Original Research Article||

Climatic Trend analysis based on rainfall and temperature in Southern Ethiopia

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Abstract

Reports show that the average global temperature has risen by roughly 0.6°C in the last century and projected to increase by 1.8°C to 4°C by 2100. This global trend is also influencing regional temperature changes in Africa and elsewhere. This study was conducted to provide up-to-date information of climatic trends for the better management of climate change impacts in the southern Ethiopia. The analysis is based on the annual rainfall, maximum, minimum and mean temperature differences across lowland, midland and highland agro-ecologies. The overall objective of the study was to investigate the trend of annual rainfall, maximum, minimum and mean temperature and to see difference between agro-ecologies. The Mann-Kendall trend test and Sen's slope estimate were employed to find the nature of the climate change trend and significance level. The data was analyzed using Microsoft Exel and Mann-Kendall Excel software. The results showed a decreasing trend of total annual rainfall by -2.56 mm, -4.66 mm, and -3.29 mm per year in the midland, lowland, and highland agro-ecologies respectively. The mean temperature has been increased by 0.014°C, 0.032°C, and 0.066°C per year for the midland, lowland and highland agro-ecologies, respectively. The maximum and minimum temperatures also have shown an increasing trend over the observed period. The negative Sen's slope values for the annual rainfall in the three agro-ecologies indicate the declining trends, and the positive Sen's slope values for the maximum, minimum and mean temperature in each of the three agro-ecologies indicate a rising trend over time. Therefore, it is recommended that the climate variability in southern Ethiopia needs further monitoring technique, and there is a need to consider the climate change trend to minimize its effects on agricultural production and overall livelihood of smallholders in the study area.

Keywords: Climate change, climate variability, Mann-Kendall trend test, Sen's slope estimate, Trend analysis

Original submission: February 23, 2025; **Revised submission**: May 08, 2025; **Published online**: October 15, 2025
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INTRODUCTION

Changes in the mean state of temperature and rainfall at global, regional, national and local levels are the key variables as a proxy for the prevalence of climate change. The effects of climate change, such as rising sea levels, melting polar ice caps, wild bushfires, severe droughts, etc., are felt all over the world and have made it one of the most important issues in the field of sustainable development (Ali et al., 2013; Dioha and Kumar 2020). Over the last century, the average global temperature has risen by roughly 0.6°C (IPCC, 2014). The Intergovernmental Panel on Climate Change's Fourth Assessment Report projects that by 2100, the average global surface temperature will increase by 1.8°C to 4°C. Africa has been identified as one of the continents that is most susceptible to the effects of climate change, with the most sensitive economic sector, agriculture (Serdeczny et al., 2017).

Climate change primarily affects developing countries, with Ethiopia being one of the most vulnerable (Cherie and Fentaw 2015). Ethiopia has historically struggled with climate variability, which has an impact on food security, economic growth, and agricultural production (Conway and Schipper, 2011; Tigchelaar et al., 2018). Climate change poses a threat to Ethiopia's agriculture sector which is heavily reliant on rainfall resulting in very poor productivity (Deressa et al., 2011). This is due to the fact that temperature and precipitation are impacted by climate change as expressed by extreme events such as drought and flooding (Muleta et al., 2019). Smallholder farmers in Ethiopia are challenged by increased rainfall variability, rising temperatures, and a high frequency of extreme events as well as the increasing occurrences of pests and diseases (Tesfaye et al., 2016). Indeed, these climatic variations could decrease agricultural production and productivity causing an impact on smallholders' standard of living (Yalew et al., 2017). Consequently, smallholder farmers' status in terms of food security has suffered to a greater extent (Alemu and Mengistu, 2019).

Due to their limited adaptive capacity to climate change impacts and reliance on steady agricultural output from year to year, subsistence farmers are especially susceptible to climate unpredictability (Schlenker and Lobell, 2010; Mekasha et al., 2014; Asfaw et al., 2018). Ethiopia's rainfall and temperature variability are predicted to worsen due to climate change, which could expose farmers to more climate-related risks (Ayanlade et al., 2018; Samy et al., 2019) and the resulting food insecurity (Simane et al., 2016). Ethiopia's rainfall is extremely variable, exhibiting a broad range of patterns with no discernible trend toward change (Conway and Schipper, 2011). Unprecedented extreme occurrences may result from changes in the frequency, severity, spatial expanse, and time scale of extreme climate conditions brought on by climate change (Wagaye and Endalew, 2020).

Ethiopia, like any other low-income and vulnerable country, relies mostly on rain-fed agriculture, which is particularly vulnerable to and has been most negatively impacted by climate change and variability (Moges and Bhat, 2021). Temperature and rainfall trend analysis at the national level is prevalent, but there is very limited study on the local level dealing with this issue. Therefore, the objective of this study was to examine the state of temperature and rainfall trends and their significance level in southern Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted in Dilla-zuria and Bule districts of the Gedeo zone and Abaya district West Guji Zone in the southern part of Ethiopia. Dilla-zuria district is located between 6º15′05″ N-6º26′35″N latitude and 38º 15′ 55″ - 38º 24′ 02″ E longitudes. The altitudinal range of Dilla-Zuria district ranges from 1350 m to 2550 m a.s.l. The mean monthly rainfall of the district ranges from 83.7-310 mm with an average of 172.9 mm. The rainfall is bimodal occurring between March up to June and September to October with the highest amount of rainfall occurring between May and September and the lower between October and February. The mean monthly temperature ranges from 15.4°C to 17.9°C. Based on traditional agro-ecological zones classification, the district is mainly categorized under mid-land agro-ecology which lies between 1500–2300 m.a.s.l. (Gorfu & Ahmed, 2012). Communities rely on agroforestry elements including trees, coffee, enset, fruits and annual and perennial crops.

Bule district is located between 60 04' 16"-60 23' 50" North latitude and 38^0 16' 20"-38^0 26' 11" East longitudes. The mean annual rainfall of Bule district ranges from 1,200 mm - 1,800mm and the mean annual temperature is between 15.1°C and 22.5°C. The district has two rainy seasons namely, the short rainy season (from March to May) and the long rainy season (from July to December). Bule district is categorized under highland agro-ecology. Rain-fed annual crop cultivation, including barley, wheat, maize, and pulse crops like beans and peas, dominates the district's primary land use types overall.

Abaya district is located between latitudes 6°10′ N and 6°20′ N and longitudes 38°00′ E and 38°10′ E. The altitude of the district ranges from 1200-2060 m.a.s.l. It has an estimated average annual rainfall of about 1223 mm and the average annual temperature ranges from 16°C–28°C. Maize, groundnuts, barley, "teff," sorghum, haricot beans, wheat, field peas, and faba beans were the main crops grown. The midland and lowland agro-ecologies share 70% and 30% of the total area of the district respectively.

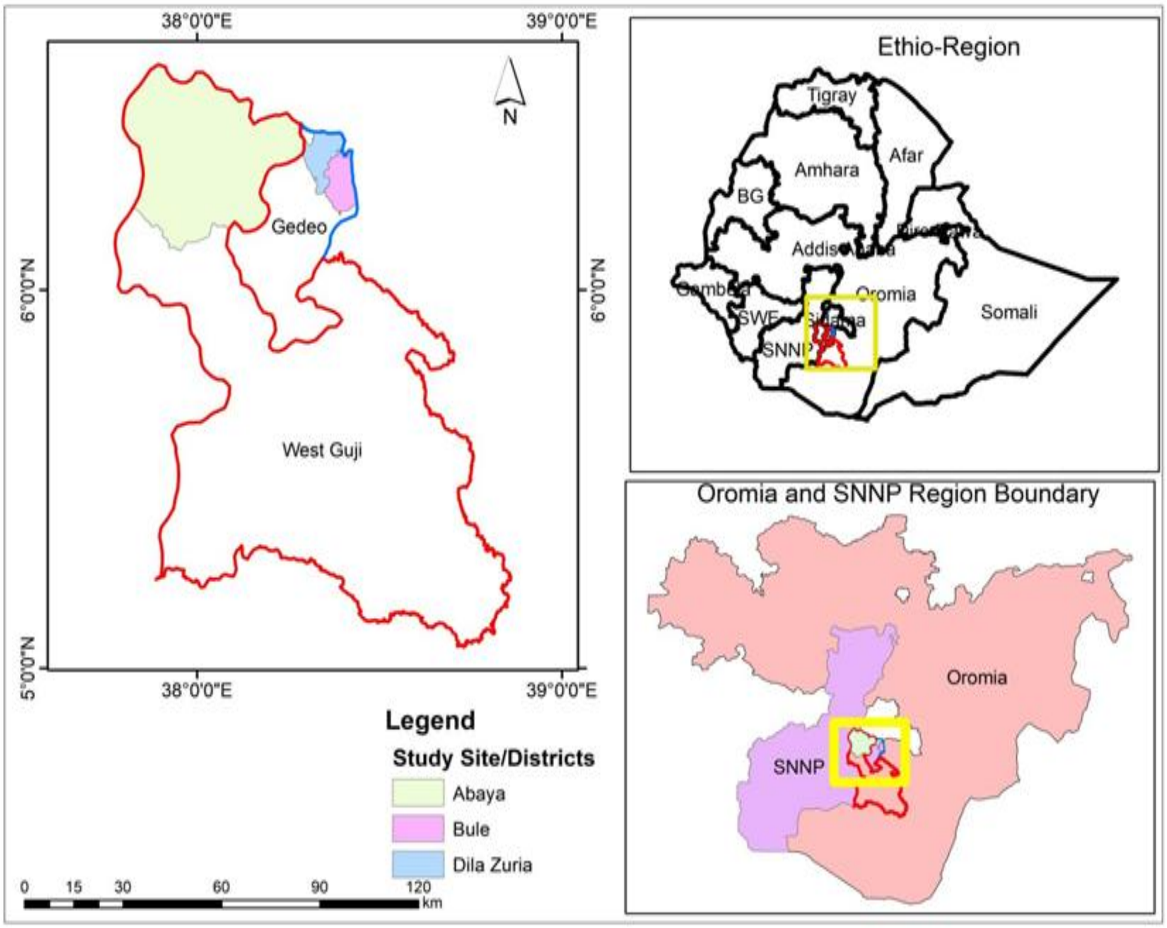

Figure 1. Map of the study area

Data Collection The daily climatic data for rainfall, maximum, minimum and mean temperatures were obtained from the National Meteorological institute (NMI). The historic data of for rainfall, maximum, minimum and mean temperatures was collected from 1981 to 2018. The overall research data for this study were collected based on secondary data sources to address the goals of the study. The data was used to analyses the climate change trend and variability in the study area.

Data Quality Control

The quality of the data was visually and statistically assessed. Visually, the data were checked and detected for outlier and missing data to avoid erroneous/typing error data that can cause changes in the final result. Whereas, the MK test method was checked and tested statistically with the trend free pre-whiting process and the variance correction approaches before applying the test. The trend free pre-whiting process was proposed to remove the serial correlation from the data before applying the trend test (Yue et al., 2002; Hamed, 2009). Likewise, to overcome the limitation of the occurrence of serial autocorrelation in time series, the variance correction procedure was applied as proposed by Hamed and Rao (1998).

Data Analysis

The long-term change of climate factors over time can be studied using a variety of experiments.

Several methods, such as the Standardized Rainfall Anomaly Index to assess the frequency and intensity, were used to measure the variations in observed climatic trends and variability across time. The Mann-Kennel (MK) trend test was used to identify climate trends in time series data, the Standard Precipitation Index (SPI) was used to measure the rainfall deficit of the observed time in the study area, and the coefficient of variation (CV) was used to estimate the seasonal and annual variation of climate change patterns.

Descriptive Statistics

The binning input variables are summarized in the descriptive statistics table. In a single table, the descriptive approach presents univariate summary statistics for many variables. The sample size (number of observations), mean, minimum, maximum, variance, standard deviation, and number of instances with valid values are all examples of statistics. The factor variable's lowest and greatest categories are represented by the values for Minimum and Maximum. On the other hand, the mean is calculated by dividing the sample size (n) by the total of all data values (Xi)

$$Mean(\overline{x}) = \sum_{i=1}^{n} \frac{xi}{n} \quad (1)$$

When Xi is the sum of all data values, n is the sample size

Coefficient of Variation (CV)

During the observation period, CV was used to identify climate variability. Climate variability is divided into three categories: low (CV < 20), moderate (20 < CV > 30), and high (CV > 30). Therefore, the more variable the climate in the study area, the greater the CV value, and vice versa. Equation (2) can be used to get the value of CV.

$$\frac{\delta}{\mu} x100 \quad (2)$$

Where CV is the coefficient of variation, δ is the standard deviation and μ is the mean precipitation of the recording period.

Standard Anomaly Index (SAI)

The SAI was used to calculate the negative and positive anomalies of climate change in the study area. It helps to identify the drought period by determining the dry and wet years of the recording period for precipitation and the hot and cold years of the period for temperature. This index is calculated using the equation given below:

$$\boldsymbol{z} = \frac{\boldsymbol{xi} - \overline{\boldsymbol{xi}}}{\boldsymbol{s}} \quad (3)$$

Where Z is standardized climate anomaly; xi is the annual climate for the historical record; $\overline{xi}$ is the mean of annual rainfall and s is the standard deviation of the annual climate for the historical observation of the time series.

Mann- Kendall (MK)

One popular technique for identifying climatic patterns in time series data is the MK trend test. The MK test is used to identify seasonal and annual trends of climate parameters that are monotonically growing or decreasing. The Mann–Kendall (MK) (non-parametric) test is usually used to detect an upward trend or downward (i.e. monotonic trends) in a series of hydrological data (climate data) and environmental data. The null hypothesis for this test indicates no trend, whereas the alternative hypothesis indicates a trend in the two-sided test or a one-sided test as an upward trend or downward trend (Pohlert, 2016). Climate outliers have less of an impact on the MK test's ability to detect annual and seasonal trend changes. However, if autocorrelation is present in the time series data, the MK test result might contain some mistake. This issue was resolved by doing the pre-whitening technique without making any changes, and there was no discernible amount of serial autocorrelation at any lags.

Following the serial autocorrelation test, the MK test from the Z value and trend from Sen's slope (β) estimation was computed based on monthly, seasonal, and annual rainfall data from 1981–2018 in the study area.

The MK test statistic (S) is calculated as follows:

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\ (xj - xi) \quad (4)$$

$$\text{Sign (x)} = \begin{cases} 1\ if\ x > 0 \\ 0\ if\ x = 0 \\ -1\ if\ x < 0 \end{cases} \quad (5)$$

If S>0, then later observations in the time series tend to be larger than those that appear earlier in the time series and it is an indicator of an increasing trend, while the reverse is true if S<0 and this indicates a decreasing trend.

Sen's estimator is another non-parametric test used to identify a trend in a series as well as the magnitude of the trend. The Sen's slop estimate requires at least 10 values in a time series. This test computes both the slope (i.e. linear rate of change) and intercepts according to Sen's method (Sen 1968). Likewise, as Drápela and Drápelová (2011) described the linear model can be calculated as follows:

$$f(x) = Qx + B \quad (6)$$

Where Q is the slope, B is constant.

RESULT AND DISCUSSIONS

Analysis of Rainfall Variability

The results of the research showed that all the three agro-ecologies exhibited rainfall variability. Bule district (the highland agro-ecology) had highest rainfall variability with the highest CV (16.2) as compared to the two districts, while Dilla-zuria (the midland agro-ecology) had the lowest variability with lowest coefficient of variation (13.3) (Table 1). The highest rainfall variability in Bule district implies that there is unpredictable highest and lowest rainfall occurrence between years which will affects farmers' decision to set planting time of their crop. The rainfall variability can also be explained by occurrence of erratic rain which will also have negative impact on the farming activity in the area. During the focus group discussion, the farmers in the area has witnessed their occurrence of erratic rainfall is becoming the most important problem for the agricultural practices in the area. The farmers also added that the erratic nature of rain had negatively affected their agricultural farm. According to the famers in the study area, the problem even worse in annual cropping than perennial crop farming. Farmers in Abaya district have also informed as high yield loss has been recorded particularly on maize and teff crop. Farmers in Bule district have also told us as they are in fear of land slayed due to erratic rainfall in the district.

Table 1. **Rainfall Summary of the three study districts for the years 1981-2018**

District	N	Minimum	Maximum	Mean	Std.Deviation	CV
Dilla	38	858.4	1461.1	1185.9	157.7	13.3
Abaya	38	780.7	1489.9	1175.3	173.0	14.7
Bule	38	816.5	1696.4	1232.9	199.2	16.2

Analysis of Rainfall Trend

The findings indicated a downward tendency and implied a declining trend over time, with the Mann–Kendall statistic values for the annual total rainfall for Dilla-zuria, Abaya, and Bule district being -1.11, -1.68, and -0.93 respectively (Table 2). The findings also showed that, there was downward trend of rainfall across all agro-ecologies. This implies that the amount of total annual rainfall is declining. For Dilla-zuria, Abaya, and Bule district, the Sen's slope estimate for the annual total rainfall was -2.56, -4.66, and -3.29, respectively. These values indicate a downward tendency and a declining trend over time. Both Sen's slope estimates and the Mann-Kendall statistic indicated a declining trend in the annual total rainfall for each of the three agro-ecologies.

Table 2. **Mann-Kendall trend and Sen's slope estimate of annual rainfall for the years 1981-2018**

District	N	Test Z	Sig.	Q
Dilla	38	-1.11		-2.56
Abaya	38	-1.68	+	-4.66
Bule	38	-0.93		-3.29

Figure 2 shows the calculated yearly rainfall anomalies in the study area from 1981 to 2018. Both positive and negative anomalies were found in the computed standard rainfall anomalies result, suggesting that the observed time series had rainfall variability between districts and years. The year 2010 had the highest positive anomaly (+1.75) and the year 2016 had the highest negative anomaly (−2.08) for the Dilla-zuria district. The year 2010 saw the most positive anomaly (+1.82) for the Abaya district, while the year 2016 saw the highest negative anomaly (−2.28) (Figure 2).

The year 2010 saw the highest positive anomaly (+2.33) for Bule district, while the year 2016 exhibited the highest negative anomaly (−2.09). Based on the results, we can say that 2016 was the driest year for the districts of Dilla-zuria and Abaya. In 2015, these two districts also received a little rain. This is probability due to the fact that Ethiopia endured its first drought in history in 2015 as a result of El Niño that struck several regions of the nation. In contrast to Dilla-zuria and Abaya districts, Bule (highland), still has negative anomalies, but the value does not significantly differ from the mean value. This implies that the highland district is less affected by El Niño as compared to Dilla- zuria and Abaya district. In other word the two districts; Dilla-zuria (the mid-land) and Abaya (the low-land) are more affected by El Niño.

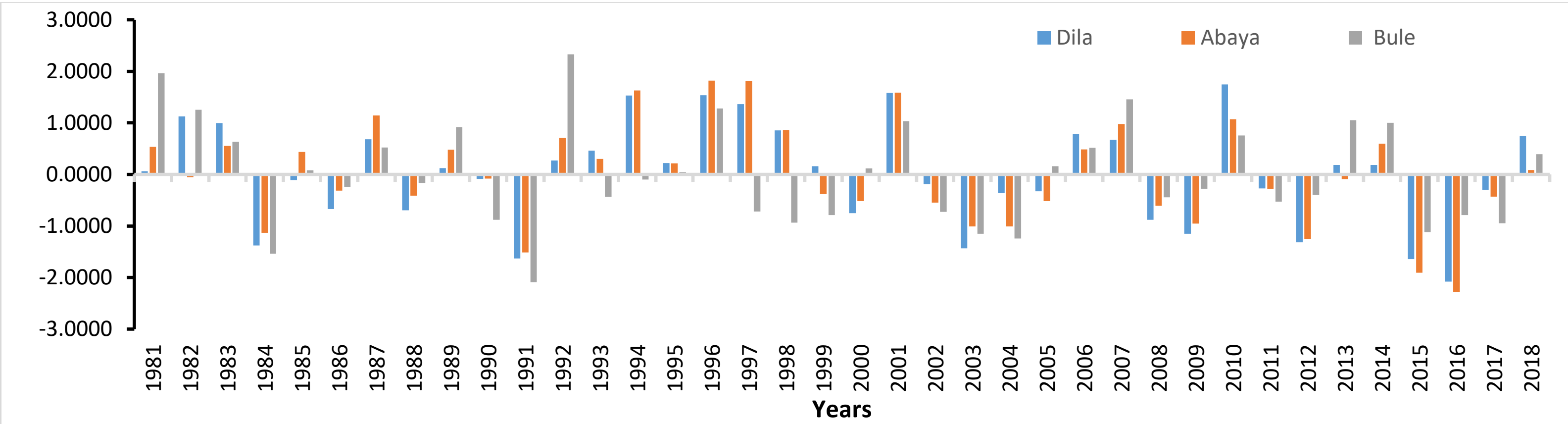

Figure 2. Standard anomalies of Total annual rainfall 1981-2018

Analysis of temperature variability

Table 3 illustrates how the three districts' mean, minimum, and maximum temperatures varied between 1981 and 2018. The highest variability for maximum temperature is was recorded in Abaya district (the lowland agro-ecology) with the coefficient of variation of 3.90%. The highest variability for minimum and maximum temperature was recorded in Dilla-zuria district (the midland agro-ecology) with the coefficient of variation of 23.33 and 14.97% respectively (table 3).

Table 3. Statistics of annual temperature for years 1981-2018

District	Temperature	N	Max.	Min.	Mean	Std.Dev	CV
Dilla-zuria	TMax	38	26.6	22.7	24.4	0.8	3.33
	TMin	38	12.5	0.7	9.0	2.1	23.33
	Tmean	38	18.9	12.9	16.7	2.5	14.97
Abaya	TMax	38	30.3	23.3	28.2	1.1	3.90
	TMin	38	13.8	2.4	11.5	2.2	19.13
	Tmean	38	21.9	15.6	19.9	1.2	6.03
Bule	TMax	38	23.8	20.0	22.3	0.8	3.58
	TMin	38	11.6	8.5	10.2	0.9	8.82
	Tmean	38	17.5	14.8	16.2	0.7	4.32

Analysis of Temperature Trends

Maximum Temperature

According to the results, the maximum temperatures for the three districts had positive Mann–Kendall values. These values indicate that there is an increasing trend and suggest that the temperatures will continue to rise over time. The findings also showed that, although the increases in Dilla-zuria and Abaya were not significant, the trend of the maximum temperature increase in Bule district was significant at a 99.9% confidence level ($p < 0.001$) (Table 4). In this research, the Sen's estimate for the maximum temperature was calculated. The result showed that there was positive Sen's estimate's value indicating that the maximum temperature in each of the three districts has been rising over time. Sen's slope estimates and the Mann-Kendall statistic both reveal a rising trend in the mean maximum temperature across all three districts; therefore, the results are consistent. Figure 3 shows the calculated mean Maximum Temperature anomalies in the research area from 1981 to 2018. The results of the computation of standard rainfall anomalies showed both positive and negative anomalies, suggesting that the observed time series had fluctuation in mean maximum temperature between districts and years. The biggest negative anomaly (-2.00) and highest positive anomaly (+2.58) for the Dilla-zuria district were recorded in 2010 and 2015, respectively. The year 2015 saw the most positive anomaly (+1.81) for the Abaya district, while the year 2010 saw the highest negative anomaly (-4.36). The year 2015 saw the most positive anomaly (+1.71) for Bule district, while the year 2010 saw the highest negative anomaly (−2.74). Given that all three districts had the highest negative anomalies, we can infer from the results that 2010 was the coldest year overall. Since the district as a whole had the largest positive anomalies, 2015 was the hottest year for all three districts. Ethiopia suffered from a catastrophic drought in 2015 as a result of El Niño that struck at various locations throughout the nation.

Minimum Temperature

According to the results, the minimum temperatures for all the three districts had positive Mann-Kendall statistic. The positive values indicate an upward trend and suggest that the temperatures will continue to rise over time. As per Table 4, the results also showed that the minimum temperature increment trend in Bule district is significant at 99.9% confidence level ($p < 0.001$), and in Dilla-zuria, it is significant at 99% confidence level ($p < 0.01$). Meanwhile, the minimum temperature increment trend in Abaya district is significant at 95% confidence level ($p < 0.05$). In this research, the Sen's estimate for the minimum temperature was also calculated. For all the three districts, Sen's estimate for the maximum temperatures had positive value. The positive Sen's estimate's value indicates that the maximum temperature in each of the three districts has been rising over time. Both Sen's slope estimate and the Mann-Kendall statistic reveal an increasing trend in the mean maximum temperature across all three districts, therefore the results are consistent.

Figure 4 shows the calculated mean Minimum Temperature anomalies in the research area from 1981 to 2018. The results of the computation of standard rainfall anomalies showed both positive and negative anomalies, suggesting that the observed time series had fluctuation in mean minimum temperature between districts and years. The year 1993 had the highest positive anomaly (+1.59) and the year 1983 had the highest negative anomaly (-3.80) for the Dilla-zuria district. The highest positive anomaly (+1.021) and negative anomaly (-4.04) were observed in 1993 and 1986, respectively, for the Abaya district. In the Bule district, the largest negative anomaly (−1.73) was recorded in 1989, while the highest positive anomaly (+1.62) was recorded in 2009. The results show that every district experienced negative anomalies between 1984 and 1988. Although the largest negative anomaly for Bule district was recorded in 1989, the highest negative anomalies for Dilla-zuria and Bule districts were also recorded during this time period. Abaya and Bule districts saw positive anomalies from 2010 to 2018, meaning that the lowest temperatures recorded in each of the aforementioned years were higher than the average minimum temperatures over the 1981–2018 time frame. The period from 2010 until 2018 is a period during which Dilla-zuria district also had the majority of positive anomalies, with the exception of 2015 and 2016, during which Dilla-zuria district experienced negative abnormalities.

Annual Mean Temperature

According to the results, the average temperatures for Dilla-zuria, Abaya, and Bule districts had positive Mann-Kendall statistic values. The positive values indicate an increasing trend and suggest that the temperatures will continue to rise over time. Additionally, the results showed that the minimum temperature increment trend in Bule district is significant at 99.9% confidence level ($p < 0.001$) and in Dilla-zuria, it is significant at 95% confidence level ($p < 0.05$). In contrast, the minimum temperature increment trend in Abaya district is non-significant ($p < 0.05$) (Table 4). The results of this study concur with those of the study of Asfaw et al., (2018); Roy and Das (2013), Tabari and Talaee (2011), Conway et al., (2005) and Stafford et al., (2000). In this study, the Sen's estimate for the annual mean temperature was also calculated. For the all the three districts Sen's estimate's value was positive indicating that the maximum temperature in each of the three districts has been rising over time. Both Sen's slope estimate and the Mann-Kendall statistic reveal a rising trend in the mean maximum temperature across all three districts, therefore the results are consistent.

Figure 5 shows the calculated mean annual temperature anomalies in the research area from 1981 to 2018. The calculated standard mean annual temperature anomalies result showed both positive and negative anomalies, suggesting that the observed time series had mean annual temperature fluctuation between districts and years. The maximum positive anomaly (+1.9248) and the highest negative anomaly (-3.46) for the Dilla-zuria district were recorded in 1993 and 1986, respectively. The maximum negative anomaly (-3.54) and highest positive anomaly (+1.63) for the Abaya district were recorded in 1986 and 1993, respectively. Bule district's had greatest positive anomaly. The largest negative anomaly (−1.97) was recorded in 1989, while the highest positive anomaly (+1.68) was recorded in 2009. The results show that every district experienced negative anomalies between 1984 and 1990. During this period, the three districts' highest negative anomalies were also noted. However, from 2011 to 2018, all three districts saw positive anomalies, meaning that the lowest temperature recorded in each of the aforementioned years was higher than the average minimum temperature throughout the 1981–2018 time frames. According to the results, the average temperatures for Dilla-zuria, Abaya, and Bule districts had Mann-Kendall statistic (Z) values of 0.53, 2.16, and 5.10, respectively. These values indicate an upward trend and suggest that the temperatures will continue to rise over time. Additionally, the results showed that the minimum temperature increment trend in Bule district is significant at 99.9% confidence level ($p < 0.001$) and in Dilla-zuria, it is significant at 95% confidence level ($p < 0.05$). In contrast, the minimum temperature increment trend in Abaya district is non-significant ($p < 0.05$) (Table 4). The results of this study concur with those of the study of Asfaw et al., 2018; Roy and Das (2013), Tabari and Talaee (2011), Conway et al., (2004), Daniel et al., (2014), and Stafford et al., (2000). In this study, the Sen's estimate (Q value) for the yearly mean temperature was also calculated. For the districts of Dilla-zuria, Abaya, and Bule, the Sen's estimate (Q value) for the mean temperatures was 0.014, 0.032, and 0.066, respectively. Sen's estimate's positive value (Q value) indicates that the maximum temperature in each of the three districts has been rising over time. Sen's slope estimate (Q) and the Mann-Kendall statistic (Z) both reveal a rising trend in the mean maximum temperature across all three districts; therefore, the results are consistent. Figure 5 shows the calculated mean annual temperature anomalies in the research area from 1981 to 2018. The calculated standard mean annual temperature anomalies result showed both positive and negative anomalies, suggesting that the observed time series had mean annual temperature fluctuation between districts and years. The highest positive anomaly (+1.9248) and the highest negative anomaly (-3.46) for the Dilla-zuria district were recorded in 1993 and 1986, respectively. The highest negative anomaly (-3.54) and highest positive anomaly (+1.63) for the Abaya district were recorded in 1986 and 1993, respectively. Bule district has highest positive anomaly. The highest negative anomaly (−1.97) was recorded in 1989, while the highest positive anomaly (+1.68) was recorded in 2009. The results show that every district experienced negative anomalies between 1984 and 1990. During this period, the three districts' highest negative anomalies were also noted. However, from 2011 to 2018, all three districts saw positive anomalies, meaning that the lowest temperature recorded in each of the aforementioned years was higher than the average minimum temperature throughout the years1981–2018.

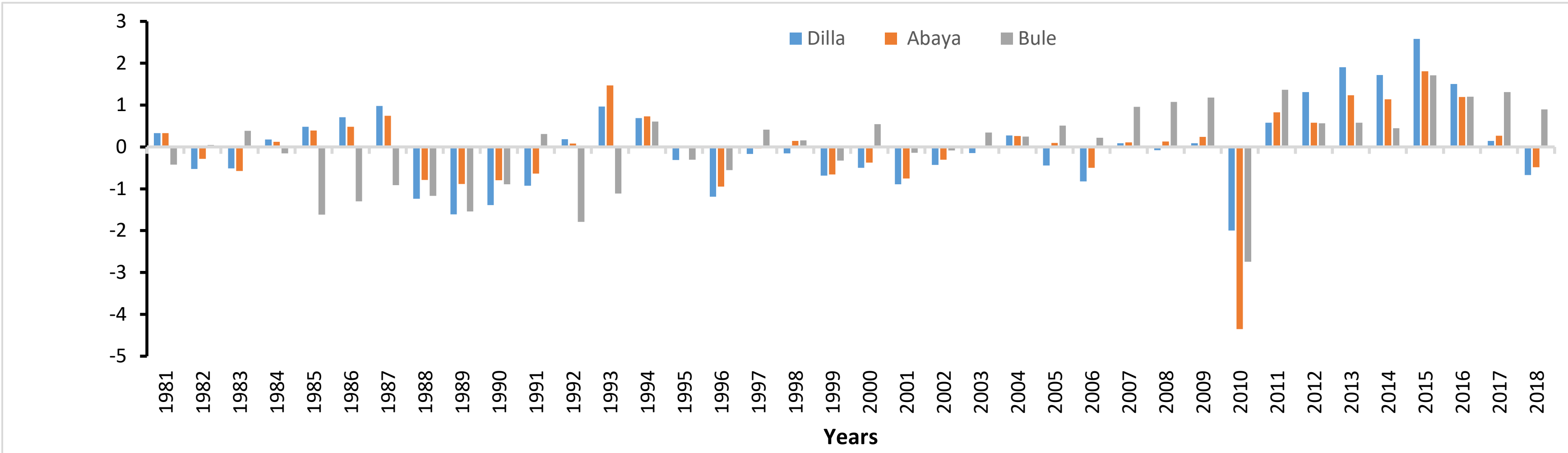

Figure 3. Standard anomalies of maximum Temperature 1981-2018

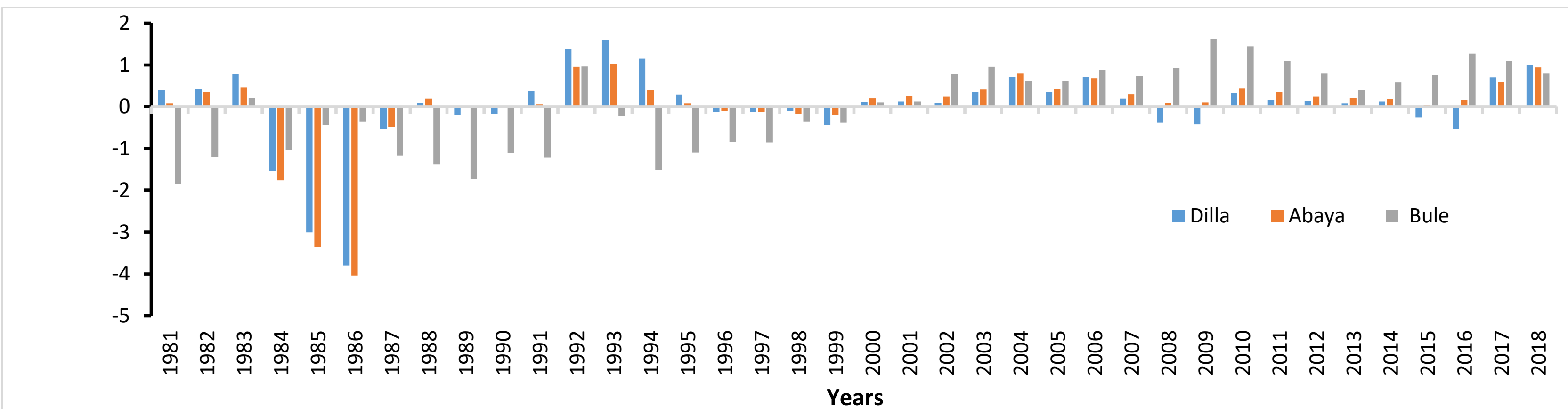

Figure 4. Standard anomalies of minimum Temperature 1981-2018

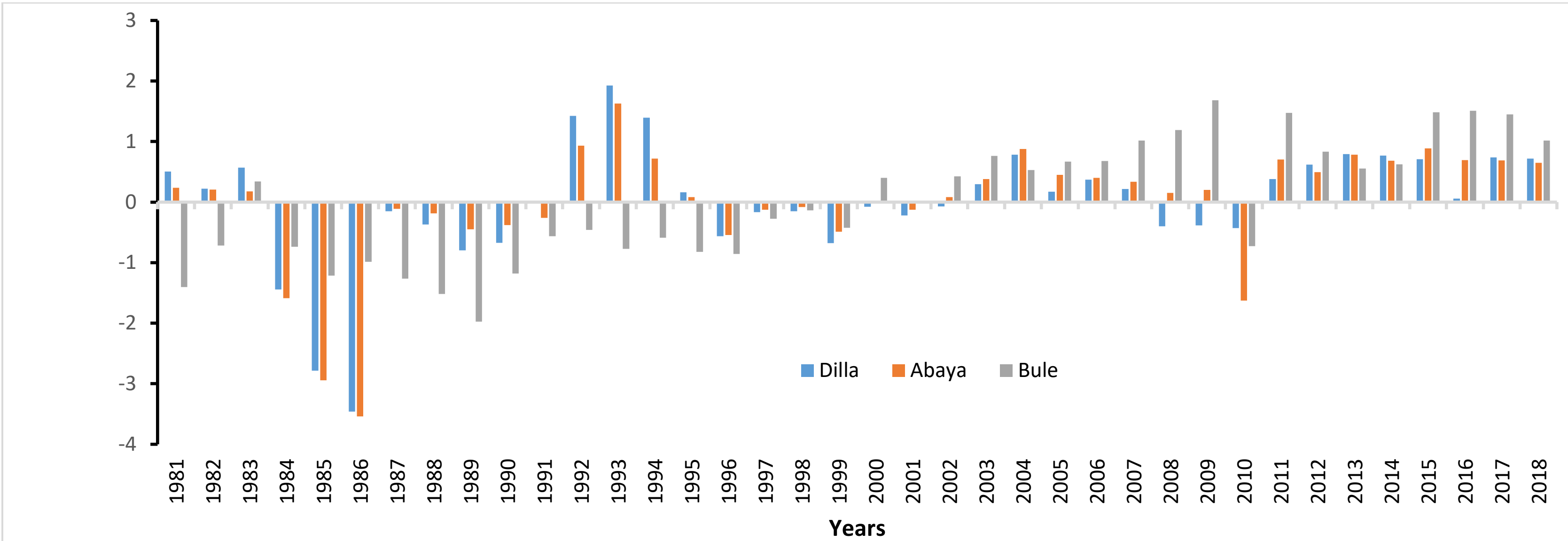

Figure 5. Standard anomalies of mean Temperature 1981-2018

Table 4. Mann-Kendall trend and Sen's slope estimate of maximum, minimum and mean Temperature Dilla-zuria, Abaya and Bule district 1981-2018

Variable	District											
	Dilla-zurial				Abaya				Bule			
	N	Test Z	Sig.	Q	N	Test Z	Sig.	Q	N	Test Z	Sig.	Q
T max	38	1.73		0.022	38	1.84		0.023	38	4.60	***	0.052
T min	38	2.34	*	0.03	38	3.21	**	0.04	38	5.85	***	0.05
T mean	38	0.53		0.014	38	2.16	*	0.032	38	5.10	***	0.066

CONCLUSIONS

In this study, variability and trend analysis of annual rainfall, minimum temperature, and mean temperature has been conducted for highland, midland and lowland agro-ecologies in southern Ethiopia. The result showed that highest rainfall variability was recorded in highland agro-ecology there was downward trend of rainfall in all agro-ecologies.

Both Sen's slope estimates and the Mann-Kendall statistic indicated a declining trend in the annual total rainfall for all the three agro-ecologies. Sen's slope estimates and the Mann-Kendall statistic both reveal increasing trend in the maximum, minimum and mean temperature across all the three agro-ecologies. The result also showed that there is significant increment on minimum temperature in midland agro-ecology. There was also significant increment on minimum and mean temperature in midland agro-ecology. In highland agro-ecology, there was strong significant increment in maximum, minimum and mean temperature in highland agro-ecology. From the result we can conclude that the result of both Sen's slope estimate and the Mann-Kendall statistic are consistent. Thus, the decreasing trend of rainfall and increasing trend of temperature due to climate change and other factors can lead to weather extremes in the study area.

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