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Analysis of current rainfall variability and trends over Bale-Zone, South Eastern highland of Ethiopia

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ABSTRACT

This study was mainly designed to explore current rainfall variability and trends in Bale zone for the period 1983-2015. We employed standard deviation, mean, percentage contribution and coefficient of variation for analyzing seasonal and annual rainfall variability. Results of Coefficients of variability demonstrates that kiremt (JJAS) rainfall total has the highest coefficient of variability (32.6-51.2%) compared to belg (FMAM) rainfall total (17-46.7%). The seasonal rainfall contribution to the annual rainfall totals varied largely over the study area mainly due to altitudinal change. In order to detect increasing or decreasing trends and its magnitude in a time series the non-parametric test were employed. We found that there is an observed statistically significant trend at 5 and 10% significance level over most of belg benefiting areas. In addition, annually belg rainfall had decreased with the range of 2.6-4.8mm over Bale zone. The result further indicates that decreasing non-statistical trends of annual rainfall totals were observed over most of the

stations except Dire-Shekhusen and Bidre. Due to annual and inter-annual rainfall variability and decreasing rainfall trends over the study area, it could be suggested that adaptation option should be implemented to offset the impacts related to it.

1. INTRODUCTION

Rainfall is one of the most key climate elements which regulate and determine agricultural activities and production throughout the world (Adams et al., 1998; Adiku and Kuatsinu, 1992; and Adiku *et al,* 2007ab, Mawunya et al., 2011; Magreth Bushesha, 2015; Katunzi et al. 2016; Mesike and Agbonaye, 2016). Therefore, in most African countries particularly in Ethiopia accurate estimation of the spatial and temporal distribution of rainfall including its trend are vital input parameters in order to secure sustainable agricultural activities (Ayalew et al., 2012). According to NMSA (1996), Nicholls and Katzk (1991), most of the time agricultural planning in Ethiopia is difficult during small rainy season due to erratic nature of the rains. Moreover, in relation to ENSO phenomena, significant year to year variation in the performance of the rainy season has favored the agricultural activities of the country mainly due to the eastward moving mid latitude troughs facilitate the interaction between the mid latitude cold air with tropical warm and moist air so that unstable conditions often produce abundant rains during the small rainy season (February to May). Studies in Ethiopia have shown that rainfall variability usually result in reduction of 20% production and 25% raise in poverty rates in Ethiopia (Hagose *et al*., 2009; Osman and Sauerborn, 2002). Rainfall in much of the country is erratic and variable and the associated drought have historically been the major cause of food shortage and famine (Wood, 1997). Economic dependence of agricultural sector in Ethiopia on natural rainfall makes the production projected to be widen variation of yields and spatially and temporary. In line with this, the recorded famine in Ethiopia in 1973 and 1984 mainly due to severe drought (Wolde-Georgis, 1997) and hence caused crop damage and decline of food availability in the country (Degefe and Nega, 1999/2000).

The rainfall is highly variable both in amount and distribution across regions and seasons (Tilahun, 1999; Mersha, 1999). The seasonal and annual rainfall variations are results of the macro-scale pressure systems and moisture flows which are related to the changes in the pressure systems (Haile, 1986; Beltrando and Camberlin, 1993; NMSA, 1996). The spatial variation of the rainfall is, thus, influenced by the changes in the intensity, position, and direction of movement of these rain-producing systems over the country (Taddesse, 2000). Moreover, the spatial distribution of rainfall in Ethiopia is significantly influenced by topography (NMSA, 1996), which also has many abrupt changes in the Rift Valley. However, the detail spatial and temporal variability of rainfall over the horn of Africa in general and Ethiopia in particular is highly complex and not well known yet. This variability of the rainfall and recurrent droughts in the country affects the lives of millions of people whose livelihood is mainly dependent on subsistence agriculture.

According to the National Meteorological Agency, average countrywide annual rainfall trends remained more or less constant between 1951 and 2006. However, both seasonal and annual rainfall has exhibited high variability (NMA, 2007). However, some studies have indicated that rainfalls have been declining over some parts of the country. Considerable declining in March-September rainfall was observed in northeast, southeast, and southwestern portions of Ethiopia after 1997 (Oxfam, 2010). In particular, rainfall amounts have significantly decreased during the *belg*(February-May) season. *Belg*rainfall in the east and southeast exhibited the largest percent reductions. Declines in *belg* rains may impact long cycle crop production with crippling consequences for agricultural production. In much of Ethiopia, similar to the Sahelian countries to its west, rainfall from June to September contributes the majority of the annual total, and is crucial to Ethiopia's water resource and agriculture operations (Korecha and Barnston, 2007).

The Study area Bale Zone is characterized by bimodal rainfall pattern *Kiremt* and *Belg* (Alemayehu and Frazel, 1987, NMSA, 1996). Some studies have been carried out in few districts of Bale Zone which highlighted variability of rainfall and its implication in hindering agricultural activities of the area, additionally the record data on rainfall from1995 to2013 showed that there is a slight increasing trend in annual and seasonal (June-September and February-May) rainfall over Sinana District. Climate related risks such as meteorological drought, water logging, erratic rainfall, and partial and full crop damage, increased crop disease and pests were observed in one of the district which is the main causes for crop failure (Bekele, 2015; Bessie, 2010; Segele and Lamb, 2005). In depth scientific studies on spatial and temporal rainfall variability, distribution, trend detection and the likes is lacking over the study area. Therefore, this study was mainly designed to explore currentrainfall variability and trendover the study area.

Description of the study area

The study area (Fig.1), Bale zone is geographically located between 5.36^0N-8.12^0N and 39.21^0E-42.23^0E in the South Eastern parts of Ethiopia. The region extends over 18 districts. Based on traditional agro-climatic classification which is mainly depends on altitude and mean temperature the study area is classified in to Highland (Dega), Weina Dega (midland) and Quolla (lowland) (MoA, 2000).

The area is characterized by bimodal rainfall pattern *Kiremt (*JJAS*)* and *Belg (*FMAM*)*. The study area is under Indian Ocean influences as southerly fluxes generating rainfall when strong southerly moisture flow and easterly perturbation engulf. This can be also affected by heavy rainfall events coming from northward advancement and southward retreat of ITCZ (Kassahun, 1987; Camberlin, 1997; NMSA, 1996; Korecha and Barnston, 2007). There are two cropping seasons in the region *Ganna* (March to June) and *Bona* (July to December); crops which are planted on *Kiremt* season are collected in *Bega* season which is the dry period of the area. During this period feed shortage for livestock occurs. Most farmers prefer to plant bread Wheat in the *Kiremt* season to minimize the problem of grain sprouting (i.e. Wheat matures during the dry December-January period) and also suitable for barley production especially on the highland part of the region (Alemayehu and Frazel, 1987).

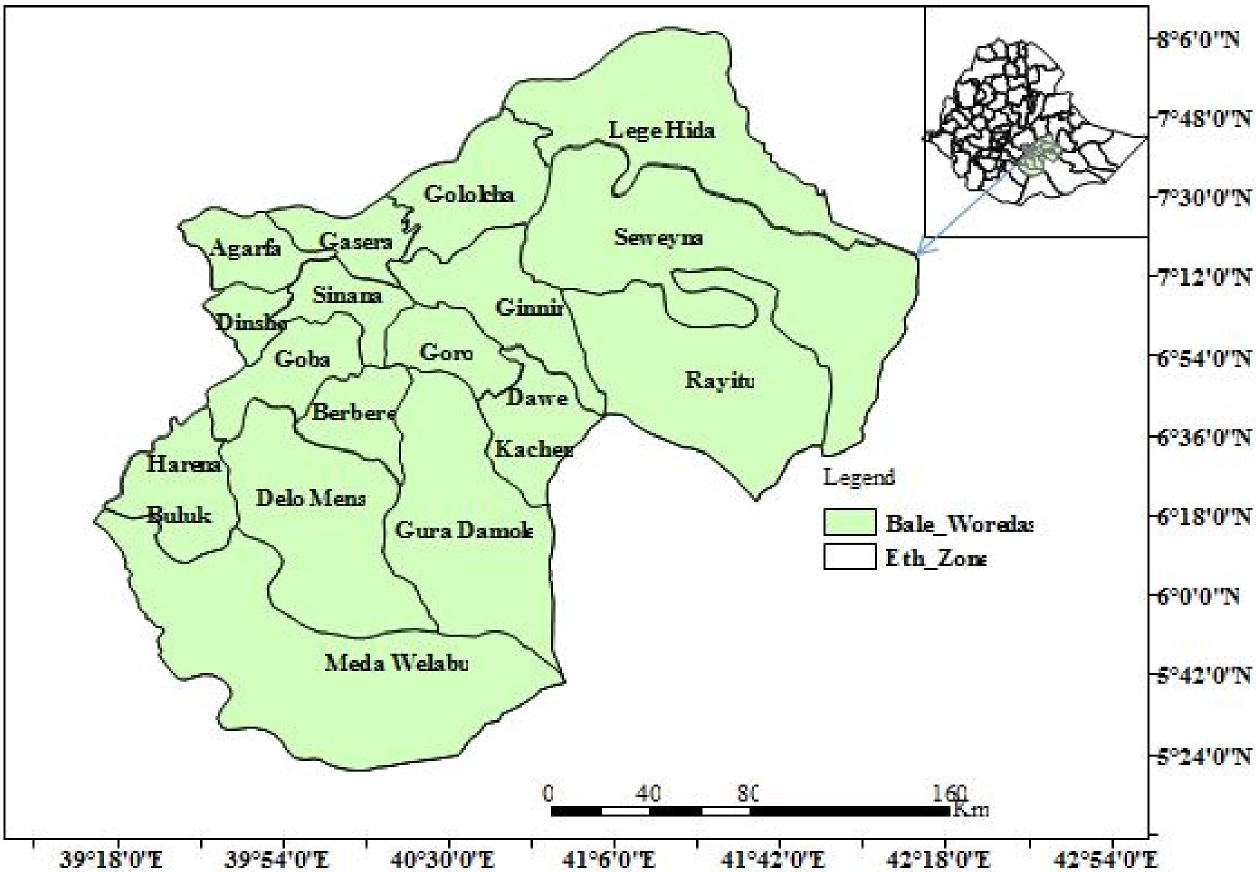

Figure 1 Map of Bale zone (study area)

2. DATA AND METHODS

Data

The study employed rainfall data (surface station figure 2 and merged satellite-surface station) for the period of 1983-2015, which were obtained from National Meteorological Agency of Ethiopia. In order to avoid potential problems during climate analysis, rainfall data were plotted for visual inspection and detection of outliers. Identification of outlier values should be done carefully to make sure that the outliers found is truly erroneous and is not naturally extreme values (Abbas et al., 2013). Simple statistical parameters noticeably; mean and standard deviations were computed according to their standard formula. A standard outlier threshold, which is defined using a parameter of inter-quartile range (IQR), was used for this study (Gonzalez-Rouco et al, 2001). Mathematically, it is defined by formula as:

$$\text{Threshold} = Q_3 + (3*IQR) \qquad \textbf{(Equation 1)}$$

Where Q_3 is third quartile and IQR is an inter-quartile range. The inter-quartile range method is known as a technique which is resistance to outliers but still keep the information of extremes (Gonzalez-Roucoet al., 2001). The detected outlier values were removed and substituted by outlier threshold (SUPARI, 2012).

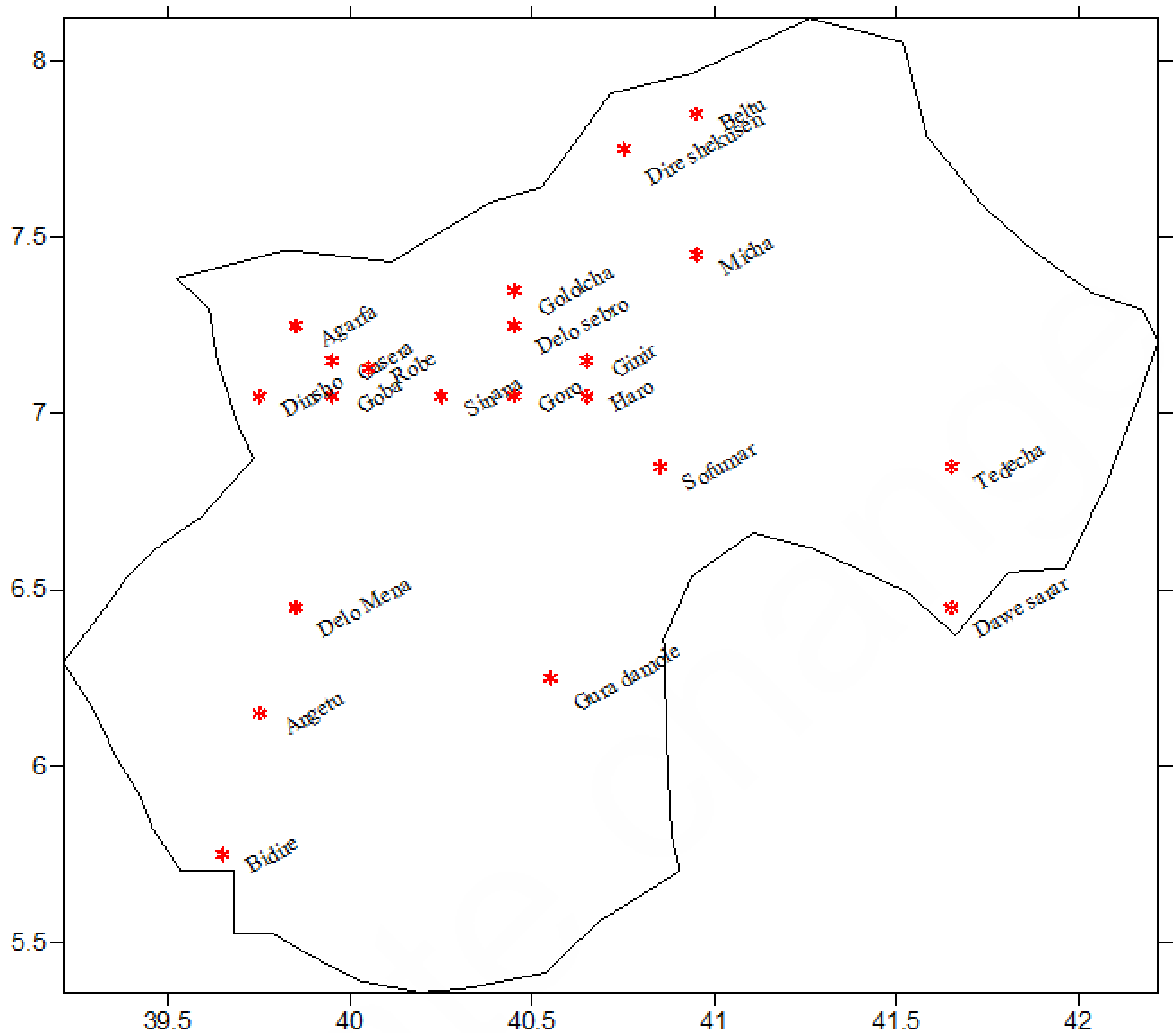

Figure 2 Spatial distribution of surface meteorological stations used for the study

Normality test of the data series

The standardized coefficients of Skeweness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) were used to test for the normality of seasonal and annual rainfall series for the study area. The standardized coefficients of Skeweness (Z_1) can be calculated as follows:

$$Z_1 = \left[\left(\sum_{i=1}^{N} (xi - \bar{x})^3 / N \right) \Big/ \left(\sum_{i=1}^{N} (x_i - \bar{x})^2 / N \right)^{3/2} \right] \Big/ (6/N)^{1/2}$$

(Equation 2)

and the standardized coefficients of kurtosis (Z_2) can be calculated as:

$$Z_2 = \left[\left(\sum_{i=1}^{N} (xi - \bar{x})^4 / N \right) \Big/ \left(\sum_{i=1}^{N} (x_i - \bar{x})^2 / N \right)^2 \right] - 3 \Big/ (24/N)^{1/2}$$

(Equation 3)

Where, $\bar{X}$ is the long term mean of xi values and N is the number of years in the sample. In this study the two statistics were used to test the null hypothesis that the individual temporal samples came from a population with a normal distribution. Thus, if the computed absolute value of Z1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at the 95% confidence level. If the data series are not found to be normally distributed, various transformation models could be used to normalize the series such as Log transformation and Lambda transformations of Box and Cox (1964) and Square and Cube Root transformations (Stidd, 1970) amongst others. SYSTAT version 8.0 was used to determine Skeweness (Z_1) and Kurtosis (Z_2) statistics.

Methods

Statistical analysis of rainfall variability Standard deviation, mean, coefficient of variation and percentage contribution were used in analyzing seasonal and annual rainfall over the study area. Scientifically, it is computed using the following formula:

$$CV = \left(\frac{SD}{\overline{X}}\right) * 100$$

(Equation 4)

Where CV is Coefficient of variation, S is the standard deviation and $\bar{x}$ mean for rainfall.

According to Australian Bureau of Meteorology (2010), Hare (1983) and NMSA (1996), magnitude of coefficient of variability is classified as follows: < 20% as less variable, 20- 30% as moderately variable, and > 30% as highly variable and vulnerable to drought.

Trend detection and analysis

According to Helsel and Hirsch (1992) the aim of trend testing is to determine if the values of a random variable generally increase (Or decrease) over some period of time in statistical terms. Hence, In order to detect increasing or decreasing trends in a time series the non-parametric Mann-Kendall's test is widely used by different authors (Partaland Kahya, 2006). The Mann-Kendall's statistical test is preferable among others, because it is simple, is expected to be less affected by the outliers because its statistic is based on the sign of differences, not directly on the values of the random variable, no need to change the existed data type to any statistical distribution (Yenigun et al., 2008).

The non-parametric Mann-Kendall's test statistic is given as:

$$S = \sum_{i-1}^{N-1} \sum_{j-i+1}^{N} sgn(X_j - X_i)$$

(Equation 6)

Where S is the Mann-Kendal's test statistics; *x*i and *x*j are the sequential data values of the time series in the years *i* and *j* (j>*i)* and *N* is 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 is given as:

$$Sgn(x_i - x_i) = \begin{cases} +1 \; if\left(x_j - x_i\right) > 0 \\ 0 \; if\left(x_j - x_i\right) = 0 \\ -1 \; if\left(x_j - x_i\right) < 0 \end{cases}$$

The variance of *S*, for the situation where there may be ties (that is, equal values) in the *x* values is given by: $Var(S) = \frac{1}{18}[N(N-1)(2N+5) - \sum_{i-1}^{m} t_i\,(t_i - 1)(2t_i + 5)]$

Where *m* is the number of tied groups in the data set and t_i is the number of data points in the *ith* tied group. For n larger than 10, Z_{MK} approximates the standard normal distribution (Partal and Kahya, 2006; Yenigun et al., 2008) and computed as follows:

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \, if S > 0 \\ if s = 0 \\ \frac{S-1}{\sqrt{Var(S)}} \, if S < 0 \end{cases}$$

(Equation 7)

The presence of a statistically significant trend is evaluated using the Z_{MK} value. In a two-sided test for trend, the null hypothesis Ho should be accepted if $|Z_{MK}| < Z_{1-\alpha/2}$ at a given level of significance. $Z_{1-\alpha/2}$ is the critical value of Z_{MK} from the standard normal table. For 5% and 10% significance level, the value of $Z_{1-\alpha/2}$ is 1.96 and 1.64 respectively. In MAKESENSE the tested significance levels α are 0.001, 0.01, 0.05 and 0.1.MAKESENS1.0, which is primarily developed for detecting and estimating trend in time series, was adopted in this study.

The Sen's estimator of slope: to estimate the true slope of an existing trend (as change per year) of rainfall time series on seasonal and annual basis, the Sen's non parametric method is used. The value of slope estimator (Q) can be positive, negative and zero, which indicates an increasing values with time (upward trend), decreasing value with time (downward trend) and data fluctuation around the mean, respectively. The Sen's method is not greatly affected by single data errors or outliers and also it can be computed when data are missing (Sen's, 1968; partal and kahya, 2006; karpouzos et al., 2010).

3. RESULTS AND DISCUSSION

Normality analysis of the data series

Based on results of descriptive statistics, standardized coefficients of skewness and kurtosis of annual and seasonal rainfall for Bale zone are presented in table 1. Accordingly, the results of the standardized coefficients of skewness and kurtosis revealed that all annual and seasonal time series were accepted as an indicative of normality at 5 and 1 % significance level. With the exception of kurtosis result over Sewena, a Robe and Dinsho station, which shows a significant deviation from normal distribution, based on this finding no transformation were employed to the data series.

Table 1 Descriptive statistics of annual and seasonal rainfall in Bale zone for the period 1983-2015

	Annual		Belg season		Kiremt season	
Stations	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Haro	.84	.26	.46	-.88	.32	.60
Rayetu	.39	-.18	.43	-.84	.79	.58
G/damole	.84	.09	.44	-.95	.50	-.60
Beltu	1.15	1.89	.76	.34	1.29	3.55
Sewena	1.26	1.75	.70	.05	1.10	2.78**
Agarfa	.15	-.44	1.06	1.05	-.23	-.07
Gololcha	.57	.16	.83	.25	.03	.02
D/sheksen	.90	.26	.67	.09	.56	1.12
Angetu	.21	.70	.35	-.73	.29	-.14
D/mena	.58	.43	1.02	1.45	.25	.68
Ginnir	.93	.02	.50	-.69	.10	-.15
Goba	.61	-.02	.94	.96	.15	.52
Bidre	.16	-.10	.28	-1.02	.43	-.22
Robe	-2.2	10.5**	-.35	2.30	-1.50	4.98**
Dinsho	.61	.52	1.18	2.85**	-.38	-.64
D/serer	.46	-.36	.66	-.42	.96	.30
Sinana	.90	.85	.58	-1.01	.10	-.17
Sofumar	.57	.29	.27	-1.05	1.25	2.35*

Gasera	.68	.01	.82	.56	-.19	-.26
D/sebro	.99	.97	.73	-.29	.41	.48
Goro	.95	.22	.23	-1.27	.34	-.21

**and **: Statistically significant at 95% and 99% confidence level*

Analysis of seasonal and annual rainfall total variability

The seasonal rainfall contribution to the annual rainfall totals varies largely over the study area, mainly in relation to elevations. The main rainy season (kiremt) contributes mostly to the annual rainfall totals (Table 2), especially over the highland areas of bale zone whose altitude exceeds 2300 meter above sea level (Figure 3). Specifically, kiremt rainfall total contributes 37-49% for highland areas, 25-46% for mid land areas and 20-35% for lowland areas of Bale zone to the annual rainfall totals. Similarly, Belg rainfall also has a considerable contribution to the annual rainfall totals, typically for midland and mid land areas of Bale zone which ranges between 34-51%. Moreover, the annual contribution of Bega rainfall varied from 17-33% over the mid and low land areas of the study region (Table 2).

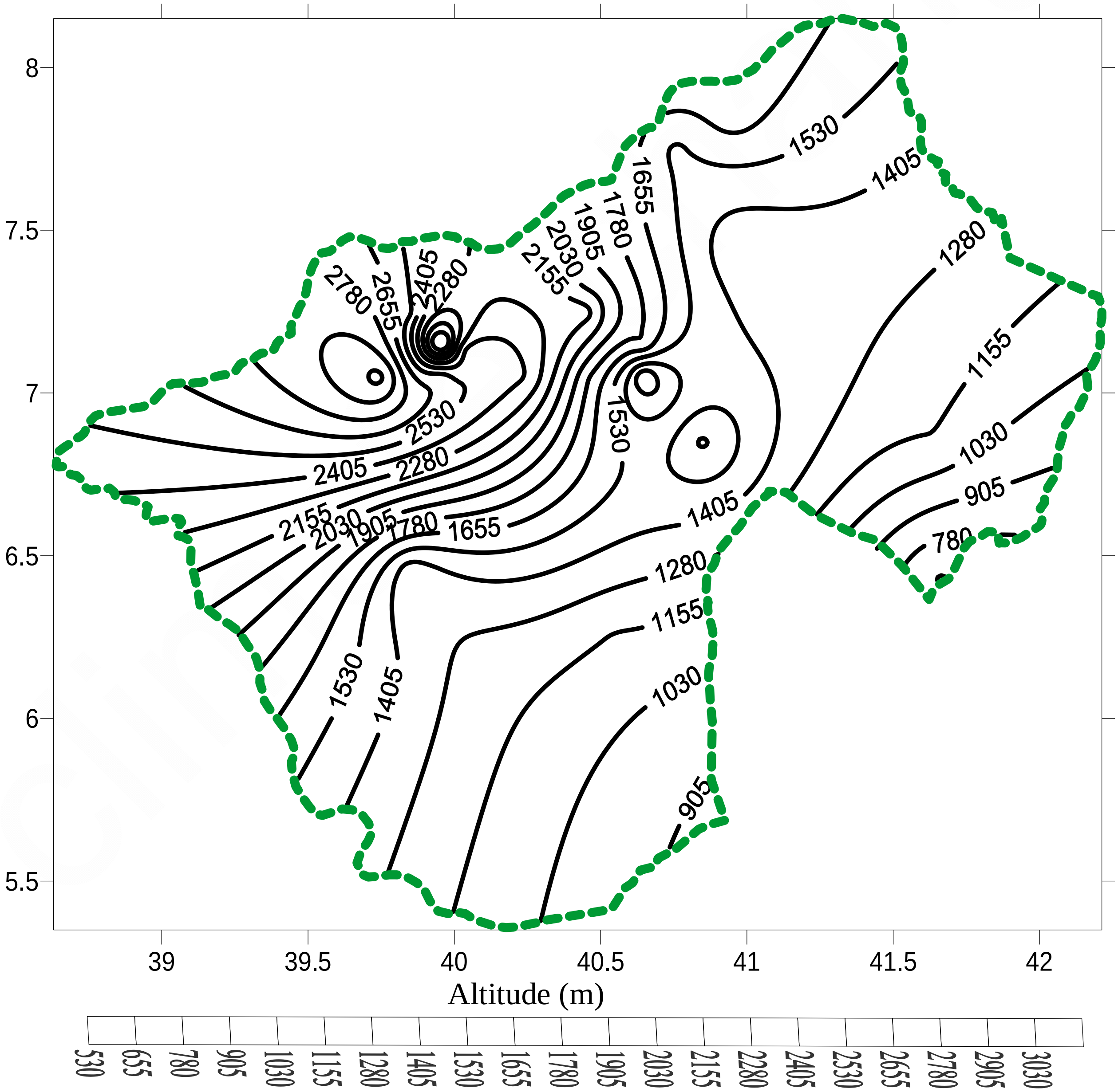

Figure 3 Elevation map of the study meteorological station over Bale zone

Table 2 Average seasonal rainfall contribution to annual rainfall total in Bale zone from 1983-2015

Stations	Annual rainfall (mm)	Belg rainfall (mm)	Percentage contribution	Kiremt rainfall (mm)	Percentage contribution	Bega rainfall (mm)	Percentage contribution
Haro	860.1	384.8	45%	247.6	29%	227.7	26%
Rayetu	683.3	287.15	42%	172.5	25%	223.7	33%
Guradamole	804.2	404	50%	157.7	20%	242.5	30%
Beltu	859.5	351	41%	300.6	35%	207.9	24%
Sewena	828.3	355.4	43%	259.7	31%	213.2	26%
Agarfa	927	317.9	34%	454.3	49%	154.8	17%
Gololcha	917.8	366	40%	352.9	38%	198.9	22%
D/shekhusen	853.1	347.5	41%	307.8	36%	197.8	23%
Angetu	880.8	428.5	49%	190.6	22%	234.5	29%
Dmena	819.3	427.3	52%	216.8	26%	236.7	22%
Ginnir	864.3	372.9	43%	269.5	31%	221.9	26%
Goba	899.5	338.5	38%	386	43%	175	19%
Bidre	821.8	421.6	51%	163.3	20%	236.9	29%
Robe	924.3	341.9	37%	415.2	45%	167.2	18%
Dinsho	892.5	312	35%	424.5	48%	156	17%
Dserer	643.1	282	44%	141.8	22%	219.3	34%
Sinana	895.1	368.5	41%	331.6	37%	195	22%
Sofumar	792.5	364.6	46%	199.1	25%	228.8	29%
Gasera	931.2	335.8	36%	428.8	46%	166.6	20%
D/sebro	925.3	372.5	40%	358.1	39%	194.7	21%
Goro	895.6	390.5	44%	289.3	32%	215.8	24%

Results of coefficient of variation of seasonal to annual rainfall over the study area demonstrates that Bega rainfall total has the highest coefficient of variation (32.6 - 51.2%), followed by kiremt rainfall (17.9% - 46.7%) and the lowest variability of 24-37% were found in Belg rainfall. Therefore, as less variability implies that patterns could be more understood compared to kiremt and bega seasons. This finding is in line with a study conducted by Gissila et al. (2004), who reported that kiremt (JJAS) rainfall over the whole regions of the country is difficult to predict due to seasonality variability (Table 3).

Table 3 Standard deviation and coefficient of variation for annual and seasonal rainfall in Bale zone for the period 1983-2015

Stations	Annual		Belg season		Kiremt season		Bega season	
	SD	CV	SD	CV	SD	CV	SD	CV
Haro	124.4	14.5%	100.8	26.2%	60.5	24.4%	85.2	37.4%
Rayetu	117.3	17.2%	101.2	35.2%	60.2	34.9%	90.0	40.3%
G/damole	110.6	13.8%	114.8	28.4%	52.3	33.2%	94.5	39%
Beltu	140.1	16.3%	111.1	31.7%	80.8	26.9%	88.2	42.4%
Sewena	129.8	15.7%	106.3	29.9%	66.8	25.7%	87.5	41.0%
Agarfa	133.9	14.5%	99.5	31.3%	82.5	18.2%	75.6	48.8%
Gololcha	139.5	15.2%	97.9	26.7%	86.5	24.5%	83.7	42.1%
D/sheksen	130.2	15.3%	101.6	29.2%	70.5	22.9%	84.9	43%
Angetu	145.7	17.1%	102.9	24%	78.9	41.4%	82.9	35.4%

D/mena	141.6	16.1%	102.9	24.1%	59.4	27.4%	94.9	40.1%
Ginnir	125.2	14.5%	100.2	26.9%	67.3	25%	88.3	39.7%
Goba	117.9	13.1%	94.3	27.8%	68.9	17.9%	75.4	43.0%
Bidre	152.3	18.5%	106.2	25.2%	76.3	46.7%	77.1	32.6%
Robe	207.2	23%	106.7	32%	108.1	26.7%	84.4	51.2%
Dinsho	128.9	14.4%	95.6	30.6%	71.7	16.9%	79.7	51.1%
D/serer	120.9	18.8%	104.4	37%	59.9	42.3%	88.5	40.4%
Sinana	118.1	13.2%	87.8	23.8%	66.7	20.1%	79.1	40.5%
Sofumar	115.9	14.6	105.7	29%	58.6	29.4%	83.5	36.5%
Gasera	119.4	12.8%	89.9	26.8%	71.5	16.7%	75.8	45.5%
D/sebro	123.6	13.4%	93.9	25.2%	70.5	19.7%	81.8	42.0%
Goro	128.7	14.4%	95.9	24.6%	62.2	21.5%	84.7	39.3%

Analysis of Spatial rainfall distribution

On annual basis, rainfall over the study area ranged from 640 mm to more than 915mm over the lowland and highland areas, respectively (Table 4). Similarly, the highest observed mean seasonal rainfall were observed over the highland parts of the study area compared to mid and low land areas except some pocket areas of the study region (Figure 5-7). From figure 5-7, it is observed that the mean belg rainfall in Bale zone varies from 270 mm to 420mm over the lowland and highland areas, respectively. In addition, the mean kiremt rainfall varied from 100mm to 450mm in the lowland and highland areas of the region. The highest amounts of bega rainfall were observed over the lowland and mid land areas of the region.

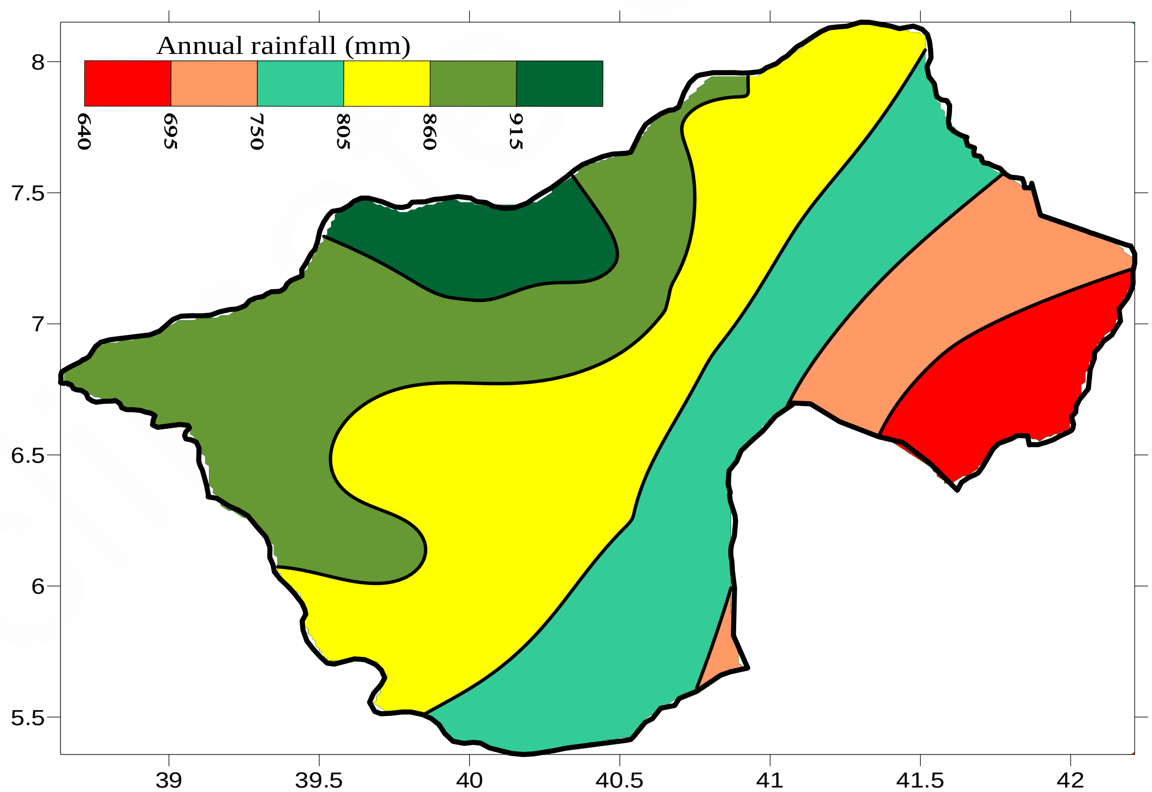

Figure 4 Spatial distribution of annual rainfall over Bale zone

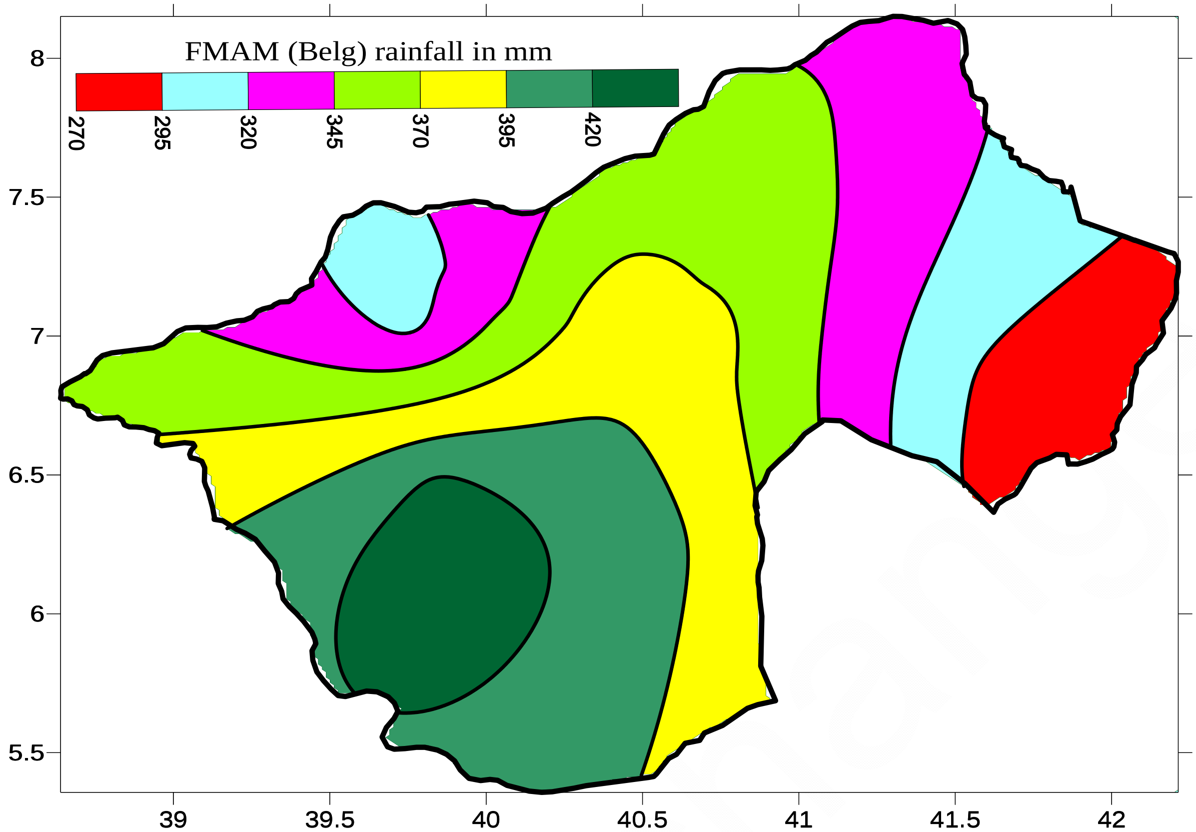

Figure 5 Spatial distribution of FMAM (Belg) season rainfall over Bale zone

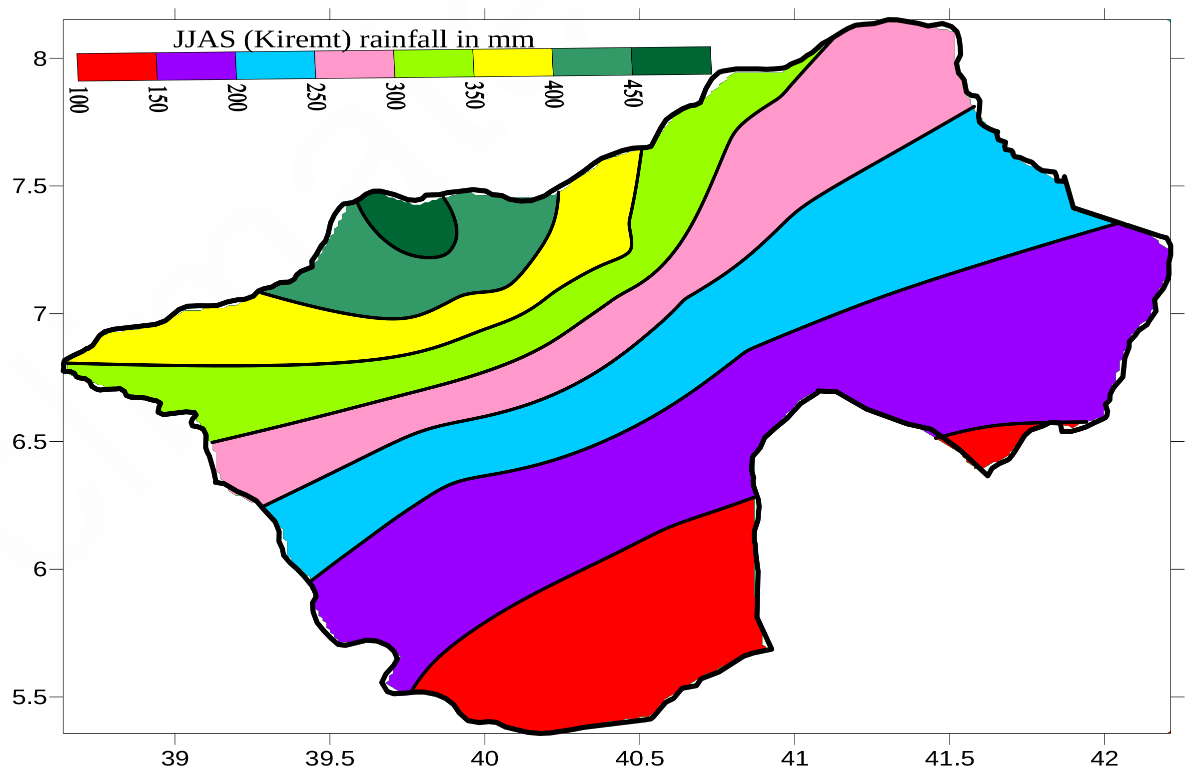

Figure 6 Spatial distribution of JJAS (Kiremt) season rainfall over Bale zone

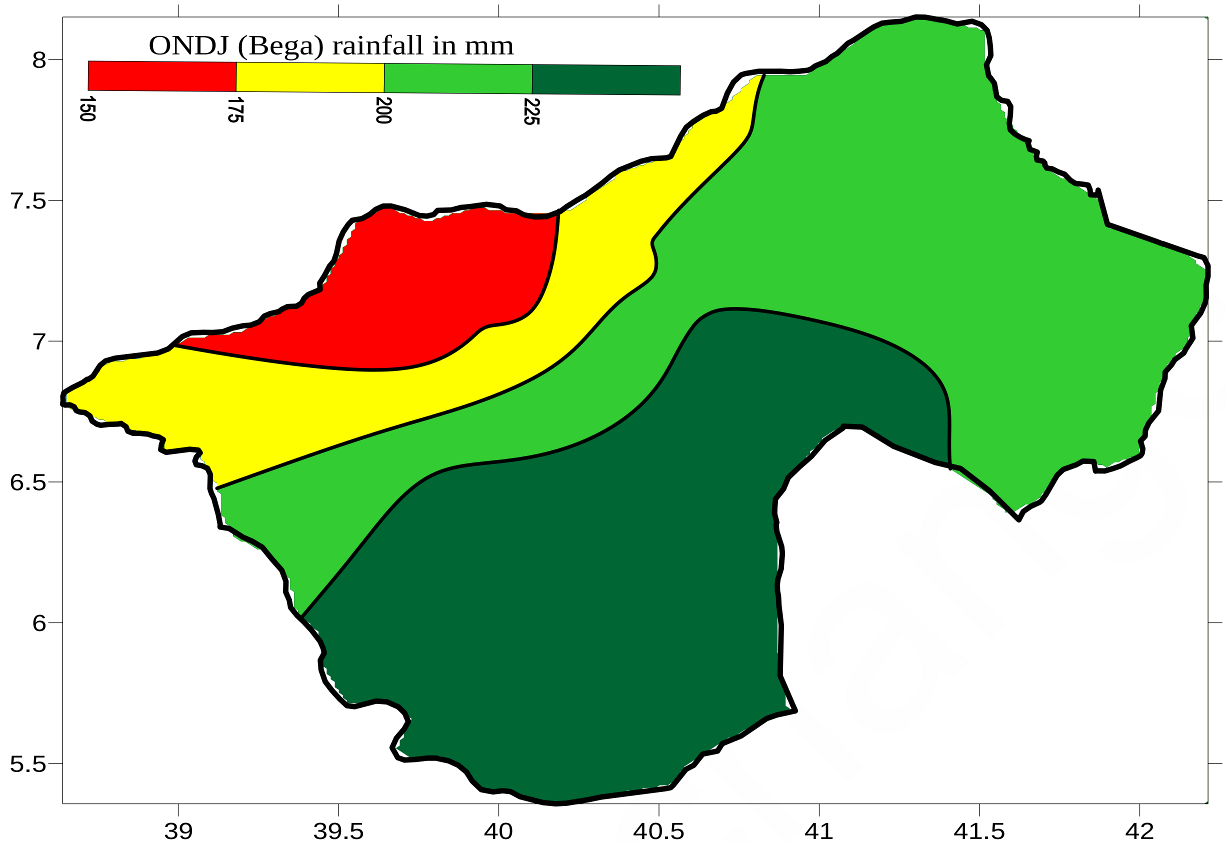

Figure 7 Spatial distribution of ONDJ (Bega) season rainfall over Bale zone

Analysis of annual and seasonal rainfall trends

The results of trend analysis of annual and seasonal rainfall are presented in table 4. There is an observed statistically significant trend (P< 0.1, 0.5 and 0.01) over most of belg benefiting areas of the region. Annually belg rainfall had decreased on the range of 2.6-4.8mm over Bale zone. The results further shows non -statistically increasing trend over most of kiremt benefiting areas. onthe seasonal scale bega rainfall shows non statistical increasing trend. Moreover, decreasing trend of annual rainfall totals were not statistically significant except over Dire-shekhusen and Bidre station which is statistically significant decreasing trend at 5% significance level. On annual scale rainfall had decreased on the range of 0.2-7.8mm over Bale zone. The analysis further revealed that the trend magnitude was lowest for bega rainfall benefiting areas of the region (Table 4).

Table 4 Trends of annual and seasonal rainfall total in Bale zone for the period 1983-2015

	Annual		Belg (FMAM) season		Kiremt (JJAS) season		Bega (ONDJ) season	
Stations	Z_{MK}	Slope	Z_{MK}	Slope	Z_{MK}	Slope	Z_{MK}	Slope
Haro	-1.36^{ns}	-3.098	-1.55^{ns}	-2.935	0.29^{ns}	0.429	0.22^{ns}	0.348
Rayetu	-1.33^{ns}	-2.599	-1.80^{+}	-3.343	0.36^{ns}	0.529	0.98^{ns}	1.513
Guradamole	-1.44^{ns}	-2.547	-2.36*	-4.667	0.88^{ns}	1.000	1.39^{ns}	1.964
Beltu	-1.67^{+}	-4.074	-2.14*	-4.657	0.02^{ns}	0.000	0.39^{ns}	0.574
Sewena	-1.44^{ns}	-2.859	-2.05*	-3.173	-0.12^{ns}	-0.142	-0.15^{ns}	-0.179
Agarfa	-0.93^{ns}	-3.000	-2.32*	-4.444	-0.11^{ns}	-0.173	0.29^{ns}	0.346
Gololcha	-1.13^{ns}	-3.494	-1.94^{+}	-2.721	-0.06^{ns}	-0.075	0.36^{ns}	0.722
D/Shekhusen	-1.21^{ns}	-3.019	-2.17*	-3.619	0.70^{ns}	1.000	0.11^{ns}	0.275
Angetu	-2.25*	-5.784	-2.22*	-4.171	-2.01*	-3.157	0.95^{ns}	1.738
Dmena	-0.65^{ns}	-2.438	-1.61^{ns}	-2.829	-1.43^{ns}	-1.617	1.83^{+}	2.596

Ginnir	-0.84^{ns}	-1.488	-1.35^{ns}	-2.292	0.11^{ns}	0.172	0.77^{ns}	1.426
Goba	-0.29^{ns}	-0.913	-2.17*	-3.667	0.46^{ns}	0.552	0.95^{ns}	1.074
Bidre	-2.49*	-7.899	-2.19*	-4.823	-2.00*	-3.146	0.71^{ns}	1.050
Robe	-0.33^{ns}	-0.400	-1.75^{+}	-2.740	0.57^{ns}	0.865	0.23^{ns}	0.582
Dinsho	-0.77^{ns}	-2.208	-1.78^{+}	-3.117	-0.09^{ns}	-0.144	1.24^{ns}	1.586
Dawe serer	-0.68^{ns}	-1.477	-2.40*	-3.675	1.52^{ns}	1.838	1.04^{ns}	1.563
Sinana	-0.67^{ns}	-1.767	-2.19*	-2.707	0.96^{ns}	1.060	0.65^{ns}	0.825
Sofumar	-1.91^{+}	-3.962	-2.67**	-4.750	0.56^{ns}	0.774	0.99^{ns}	1.385
Gasera	-0.60^{ns}	-1.366	-2.14*	-3.207	0.14^{ns}	0.129	0.71^{ns}	1.000
Dsebro	-1.16^{ns}	-3.045	-2.00*	-2.659	0.05^{ns}	0.183	0.39^{ns}	0.696
Goro	-1.22^{ns}	-2.550	-1.92^{+}	-3.483	0.68^{ns}	0.813	0.51^{ns}	0.779

*ZMK is Mann–Kendall trend test, Slope (Sen's slope) is the change (mm)/annual; ns is non-significant trend at 0.01, 0.05 and 0.1 and $^{+,}$ * and** indicates significant trend at 0.1, 0.05 and 0.01 significant level.*

4. CONCLUSIONS AND RECOMMENDATION

Rainfall variability which is a natural gift was manifested in different amount over the three agro-ecological climatic zones of the study area. The three seasons has different magnitude of seasonal rainfall contribution to the annual rainfall totals on the basis of the three agro-ecological zones. For instance**,** the main rainy season (kiremt) contributes more to the annual rainfall totals (37-49 mm) over the highland areas of bale zone compared to low and midland areas. The results of trend analysis of seasonal rainfall using Mann-Kendal shows statistically significant trend (P< 0.1, 0.5 and 0.01) over most of belg benefiting areas of the region and some stations of the rest seasons. Furthermore, annual and belg rainfall showed a decreasing trend with statistically non-significant over most of the stations. Due to annual and inter-annual rainfall variability and decreasing rainfall trend it could be suggested that adaptation option should be implemented to offset the impacts related to it.

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REFERENCE

1. Adams, R. M., Hurd, B. H., Lenhart, S., & Leary, N. 1998.Effects of global climate change on agriculture; an interpretative review. Climate Research, 11, 19-30.
2. Adiku S. G. K. Atika E, Jagtap S. S., Nkansah A., Atidoh L., Jones J. W,, Duadze S. and Naab J. B.(2007b). *Climate variability and farmers' response in the groundnut producing areas of the AkatsiDistrict of Ghana.* Conference Paper. African SoilScience Society, Accra, Ghana.
3. Adiku S. G. K., Mawunya F. D., Jones J. W. and Yangyuoru M. (2007a). Can ENSO help in Agricultural decision-making in Ghana? In *Climate prediction and agriculture advances and*
4. Alemayehu Mamo and S.Franzel. 1987. Initial Results of Informal Survey: Sinana Mixed Farming System Zone. Working Paper No.1/87.IAR,Addis Ababa, Ethiopia. pp52.
5. Australian Bureau of meteorology, 2010. Rainfall variability in Australia. (http://www.bom.gov.au/climate /data/index.shtml). Accessed on April 1, 2017.
6. Bates, B.C., Z.W. Kundzewicz, S.Wu and J.P. Palutikof .2008.Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, pp: 210. Retrieved from: http://www.ipcc.ch/meetings/session28/doc13.pdf. (Accessed date: March 10, 2017)
7. Bekele, F. 1997. Ethiopian use of ENSO information in its seasonal forecast. Internet Journal for African Studies (IJAS), Vol.1, No.2.Case studies.
8. Beltrando, G. and Camberlin, P. 1993. International variability of rainfall in the eastern horn of Africa and indicators of atmospheric circulation. *International Journal of Climatology* 13: 533-546.
9. Bessie, S.2010.Input Supply and Output Marketing Role of Multipurpose Cooperatives in Increasing Cereal Production in Bale Zone (Oromia Regional State), Ethiopia, MSc thesis, Addis-Ababa University.
10. Box, G.E.P. and D.R. Cox, 1964.An analysis of transformation. Roy. Stat. Soc., B., 26: 211-252.
11. Brazel, S.W. and R .C. Balling .1986. Temporal analysis of long-term atmospheric moisture levels in phoenix, Arizona. J. Climate Appl. Meteorol., 25: 112-117.
12. Camberlin P., 1997: Rainfall anomalies in the source region of the Nile and their connection with the Indian summer monsoon. J. Climate, 10, 1380–1392.

13. Degefe B. and Nega B. (1999/2000). Annual report on the Ethiopian economy. The Ethiopian Economic Association.Vol.1.1999/2000.
14. FitsumBekele. 2015. Characterizing Current and Future Rainfall Variability and its Effect on Wheat and Barley Production in Sinana District, South Eastern Ethiopia.M.Sc thesis (published), Haramaya University, Haramaya.
15. Gissila, T., E. Black, D.I.F. Grimes and J.M.Slingo.2004. Seasonal forecasting of the Ethiopian Summer rains. Int. J. Climatol., 24, 1345-1358.
16. Gonzalez-Rouco JF; JL Jimenez,V Quesada and F Valero.2001. Quality Control and Homogeneity of Precipitation Data in the South West of Europe. Journal of Climate.14.pages:967-978.
17. Hagos F, Makombe G, Namara RE, Awulachew SB. 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. (IWMI Research Report 128)
18. HaileT. 1986. Climatic Variability and Support Feedback Mechanisms in Relation to the Sahel-Ethiopian Droughts. Master of Science thesis in Meteorology. Reading University, UK.
19. Hare, F.K. 1983.Climate and Desertification. Revised analysis (WMO-UNDP) WCP-44 pp5-20. Geneva, Switzerland.
20. Helsel, D.R., and Hirsch, R.M., Statistical Methods in Water Resources, Elsevier, Amsterdam 1992.
21. Indeje, M., Semazzi, F. and Ogallo, L. (2000). ENSO signals in East African rainfall and their prediction potentials. *Int. J. Climatol*. V. 20, p.19-46.
22. Karpouzos Dk, Kavalieratou S, Babajimopoulos C (2010). Trend analysis of Precipitation data in Pieria Region (Greece). European Water, 30:31-40.
23. Kassahun, B. (1987). Weather systems over Ethiopia. Proc. First Tech. Conf. on Meteorological Research in Eastern and Southern Africa, Nairobi, Kenya, UCAR, 53–57.
24. Katunzi, Bushesha, Mwakalila. Examining Rainfall and Temperature Pattern Change over Time: A Case of Kishapu District, Shinyanga Region in Tanzania. *Climate Change*, 2016, 2(8), 557-572
25. Korecha,D and A.G.Barnston (2007). Predictability of June-September Rainfall in Ethiopia. *Monthly Weather Review* 135(2): 628–650.
26. Mawunya F. D., Adiku S. G. K., Laryea K. B., Yangyuoru1 and M., Atika E .2011.Characterizations of Seasonal Rainfall for Cropping Schedules*West African Journal of Applied Ecology,* vol. 19, p108-118
27. Magreth Bushesha. Analysis of Seasonality Variations and Copping Strategies among Cocoa Growers: A Case of Kyela and Rungwe Districts. *Climate Change*, 2015, 1(2), 112-121
28. Mersha, E. 1999.Annual rainfall and potential evapotranspiration in Ethiopia.*Ethiopian Journal of Natural Resources* 1: 137–154.
29. Mesike CS, Agbonaye OE. Effects of rainfall on rubber yield in Nigeria. *Climate Change*, 2016, 2(7), 141-145
30. MoA (Ministry of Agriculture) .2000.Agro-ecological zonations of Ethiopia.Addis Ababa, Ethiopia.
31. NMA-NAPA. 2007. Climate change National Adaptation Program of Action (NAPA) of Ethiopia. Ministry of Water Resources, Addis Ababa.
32. NMSA. 1996. Climate & agro climate resources of Ethiopia. NMSA Meteorological Research Report Series, Vol.1, No.1, and Addis Ababa.
33. NOAA (National Oceanic and Atmospheric Administration), 2007.Observing Climate Variability and Change. Retrieved from: http://www.oar.noaa.gov/climate/t_observing.html. (Accessed date: March 20, 2017).
34. Osman M and Sauerborn P. 2002. A preliminary assessment of characteristics and long-term variability of rainfall in Ethiopia basis for sustainable land use and resources management.Conference on International Agricultural Research for Development, Deutscher Tropentag Witzenhausen, Germany.
35. Oxfam. 2010. Poverty, Vulnerability and Climate Variability in Ethiopia. International Research report. Addis Ababa, Ethiopia.
36. Partal T, Kahya E (2006).Trend analysis in Turkish precipitation data. Hydrol. Processes, 20: 2011–2026. DOI: 10.1002/hyp.5993.
37. 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.
38. 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.
39. Sen PK (1968). Estimates of the regression coefficient based on Kendall's tau. J. Am. Stat. Assoc. 39:1379–1389
40. Stidd, C.K., 1970. The nth Root Normal Distribution of Precipitation. Water Resour. Res., 6: 1095-1103.
41. SUPARI .2012.Spatiotemporal Characteristics of Extreme Rainfall Events over Java Island. Submitted to M.Sc program. Faculty of Geo-Information and Earth Observation, University of Twente.
42. Taddesse, T. 2000. Drought and its predictability in Ethiopia. In: Wilhite, D.A. (Ed.), Drought: A Global Assessment, Vol. I. *Routledge,* pp. 135-142.
43. Tilahun, K. 1999. Test of homogeneity, frequency analysis of rainfall data and estimate of drought probabilities in Dire Dawa, eastern Ethiopia. *Ethiopian journal of Natural Resources 1: 125-136.*

44. Wolde-Georgis T. (1997). The Use of El Nino Information as Drought Early Warning in Ethiopia. IJAS, Vol.1, No.2. Case studies.
45. Wood, A. 1977.A preliminary chronology of Ethiopian droughts. In Drought in Africa, Vol. 2, Dalby, D., Church, R.J.H. and Bezzaz, F. (eds). *International African Institute: London;pp*. 68–73.
46. Yenigun K, Gumus V, Bulut H (2008). Trends in stream flow of the Euphrates basin, Turkey. Proc. Inst. Civil Eng. Water Manage. 161:189–198. doi: 10.1680/wama.2008.161.4.189