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Characterizing Rainfall and Temperature Variability in Deder *District*, Eastern Oromia, Ethiopia

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Research Article

Abstract
The main objective of this study was to assess the rainfall and temperature variability in Deder District, Eastern Oromia, Ethiopia. Historical climate (1989-2018) data were obtained from the National Meteorological Agency (NMA). Rainfall and temperature variability and trend analyses were carried out using Instat (v3.37) and XLStat statistical software. Seasonal and annual rainfall totals and numbers of rainy days were highly variable. Belg (Short season) (FMAM) and annual rainfall totals showed a decreasing trend by the factors of -8.2 and -6.25 mm per year respectively but, kirimt (long season) (JJAS) *rainfall total increased with 6 mm per year. The average belg onset date, kiremt cessation date, and length of growing (belg-kiremt) period were 15 April, 26 October, and 174 days respectively, and fewer variables. Monthly, seasonal, and annual mean minimum and maximum temperatures were fewer variables. Belg, kiremt and annual maximum mean temperatures were 23.87, 22.56, and 22.75°C respectively, and had increasing trend by the factors of 0.07, 0.02, and 0.01°C per year respectively. Belg, kiremt, and annual mean minimum temperature were 13.65, 14.81, and 13.18°C respectively, and kiremt and annual mean temperatures showed increasing trend by the factors of 0.01 and 0.01°C per year respectively. But belg mean minimum temperature showed a decreasing trend by the factors of -0.02°Cper year.*

Keywords: *Belg, kiremt,* Rainfall, Temperature Variability, Deder District, Ethiopia

1. Introduction
Climate change is one of the biggest environmental challenges in the world. It has become a major concern to society because of its potentially adverse impacts worldwide. There are already increasing concerns globally regarding changes in climate that are threatening to transform the livelihoods of the vulnerable population segments. The earth's climate has warmed on average by about 0.7◦C over the past 100 years with decades of the 1990s and

2000s being the warmest in the instrumental record (Watson, 2010). Climate change and variability are posing the greatest challenge to the humankind at global as well as local levels (Slingo et al., 2005) because it affects the earth's surface widely from tropical to arctic regions and from sea to land and atmosphere (IPCC, 2007).

In general, climate change and variability have differential impacts across locations. The poor developing countries of Africa are among the most vulnerable to experience the worst of climate change impacts. This is because the majority of the population depends on economic activities that are highly exposed and extremely sensitive to climatic variability, and national adaptive capacities are very low due to the high level of poverty, and unfavorable and deteriorating environmental conditions (Kihupi et al., 2015).

Ethiopia, one of the most populous countries in Africa, is vulnerable to climate change and variability due to its high dependence on rain-fed agriculture and relatively low adaptation capacity (Fikreyesus et al., 2014). Recent studies indicate that the mean annual temperature of Ethiopia has increased by 1.3 °C between 1960 and 2006, at an average rate of 0.28 °C per decade and by 0.3°C per decade in the south-west and Amhara in the north (Fazzini et al. 2015). Furthermore, there is a strong variability within Ethiopia's annual and decadal rainfall, which makes country-wide trends difficult to detect in the long-term. A study by Jury and Funk (2013) showed that February to May and June to September rains have declined 15–20% since the mid-1970s and late 2000s in southern, south-western, and southeastern Ethiopia. Similar to other parts of the country, Deder District has been experiencing drier growing periods leading to a reduction in agricultural production. Therefore, the study was aimed to rainfall and temperature variability for the past thirty years (1989-2018).

2. Materials and Methods

2.1 Description of the Study Area

The study was carried out in Deder District, which is one of the major coffee-producing districts of East *Hararghe* administrative zone of Oromia Regional State. Geographically, Deder District is located between 9° 09'- 9° 24' N and 41° 16'- 41° 32' E. It is located 430 km from Addis Ababa, the capital city of Ethiopia. The district is bounded by Meta District to the east, West Hararge zone to the west, Malka Balo District to the south, and Goro Gutu District to the north Figure 1.

The topography of the *woreda* characterized by undulated and rugged landscape with *Jamjemxeta* considered to be the highest point. Agro-climatically, the district encompasses highland (33%), midland (50%), and lowland (17%) with altitude ranging from 1200 to 3119 m.a.s.l (Deder Agricultural and Natural office 2018). Annual average rainfall ranges from 600mm to 1500 mm. The district gets biannual rainfall, *belg* (short season), and *kiremt* (long season). The average precipitation is generally considered adequate for rain-fed agriculture. But uneven nature of its distribution especially in the lowland and midland parts of the district has resulted in frequent crop failure. The temperature of the area ranges from 11°C (min.) to 25°C (max.) (Deder District Agricultural Office and NMA, 2018). Cereals and cash crops are commonly grown in the district. Notable among the cereal crops are sorghum, maize, wheat, barley. *Khat*, coffee, and vegetables are known as cash crops. Cattle, goat, and sheep are among the livestock reared by the community. The district has an estimated total land area of about 67,428 ha of which 39 % is cultivable,3.8% forest and bushland, 3.4% residence and others, and the remaining 39.2% is considered rugged and mountains.

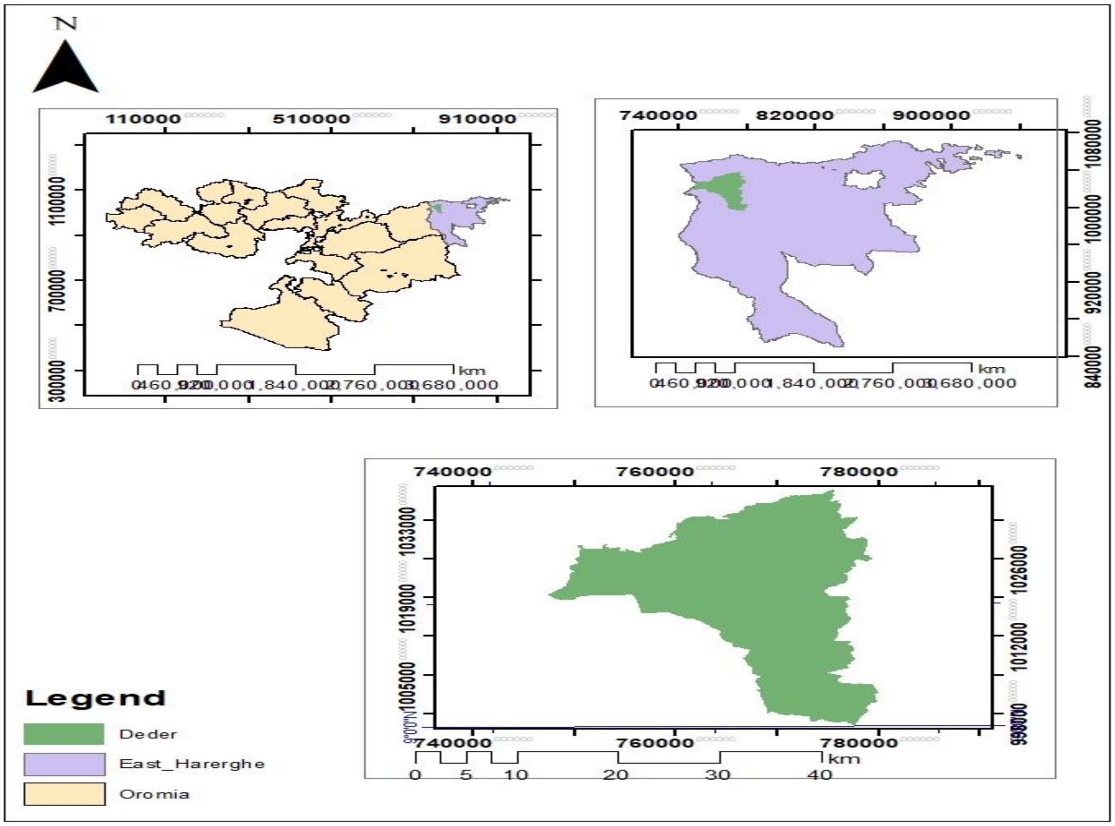

Figure 1. Map of the study area

2.1.1 Secondary data

Thirty (30) years of rainfall and temperature data for the period 1989-2018 were obtained from the National Meteorological Agency (NMA).

2.1.2 Analyzing variability of temperature and rainfall characteristics

The selected rats were divided into five sets of four (4) rats each and subjected to five different feed treatments (T_1, T_2, T_3, T_4, and T_5). The feed treatments were; T_1 (grower mash), T_2 (yam peel), T_3 (fresh cassava tuber), T_4 (sorghum seed), and T_5 (guinea grass – *Panicum maximum*). Each of the treatments was set up in four (4) replications containing 4 rats (2 males and 2 females) per replicate. The rats were fed regularly and water provided *ad libitum*.

The experiment was set up for one hundred and fifty days (150 days). A cage size of 60 cm x 30 cm x 30 cm was used to house each of the treatment replicates.

Rainfall characteristics such as; *belg* season rainfall onset, *kiremt* cessation date, length of growing period (*belg* - *kiremt*), monthly, seasonal and annual rainfall totals and number of rain days and mean minimum and maximum temperature were characterized with Instat (v3.37). In order to examine variability; statistical tools like mean, standard deviation (SD), coefficient of variation (CV) were used in Instat (v 3.37) software. CV was used to classify the degree of temperature and rainfall characteristics variability as less, moderate, and high. When CV < 20% it is less variable, CV from 20% to 30% is moderately variable, and CV > 30% is highly variable (Gebremichael *et al.*, 2014). Reddy (1990), the stability of rainfall is examined as follows: when standard deviation < 10 as very high stability, 10-20 as high stability, and 20-40 as moderate stability and > 40 as less stability.

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2.1.3 Analysis of Rainfall and Temperature trend

Mann-Kendall trend test was used to detect the trend and normalized Z-score for the significant test. A score of +1 is awarded if the value in a time series is larger, or a score of -1 is awarded if it is smaller. The total score for the time-series data is the Mann-Kendall statistic, which is then compared to a critical value, to test whether the trend in rainfall is increasing, decreasing, or if no trend in rainfall and temperature were determined using the XLstat software.

3. Results and Discussion

3.1 Monthly, seasonal and annual rainfalls total Variability and trends

The mean annual rainfall total was 1042.3mm with an SD of 320.16 mm and a CV of 30.7% (Table 1). The minimum and maximum total amounts of rainfall recorded during the study period were 547.43 mm and 1908.8 mm respectively. The main (*kiremt*) rainy season contributed 46.7% of the total annual rainfall whereas short (*belg*) rainy season contributed only 31.3% of the annual rainfall.

Table 1. Descriptive statistics for monthly, seasonal and annual rainfalls total Variability and trends

Variable	Mean(°C)	Min. (°C)	Max. (°C)	SD(°C)	CV %	Sen's slope	p-value
January	15.57	0	156.1	30.59	196.49	0	0.678
February	27.01	0	233.3	45.51	168.5	-0.794	0.010
March	85.41	1.2	221.3	61.07	71.5	-3.022	0.028
April	138.5	0	318.5	76.92	55.54	-1.86	0.256
May	100.04	0	364.1	77.25	77.22	-1.556	0.396
June	55.55	0	184.6	47.28	85.11	1.353	0.044
July	172.64	30.2	314	74.54	43.18	-0.723	0.643
August	236.88	51.5	484.8	118.42	49.99	1.58	0.475
September	147.12	59	375	84.25	57.26	-1.12	0.344
October	35.16	0	251.9	54.61	155.31	-0.138	0.641
November	14.77	0	68.9	17.35	117.51	0.3	0.085
December	13.67	0	83.4	21.24	155.42	0	0.636
Belg	350.97	10.13	847.7	167.05	47.6	-8.2	0.016
Kiremt	612.19	336.8	1116.1	198.24	32.38	6	0.160
Annual	1042.3	547.43	1908.8	320.16	30.7	-6.25	0.242

Trend analysis indicated that the annual rainfall showed a non-significant (P = 0.242) decreasing trend by a factor of -6.25 mm per year. Similarly, *kiremt* rainfall total showed non-significant (P = 0.016) increasing trend by a factor of 6 mm/year. Moreover, the study indicated that *belg* rainfall total showed significant (p = 0.016) decreasing trend by a factor of -8.2 mm per year at *Deder*. Trends of rainfall total for each month showed decreasing trend except for June, August, and November which increase by a factor of 1.35 mm, 1.58 mm, and 0.3 mm per year respectively, and neither increase nor decrease for January and December (Table 1).

3.1.1 Monthly, seasonal and annual rainy days variability and trend

The observed mean number of *belg* rainy days was 9.42 and highly variable (CV=50.2%) (Table 2). The number of *belg* rainy days for all months in the *belg* seasons was highly variable, with a CV of 120.5%, 65.1%, 30.4%, and 49.3% for February, March, April, and May respectively. The observed *kiremt* average number of rainy days was 14.34 and showed high variability (CV=38.9%). The number of rainy days for June (CV = 59.4) and September (CV=39.5%) was highly variable in *kiremt* rainy season but moderately variable in July and August (CV=27.7% and 29% respectively). On average annual number of rainy days was 104.6 and highly variable (CV=78.425%) for the period of 1989-2018 at the study area. Moreover, the present study showed that the number of rainy days was more variable during the *belg* season than during the *kiremt* season. In line with this, Misgina *et al*. (2015) reported high variability of *belg* rainy days than *kiremt* rainy days at Southern Tigray.

Table 2. Descriptive statistics for monthly, seasonal and annual numbers of rainy days

Variable	Mean(°C)	Min. (°C)	Max. (°C)	SD(°C)	CV %	Sen's slope	p-value
January	1.97	0	10	2.70	137.1	0.00	0.16
February	3.57	0	18	4.30	120.5	-0.14	0.03
March	9.70	1	23	6.31	65.1	-0.2	0.10
April	13.10	7	21	3.98	30.4	-0.08	0.39
May	11.33	1	22	5.20	45.9	-0.15	0.11
June	7.77	0	17	4.61	59.4	0.24	0.04
July	15.73	6	26	4.56	29	0.06	0.48
August	18.20	7	30	5.05	27.7	0.00	0.73
September	15.67	7	28	6.19	39.5	0.00	0.69
October	4.20	0	19	4.77	113.5	0.00	1.00
November	2.23	0	13	2.92	130.8	0.00	0.12
December	2.33	0	12	3.03	130	0.00	0.50
Belg	9.42	0	23	4.95	50.2	-0.74	0.02
Kiremt	14.34	0	28	5.10	38.9	-0.67	0.33
Annual	8.82	0	30	4.47	77.41	0.00	1.00

The number of rainy days for *belg* rainy season showed a significant (P = 0.02) decreasing trend by a factor of -0.74 days per year in the study area. Similarly, *the* number of rainy days for *kiremt* season showed a non-significant (P = 0.33) decreasing trend by a factor of -0.67 days per year. The number of rainy days for all months were not significant except February (P = 0.03) and June (P = 0.04). On the other hand, June rain day and July rain day were increased by a factor of 0.24 and 0.06 respectively; February, March, April, and May rainy days were decreased by a factor of -0.14, -0.2, -0.08 and -0.15 respectively, and other months' rainy days were neither increased nor decreased. In line with this, Muluneh (2015) reported decreasing trends in the number of rainy days for the *kiremt* season at Srinka and Kobo, and conversely increasing trends were observed at Kombolcha and Lalibela stations indicating lack of consistent trend in the number of annual rainy days. Moreover, the observed trends were not statistically significant at all studied stations during the study period (1992-2012). High variability and decreasing trend of *belg* number of rainy days have been imposing a negative effect on coffee production in the study area.

3.1.2 Start date of the *belg* (FMAM) rainy season

The average onset date of *belg* rainfall for Deder station was 15 April (115 DOY) with CV of 28.82% and SD (33.15) (Table 3). The onset date for Deder station was 92 DOY (5 April) and 192 DOY (4 June) for lower and upper quartile respectively, which indicates that the chance of getting onset on 15 April or below is 25 % (1 out of 4 years) and 4 June or below 75% (3 out of 4 years) and varied between 92 and 192 DOY for minimum and maximum respectively. The earliest possible onset for Deder station was 92 DOY (05 April) while the latest was 192 DOY (June 4) and the optimal planting date was 93 DOY (5 April). The variability of onset date of rainfall was moderate (CV= 28.82%). This result inconsistent with, Study conducted by Mesay (2006) noted that northern and northeastern regions have a late start of *belg* rain in April with standard deviations of 31.9-46.1. The result is also similar to that done by Hoefsloot, (2009) which indicates that the mean onset of rainfall in the Hosaina and Welkite area varies from March 01 to April 20.

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Table 3. Descriptive statistics of onset, cessation, and length of growing period for Deder District

variables	Mean	Min.	Max.	SD	Q1(25%)	Q2(50%)	Q3(75%)	CV%
Onset date	115	92	192	33.15	93	99	122	28.8
Cessation date	288.7	245	347	20.47	279.8	290	299.3	7.1
LGP	173.7	89	251	38.88	154.5	185.5	200	22.4

3.1.3 Cessation date of the *kiremt* (JJAS) rainy season

In this area, the minimum and maximum values of Cessation *kiremt* date of rainfalls recorded was 245 days (first week of September) and 347 days (early week of December) with a mean (288.7 days, last week of October), SD (20.47 days) and CV (7.09%). For the Cessation date, the respective lower and upper quartiles fall between 279.8 (5 October) and 299.3 DOY (24 October) with a CV of 7.1 %. In other words, the end of the growing period earlier than 279.8 DOY (02 October) was possible only once in every four years and it ends earlier than 299.3 DOY (24 October) three years out of every four years. This finding present hare has parallels with the findings of Study conducted on cessation of the rainy season in the northwest of Ethiopia revealed that on average the *kiremt* rain ends on 302, 304, 292, 302 and 317 DOY at Bahir Dar, Motta, Yetmen, Debre Markos and Dangla, respectively (Taye *et al*., 2013).

3.1.4 Length of the growing period

The average length of the growing period at the study area was 174 days while the shortest and longest length of the growing period was 89 and 251 days respectively in the study area (Table 3). The respective lower and upper quartiles fall between 154.5 and 200 (minimum of six months, one year out of four years and roughly eight months three years out of four years) with SD and CV were 38.88 and 22.4% respectively. In line with this, Abiy *et al*. (2014) reported that the length of the growing period in the Hosaina area ranges from 124 to 253 days with a mean of 193 days, CV, and SD of 8% and 35 days respectively.

3.1.5 Monthly, seasonal and annual maximum temperature variability and trend

The annual maximum temperature ranged between 20.457°C and 22.75°C and the average annual maximum temperature at *Deder* district was 21.80°C. The average annual SD and CV of maximum temperature were 0.60 and 2.73% respectively, this indicated maximum temperature over the study period was less variable and stable in the study area Table 4 and Figure 2.

Table 4: Descriptive statistics for monthly, *belg, kiremt* and annual maximum temperature

Variable	Mean(°C)	Min. (°C)	Max. (°C)	SD(°C)	CV %	Sen's slope	p-value
January	21.4	19.2	22.85	0.87	4.10	0.039	0.02
February	22.25	20.62	24.44	1.26	5.70	0.044	0.05
March	22.56	20.35	24.54	1.05	4.60	0.025	0.43
April	21.84	19.19	24.16	1.23	5.60	0.045	0.06
May	22.3	20.42	24.14	1.06	4.70	0.031	0.08
June	22.13	20.77	24.59	0.92	4.20	0.009	0.63
July	21.09	19.35	22.55	0.72	3.40	0.025	0.17
August	21.16	19.55	22.62	0.79	3.70	0.03	0.08
September	21.77	19.76	23.52	0.87	4.00	0.041	0.04
October	21.85	20.07	22.92	0.72	3.30	0.028	0.12
November	21.95	19.73	23.28	0.99	4.50	0.08	0.00
December	21.26	19.3	22.57	0.94	4.40	0.078	0.00
Belg	22.24	20.61	23.87	0.93	4.20	0.038	0.07
Kiremt	21.54	20.53	22.56	0.58	2.70	0.037	0.02

Annual	21.8	20.46	22.75	0.60	2.75	0.044	0.001

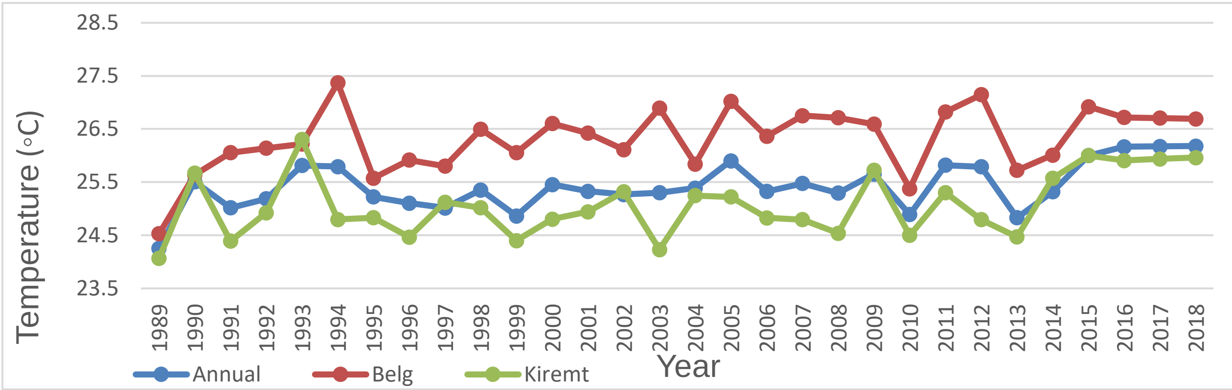

Figure 2. *belg*, *kiremt* and annual maximum temperature variability and trends

The average *kiremt* maximum temperature ranged between 20.53°C and 22.48°C and *kiremt* mean maximum temperature was 21.17°C with SD and CV of 0.58°C and 2.75% respectively. This indicates that *kiremt* maximum temperature was less variable and stable. Similarly, *belg* maximum temperature ranged between 20.61°C and 23.87°C with mean 21.78°C, SD = 0.93°C and CV 4.20% at *Deder* district, this indicates less variable and less stable observation in the study area.

Mann-Kendall test statistics value of Sen's slope indicated that *belg* maximum temperature revealed statistically not significant (P = 0.07) at P < 0.05 and an increasing trend by a factor of 0.038°C per year. Similarly, the value of Sen's slope indicated significantly (P = 0.02) and an increasing trend by a factor of 0.037°C per year. The annual maximum temperature showed a statistically significant (P = 0.001) and increasing by a factor of 0.044°C per year. The monthly maximum temperature showed a decreasing trend from November to January. However, the maximum temperature showed an increasing trend from July to September but, the trend is significant for January, November, and December only. This result corroborates with the evidence suggested that Africa is warming faster than the global average and African drylands are likely to continue to warm (Boko et al., 2007).

3.2.5 Monthly, seasonal and annual minimum temperature variability and trend

The average annual minimum temperature ranged between 5.08°C and 17.10°C and an annual average of minimum temperature at *Deder* District was 13.18°C with a CV of 11.02% (high stability) and SD of 1.33°C (Table 5 and Figure 3). This indicates that annual minimum temperature over the study period was less variable and stable in the study period but, more variable than average annual maximum temperature (CV=2.73%). *Belg* average minimum temperature ranged 5.93°C to 17.10°C and *belg* average minimum temperature at *Deder* was 13.65°C with CV and SD 1.45% (very high stability) and 11.23°C respectively but, less variable than *Belg* maximum temperature (CV=4.2%). The minimum temperature was less variable for all month except for January and February (moderately variable). The average *kiremt* minimum temperature ranged between 12.59°C and 16.03°C and *kiremt* average of minimum temperature at Deder district was 14.81°C with CV and SD 3.85% and 0.57°C respectively, this indicates that *kiremt* minimum temperature was less variable and also highly stable but, more variable than average *Kiremt* maximum temperature (CV=2.75%).

Mann-Kendall test statistics value of Sen's slope indicated that *belg* minimum temperature revealed a decreasing trend by a factor of -0.02°C per year (Table 5). The *belg* minimum temperature revealed a statistically not significant trend (P = 0.06) (Table 5). Similarly, the value

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of Sen's slope indicated an increasing trend *of kiremt* minimum temperature by a factor of 0.01 °C per year. But the trend was statistically not significant (*P* = 0.75).

Table 5: Descriptive statistics for monthly, belg, kiremt and annual minimum temperature

Variable	Mean(°C)	Min. (°C)	Max. (°C)	SD(°C)	CV %	Sen's slope	p-value
January	11.26	5.25	14.52	2.63	23.3	0.10	0.03
February	11.64	5.93	16.36	2.63	22.6	0.20	0.00
March	13.59	12.13	17.1	1.23	9.1	0.06	0.02
April	14.55	12.53	16.97	1.14	7.8	0.09	0.00
May	14.82	13.19	16.31	0.8	5.4	0.06	0.00
June	14.95	13.91	15.95	0.54	3.6	0.02	0.03
July	15.04	14.1	15.97	0.37	2.5	0.02	0.01
August	14.88	12.59	16.03	0.74	5	0.01	0.39
September	14.37	12.62	15.45	0.62	4.3	0.01	0.78
October	11.59	8.77	15.71	1.52	13.2	-0.01	0.80
November	10.24	5.77	12.49	1.81	17.7	0.06	0.12
December	11.17	5.08	14.1	1.98	17.7	0.01	0.30
Belg	13.65	5.93	17.1	1.45	11.23	-0.02	0.06
Kiremt	14.81	12.59	16.03	0.57	3.85	0.01	0.75
Annual	13.18	5.08	17.1	1.33	11.02	0.01	0.40

Annual minimum temperature showed an increasing trend by the factor of 0.01°C per year (0.1°C/decade). The trend of annual minimum temperature showed a statistically not significant trend (*P* = 0.40) at $P < 0.05$ (Table 5). All month's average minimum temp trend shows increasing trend except October. All are significant at $P < 0.05$ except August, September, October, November, and December. In agreement with this result, the analysis of historical climate data across Ethiopia has presented increasing rates of 0.13°C/decade and 0.37°C/decade for mean annual minimum and maximum temperature respectively (NMA, 2007).

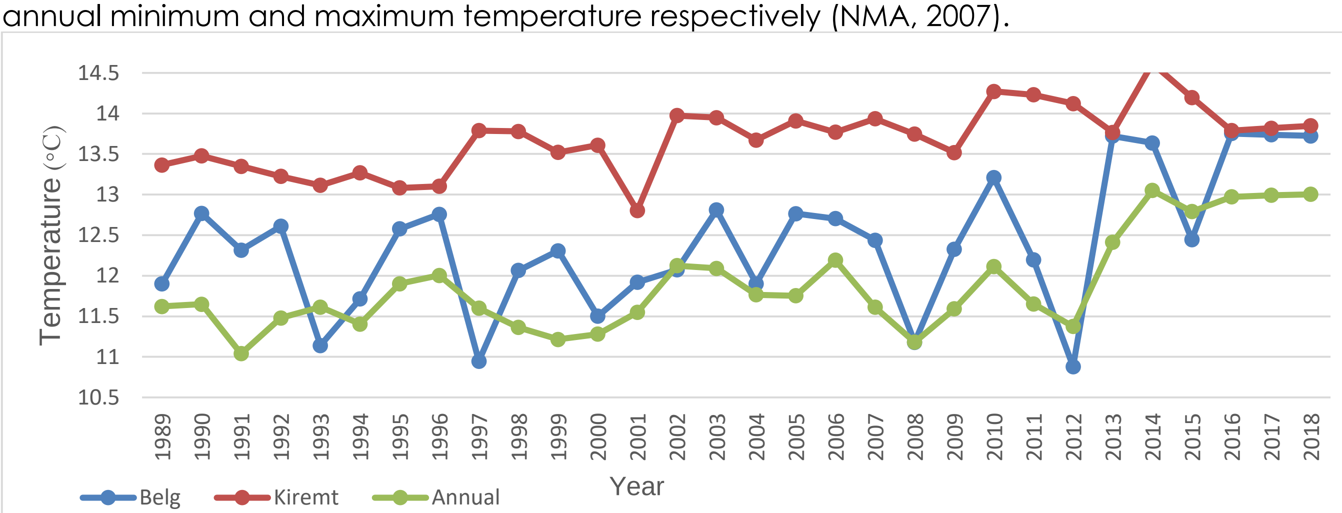

Figure 3. *belg, kiremt,* and annual minimum temperature variability and trends

4. Conclusion

This study was undertaken to assess rainfall and temperature variability and trend in the past 1989-2018 intervals. Rainfall and temperature data were collected from the National Meteorology Agency of Ethiopia. In order to examine the temperature and rainfall variability of

Deder district Statistical tools like mean, standard deviation, coefficient of variability (CV), and p-value comparison were used in Instat(v3.37) statistical software.

In the context of the above-mentioned objectives, the study analyzed the following important rainfall features; rainfall *belg* onset, *kiremt* cessation date, length of growing period (*belg* - *kiremt*), monthly, seasonal and annual rainfall totals and number of rain days and mean temperature were characterized with Instat (v3.37). The observed seasonal and annual rainfall totals were highly variable. *Belg* and annual rainfall totals decrease non-significantly in the study area. The numbers of seasonal *kiremt* and *belg* rainy days at the study area were moderately variable. Moreover, the number of rainy days was more variable during the *belg* season than during the *kiremt* season.

The average onset date of *belg* rainy season, secession date of *kiremt* season rainfall, and length of the growing period was 15 April (115 DOY), 28 October (288 DOY), and 173 respectively. The variability of observed onset date of *belg* rainy season, secession date of *kiremt* season, and length of the growing period was less variable. The average maximum temperature of *belg, kiremt* and annual were; 21.78, 21.17, and 21.8°C with CV of 4.2%, 2.75%, and 2.73% respectively. The average minimum temperature of *belg, kiremt* and annual were; 13.65, 14.81, and 13.18°C with CV of 11.23, 3.85, and 11.02°C respectively. *Belg, kiremt* and annual maximum temperature revealed an increasing trend by the factors of 0.038, 0.037, and 0.044°C per year respectively. Similarly, *kiremt* and annual minimum temperature had revealed an increasing trend by the factors of 0.01 and 0.01°C per year respectively. *Belg,* minimum temperature had revealed a decreasing trend by the factors of -0.02°C.

Authors' Contribution: All the authors jointly contributed to planning, data collection, and writing the article.

Conflicts of Interest: The authors declare no conflict of interest.

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