Characterization Of Future Climate Variability In Oromia Special Zone, North Eastern Ethiopia

Yimer Mohammed[1*],Gashaw Bimrew[2] & Lisanwork Nigatu[3]

1. National Meteorology Agency of Ethiopia, East Amhara Meteorolgy Service Center, Kombolcha, Ethiopia, P.O. Box 94, e-mail: myimer10@yahoo.com or yimerm67@gmail.com
2. College of Agriculture and Environmental Sciences, BahrDar University, BahrDar, Ethiopia, e-mail :gashbimrew@gmail.com.
3. School of Natural Resource Mang & Environmental Sciences ,Haramaya University. P.O.Box 138, Dire Dawa, Ethiopia, e-mail: *lisaneworkn@yahoo.com; or lisaneworkn@gmail.com*

* Corrospondant Autour ;- Yimer Mohammed Adem, National Meteorology Agency of Ethiopia, East Amhara Meteorolgy Service Center, Kombolcha, Ethiopia, P.O. Box 94.

Abstract

This study was undertaken in Oromia special zone of nort eastern Ethiopia to analyze future climate variability. Downscale future rainfall and temperature data from ensemble of three GCMs by RCP4.5 emission scenario using a web based software tool (Marksim GCM). Standard statistical descriptors and statistical software like Instat V3.37, MAKESENS, XLSTAT 2014 and Arc GIS 10.1 were employed for the analysis data. The results indicated that the study area experienced moderate rainfall variability in Kiremt season and very high variability in Belg season . The trend test used to evaluate change showed increasing trend in Kiremt rainfall while decreasing trend in Belg rainfall in the future. However, the trend test is statistically significant in all studied stations during Belg season. The study area will most likely get warmer under the future climate. Future of Kiremt season length of growing period and number of rainy days there will be the likely occurrence of the significant decreasing of both in the future. In general, understanding a local climate variability is used for agricultural planning and reduce the challenges for cropping practices. Therefore, this study revealed that main local future climate variability information. This has been fill the gape of knowledge for specific local future climate information and climate variability and the associated decision responses. District level of upcoming season climate information in terms of climate variability and encourage farmers to benefit from these services, apply adaptation and mitigation strategy are important for reduce the challenges of cropping practices in the study area.

Key words:- Belg, Future, Kiremt, Rainfall, Temperature

1. Introduction

Climate is the major factor controlling the patterns of vegetation structure, productivity, and plant and animal species composition (Gitay *et al*., 2002). Many plants can successfully reproduce and grow only within a specific range of temperature and respond to specific amounts and seasonal patterns of rainfall, and fail to survive if climate changes. Thus, there is now a substantial concern over the global problem of climate change and its current and future impacts.

Agriculture is a challenge to access climate information relevant to agricultural activities to enable the farmers to make prior decision about which crops to plant, where to plant and when to plant will increase the ability of agricultural sector to make informed decision (Zermoglio, 2011).

Studies in Ethiopia have shown that the causes for rainfall variability are erratic nature of rainfall distribution and late onset and early offset contribute to decline in crop yields with reasonable amount in almost all parts of the country (Godswill *et al*., 2007). Similarly Bewket (2009) stated that rainfall variability has historically been found as a major cause of food insecurity in Ethiopia.

Assessing the characteristics of temperature and rainfall for a location is useful for choosing the most appropriate enterprises, and the most productive plant cultivars (Mavi and Tupper, 2004). Case study made in parts of Ethiopia by Stefan and Krishnan (2000) suggested that 50 percent below average rainfall would give a poverty rate of about 60 percent. Other study examined the impact of rainfall variability on the Ethiopia economy, and found that rainfall variability in the country led to a production deficit of 20%, and increase in poverty rates by 25% which costed by the economy over one-third of its growth potential (Hagos *et al*., 2009).

2 Materials and Methodlogy

2.1 Description of the Study Area

The study area covers Oromia Specia Zone (OSZ) found in Eastern Amhara National Regional State (ANRS) in the north eastern Ethiopia. Geographically, it is located between 10^0 00´ N to 11^0 30´ N latitude and 39^0 40´ E to $40^0$20´ E longitude (Figure 1). The study area shares administrative boundary with North Shewa Zone to the southwest , to the northwest by South Wollo Zone and Argobba special woreda, and on the east by the Afar Region. Kemisse is the administrative center of the Zone which is located at 326 km north east of Addis Ababa, the capital city of Ethiopia. Four point weather stations located at four districts of the special zone were selected for the study purpose by availability of past climate data (Fig. 1).

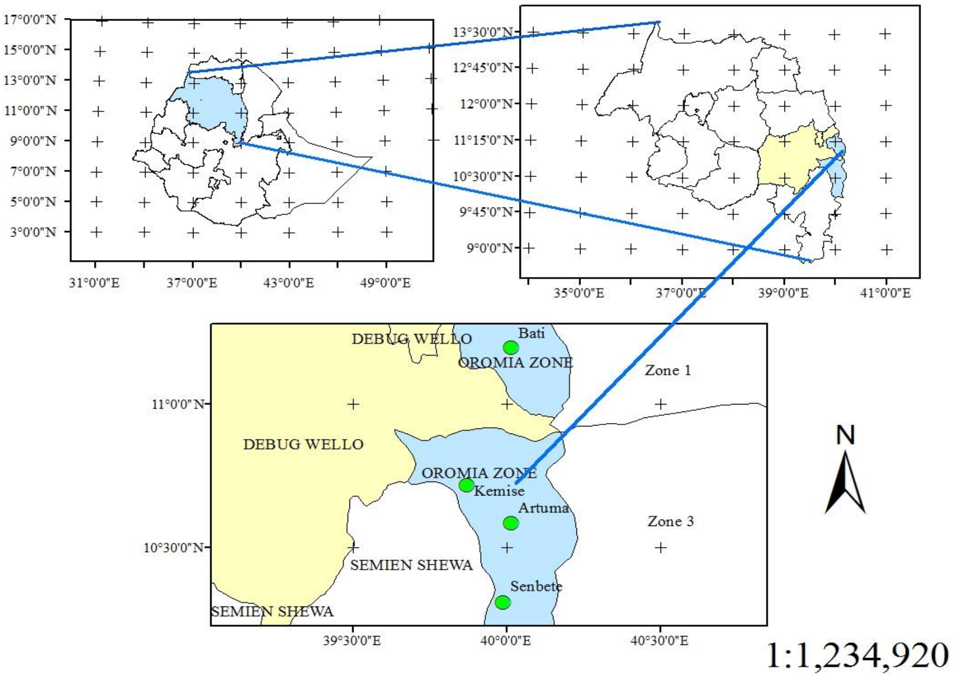

Figure 1. Map of the study area with selected stations

2.2 Projected Rainfall and Temperature Data

The future daily rainfall and temperature data were downloaded from three GCMs, namely; CSIRO-Mk3-6-0, Had GEM2-ES and MIROC-ESM-CHEM under the RCP4.5 (representative concentration pathways) using Marksim tool (Jones and Thornton 2013) for time slot 2021– 2050. Hadgu *et al*. (2014); Fitsum (2015); Muluneh (2015) also used Marksim GCM online tool (http/: WWW.Marksim GCM Weather Generator.Com) to downscale future climate data for the same purpose. As the difference between the four RCPs (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) is insignificant before 2050 (Chaturvedi *et al*., 2012) to predict precipitation and temperature, the medium range emission scenario RCP4.5 were used in this study. RCP 4.5 is a stabilization scenario where total radiative forcing is stabilized before 2100 by employing a range of technologies and strategies for reducing greenhouse gas emissions. The GCM models were selected based on Interaction of Atmosphere-Ocean- Earth, also takes advantage of specific Coupled Model Inter-comparison Project Phase5 (CMIP5) regional assessments documented in the existing literature and due to its better estimation of areal rainfall and temperature compared to the gridded data (2010-2015) on annual and seasonal basis, in addition to seasonal contribution to the annual total by plotting values on bar graphs for visual inspection of the data.

According to Yang *et al.* (2014), out of 43 models of the Coupled Model Inter-comparison Project Phase5 (CMIP5) CSIRO MK 3.6.0 was the only model that captures both the East African precipitation climatology and the East African long rains-SST relationship in the observation. The Had GEM2-ES has also good representation of the African monsoon and a good record for Africa

(Xue *et al*., 2010). According to McSweeney *et al*.(2014), the MIROC-ESMCHEM models were found to perform poorly in Europe and Southeast Asia. However, no such performance issues were found in Africa, and exclusion of those models based on performance in other regions of the world lead to exclude the projections of largest JJA rainfall increase in Africa from the subset. Hence, I included this model in the present study

2.3 Data Analysis

2.3.1 Variability analysis using statistical parameters

Various methods of data analys were employed in the study. Analysis of the rainfall and temperature data involved characterizing long-term mean values, and calculation of indices of variability, and trends at seasonal time scales.

Coefficient of variation, standard deviation, and mean were used to analyze the variation in rainfall characteristics and temperature. Scientifically, using the following formula.

$$CV = \frac{SD}{\overline{X}} * 100 \qquad \text{(EQ 1)}$$

Where, CV is coefficient of variation, SD is the standard deviation and $\bar{x}$ is mean of observed data.

According to Hare (1983), CV (%) values are classified as follows: < 20% as less variable, 20- 30% as moderately variable, and > 30% as highly variable.

Standard deviation was calculated from the observed data, mean and number of the observations as follows:

$$SD = \sqrt{\frac{\sum_{i=1}^{n}\left(x - \overline{x}\right)^2}{n}} \qquad \text{(EQ 2)}$$

Where, SD is the standard deviation, x is an observed value, $\bar{x}$ is mean of observation data and n is number of observations (years). Using the classification of Reddy (1990), the stability of rainfall is examined as follows: when standard deviation <10 as very high stabilities, 10-20 as high stability, and 20-40 as moderate stability and >40 as less stability. In addition standard statistical tool and software like instat V3.37, XLSTAT 2014 and Microsoft Excel 2016 were used for the purpose of anyalysis.

2.3.2 Seasonal Rainfall Anomaly

As described by Agnew and Chappel (1999) the standardized rainfall anomaly (Zij) were used to characterize the annual and seasonal drought frequency and intensity, and inter seasonal fluctuations of rainfall.

$$Z_{ij} = \frac{x - \bar{x}}{SD} \qquad \text{(EQ 3)}$$

Where, Z_{ij} is normalized rainfall total for station i during a year (or season) j; x is an observed seasonal rainfall value, $\bar{x}$ is mean and SD is the standard deviation. This statistic enables us to

determine the dry (-ve values) and wet (+ve values) years in the records. The drought severity classes are extreme drought ($Z_{ij} < -1.65$), severe drought ($-1.28 > Z_{ij} > -1.65$), moderate drought ($-0.84 > Z_{ij} > -1.28$), and no drought ($Zij > -0.84$) (Agnew and Chappel, 1999).

2.3.3 Trend Analyses

In this study, non-parametric Mann-Kendall's trend test were used for the assessment of future climate trend at seasonal time scales. Mann-Kendall's trend test which is less sensitive to outliers and test for a trend in a time series without specifying whether the trend is linear or non-linear (Hadgu *et al*.,2013; Muluneh, 2015; Tsegaye *et al*., 2015).

The Mann-Kendall's test statistic was given as:

$$S = \sum_{i=1}^{N-1} \sum_{J=i+1}^{N} Sgn(X_j - X_i) \qquad \text{(EQ 4)}$$

Where, S was the Mann-Kendal's test statistics; X_i and X_j were the sequential data values of the time series in the years i and j (j>i) and N was the length of the time series. A positive S value indicates an increasing trend and a negative value indicates a decreasing trend in the data series.

The sign function was computed as:

$$Sgn(X_J - X_i) = \begin{Bmatrix} +1 if (X_j - X_i) > 0 \\ 0 if (X_j - X_i) = 0 \\ -1 if (X_j - X_i < 0 \end{Bmatrix} \qquad \text{(EQ 5)}$$

The variance of S, for the situation where there may be ties (that is, equal values) in the x values is given by:

$$Var(S) = \frac{1}{18}\left[N(N-1)(2N+5) - \sum_{i=1}^{m} t_i (t_i - 1)(2t_i + 5) \right] \qquad \text{(EQ 6)}$$

Where, m was the number of tied groups in the data set and t_i was the number of data points in the i_{th} tied group. For N larger than 10, Z_{MK} approximates the standard normal distribution (Yenigun *et al.*, 2008) and computed as follows:

$$Z_{MK} = \left\{ \begin{array}{l} \frac{S-1}{\sqrt{Var(S)}} \quad if S > 0 \\ 0 \quad if S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} \quad if S < 0 \end{array} \right\} \qquad \text{(EQ 7)}$$

The presence of a statistically significant trend was evaluated using the Z_{MK} value. In a two-sided test for trend, the null hypothesis Ho was accepted if $|Z_{MK}| < Z_{1-\alpha/2}$ at a given level of significance. $Z_{1-\alpha/2}$ was the critical value of Z_{MK} from the standard normal table. For example: for 5% significance level, the value of $\mathbf{Z_{1-\alpha/2}}$ is 1.96. A positive value of Z_{MK} indicates an increasing trend while a negative value indicates a decreasing trend. In the present study, the significance of the observed change was examined at $p \leq 0.05$ significance level. The Mann-Kendall's trend test done by using Excel template MAKESENS (**M**ann-**K**endall test for trend and **Sen's** slope estimates) 1.0.

2.4 Determination of Rainfall Characteristics

2.4.1 The Start and End of the Growing Season

In setting an onset date of the past records, many different criteria could be use for different crops exhibiting different maturity plus drought tolerance levels and soil types. Here, the one with 20 mm of total rainfall received over three consecutive days that were not followed by greater than 10 days of dry spell length within 30 days from planting was adopted (Raman, 1974). These criteria was used also by Mamo (2005), and Fitsum (2015) for determining the start of rainy seasons.

On the other hand, the end of growing season is mainly dictated by the water stored in soil and its availability to the crop after the rain stops. The growing periods for most crops continue beyond the rainy season and crops often mature on soil moisture reserves. Soil moisture must, therefore, be considered for determining LGP. However, data on soil moisture is not easily available in Ethiopia. Hence based on an experimental evidence from Africa (FAO, 1978), a figure of 100 mm of soil water is added during the rainy season, to determine the end of the growing period. Additionally, according to Israelson and Hansen (1967), the water holding capacity of sandy soil is 70 to 100 mm/m and sandy loam is 90-150 mm/m. As result, in this study 100 mm/meter of the plant available soil water and site specific daily reference evapotranspiration (ETo) values were considered, and the end of the growing season was taken defined as any day after 1st of September for *Kiremt* seasons when the soil water balance reaches zero (Stern *and Coa*., 1982). The same method was used by several authors to determine end date of growing season (Mamo, 2005; Mesay, 2006; Taye *et al*., 2013; Muluneh, 2015).

Based on projected daily rainfall data to determining the end date, set an estimated evapotranspiration showed in table 1 and 100 mm/m of the plant available soil water were considered. For the present study, Hargreaves and Samani (HS) method was applied to estimate ETo based on projected daily temperature data after calibration and validation of HS model against of FAO Penman Monteith cropwat 8.0 calibrated by Bati station. Estimat ETo at Bati, Kemisse, Artuma and take an average value for Senbete district.

Table 1. Estimated daily mean *Kiremt* and *Belg* season ETo in mm/day after calibration

Seasons/ Stations	Bati	Kemisse	Artuma	Senbete
Period	2021-2050			
Kiremt	4.67	4.63	4.43	4.53
Belg	4.19	4.41	4.24	4.47

The onset and cessation of rainfall date are analyzed using an Instat version 3.37 package developed by the Statistical Services Centre of the University of Reading (Stern *et al*., 2006).

2.4.2 Length of Growing Period

Length of *Kiremt* growing season (LGP) were determined as the difference between the end and start of rainy seasons. Mamo (2005), Mesay (2006), Hadgu *et al*. (2013) and Hadgu *et al*. (2014) used the same method to determined LGP.

2.4.3 Rainfall Totals and Number of Rainy Days

In the context of Ethiopia, Segele and Lamb (2005) employed three rainfall thresholds to define a rainy day (0.1mm, 0.5mm and 1mm) but a threshold value of 1mm were used to define days as wet or dry; because < 1mm of rainfall value almost has no effect on growth of crops (Robel *et al*., 2013). Thus, in present study, number of rainy days were determined by counting all days with rainfall greater or equal to1.0 mm as outlined by (NMSA, 2001). Seasonal (for *Kiremt* June to September and for *Belg* February to end of May) rainfall totals were determined as sum of rainfall of each day with greater or equal to 1 mm. Different researchers used the same methods (Segele and Lamb, 2005; Mesay, 2006; Hadgu *et al*., 2013; Muluneh, 2015).

2.4.4 Probability of Dry Spell

The dry spell probabilities were determined as consecutive number of days with rainfall less than 1 mm per day exceeding 5, 7, 10 and 15 consecutive days. Dry spell length was analyzed by first order Markov Chain analysis (Stern *et al*., 2006; Stern and Cooper, 2011) using INSTAT v3.37 software.

3 Result and Discussions

3.1 Rainfall Variability (2021-2050)

***Kiremt* rainfall variability** The future *Kiremt* rainfall totals is expected to vary from the minimum of 556.9 mm at Bati to the maximum of 704.3 mm at Senbete with projected mean rainfall of 582.3 mm and 687.2 mm, respectively (Table 2). Likewise, Muluneh (2015) found that, by CSIRO model the predicted future rainfall will vary from 365.9 mm at Kobo to 752.4 mm at Lalibela with the projected mean of 379.4 mm and 719.5 mm, respectively. The same author used, MIROC model and found that, the future *Kiremt* rainfall totals will vary from 289.4 mm at Kobo to 750.9 mm at Kombolcha with mean 343.6 mm and 711.2 mm for the year 2021-2040, respectively.The coefficient of variability value of *Kiremt* rainfall totals over the Special Zone will have less variations. Whereas, the SD of the *Kiremt* rainfall totals is expected to vary from the minimum of ±2.5 mm at Kemisse to the maximum of ±18.4mm at Bati (Table 2).

Table 2. Future seasonal rainfall variability at OSZ, during 2021-2050.

Seasons	District	Descriptive statistics				
		Min (mm)	Max (mm)	Mean (mm)	SD (mm)	CV %
Kiremt	Bati	556.9	619.5	582.3	18.4	3.2
	Kemisse	615.5	623.3	618.8	2.5	0.4
	Artuma	643.8	658.2	651.3	4.4	0.7
	Senbete	665.3	704.3	687.2	10.8	1.6
Belg	Bati	203.9	218.7	211.2	4.3	2.1
	Kemisse	185.8	228.7	201.9	14.9	7.4
	Artuma	187.4	240.0	200.7	17.2	8.6
	Senbete	301.5	410.3	334.7	40.7	12.2

***Belg* rainfall variability** *Belg* rainfall amount (< 335 mm) consistently low of all stations. The area will be receiving areal mean rainfall of 237 mm with maximum 334.7mm at Senbete and minimum 200.7 mm at Artuma with SD range from ± 4.3 to ±40.7 mm and CV of 2.1% at Bati to 12.2% at Senbete (Table 2). The variability increases from north to the south part of the Special Zone. Similar to this Muluneh, (2015) also found that MIROC model projected the future Belg rainfall with minimum of 186.9 mm at Kombolcha and maximum of 308.4 mm at Srinka with respective mean of 197.1 mm and 260.9 mm and by CSIRO model prediction variared from 109. 6 mm to 226.7 mm at Lalibela, with mean of 171.1 mm for the year 2021-2040.

3.2 Rainfall Trend (2021-2050)

Future *Kiremt* season rainfall trend the trend of *Kiremt* season rainfall amount (Table 3), showed in that Bati, Kemisse and Artuma will have an increasing trend, but decreasing at Senbete in which the change was significant only at Bati. The future *Kiremt* rainfall is likely to increase by 2.00

mm/year at Bati and 0.27 mm/year at Artuma but expected to decrease by 0.40 mm/year at Senbete during 2021-2050. Likewise, Muluneh (2015) reported based on CSIRO model data output for *Kiremt* season rainfall revealed significantly increasing trend over Lalibala and Srinka and decreasing trend at Kombolcha and Had GEM2-ES model data outputs showed also increasing trends at Kombolcha, Kobo and Srinka and decreasing at Lalibala by 2030s. Similarly, Hadgu *et al*. (2014) also reported that an increasing trend in future seasonal *Kiremt* rainfall in the northern Ethiopia by 2030s and NMA (2007) reported that the future *Kiremt* season may experience increment in rainfall amount at different places in Ethiopia by 2030s and 2050s.

Future *Belg* season rainfall trend Unlike trend of *Kiremt* rainfall, the future *Belg* rainfall is expected to decrease significantly in the Special Zone (Table 3).The future *Belg* rainfall is anticipated to decrease by 0.60 mm/year at Bati, 0.50 mm/year at Kemisse, 0.30 mm/year at Artuma and 0.56 mm/year at Senbete during 2021 -2050. The decline of future *Belg* rainfall reported by Muluneh (2015), Hadgu *et al*. (2014), and Kassie *et al*. (2014).

Table 3. Future trends of seasonal rainfall at OSZ, during 2021–2050.

Stations	*Kiremt*		*Belg*	
	Z_{MK}	Slop	Z_{MK}	Slop
Bati	5.78^{a}	2.00	-4.64^{a}	-0.60
Kemisse	0.18^{ns}	0.01	-2.28^{c}	-0.50
Artuma	0.57^{ns}	0.27	-2.11^{c}	-0.30
Senbete	-0.73^{ns}	-0.40	-2.34^{c}	-0.56

Where, Z_{MK} is Mann–Kendall test statistic, Slope (Sen's slope) is the rate of change mm/year; a is 0.001 level of probibility; b is 0.01 level of probablity; c is 0.05 level probability and ns is non-significant at 0.05 probability level.

3.3 Rainfall Characterization

3.3.1 Star and End of Seasons

***Kiremt* Start and End of Seasons**:-The future start and end date of *Kiremt* season under as predicted by ensemble of three GCMs (CSIRO Mk 3.6.0, Had GEM2-ES and MIROC ESM CHEM) showed in Table 4. The projected statrt of season (SOS) of future *Kiremt* growing season will vary from the earliest 175 DOY (Jun-25) at Bati to the late 186 day of year (DOY) (Jul 4) at Artuma in the Special Zone indicates less variability and high stability. Similar to start of seasons, the projected end of season (EOS) of future *Kiremt* growing season using ensemble of three models indicating that it vary from the earliest 260 DOY (Sep 16) at Senbete to the latest 290 DOY (Oct-16) at Artuma stations with very low variability and high stability.

Table 4. Future start and end date of *Kiremt* season at OSZ, during 2021-2050.

Districts	???	Early	Median	Late (DOY)	Mean	SD	CV %

		(DOY)	(DOY)		(DOY)	(DOY)	
Bati	SOS	175(Jun 23)	175(Jun 23)	176(Jun 24)	175(Jun 24)	0.4	0.2
Kemisse		185(Jul 3)	185(Jul 3)	185(Jul 3)	185(Jul 3)	0.0	0.0
Artuma		185(Jul 3)	185(Jul 3)	186(Jul 4)	185(Jul 3)	0.5	0.3
Senbete		177(Jun25)	178(Jun 25)	178(Jun 25)	178(Jun 25)	0.5	0.3
Bati	EOS	267(Sep 23)	267(Sep 23)	268(Sep 24)	267(Sep23)	0.4	0.2
Kemisse		267(Sep 23)	288(Oct 14)	288(Oct 14)	288(Oct 14)	0.4	0.2
Artuma		286(Oct 12)	286(Oct 12)	290(Oct 16)	287(Oct 13)	1.6	0.6
Senbete		260(Sep 16)	261(Sep 17)	261(Sep 17)	261(Sep 17)	0.5	0.2

This result agreed with Muluneh, (2015) who reported that by MIROC model. the SOS of *Kiremt* to vary from the earliest 176 DOY (June-24) to the latest 190 DOY (July-8) and EOS of future *Kiremt* season from the earliest 237 DOY (August-23) at kobo to the latest 262 DOY (September-18) NEA with less variability under the same RCP 4.5 emission scenario. The projected less CV value indicates more dependable patterns of SOS of future *Kiremt* growing season which is more important for decision making regarding tillage, sowing and other agricultural activities in the study area.

***Belg* Start of Season** The future start date of the *Belg* eason under RCP 4.5 as projected by ensemble of three GCMs (CSIRO Mk 3.6.0, Had GEM2-ES and MIROC ESM CHEM) showed in Table 5.

The projected SOS of future *Belg* season will vary from the earliest 108 DOY (Apr-17) at Senbete to the late 117 DOY (Apr- 26) at Kemisse indicating less variability and high stability.

Table 5.Descriptive statistics for future start of *Belg* season at OSZ, during 2021-2050.

Statistic	Bati	Kemisse	Artuma	Senbete
Early (DOY)	114 (Apr-23)	114 (Apr-23)	114 (Apr-23)	108 (Apr-17)
Late (DOY)	115 (Apr-24)	117 (Apr-26)	115 (Apr-24)	109 (Apr-18)
Median (DOY)	114 (Apr-23)	114 (Apr-23)	114 (Apr-23)	108 (Apr-17)
Mean (DOY)	114 (Apr-23)	115 (Apr-24)	114 (Apr-23)	108 (Apr-17)
SD (DOY)	0.40	1.20	0.46	0.40
CV (%)	0.35	1.05	0.40	0.37

3.3.2 Future Length of Growing Period and Number of Rainy Days

The future length of *Kiremt* growing period showed in Table 6, ranges from 83 days at Senbete to 103 days at Kemisse with very high stability and very low variability. The length of growing period sorter from the central to the north and southern part of the Special Zone.

Similar to LGP, the future mean *Kiremt* NRD ranges from 31 days at Senbete to 39 days at Artuma with very high stability and very low variability. The projected mean NRDs are 37, 34, 39, and 31 days at Bati, Kemisse, Artuma and Senbete, respectively.

Table 6. Future length of growing period and number of rainy days in *Kiremt* growing season at OSZ, during 2021-2050.

Statistic	Length of Growing Period				Number of Rainy Days			
	Bati	Kemisse	Artuma	Senbete	Bati	Kemisse	Artuma	Senbete

Short (Days)	92	102	101	83	37	34	39	31
Long (Days)	92	103	104	83	37	34	39	31
Mean (Days)	92	103	102	83	37	34	39	31
SD (Days)	0.0	0.4	1.2	0.0	0.0	0.0	0.0	0.0
CV%	0.0	0.4	1.2	0.0	0.0	0.0	0.0	0.0

3.3.3 Change of Length of Seasons and Number of Rainy Days

Comparing the LGP and NRD with the past 30 base years, the future LGP will decreas by 6.1 %, 4.9%, 4.2% and 27.8% (4–32 days) and NRD by 14.0%, 32.0%, 13.3% and 38.0% at Bati, Kemisse, Artuma and Senbete, respectively (Figure 2). In line with this, Hadgu *et al.* (2014) also reported that, the LGP will be decreasing by 14–26 days at Alamata and Mekele and 3-9 days at Adigrat and Adwa in the 2050 under the A2 and B1emission scenariosat in northern Ethiopia.Tadross *et al.* (2009) and Sarr (2012) presented spatially consistent reduction of LGP (by up to 20 %) by 2050 in West African countries due to a shift in the onset date of rainfall. Maitima *et al.* (2009) concluded that the combined effect of climatic change on temperature and rainfall would reduce LGP in most sub-Saharan countries. Muluneh (2015) also reported that, the percentage change of NRDs for future *Kiremt* season will have decreasing change with less uncertainty of models prediction, being in the range of 27.3 % at Lalibela to 43.3% at Kobo by 2030s in NEA.

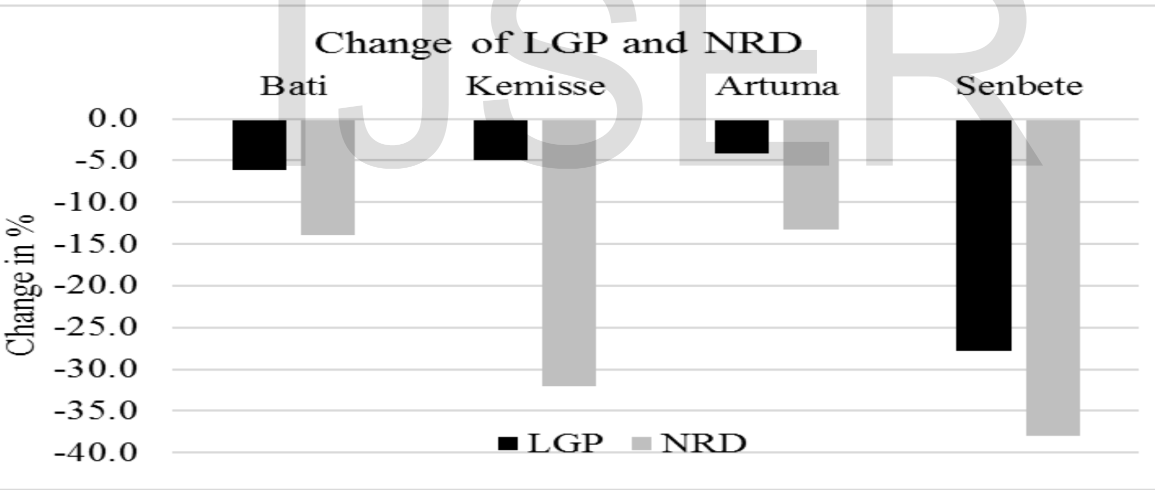

Figure2. Changes in projected length of growing period and number of rainy days in the OSZ over the base period (1986–2015).

3.4 Temperature Variability and Trend

3.4.1 Future Temperature Trend

***Kiremt* and *Belg* temperature trend** The mean *Kiremt* maximum temperature (Tmax) is expected increase by 0.031–0.048 °C/year, and the mean *Kiremt* minimum temperature (Tmin) may increase by 0.039–0.046 °C/year. Similarly,the mean *Belg* maximum temperature (Tmax) will increase by 0.041–0.042 °C/year and the mean *Belg* minimum temperature (Tmin) may increase by a range of 0.039–0.048 °C/year for the period 2021 to 2050 (Table 7).

Table 7. Future trend of seasonal maximum and minimum temperature at OSZ, during 2021–2050

Season	Station	Maximum Temperature			Minimum Temperature		
		Mean	Z_{MK}	Slopes	Mean	Z_{MK}	Slopes
Kiremt	Bati	31.6	6.39	0.031	15.7	6.07	0.039
	Kemisse	32.8	7.74	0.038	18.7	7.74	0.040
	Artuma	31.3	7.73	0.037	17.6	7.73	0.039
	Senbete	32.7	7.74	0.042	19.2	7.74	0.046
Belg	Bati	29.8	7.67	0.041	15.9	6.67	0.039
	Kemisse	31.8	7.71	0.042	17.9	7.74	0.043
	Artuma	30.4	7.62	0.041	16.7	7.73	0.041
	Senbete	31.9	7.71	0.041	17.6	7.71	0.048

Where, ZMK is Mann–Kendall test statistic, Slope (Sen's slope) is the rate change Degree Celsius per year.

4.1.1 Future Temperature Change Relates to the Past

Relative to the base period daily predicted data by (ensembled of three GCM) showed that Tmax could rise by up to 0.72 ℃,1.10 ℃ and 1.14 ℃, in *Kiremt* and *Belg* seasons, respectively (Table 8).

At the same time, Tmin could be rise by 0.64 ^{0}C ,1.21 ^{0}C and 1.24 ^{0}C , in *Kiremt* and *Belg* seasons, respectively by 2050. In line with this, Ayalew *et al* (2012) reported that, both the Tmax and Tmin will increase in mean Tmax and Tmin ranges 1.55 ^{0}C - 6.07 ^{0}C and 0.11 ^{0}C - 2.81^{0}C , respectively in the 2080s compared to the base period 1979- 2008 in northwestern Ethiopia. Hadgu *et al.*, (2014) also reports that mean annual Tmax will increase by 0.8–5.6 °C, and the mean annual Tmin by 0.8–4.0 °C in 2050 over the baseline period 1980–2009 in north Ethiopia. Other similar studies, (NMA 2007; Zeray *et al.* 2007; Yimer *et al.* 2009; Conway and Schipper 2011; Setegn *et al.* 20 11; Ayalew *et al.* 2012) this result agreed with other also indicated future warming of the air in the different parts of Ethiopia . A comparison of areal mean temperature changes over two seasons indicated that the increase in mean temperature in the 2050 will be higher during the small rainy season (Belg) than in the main rainy season (Kiremt) (Table 8).

Table 8. Seasonal mean maximum and minimum temperature changes at OSZ over the baseline period (1986-2015)

Districts	Maximum Temperature		Minimum Temperature	
	Kiremt	Belg	Kiremt	Belg
Bati	1.21	1.31	0.46	0.54
Kamisse	-0.25	0.03	0.94	0.60
Artuma	2.07	1.42	2.59	2.30
Senbete	1.36	1.81	0.85	1.51
Areal mean	1.10	1.14	1.21	1.24

5 Conclusions

This study was undertaken to analyze the characteristics of future GCM module climate data and climate characteristics OSZ of ANRS. Analysis of climate characteristics for 2021-2050 for future ensembled of three GCM model daily data under 4.5 RCP.

The Special Zone will be receiv projected *Kiremt* season mean rainfall ranged from 582.3 mm to 687.2 mm and the contribution of *Belg* season from 200.7 to 334.7 mm, respectively. Regarding temperature analyses, the projected temperature showed that the study region will get warmer under the future climate than the base period.

The projected SOS of future *Belg* season will vary from the earliest 108 DOY (Apr-17) at Senbete to the late 117 DOY (Apr- 26) at Kemisse. In the *Kiremt* SOS will vary from the earliest 175 DOY (Jun-25) at Bati to the late 186 DOY (Jul 4) at Kemisse and Artuma, respectivly. Projected less CV value indicates more dependable patterns of SOS of future growing season which is more important for decision making regarding tillage, sowing and other agricultural activities in the study area. Comparing the LGP and NRD with the past 30 base years, the future LGP will decreasing by 6.1 %, 4.9%, 4.2% and 27.8% (4–32 days) and NRD also will be decreasing 14.0%, 32.0%, 13.3% and 38.0% at Bati, Kemisse, Artuma and Senbete, respectively.

This information is very important to the farmers to decide on crop types to be cultivated and on planning sowing dates as a function of observed from the onset dates. Also used decision making with respect to selecting dry spell resistance crop and field operations within the farming system.

It used for to mitigat the adverse effects of recurring drought and to reduce challenges for cropping practices. Users can get a clear indication of future local climate variability and its implication on sorghum and teff yield for further insight to crop risk planning and management strategy.

6 Reference

Agnew, C.T. and A. Chappel. 1999. Drought in the sahel. GeoJournal 48: 299-311. agrometeorological indices. *Journal of Agro Meteorology (I): 111 – 114.*

Ayalew Dereje, Kindie Tesfaye, Girma Mamo, Birru Yitaferu and Wondimu Bayu, 2012. Outlook of future climate in northwestern Ethiopia. *Agricultural Sciences 3(4):608-624.*

Bewket Weldeamlak. 2009. Rainfall variability and crop production in Ethiopia; Case study in the Amhara region; *proceeding of the 16th International Conference of Ethiopian Studies*, Addis Ababa, Ethiopia.

Chaturvedi, R.K., Joshi, J., Jayaraman, M. and G. Bala, N.H.R. 2012. Multi-model climate change projections for India under representative concentration path ways. *Current Science, Vol.*

Conway, D. and Schipper, E.L.F. 2011. Adaptation to climate change in Africa: challenges and opportunities identified from Ethiopia. *Global Environment Change, 21:227–237.*

FAO (Food and Agricultural Organization). 1978. Report on the Agro-Ecological zone project vol.1 Methodology and Result of Africa. Rome.

Fitsum Bekele. 2015. Characterizing current and future rainfall variability and its effect on wheat and barley production in Sinana District. MSc. Thesis, Haramaya University, Haramay, Ethiopia.

Gitay,H., Suarez, A., Watson, R.T. and Dokken, D.J. (2002) Climate change and biodiversity. IPCC (Inter- governmental Panel on Climate Change) technical paper V, 86. http://www.ipcc.ch

Godswill, M., Dawit, K. and Dejene, A. 2007. A comparative analysis of rain fed and irrigated agricultural production in Ethiopia. *Journal of Irrigation and Drainage. Vol 21 No 1. Springer Netherland.*

Hadgu Gebre, Tesfaye Kindie and Mamo Girma. 2014. Analysis of climate change in Northern Ethiopia: implications for agricultural production. *Theoretical and Applied Climatology ISSN 0177798X.Vol.117: P 3-17.*

Hadgu Gebre, Tesfaye Kindie, Mamo Girma and Kassa Belay. 2013. Trend and variability of rainfall in Tigray, Northern Ethiopia: Analysis of meteorological data and farmers' perception. *Academically Journal Environmental Science, 1(8): 159-171.*

Hagos, F., Makombe, G., Namara, R.E. and Awulachew, S.B. 2009. Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation. Colombo, Sri Lanka: *Int. Water Manage. Inst. p.37.*

Hansen and Isrealson. 1967. Irrigation Principles and Practices.

Hare, F.K. 1983. Climate and desertification. Revised analysis (WMO-UNDP) WCP-44: 5-20. Geneva, Switzerland.

Jones, P. G .and Thornton, P.K. 2013. Generating downscaled weather data from a suite of climate models for agricultural modeling applications. *AgricSyst, 114:1–5*

Kassie, B. T., Rotter, R. P., Hengsdijk, H., Asseng, S., Vanittersum, M.K., Kahiluoto, H. and Van Keulen, H. 2014. Climate variability and change in the central Rift Valley of Ethiopia:

Maitima, J.M., Kariuki, P.C., Mugatha, S.M. and Mariene, L.W. 2009. Adapting East African ecosystems and productive systems to climate change: an ecosystems approach towards costing of climate change adaptations in East Africa. Report for the economics of climate change adaptations in Africa. Pp 68.

Mamo Girma. 2005. Using seasonal climate outlook to advice on sorghum production in the central Rift Valley of Ethiopia. Doctoral Dissertation in Agro-meteorology. University of the Free State, Bloemfontein, South Africa.171 p.

Mavi, H.S. and Tupper, G.J. 2004. Agro meteorology: principles and applications of climate studies in agriculture. *Food Products Press®, an imprint of the Haworth Press, Inc., 13: 904-1580.*

McSweeney C. F., Jones· R. G., Lee R. W and Rowell D. P. 2014. Selecting CMIP5 GCMs for downscaling over multiple regions. *Clim Dyn 44:3237–3260.DOI 10.1007/s00382-014-2418-8*

Mesay Abebe. 2006. The onset, cessation and dry spells of the small Rainy Season (*Belg*) of Ethiopia. National Meteorological Agency of Ethiopia, Addis Ababa. 10-13P.

Muluneh Getahune. 2015. Analysis of past and future intra-seasonal rainfall variability and its implications for crop production in the North Eastern Amhara Region, MSc. Thesis Haramaya University, Haramaya, Ethiopia.

NMA (National Meteorology Agency). 2007. Climate change national adaptation programme of action (NAPA) of Ethiopia: technical report, National Meteorological Agency, Addis Abeba, pp. 85

NMSA (National Meteorology Service Agency). 2001. Initial national communication of Ethiopia to the united nations framework convention on climate change (UNFCCC), Addis Ababa, Ethiopia, pp. 113.

Raman, C.V.R. (1974). Analyses of commencement of Monsoon rains over Maharashtra State for agricultural planning. Scientific report 216, India Meteorological Department, Poona, India.

Reddy S. J. 1990. Methodology: Agro-climatic Analogue Technique and Applications as relevant to Dry land Agriculture. Agro climatological Series Eth 86/021-WMO/UNDP/NMSA, Addis Ababa, Ethiopia. P60.

Sarr, B. 2012. Present and future climate change in the semi-arid region of West Africa: a crucial input for practical adaptation in agricultural production. *Atmospheric Science of Lett.doi, 10: 1002/asl.368.*

Segele, Z. T. and P. J. Lamb. 2005. Characterization and variability of Kiremt rainy season over Ethiopia. *Meteorology and Atmospheric Physics,89(1): 153–180.*

Setegn, S. G., Rayner, D., Melesse, A. M., Dargahi, B., and Srinivasan, R. 2011. Impact of climate change on the hydroclimatology of Lake Tana Basin, Ethiopia, Water Resource Research., 47, W04511, doi:10.1029/2010WR009248.

Stefan, D. and P. Krishnan. 2000. Vulnerability, seasonality and poverty in Ethiopia. *Journal of development studies, 36(6): 25-53.*

Stern, R., Rijks, D., Dale, I. and Knoch, J. 2006. Instat climatic guide. Statistical services center, Reading University, UK.

Stern, R.D. and Coe, R. 1982. The use of rainfall models in agricultural planning. *Agric. Meteorol., 26: 35-50.*

Stern, R.D. and Cooper, P.J.M. 2011. Assessing climate risk and climate change using rainfall data - a case study from Zambi. *Experimental Agriculture, 47: 241-266.*

Tadross, M., Suarez, P., Lotsch, A., Hachigonta, S., Mdoka, M., Unganai, L., Lucio, F., Kamdonyo, D. and Muchinda, M. 2009. Growing-season rainfall and scenarios of future change in southeast Africa: implications for cultivating maize. *Clim Res 40:147–161. doi:10.3354/cr00821.*

Taye, M., Zewdu, F. and Ayalew, D. 2013. Characterizing the climate system of Western Amhara, Ethiopia: a GIS approach. *American Journal of Research Communication, 1(10): 319-355.*

Tsegaye, G., Guta, W., G.N. Rao, Tesema, A. 2015. The current and future trend of Rainfall and iIts variability in Adami-Tulu Jido-KombolchaWoreda, Central Rift Valley of Ethiopia. *Journal of Environment and Earth Science ISSN, 2224-3216 (Paper) ISSN 2225-0948 (Online) Vol.5, No.22.*

Xue, Y., De Sales, F., Lau, K.M.W, Bonne, A., Feng, J., Dirmeyer, P., Guo, Z., Kim, K.M., Kitoh, A., Kumar, V., Poccard-Leclercq, I., Mahowald, N. and Moufouma-Okia, W. 2010. Inter comparison of West African monsoon and its variability in the West African monsoon modelling Eevaluation Project (WAMME) first model inter comparison experiment. *ClimDyn, 35:3–27. doi:10.1007/s00382-010-0778-2*

Yang, W., Seager, R., and A. Cane, M. 2014. The East African long rains in observations and models. *Journal of Climate, Volume, 27. New York*

Yenigun, K., Gumus, V. and Bulut, H. 2008. Trends in stream flow of the Euphrates basin, Turkey. Proclamation Institute of Civil Engineering Water Management. 161:189–198

Yimer G, Jonoski A, Griensven AV. 2009. Hydrological response of a catchment to climate change in the upper Beles river basin, upper Blue Nile, Ethiopia. *Nile Basin Water Eng Sci Mag 2:49–59*

Zeray, LA., Roehrig J., and Chekol DA. 2007. Climate change impact on Lake Ziway watershed water availability, Ethiopia. *Catchment and Lake Research 18–23*

Zermoglio, M.F. 2011. Climate information to support adaptation dDecisions in Africa. Technical report to international resources group and U.S. Agency for international development.