about 0.38^{o}c; 0.42^{o}c and 0.62^{o}c; 0.59^{o}c per decade seasonally (October-November-December-January and March-April-May) and annually respectively. The correlation analysis impacts of rainfall and temperature on the crops revealed barley with long rainy (June-July-August-September) season ($r=0.7021$, $P < 0.05$) and wheat ($r = 0.6265$, $P < 0.05$) were positively correlated with statistically significant effect. Similarly, barley and wheat had positive relationship with temperature ($r = 0.7136$ and 0.6550, $p < 0.05$), respectively. The June-July-August-September rainfall and temperature had positively correlated with the seasonal changes in barley and wheat production indicates that the performance of both barley and wheat in the study area mainly depends on the seasonal (June-July-August-September) rainfall and temperature.*

Keywords: *Climate, Season, Rainfall, Temperature, Growing Season.*

1. Introduction

Climate variability has become more threatening not only to food security and sustainable development of any nation, but also to the totality of human existence. The dependence of Ethiopia on agriculture makes its economy extremely vulnerable to the risks associated with climate variability. Food insecure regions and climate change vulnerable regions in Ethiopia are those that experience both the lowest and most variable rainfall patterns (UN-OHRLLS, 2009).

Temperature is also a key climatic factor that matters the timing of biological processes and controls developmental rate of plants from one stage to another in their life cycles (Parthasarathi *et al*.; 2013a). The major causes of crop failure in the northeastern Ethiopia including the study area are frequent dry spells of about 10 days length, as well as shorter growing period due to replanting or late onset and early cessation of rain (Segele and Lamb, 2005;). Therefore, site specific rainfall and temperature characterization is crucial for agricultural planning to minimize their effects on crop production.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location

The study area is located in the Tigray National Regional State of the Federal Democratic Republic of Ethiopia. Geographically, it is located between 13^0-14^{oO}N Latitude and 39^0-40^0 30'' ^{O}E Longitude. The study area shares border District's with Kilte Awlalo in the north, Degua- Temben in the west, Saharti

Samre in the south west, Hintalo Wajirat in the south and the Afar region in the east.

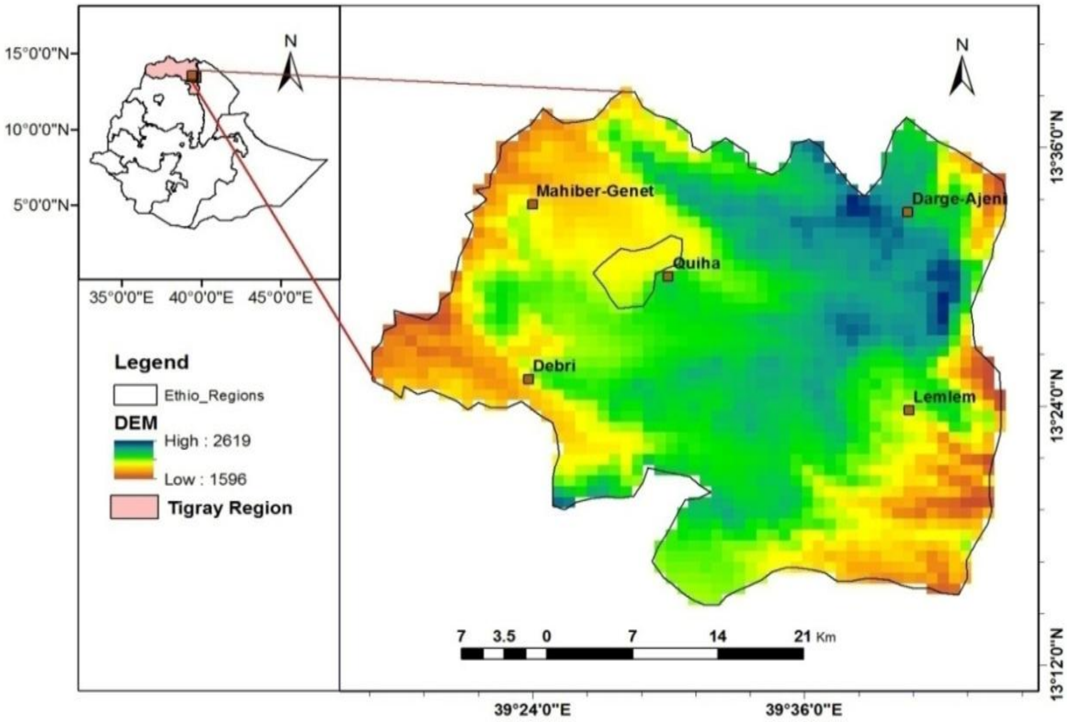

Figure 1. *Map of the study area*

2.1.2. Climate, soil and Agriculture

The District comprised of two major agro-climatic zones. A greater portion lies in the *Weynadega* altitudinal climatic zone with an elevation range between 1500 to 2300 m while a smaller portion in the eastern and western parts lay in the '*Kolla*' altitudinal climatic zone with elevation between 500 to 1500 m. The Weynadega *part* mean annual maximum and minimum temperature is 24.3 and 11.3°C, respectively with average annual rainfall of 601mm (Florence, 2008). About 70–80% of the rain falls in the *Kiremt s*eason (June–September) and *Belg* (March-May),(Araya et al., 2010b). The area is characterized by erratic rainfall and frequent droughts. The long rainy season is between June and September and short rainy season from March-May.

In a recent study of Enderta District, ten soil groups have been found, namely Luvisols, Cambisols, Calcisols, Vertisols, Phaeozems, Regosols, Arenosols, Fluvisols, Kastanozems and Leptosols (IAO, 2008).The subsistence agricultural production is almost entirely dependent on *Kiremt*. In the *'WeynaDega'* Agro-climatic zone with temperatures between 16-20oC, the main crops grown are wheat, barley, maize, *teff* and pulses. On the other hand, the dominant crop grown in the *Kolla* Agro-climatic zone (>20oC) is sorghum.(http://www.dppc.gov.et).

2.2. Climate Parameters and Database Used for the Study

Five gridded-points daily rainfall (1980-2010), maximum and minimum temperatures (1984-2010) based on data availability and relative length of time with a reasonably good geographic distribution were collected from the National Oceanic and Atmospheric Administration (NOAA), U.S.A. and the National Meteorological Agency of Ethiopia archives (NMA). In addition, wheat and barley yield data for the Meher/JJAS season (2003-2013) were obtained from central statistics agency (CSA).

2.3. Rainfall and Temperature Variability Analysis

Thirty years of rainfall and temperature (maximum and minimum) data were used to assess seasonal and annual variability. The long-term rainfall amount and temporal distribution during the growing season of the study area was assessed by processing the daily rainfall data using INSTAT Climatic Guide (Stern *et al.*, 2006). In order to determine onset of rainfall in each seasons (JJAS and MAM), the definition of effective onset of rainfall was employed from past rainfall data. In this study, the first occasion after March 1st when rainfall accumulated in three consecutive days is at least 20 mm and no dry spell of more than 7 days in the next 30 days was used as an actual onset of rainfall. The end of growing season (end date), on the other hand, was defined as the first date after 1st September when the soil water drops to 10 mm/meter within 10 days after which there is no rainfall for the next 10 days. The onset and end date criteria were used to determine the length of growing season as total number of days from the date of onset of rainfall to the end date of the rainfall. The daily rainfall data was processed to give probabilities of maximum dry spell lengths exceeding 5, 7, 10, 15 and 20 days starting from January first. Monthly pattern of average minimum and maximum temperature values were analyzed using the box and whisker plots of INSTAT-Climate Guide (Stern *et al.*, 2006). In a box and whiskers plotting, the box represents the middle 50% of the whole data set, while whiskers represent the magnitude of the spread of the rest of the data set about the median or mean (Stern *et al.*, 2006).Therefore, in order to quantify the effect of climate variability on wheat and barley production seasonal March-April-May (MAM), June-July-August-September(JJAS)rainfall, minimum and maximum temperature trends were analyzed.

3. Results and Discussion

3.1. Annual and Seasonal Rainfall Variability

The amount and distribution of annual and seasonal total rainfall, timing of onset and end dates, and length of growing season (LGS) are critical rainfall features that indicate useful information on temporal rainfall variability over an area. The seasonal total rainfall ranged from 9 to 227.3 mm in MAM and 186 to 642.3 mm in JJAS, respectively (Table 1). The CV is much higher for MAM season rainfall total than JJAS season rainfall indicating higher temporal variability of the MAM season rainfall total. The annual total rainfall also showed high interannual variability and ranged from 269.3 to 836.8 mm. The JJAS season rainfall contributes 76% of the annual rainfall whereas the MAM season contributes 17% of the annual rainfall which might benefit for land preparation, pasture growth and drinking water. The rest of the annual rainfall (7%) is obtained during the dry months of the year (ONDJ).

Table1. *Descriptive statistics of annual and seasonal (MAM and JJAS) rainfall total of Enderta district for 30 years (1984-2014)*

Descriptive statistics	Annual rainfall total (mm)	Seasonal rainfall total (mm)	
		JJAS (mm)	MAM (mm)
Maximum	836.8	642.3	227.3
Minimum	269.3	186.0	9.0
Mean	599.4	452.7	103
CV	24	25	55
SD	139	107	55
Proportion (%)		76	17

3.2. Onset, End Date and Length of Growing Season

Upon the definition set *Using INSTAT climate guide* a time series analysis of daily rainfall of a specific area from the past record gives a good picture to decide the possible onset date, cessation date and length of growing season**.** In line with this, the average onset date atLat.13.24^{O}N and Lon.39.38^{O}E in the Southeast and at Lat.13.27^{O}N and Lon.39.30^{O}E in the Central of the study area from (1980-2010) was 177DOY/25June and 184/02July followed by the early onset date 147DOY/26May and 166DOY/14Jun with the late onset date 189DOY/07JUL and 198DOY/16JUL respectively. The early offset date at Lat.13.24^{O}N and Lon.39.38^{O}E in the Southeast and at Lat.13.27^{O}N and Lon.39.30^{O}E in the Central of the study area was 245DOY/01SEP and the late offset was also 284DOY/10OC and 283/09DOY respectively. The average cessation of the season JJAS at Lat.13.24^{O}N and Lon.39.38^{O}E in the Southeast and at Lat.13.27^{O}N and Lon.39.30^{O}E in the Central of the study area was ranged from258DOY/14SEP to 261DOY/17SEPrespectively. Therefore, the onset date, offset date and length of the rainy season/JJAS atLat.13.24^{O}N and Lon.39.38^{O}E in the Southeast and at Lat.13.27^{O}N and Lon.39.30^{O}E in the Central of the study area(Figure 2) would beon 177DOY/25JUN, 184DOY/02JUL, 258DOY/14SEP, 261DOY/17SEP and 87, 79 days respectively. In line with this, Araya and Stroosnijder (2011) and Hadgu et al. (2013) also reported similar findings.

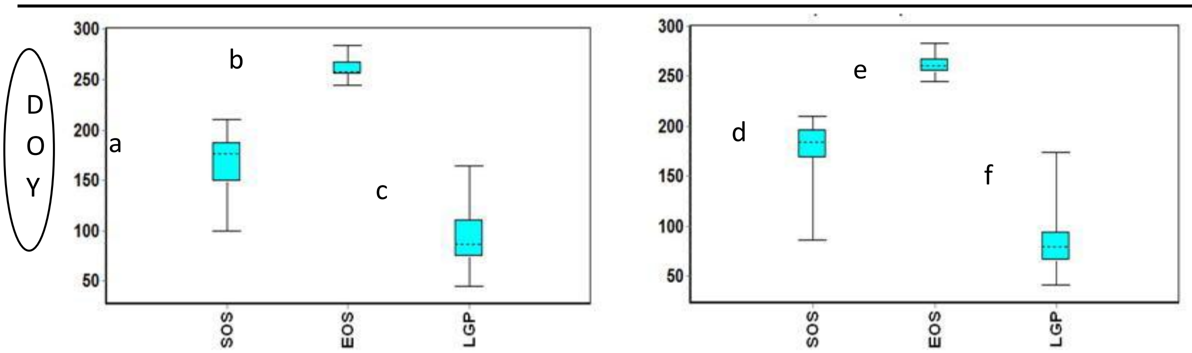

Figure 2. *Box whisker plots of onset date, end date and length of growing period for Kiremt Season at gridded-points (n)/SE and (e)/Central of the study area (1980-2010)*

On the other hand, the start date (SOS), cessation date (EOS) and length of growing season (LGS) during the *belg(MAM)* season in the study area for the period (1980-2010) is depicted in Figure3. In the present study, the observed SOS, EOS and LGS for *belg(MAM)* season revealed that the season was challenging for crop growth rather it might benefit for land preparation, pasture growth and drinking water across the study area due to the late onset date, early cessation date and decreasing in LGS. Thus, the *belg*(MAM) season was challenging for crop production and to determine its SOS-EOS-LGS during the period (1980-2010) in the study area.

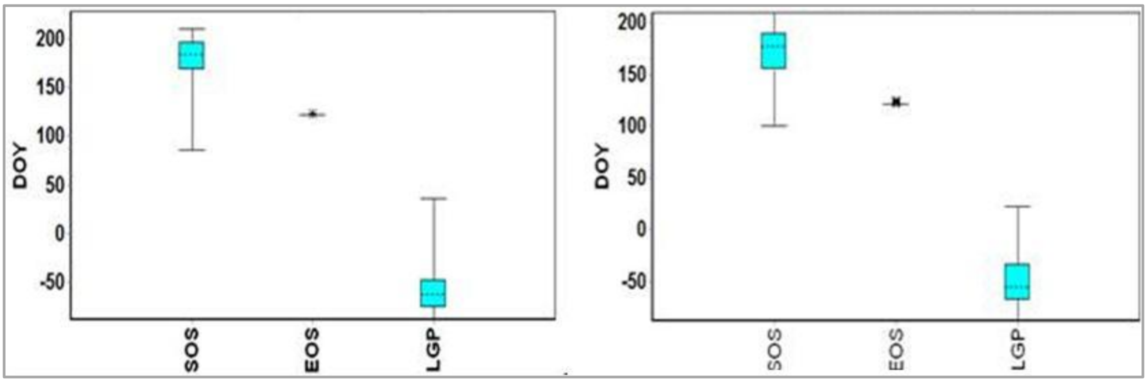

Figure 3. *Box whisker plots of onset date, end date and length of growing period for KiremtSeason at gridded-points (n)/SE and (e)/Central of the study area (1980-2010)*

3.3. Probability of Dry Spell Length

During the main/JJAS season curves of dry spell probability at different lengths converge to their minimum during months of peak rainfall periods from 201DOY-241DOY (19July-28Aug) and turn upward again from 241DOY-261DOY (28Aug-17Sep) signaling end of the growing season. This suggests that standing crops after this time will face greater risk of water shortages in the study area. Hence, it is necessary to choose a terminal drought tolerant variety if one wants to plant a crop variety with a maturing length of more than 79 and 87 days in the study area in order to fully utilize the regions' resources. Therefore, choise of a crop variety can be made based on the length of dry spells after successful planting date is established (Belachew 2002).

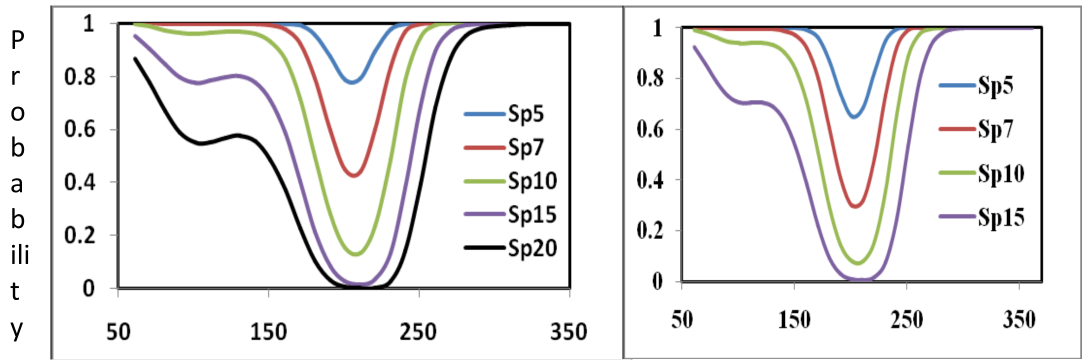

Figure 4. *Probability of occurrence of dry spell length at gridded-points (e)/Centraland (n)/SEOf the study area (1980-2010)*

3.4. Seasonal and annual minimum and maximum temperature variability and trend

The ONDJ seasonal minimum temperature was extended from 3.1^{0}C to 14.4^{0}C, with standard deviation of 1.0-1.6mm and coefficient of variation 8.7%-17%(Table 2).Observed seasonal and annual minimum temperature in the study area showed increasing trend (Figure 5) about 0.38 ^{0}C and 0.42^{0}C every ten years. Similar result was reported by (NMA, 2007).

Table 2. *Descriptive statistics of average monthly and seasonal minimum temperature characteristics for the study area (1984-2010)*

Descriptive statistics	Oct	Nov	Dec	Jan	ONDJ
Maximum	14.4	12.0	12.4	11.5	12.3
Miimum	9.8	5.4	3.1	4.0	7.4
Mean	11.5	10.1	9.4	9.7	10.2
STDV	1.0	1.4	1.6	1.4	1.0
CV	8.7	13.9	17.0	14.0	9.8

CV= Coefficient Variation, ONDJ= October-November-December-January

District average ONDJ seasonal minimum temperature standardized (1984-2010)

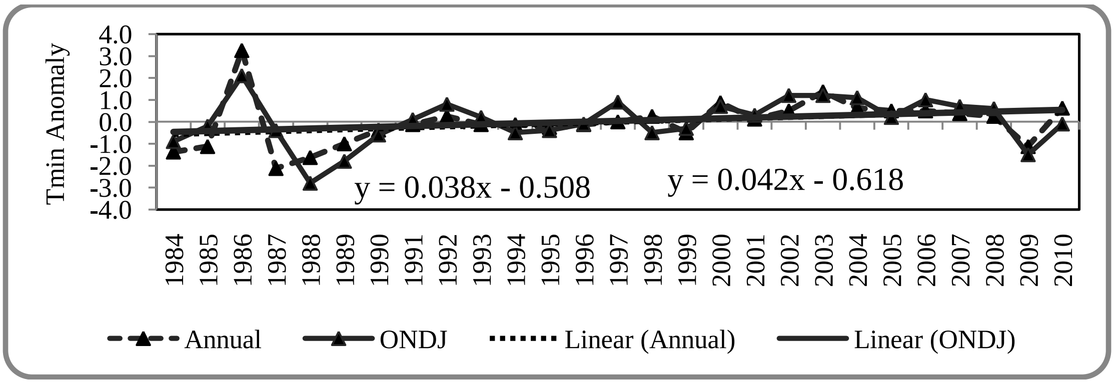

Figure 5. *Year to year ONDJ seasonal minimum temperature variability (1984-2010)*

On the other hand, the highest maximum temperature in the study area is during the MAM season. The dry seasonal MAM maximum temperature in the study area (Table 3) extends from 25.3 ^{0}C to 30.6 ^{0}C with standard deviation and coefficient variation from 1.2mm-1.3mmand 4.3%-4.9mm respectively. Observed seasonal and annual maximum temperature at the study area(Figure 6) showed an increasing trend about 0.62 ^{0}C and 0.59^{0}C every ten years. Similar result was reported by (NMA, 2007). The variability of maximum temperature during the seasonal MAM was less compared to the variability of ONDJ minimum temperature. Increasing in temperature stress in the study area during crop growing season affects crop production in many aspects. Van Emden (1988) reported yield losses by individual pests, diseases or weeds range from 5-10 % in temperate regions and 50%-100 % in tropical regions like Ethiopia.

Table 3. *Descriptive statistics of monthly and seasonal maximum temperature characteristics for the study area (1984-2010)*

Descriptive statistics	March	April	May	MAM
Maximum	29.1	29.1	30.6	28.7
Miimum	24.0	23.7	25.3	24.5
Mean	26.1	26.7	27.8	26.8
STDV	1.2	1.3	1.2	1.0
CV	4.9	4.9	4.3	3.7

CV= Coefficient Variation, MAM= March-April-May

District average MAM seasonal maximum temperature standardized from (1984-2010)

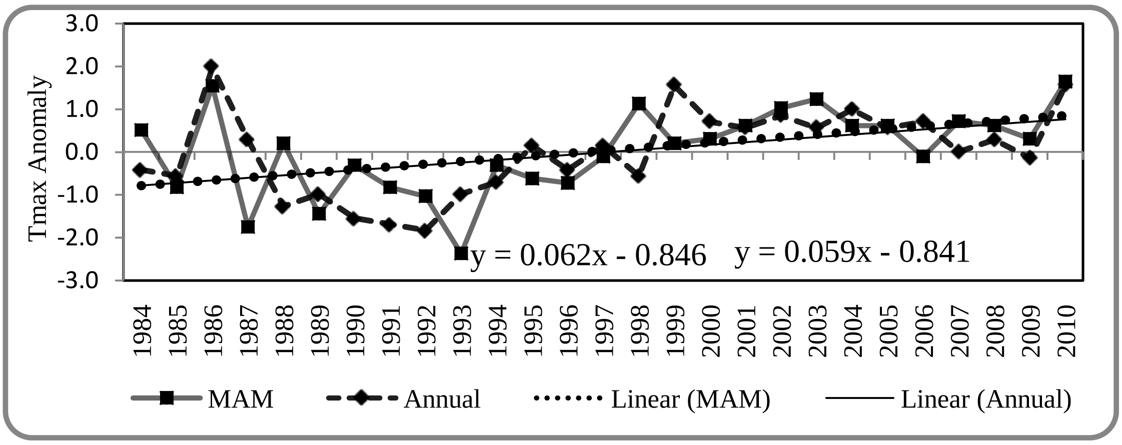

Figure 6. *Year to year MAM seasonal maximum temperature variability for the study area (1984-2010)*

3.5. Effect of Rainfall and Temperature Variability on Crop Production

Spatial rainfall distribution and amount is the most important determinant of inter-annual rain fall fluctuations and intra-seasonal rainfall indices that in turn results in fluctuations of rain fedcrop production in Ethiopia (Araya and Stroosnijder, 2011; Conway and Schipper, 2011). Because of late start and the early end date of growing seasons, most of the rain fed crops cultivated in the study area was most likely to be exposed to moisture stress. Earlier studies by Segele and Lamb (2005) and Araya and Stroosnijder (2011) also indicated that dry spells of about 10 days length is one of the major causes of crop failure in rain fed farming systems of Ethiopia. Temperature could also lead to an increase in evapotranspiration loss and other risky causes have to be also considered (Zeray*et al.*, 2007; Conway and Schipper, 2011). Changing pattern of rainfall and temperature, there can be opportunities to change the patterns of cropping to mitigate risks of crop failure due to little or excessive rainfall and temperature. Therefore, the seasonal (JJAS) rainfall and temperature variability (Figure 7) revealed that wheat and barley production were associated with the long rains and temperature.

In most cases, it was the sequential rain failures of long rainy /JJAS season.

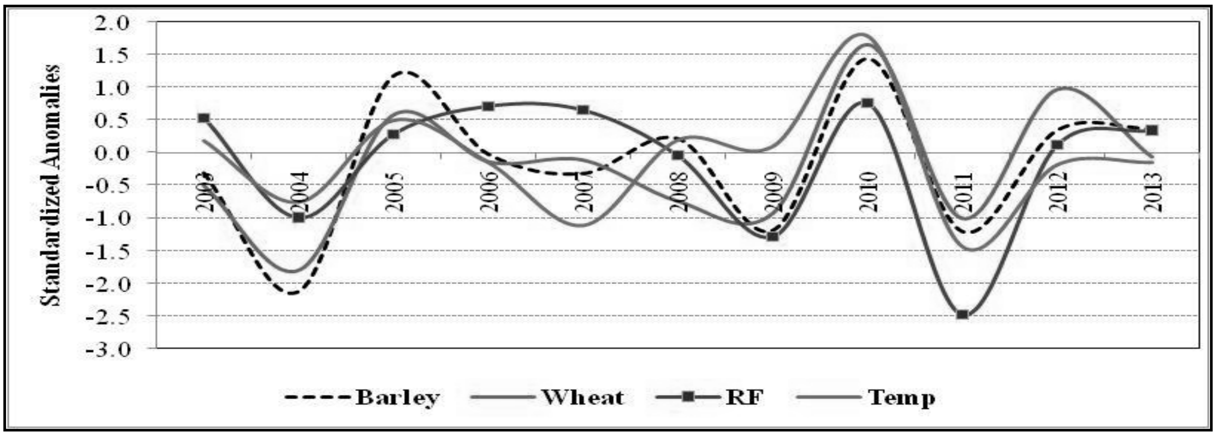

Figure 7. *Standardized seasonal JJAS rainfall and temperature anomaly versus barley and wheat production in the study area (2003-2013)*

The correlation analysis of impacts of temperature and rainfall on crops revealed barley with long rainy (JJAS) season (r=0.7021, $P < 0.05$) and wheat (r =0.6265, $P < 0.05$) were positively correlated with statistically significant effect. On the other hand, barley and wheat had positive relationship with temperature (r = 0.7136 and 0.6550, $p < 0.05$), respectively (Table 7). The JJAS rainfall and temperature had positively correlated with the seasonal changes in barley and wheat crops indicate that the performance of both barley and wheat in the study area mainly depends on the long rainy season.

Table 4. *Time series multivariate cross correlation matrix*

Variables	Barley	Wheat	JJAS	Temp
Barley	1.0000	0.8966	0.7021	0.7136
Wheat		1.0000	0.6265	0.6550
JJAS			1.0000	0.5355
Temp				1.0000

Correlation is significant at the 0.05 level (1 tailed), level (1-tailed), JJAS: long rain (June-September) season and mean temperature

4. CONCLUSION

Except rainfall end date all rainfall variability indices analyzed showed high temporal variability. Both average maximum and minimum temperatures also showed an increasing trend seasonally and annually. Therefore, wheat and barley producing farmers at Enderta district should use seasonal climate outlook for adjusting their farm operations and farming system decisions to avert the risk of rainfall and temperature variability.

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