

Research Article

Climate Change, Analysis of Temperature and Rainfall Trend in Northern Ethiopia: In the Case of Dessie Zuria

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Abstract

This study presented an analysis of long-term temperature and precipitation trends in the Dessie Zuria from 1981 to 2022. To monitor climate change in the study area, it was necessary to analyze the trends in temperature and rainfall in particular. The aim of this study was to assess the monthly and annual rainfall and temperature trends, descriptive statistical analysis, and the impact of climate change in the study area. In this study, CDT, R software, Arc Map, and Excel 2010 were used for data and map preparation, as well as descriptive statistical analysis. The Mann-Kendall and Sen's slope trend test were to detect trends and the magnitude of change. According to the analysis of average yearly maximum temperature coefficient of variation was varied from 1.9% (Tita) and 4.5% (Guguftu). The average yearly maximum temperature was a non-significant increasing trend at Dessie, Tita and Tebasit station but a significant increasing trend at Guguftu station. The annual minimum temperature coefficient of variation was 13.9%, 19.1%, 10.6% and 15.4% at Dessie, Guguftu, Tita and Tebasit station respectively. The average yearly minimum temperature was a non-significant increasing trend at Guguftu and Tebasit station but a non-significant decreasing trend at Dessie and Tita station. The monthly rainfall coefficients of variation were moderate variability in July and August, but other months were high variability. The annual rainfall was a non-significant increasing trend at Dessie and Guguftu station but significant increasing trend at Tita and Tebasit station. The slopes of annual rainfall were changed at 4.7mm, 7.4mm, 6.2mm and 6.1mm per year at Dessie, Guguftu, Tita and Tebasit station respectively. The slope of average annual minimum temperature was changed at -0.02 °C, 0.01 °C, -0.004 °C and 0.014 °C per year at Dessie, Guguftu, Tita and Tebasit station respectively. The slope of average annual maximum temperature was increased at 0.006 °C, 0.03 °C, 0.005 °C and 0.01 °C per year at Dessie, Guguftu, Tita and Tebasit stations in the study area respectively. This situation of temperature increment was influenced by climate change in the study area. Therefore, since the results of this work are necessary, relevant stakeholders must adopt policies that help prevent climate change.

Keywords

Climate Change, Temperature, Mann-Kendall, Dessie Zuria and Rainfall

1. Introduction

Climate change, driven by fluctuations in solar radiation and anthropogenic factors, has altered Earth's thermal equilibrium over millennia [1]. Climate change has also become a

real phenomenon, as it is evident from an increased world temperature, which is known as global warming while many factors continue to influence global warming [2]. Global land

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surface temperatures have risen by 0.74 °C since the early 20th century, with 0.55 °C of this increase occurring in the last three decades [3]. Regional studies corroborate these trends, noting hotter and drier conditions across Africa [4, 5]. Ethiopia, among the most climate-vulnerable nations, faces escalating droughts that threaten agricultural livelihoods [6]. The Ethiopian climate is also characterized by a history of climate extremes, such as flood, and increasing and decreasing trends in temperature and precipitation, respectively [7]. Climate is the condition of rainfall in a vast region and occurs over a long period, which is told by a major variable, similar to rainfall and temperature [8]. Climate is one of the crucial factors in the earth's system. Extended climate-associated changes in rainfall patterns and temperature are most likely to enhance the incidence of floods and droughts in Ethiopia [4]. Climate systems are also governed by variables such as temperature, and precipitation that collectively influence ecological and socioeconomic stability [6, 7]. Developing countries are substantially affected by climate change, and Ethiopia is an illustration of the most vulnerable countries [11]. Vulnerable and susceptible to climatic fluctuation and variability; the climatic trend in temperature and rainfall is more likely to result in an increase in the number and severity of natural disasters [10].

Rainfall is a pivotal component of rainfall-runoff relations and affects flood tide or failure evaluation and relief measures [12]. The periodic rainfall distribution is largely declining in the westward expansion of the climaxes, including the upper Erer sub-basin, Ethiopia [13]. The annual rainfall showed significant decreasing trends with a value ranging from 5.92 mm per year to 9.74 mm per year in the Tana basin region, Ethiopia [10]. Also, annual rainfall was significantly declined each year in northern Ethiopia [14]. An abrupt decline in rainfall and increased temperature were observed from 1970 to 2016 in the Northeastern Highlands of Ethiopia [5].

Temperature plays a significant role in evaporation, transpiration, and water demand and thus considerably influences both water accessibility and management approaches [15]. The average annual minimum temperature over the country has been increasing by about 0.25 °C every 10 years, while average annual maximum temperature has been increasing by about 0.1 °C every decade [14]. Temperature and rain can have a negative impact on crop resources and soil water available [16]. The increase in air temperature and variability in rain are formerly apparent in different corridors of the world, and their impacts on the terrain (e.g., ecosystem and biodiversity) and deathly system are getting evident [17].

Especially the increase in temperature and drop in rainfall in areas affect substantially the health, economic, rest conditioning, and well-being of civic residents. Thermal stress caused by warming largely affects the health of vulnerable people [12, 18]. In the current study area, the gap of the study is the lack of awareness about climate change due to the expansion of urbanization, which is the changing of agricultural areas similar to forest, bare land, and foliage. The aim of this

study is to assess the monthly and annual rainfall and temperature trends, descriptive statistical analysis and the impact of climate change in the study area. Hence, the purpose of this study was the discovery of significant trends or changes in the monthly and annual climatic conditions in the study area. This includes an understanding of its climate change. The findings will advance in convenience in expressing better climate change adaptation and mitigation techniques.

2. Materials and Methods

2.1. Background of the Study Area

Dessie zuria is one of the woredas in the Amhara region of Ethiopia. It is located at the eastern edge of the Ethiopian highlands and lowlands in the south wollo zone, roughly 423 kilometers from Bahir Dar. Dessie zuria is positioned 253 kilometers northeast of Addis Ababa along the main trace coming to Woldia and Mekele. The Climate of Dessie zuria is classified in the Dega, Woina Dega and Kola climatic zone. This lies between 1,670 to 3,848 meters above mean sea level.

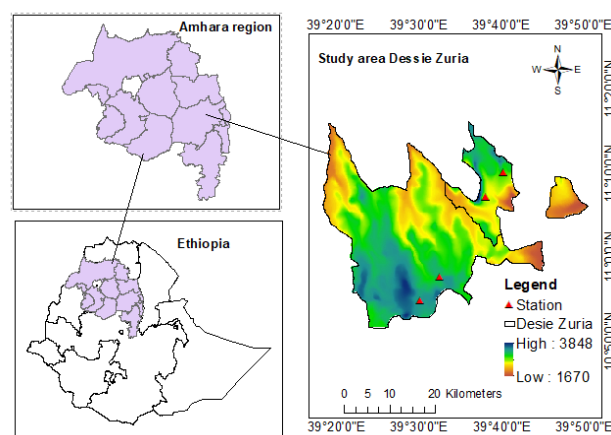


Figure 1. Geographical Map of Dessie Zuria.

2.2. Meteorological Climate Datasets

Historical Enact station based data of daily rainfall, minimum and maximum temperatures of Dessie Zuria meteorological station for 42 years (1981-2022) were obtained from the Ethiopian Meteorology Institute. Rainfall and temperature are the critical climate change data because decreased forest cover, agricultural land and urban expansions are highly exacerbated. In this paper, rainfall and temperature were analyzed in the study area.

Data Quality Control

The quality of the data was assessed visually and statistically. Finally, a Quality control check was applied for daily rainfall, maximum and minimum temperature data by running a macro automatic check [19]. Before applying the descriptive

statistics and trend test system was statistically tested with a bias-free pre-whitening process and a collision correction approach [9].

2.3. Methods

2.3.1. Descriptive Statistics

The process of measuring bivariate summary statistics such as temperature and rainfall for multiple variables in a single table is known as descriptive statistics. The sample size, average, minimum, maximum, variance, and standard deviation are all examples of descriptive statistics. Values for minimum and maximum correspond to the lowest and highest values of the given variable respectively. We calculated the mean by adding sequential data values X_i and dividing the sum by the sample size n .

$$\text{Average } (x) = \sum_{i=1}^n \frac{x_i}{n} \quad (1)$$

Where n is the number of the given sample data.

Variance is the average-squared deviations from the arithmetic average, and the standard deviation is the square root of the variance. Rainfall and temperature variability are measured using both variance and standard deviation. It can be calculated as follows [22]:

$$\text{Variance } (s^2) = \frac{\sum_{i=1}^n (x_i - \mu)^2}{(n-1)} \quad (2)$$

$$\text{Standard deviation } (s) = \sqrt{s^2} \quad (3)$$

The generalized summary of descriptive statistics used to analyze and compute using the above formula [7, 20].

2.3.2. Variability Analysis

The coefficient of variation was used to calculate the variability of temperature and rainfall time series data in the research area [7, 16]. Coefficient of variation was defined as measures of dispersion or spread, describe how spread out or dispersed the data points are in a dataset [4]. A smaller value of coefficient of variation is satisfied with less variability, and reciprocal, which is computed as [21]:

$$CV = \frac{\text{standard deviation}}{\text{mean}} * 100 \quad (4)$$

Where CV is the coefficient of variation.

$$\text{Variance } (s^2) = \frac{1}{40} \left(N((N-1)(2N+5) - \sum_{k=1}^t mk(mk-1)(2mk+5)) \right) \quad (7)$$

$$\text{Standard deviation } (S) = \sqrt{\text{variance}(s^2)} \quad (8)$$

Where N is the number time series data, t is a set of each

The rainfall and temperature variability analysis is classified as less ($CV < 20$), moderate ($20 < CV < 30$), and high ($CV > 30$) using CV [12].

2.3.3. Mann-Kendall Trend Test

The MK trend test is a non-parametric system used to determine a straight or not trend in a series. It's also indicated whether a time series has an adding or dwindling trend [9]. The MK trend test was generally to describe trends in a series of temperature and rainfall data. The non-parametric Mann-Kendall (MK) test [22, 23] is used to examine the statistical significance of the seasonal distributions and slope pitch estimator [24]. Based on the 5% significance level, if the p -value is less than 0.05, then the alternative hypothesis was rejected, which implied the presence of a trend in the data, and if the p -value is greater than 0.05, the indispensable theory was accepted, which represented the absence of a trend in the data [25].

However, to comprehend the true trend in the seasonal temperature and rainfall at Dessie Zuria, they were examined to span the time under exploration using RStudio and a Microsoft Excel spreadsheet. The MK trend test uses the sequence of n data points and supposed x_i and x_j are two data subsets where $i = 1, 2, 3 \dots N-1$ and $j = i+1, i+2, i+3 \dots N$. The data values are estimated as an order time series, and all posterior data values are likened to each data value. The sequential time data $x_1, x_2, x_3 \dots x_N$ indicates N number of data points.

The MK trend statistic is sketched a formula as follows:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^N \text{sign}(x_j - x_i) \quad (5)$$

Where n is the number of data,

x_i and x_j are the N^{th} time series data,

$\text{sgn}(x)$ is the sign function, which can be calculated by the following Equation:

$$\text{Where sign } (x) = \begin{cases} 1 & \text{if } x_i - x_j > 0 \\ 0 & \text{if } x_i - x_j = 0 \\ -1 & \text{if } x_i - x_j < 0 \end{cases} \quad (6)$$

Note that if $S > 0$, also the trend an upward and if $S < 0$ this indicates a dwindling trend or over.

It's necessary to decipher the probability associated with statistically S and roughly normal distribution. When $N > 10$, the average of S is zero, and the friction related to S can be calculated from [2, 19]:

sample climate data, and it is the sequential number of sample data in the k^{th} group. Thus, a statistically increasing or decreasing trend was determined using the MK trend test. The Mann-Kendall test statistic (Z_{mk}) is computed as follow:

$$Z_{mk} = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S < 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & \text{if } S > 0 \end{cases} \quad (9)$$

The test statistics Z_{mk} is used to determine the measure of the significance of a trend. If the value of $Z_{mk} > 0$, it indicates increasing trends, while values of $Z_{mk} < 0$ show decreasing trends [7, 10, 26].

2.3.4. Sen's Slope Estimator Test

Slope estimator is another non-parametric trend test used to identify a trend in a series, as well as show the magnitude of the trend [7]. However, the true pitch can be estimated using a simple non-parametric test known as a slope pitch system if a direct trend is present in the time series. In this method, the slopes (β) of all sample data are first calculated by:

$$\beta = \frac{x_j - x_k}{j - k} \text{ for } i=1, 2, 3 \dots N \quad (10)$$

Where x_j and x_k represent the sample value at the time-steps 'j' and 'k,' with 'j' correspondingly greater than 'k.' A positive value of β indicates an upward (increasing) trend, and a negative value indicates a downward (decreasing) trend in the time series [7]. Both the Mann-Kendall and the Sen's slope tests require time series to be serially independent, which can be accomplished using the pre-whitening technique.

3. Result and Discussion

3.1. Maximum Temperature

The descriptive analysis of monthly and yearly maximum temperature at Dessie zuria meteorological station is presented in Table 1. The descriptive statistical analysis was carried out on the parameters like average, standard deviation and coefficient of variation of monthly and average annual

maximum temperature for the period 1981-2022. The maximum temperature is high during June for all meteorological stations but at Tebasit station both in June and August. The lowest amounts of maximum temperatures were during November at Dessie, Guguftu and Tebasit and in January at Tita station. During the study period, the highest monthly maximum temperature ranges 22.2 °C and 26.7 °C with the standard deviation of 0.93 and a coefficient of variation of 3.7% was recorded at Dessie station in June while the lowest monthly maximum temperatures ranges from 9.8 °C to 17.7 with standard deviation of 1.33 and a coefficient of variation of 7.6% was recorded at Guguftu station during November. The annual maximum temperature ranged from 21.5 °C to 23.7 °C and 21.3 °C to 23.3 °C at Dessie and Tita station respectively. This is supported by [9] indicated the average yearly maximum temperature varied from 18.25 °C to 23.52 °C for Entoto and Bole stations. The average yearly maximum temperatures were 22.4 °C and 22.2 °C at Dessie and Tita station respectively. The result obtained in this study agrees with the findings of an earlier study, whose results revealed that average yearly maximum temperature is 23.5 °C for Addis Ababa meteorological station [7]. The annual maximum temperatures were ranges from 13.0 °C to 17.4 °C and 14.7 °C to 18.3 °C at Guguftu and Tebasit respectively and similarly the average annual maximum temperature 15.3 °C and 16.8 °C. The monthly maximum temperature coefficients of variation ranged from 3.7% to 5.2%, 5.3% to 7.7%, 3.0% to 5.7% and 5.0% to 7.6% at Dessie, Guguftu, Tita and Tebasit respectively. This means a clear measure of lower temperature variability, but Dessie has the most stable maximum temperatures while Tita, Guguftu and Tebasit experience the greatest relative variation as compared Dessie station. In addition, the average yearly maximum temperature coefficient of variation was varied with 1.9% (Tita) and 4.5% (Guguftu). When we came to the annual standard deviations were 0.46 °C, 0.78 °C, 0.42 °C and 0.60 °C at Dessie, Guguftu, Tita and Tebasit respectively. On the other hand, average annual maximum temperatures were recorded 22.4 °C, 15.3 °C, 22.2 °C and 16.8 °C at Dessie, Guguftu, Tita and Tebasit respectively.

Table 1. Statistical Information of Monthly Maximum Temperature Analysis in Degree Celsius.

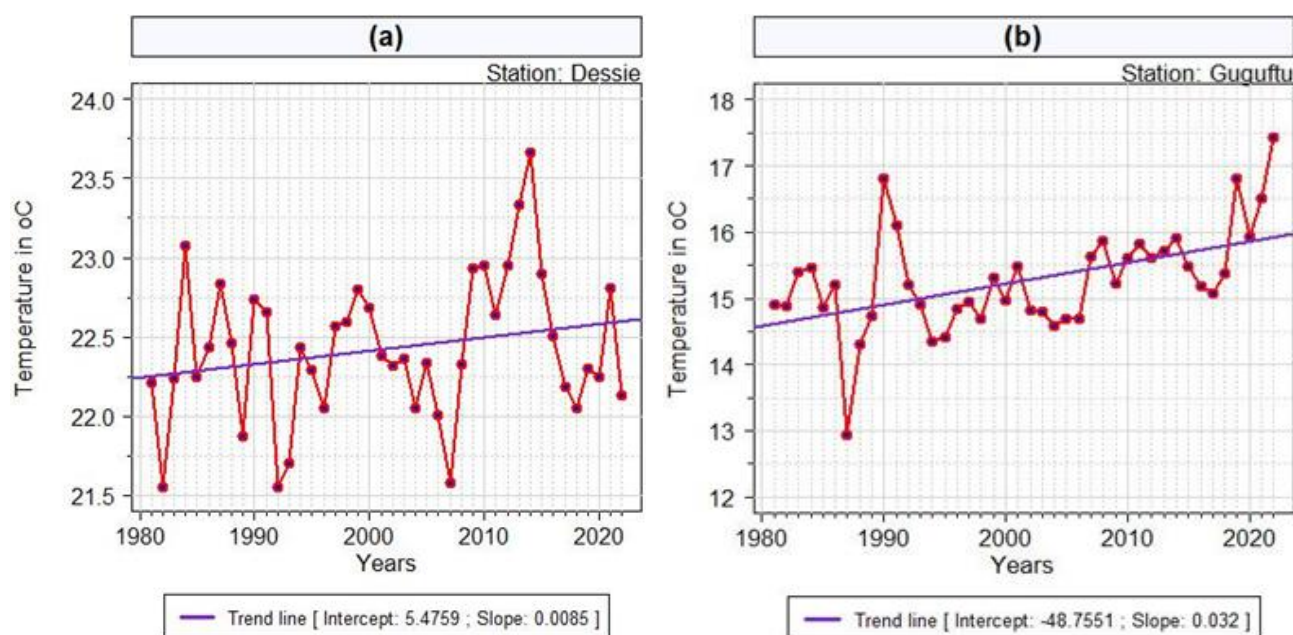
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dessie	Minimum	18.4	19.0	20.0	20.2	21.9	22.2	21.7	21.6	21.0	20.1	19.5	19.1	21.5
	Maximum	22.0	23.6	24.0	25.2	25.9	26.7	26.6	25.5	24.7	23.4	23.1	22.2	23.7
	Average	20.5	21.6	22.3	22.8	23.8	25.3	23.7	22.9	22.5	21.9	21.3	20.5	22.4
	Std Dev.	1.03	1.08	1.08	1.19	0.96	0.93	1.06	0.87	0.82	0.80	0.91	0.76	0.46
	CV	5.0	5.0	4.9	5.2	4.0	3.7	4.5	3.8	3.7	3.7	4.3	3.7	2.1
Guguftu	Minimum	11.4	13.1	12.5	14.6	14.0	12.3	11.8	12.5	11.7	11.1	9.8	10.0	13.0
	Maximum	17.9	18.2	18.2	20.4	18.8	19.5	17.3	18.0	18.9	17.3	17.7	18.0	17.4
	Average	15.3	15.7	15.7	15.9	16.0	16.2	15.0	14.8	14.8	14.6	14.6	14.8	15.3

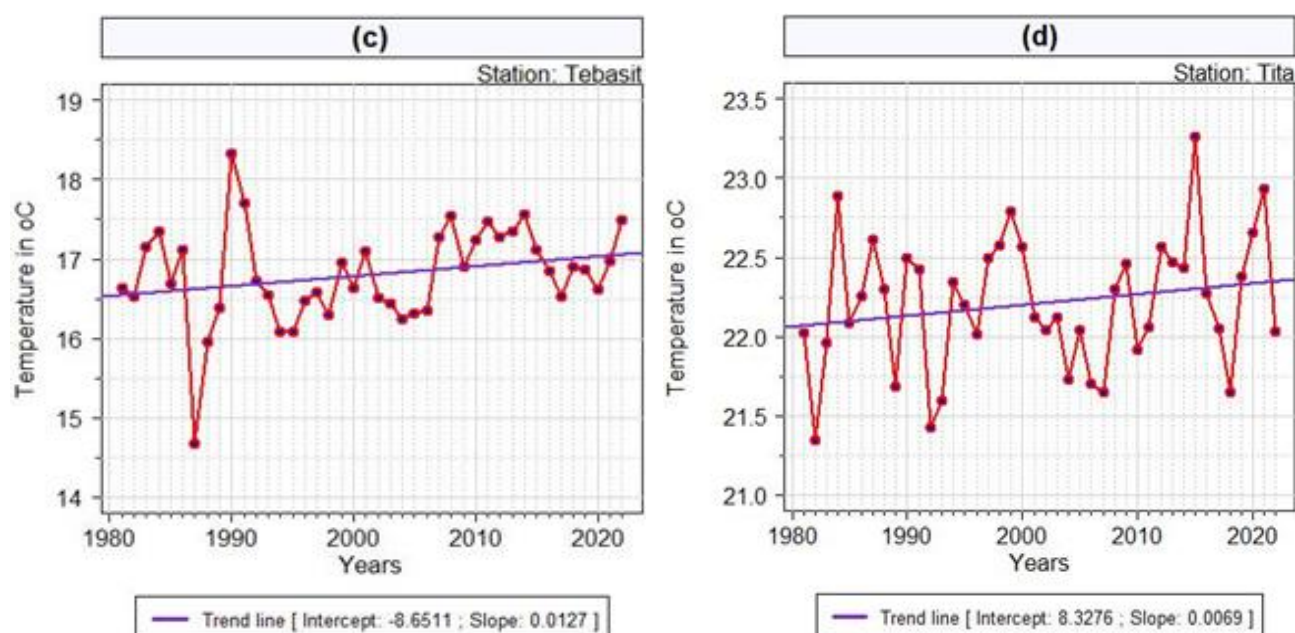
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tita	Std Dev	1.18	0.97	0.97	1.20	1.02	1.15	1.06	1.08	1.09	1.18	1.33	1.38	0.78
	CV	6.6	5.3	5.3	5.9	5.4	5.9	6.1	6.0	5.8	6.8	7.6	7.7	4.5
	Minimum	17.8	18.7	20.1	20.0	21.8	23.1	21.8	21.3	20.8	19.1	19.2	18.7	21.3
	Maximum	21.8	23.4	24.4	25.1	26.0	27.1	26.5	25.0	23.5	23.9	22.4	21.7	23.3
	Average	20.1	21.3	22.1	22.7	23.9	25.5	23.6	22.6	22.3	21.4	21.0	20.1	22.2
	Std Dev	1.06	1.12	1.02	1.29	0.96	0.77	1.03	0.73	0.66	0.80	0.77	0.73	0.42
	CV	5.3	5.3	4.6	5.7	4.0	3.0	4.4	3.3	3.0	3.7	3.7	3.6	1.9
	Minimum	13.0	14.8	14.2	16.0	15.7	14.1	13.8	14.5	13.6	12.9	11.6	11.7	14.7
	Maximum	19.2	19.6	19.3	20.2	19.6	19.7	18.8	19.7	18.8	18.7	19.1	19.3	18.3
	Average	16.6	17.1	17.2	17.4	17.5	17.9	16.7	16.5	16.3	16.2	16.1	16.1	16.8
Tebasit	Std Dev	1.15	0.94	0.87	0.95	0.80	0.93	1.00	0.99	0.92	0.99	1.19	1.22	0.60
	CV	6.9	5.5	5.0	5.5	4.6	5.2	6.0	6.0	5.6	6.1	7.4	7.6	3.6

Source: Station based ENACT temperature data from Ethiopian Meteorology Institute from 1981-2022

Annual maximum temperature trend was a statistical tool used to visually represent how temperature changes over time, typically displayed on a line graph as shown [Figure 2](#). Temperature change has a major impact on the vegetation cover, population life and aquatic system in the study area. The average yearly maximum temperature trend analysis was conducted from 1981-2022. According to this a linear regression model, the slope line change of the average annual maximum temperature was increased by 0.0085 °C, 0.032 °C, 0.0127 °C and 0.069 °C per 42-year period at Dessie, Guguftu,

Tebasit and Tita respectively. This indicates all the four stations revealed climate change and a warming temperature but Tita station a rapid change in temperature and will likely face greater environmental stress while Dessie experienced little change over the same period. In the present study, Tebasit station result is agreed with [\[27\]](#) the linear regression trend analysis of mean annual maximum temperature rate of change is the slope line which is about 0.018 °C per 20 year during the period of 1995-2014.





Source: Station based ENACT temperature data from Ethiopian Meteorology Institute from 1981-2022

Figure 2. Annual Maximum Temperature Trend over a= Dessie, b= Gugufu, c= Tebasit and d= Tita.

Based on the applied statistical trend test, the monthly maximum temperatures at Dessie station were a monotonic increasing trend except in May, June, July, August and November while at Gugufu station revealed statistically increasing trends in all months (Table 2). The maximum temperature at Tita station showed significant increasing trends except in June, July, August, November, and December. On the other hand, the maximum temperature at Tebasit station showed statistically significant increasing trends except in June, and July. There were statistically non-significant trends at Dessie station in all months except April and statistically significant trends at Gugufu station in all months except January, February, May, June and July. There were statistically significant trends at Tita station in only April and statistically significant trends at Tebasit station in April, October and November. The average yearly maximum temperature

was non-significant increasing trend as the computed p-value (0.29, 0.3 and 0.1) greater than the significance level of $\alpha=0.05$ at Dessie, Tita and Tebasit station respectively. While average yearly maximum temperature was significant increasing trend as the computed (p-value= 0.001) less than the significance level of $\alpha=0.05$ at Gugufu station. This study is agreed with [24] exhibits the annual maximum temperature is significant increasing trend as the computed p-value (0.036 and 0.015) lower than the significance level of $\alpha=0.05$ for Addis Zemen and Nefas Mewucha station. The slope of average annual maximum temperature was increased at 0.006 °C, 0.03 °C, 0.005 °C and 0.01 °C per year at Dessie, Gugufu, Tita and Tebasit station in the study area respectively. This slope and Mann-Kendall values represent the monthly temperature increasing or decreasing trend rate per year.

Table 2. Average Monthly and Yearly Maximum Temperature Mann-Kendall and Sen's Slope Trend from 1981-2020.

statistics		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dessie	P-value	0.32	0.07	0.11	0.04	0.91	0.15	0.28	0.61	0.102	0.18	0.94	0.48	0.29
	ZMK	0.11	0.19	0.17	0.23	-0.01	-0.16	-0.12	-0.06	0.17	0.145	-9.3	0.07	0.113
	Slope	0.014	0.02	0.02	0.04	-0.002	-0.02	-0.01	-0.005	0.018	0.015	-0.005	0.009	0.006
Gugufu	P-value	0.07	0.3	0.03	0.01	0.07	0.74	0.87	0.04	0.0007	0.0008	0.002	0.001	0.001
	ZMK	0.19	0.108	0.23	0.27	0.19	0.04	0.019	0.2	0.37	0.48	0.4	0.34	0.34
	Slope	0.02	0.01	0.02	0.02	0.02	0.004	0.003	0.03	0.04	0.06	0.05	0.05	0.03
Tita	P-value	0.46	0.08	0.07	0.01	0.38	0.58	0.09	0.12	0.2	0.87	0.32	0.95	0.3

statistics		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tebasit	ZMK	0.08	0.19	0.2	0.26	0.09	-0.06	-0.18	-0.17	0.13	0.02	-0.1	-0.008	0.1
	Slope	0.01	0.02	0.03	0.05	0.01	-0.005	-0.02	-0.01	0.01	0.002	-0.01	-0.001	0.005
	P-value	0.78	1.00	0.26	0.02	0.4	0.4	0.08	0.47	0.07	0.0006	0.02	0.2	0.10
	ZMK	0.03	0.001	0.12	0.25	0.08	-0.09	-0.2	0.08	0.20	0.37	0.26	0.15	0.18
	Slope	0.003	0.0001	0.009	0.02	0.009	-0.007	-0.02	0.006	0.02	0.04	0.03	0.02	0.01

Source: Station based ENACT temperature data from Ethiopian Meteorology Institute from 1981-2022
ZMK is Mann-Kendall trend test, Slope (Sen's slope) is the change month/year

3.2. Minimum Temperature

The highest monthly minimum temperature was recorded in July with 12.4 °C, April with 8.4 °C, June with 12.8 °C and February with 9.4 °C, while the lowest monthly minimum temperature was recorded during November with 1.1 °C, December with -1.9 °C, November with 1.3 °C and December with -0.9 °C at Dessie, Gugufu, Tita and Tebasit respectively (Table 3). Annual minimum temperature was between 4.0 °C to 10.6 °C, 3.0 °C to 6.3 °C, 5.1 °C to 10.6 °C and 4.1 °C to 7.2 °C, while average annual minimum temperature showed at 8.7 °C, 4.5 °C, 9.3 °C and 5.6 °C at Dessie, Gugufu, Tita and Tebasit respectively. This result is completely agreed with [2]: the average yearly minimum temperature ranges between 5.0 °C to 9.0 °C for Nefas Mewcha and Mekane Eyesus stations it ranges between 7.7 °C to 9.0 °C respectively. Also, the present study monthly minimum temperature coefficient of variation ranges from lower to high variability. When we come to average monthly minimum temperature ranges from 5.9 °C to

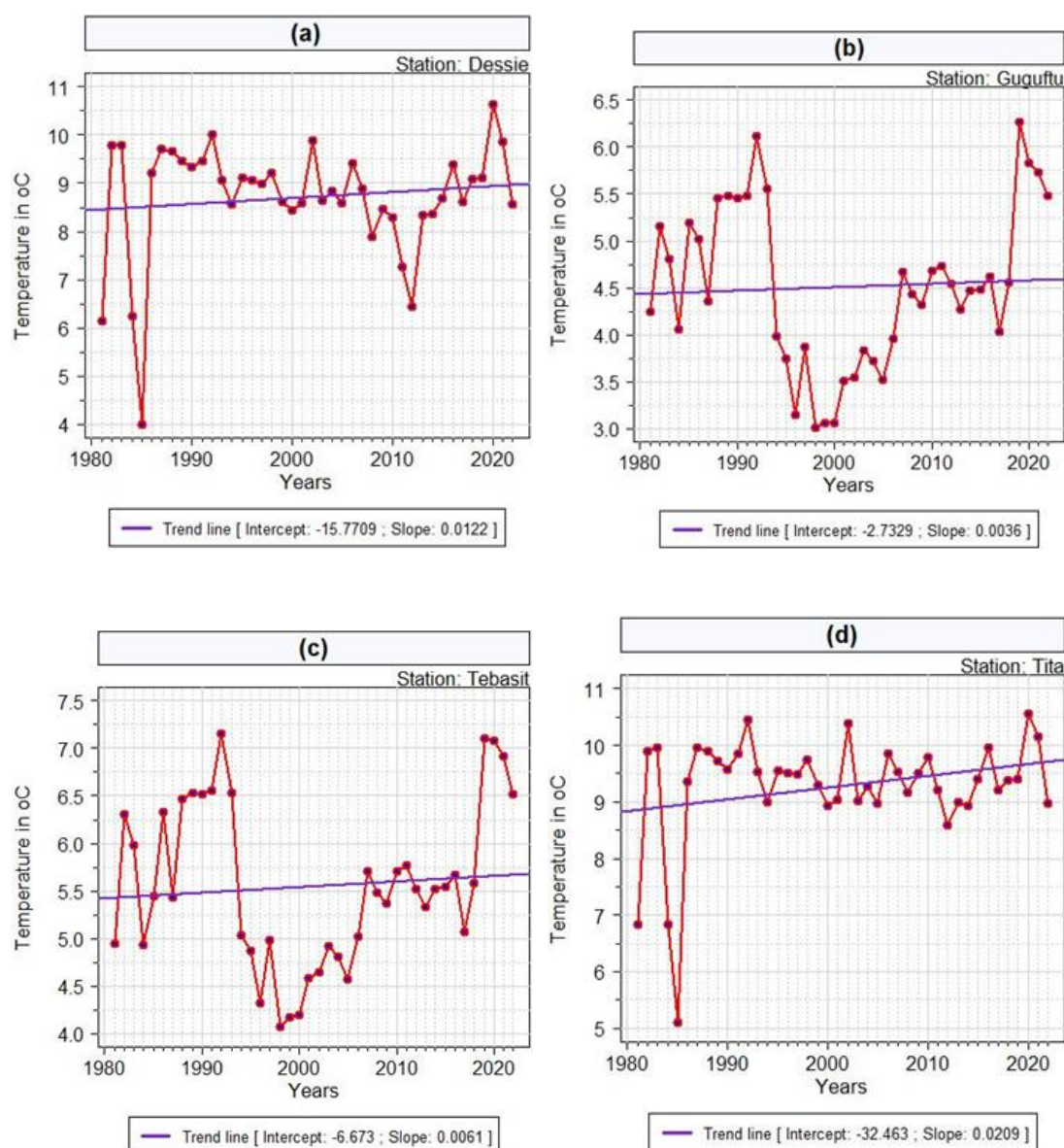
11.0 °C, 2.8 °C to 5.6 °C, 6.3 °C to 11.6 °C and 3.7 °C to 6.7 °C at Dessie, Gugufu, Tita and Tebasit respectively. In this study, the highest average monthly minimum temperature was observed in June and July. The highest value of coefficients of variation in monthly minimum temperatures was found in December with 34.1%, December with 64.3%, December with 30.0% and December with 46.1% at Dessie, Gugufu, Tita and Tebasit respectively. Otherwise, the lowest coefficient of variation was recorded in September with 10.6%, September with 18.1%, September with 8.8% and July with 14.2% at Dessie, Gugufu, Tita and Tebasit respectively. On the other hand, the annual minimum temperature coefficient of variation was 13.9%, 19.1%, 10.6% and 15.4% at Dessie, Gugufu, Tita and Tebasit station respectively. The annual standard deviation was highest at Dessie with 1.21 °C and also the lowest annual standard deviation was 0.86 °C both at Gugufu and Tebasit station. This indicated that the data points are closely clustered around the mean, but a larger value of standard deviation means the data was more variable at Dessie station.

Table 3. Statistical Information of Monthly Minimum Temperature Analysis in Degree Celsius.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dessie	Minimum	1.8	2.4	4.0	5.4	5.2	5.0	4.7	4.4	6.7	1.1	0.6	2.8	4.0
	Maximum	9.7	10.8	11.4	11.9	12.1	12.2	12.7	12.3	11.1	10.4	9.5	9.9	10.6
	Average	6.6	7.6	8.9	9.8	10.1	10.7	11.0	10.7	9.7	7.3	6.0	5.9	8.7
	Std Dev.	1.83	2.28	1.49	1.27	1.19	1.30	1.41	1.39	1.03	1.86	1.77	2.02	1.21
	CV	27.6	30.1	16.8	13.0	11.7	12.1	12.8	12.9	10.6	25.7	29.2	34.1	13.9
Gugufu	Minimum	0.3	0.6	2.2	2.6	2.0	3.0	3.8	3.5	3.0	1.7	-0.3	-1.9	3.0
	Maximum	8.1	8.6	7.4	8.4	7.5	8.1	7.9	7.7	7.0	6.5	5.6	6.3	6.3
	Average	3.6	4.0	4.9	5.2	5.6	5.6	5.3	5.1	5.1	4.0	2.9	2.8	4.5
	Std Dev	1.43	1.71	1.17	1.10	1.25	1.24	0.98	1.03	0.93	1.04	1.42	1.79	0.86
Tita	CV	39.3	42.5	23.9	21.4	22.5	22.3	18.4	20.1	18.1	25.8	48.8	64.3	19.1
	Minimum	2.8	3.6	5.2	6.8	6.5	6.3	6.3	6.1	7.6	2.3	1.3	3.1	5.1
	Maximum	10.2	11.5	11.6	12.3	12.1	12.8	12.8	12.5	11.9	10.8	10.0	10.2	10.6

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tebasit	Average	7.2	8.3	9.5	10.4	10.7	11.5	11.6	11.3	10.4	7.8	6.4	6.3	9.3
	Std Dev	1.71	2.11	1.33	1.08	1.01	1.08	1.20	1.19	0.91	1.69	1.66	1.89	0.98
	CV	23.7	25.5	14.1	10.4	9.4	9.4	10.3	10.5	8.8	21.8	26.0	30.0	10.6
	Minimum	1.1	1.5	3.4	3.9	3.3	4.2	5.1	4.8	4.3	2.8	0.7	-0.9	4.1
	Maximum	8.6	9.4	8.3	9.2	8.5	9.3	8.9	8.5	8.2	7.2	6.5	7.0	7.2
	Average	4.5	5.0	5.9	6.3	6.6	6.7	6.5	6.3	6.2	5.0	3.9	3.7	5.6
	Std Dev	1.38	1.72	1.14	1.05	1.18	1.17	0.93	1.00	0.89	1.04	1.40	1.72	0.86
	CV	30.4	34.4	19.3	16.7	17.9	17.5	14.2	15.8	14.4	20.9	36.2	46.1	15.4

Source: Station based ENACT temperature data from Ethiopian Meteorology Institute from 1981-2022



Source: Station based ENACT temperature data from Ethiopian Meteorology Institute from 1981-2022

Figure 3. Annual Minimum Temperature Trend over a= Dessie, b= Gugufu, c= Tebasit and d= Tita.

Annual minimum temperature trend was a statistical tool used to visually represent how temperature changes over time, typically displayed on a line graph as shown [Figure 3](#). The average yearly minimum temperature trend analysis was conducted from 1981-2022. According to this a linear regression model, the slope line change of the average annual minimum temperature was increased by 0.0122 °C, 0.0036 °C, 0.0061 °C and 0.0209 °C per 42-year period at Dessie, Gugufu, Tebasit and Tita respectively. This indicates all the four stations revealed a warm temperature and the rates of climate change were not uniform but at Tita station the most rapid warm in minimum temperature and a notable for climate change while Dessie experienced the second-highest warm minimum temperature over the same period. Tebasit and Gugufu station both showed a more gradual warming minimum temperature.

The Kendall's tau (ZMK) and Sen's slope values were to assess trends in yearly and monthly minimum temperature series at Dessie zuria station. The monthly Mann-Kendall's test was used to analyze that the monthly minimum temperatures at Dessie station was increasing trend in January, May, October, November and December because sen's slope and Kendall's tau (ZMK) values were both positive while at Gugufu station revealed statistically decreasing trends in

January, February and March this indicated that both sen's slope and Kendall's tau (ZMK) values were negative ([Table 4](#)). The minimum temperature at Tita station showed statistically increasing trends in January, May, June, October, November, and December. On the other hand, the minimum temperature at Tebasit station showed statistically increasing trends in January, February and March. There were statistically significant trends at Dessie only in July (p-value=0.04) and at Tita station only November at p-value 0.01. There were statistically non-significant trends both at Gugufu and Tebasit station in all months. The average yearly minimum temperature was non-significant increasing trend as the computed p-value (0.46 and 0.26) greater than the significance level of $\alpha=0.05$ at Gugufu and Tebasit station respectively. While average yearly minimum temperature was non-significant decreasing trend as the computed p-value (0.27 and 0.57) greater than the significance level of $\alpha=0.05$ at Dessie and Tita station respectively. The slope of average annual minimum temperature was changed at -0.02 °C, 0.01 °C, -0.004 °C and 0.014 °C per year at Dessie, Gugufu, Tita and Tebasit station respectively. These slope values represent the monthly temperature increasing or decreasing trend rate per year.

Table 4. Average Monthly and Yearly Minimum Temperature Mann-Kendall and Sen's Slope Trend Test from 1981-2020.

statistics		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dessie	P-value	0.99	0.62	0.06	0.7	0.96	0.55	0.04	0.13	0.17	0.45	0.09	0.76	0.27
	ZMK	0.002	-0.05	-0.019	-0.004	0.006	-0.06	-0.2	-0.15	-0.14	0.08	0.17	0.03	-0.11
	Slope	0.00	-0.02	-0.03	-0.008	0.0005	-0.008	-0.02	-0.02	-0.02	0.02	0.04	0.01	-0.02
Gugufu	P-value	0.52	0.4	0.43	0.67	0.8	0.79	0.57	0.2	0.17	0.17	0.39	0.53	0.46
	ZMK	-0.07	-0.08	-0.08	0.04	0.027	0.028	0.058	0.12	0.14	0.14	0.088	0.064	0.05
	Slope	-0.01	-0.01	-0.014	0.005	0.004	0.005	0.008	0.02	0.02	0.02	0.016	0.02	0.01
Tita	P-value	0.81	0.81	0.26	0.76	0.68	0.99	0.26	0.29	0.32	0.15	0.01	0.56	0.57
	ZMK	0.025	-0.025	-0.12	-0.03	0.04	0.003	-0.11	-0.11	-0.1	0.15	0.26	0.06	-0.058
	Slope	0.007	-0.01	-0.02	-0.004	0.005	0.004	-0.009	-0.01	-0.012	0.028	0.05	0.018	-0.004
Tebasit	P-value	0.57	0.34	0.35	0.28	0.42	0.58	0.36	0.09	0.06	0.05	0.28	0.54	0.26
	ZMK	-0.06	-0.1	-0.065	0.12	0.087	0.06	0.09	0.18	0.2	0.21	0.12	0.07	0.12
	Slope	-0.01	-0.016	-0.012	0.012	0.016	0.007	0.013	0.02	0.026	0.03	0.02	0.02	0.014

Source: Station based ENACT temperature data from Ethiopian Meteorology Institute from 1981-2022
ZMK is Kendall's tau and Slope (Sen's slope) is the change month/year

3.3. Rainfall

The peak monthly maximum rainfall was shown in July and

August, which was part of summer in Ethiopia ([Table 5](#)). The highest monthly mean rainfall amount was recorded during August about 305.8 mm, 410.8 mm, 299.7 mm and 409.4 mm at Dessie, Gugufu, Tita and Tebasit respectively. This study

suggested a clear monthly peak and the core of the rainy season during these months. During the month of July, the second highest mean monthly rainfall was recorded in all stations over the study area. In July and August the average monthly rainfall was 281.8mm and 305.8mm at Dessie and 276.3mm and 299.7mm at Tita station respectively. This is supported by [16], August and July; the highest amount of average monthly rainfall was observed at 280.4 mm and 318.7 mm at the Kombolcha and Dessie stations, respectively. In this study, the annual amount of rainfall ranges from 630.7 mm to 1391.5 mm, 466.4 mm to 1924.5 mm, 575.6 mm to 1415.2 mm and 536.3 mm to 1841.2 mm at Dessie, Gugufu, Tita and Tebasit respectively. The monthly rainfall coefficients of variation were moderate variability in July and Au-

gust. This shows medium interannual variability in rainfall amounts during these months. Rainfall in these months was predictable; some years may have heavy rainfall and others less. Contrarily, the coefficients of variation for other months were high variability. The highest value of coefficients of variation was shown in December (153.4%) and lowest recorded in July (35.8%) at Gugufu station. This result completely agreed with [7] the peak value of coefficient of variation was shown in December and the lowest recorded in July. Based on the statistical information, the annual rainfall coefficient of variations was 15.2%, 23.8%, 15.4% and 20.7% at Dessie, Gugufu, Tita and Tebasit station respectively. This indicated that relatively stable annual rainfall and the annual average rainfall was larger than standard deviation.

Table 5. Statistical Information of Monthly Rainfall Analysis from 1981-2020.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dessie	Minimum	0.0	0.0	0.0	0.0	6.2	0.0	36.5	66.0	38.8	2.8	0.0	0.0	630.7
	Maximum	62.4	101.4	212.0	200.7	193.0	185.1	516.9	501.2	274.8	147.3	110.0	74.2	1391.5
	Average	17.9	26.4	64.2	82.2	72.4	35.9	281.8	305.8	130.2	48.5	19.3	15.3	1099.9
	Std Dev.	17.5	27.8	44.0	47.0	51.9	37.7	104.8	88.4	55.0	36.9	27.2	19.2	166.9
	CV	97.9	105.5	68.5	57.2	71.7	104.9	37.2	28.9	42.2	76.2	140.9	125.9	15.2
Gugufu	Minimum	0.0	0.0	0.0	0.1	0.5	0.9	65.8	57.4	22.5	0.4	0.0	0.0	466.4
	Maximum	73.7	150.5	191.6	234.4	217.8	231.6	742.3	735.9	276.0	101.6	70.0	68.4	1924.5
	Average	20.5	32.0	67.9	74.0	58.9	57.4	378.2	410.8	114.7	28.5	12.9	10.6	1266.4
	Std Dev	22.6	33.7	42.8	50.5	49.7	55.4	135.4	147.6	55.9	23.3	17.9	16.3	301.8
	CV	110.5	105.3	63.0	68.3	84.3	96.5	35.8	35.9	48.7	82.0	138.7	153.4	23.8
Tita	Minimum	0.0	0.0	0.0	0.1	4.9	0.0	43.7	55.7	34.9	3.1	0.0	0.0	575.6
	Maximum	63.6	87.4	218.1	193.3	193.9	160.9	520.1	511.4	230.2	160.5	106.2	89.6	1415.2
	Average	18.4	26.3	72.8	85.6	71.9	35.0	276.3	299.7	116.5	45.2	19.0	16.1	1082.8
	Std Dev	17.7	26.3	45.4	45.0	53.3	35.2	99.3	91.1	48.3	37.3	25.7	21.0	166.9
	CV	96.6	100.0	62.4	52.6	74.1	100.5	35.9	30.4	41.5	82.4	134.9	130.5	15.4
Tebasit	Minimum	0.0	0.0	0.0	0.0	1.2	1.1	24.7	48.4	17.6	1.4	0.0	0.0	536.3
	Maximum	71.2	165.7	180.6	199.9	243.2	226.5	716.7	729.7	284.2	102.0	88.3	61.3	1841.2
	Average	19.0	29.1	65.1	73.9	67.1	54.2	372.1	409.4	124.5	32.3	16.5	10.7	1273.9
	Std Dev	20.5	33.1	39.9	48.8	56.9	49.2	130.3	140.9	54.9	25.3	23.0	14.4	264.2
	CV	108.2	113.7	61.2	66.0	84.8	90.8	35.0	34.4	44.1	78.5	139.6	134.9	20.7

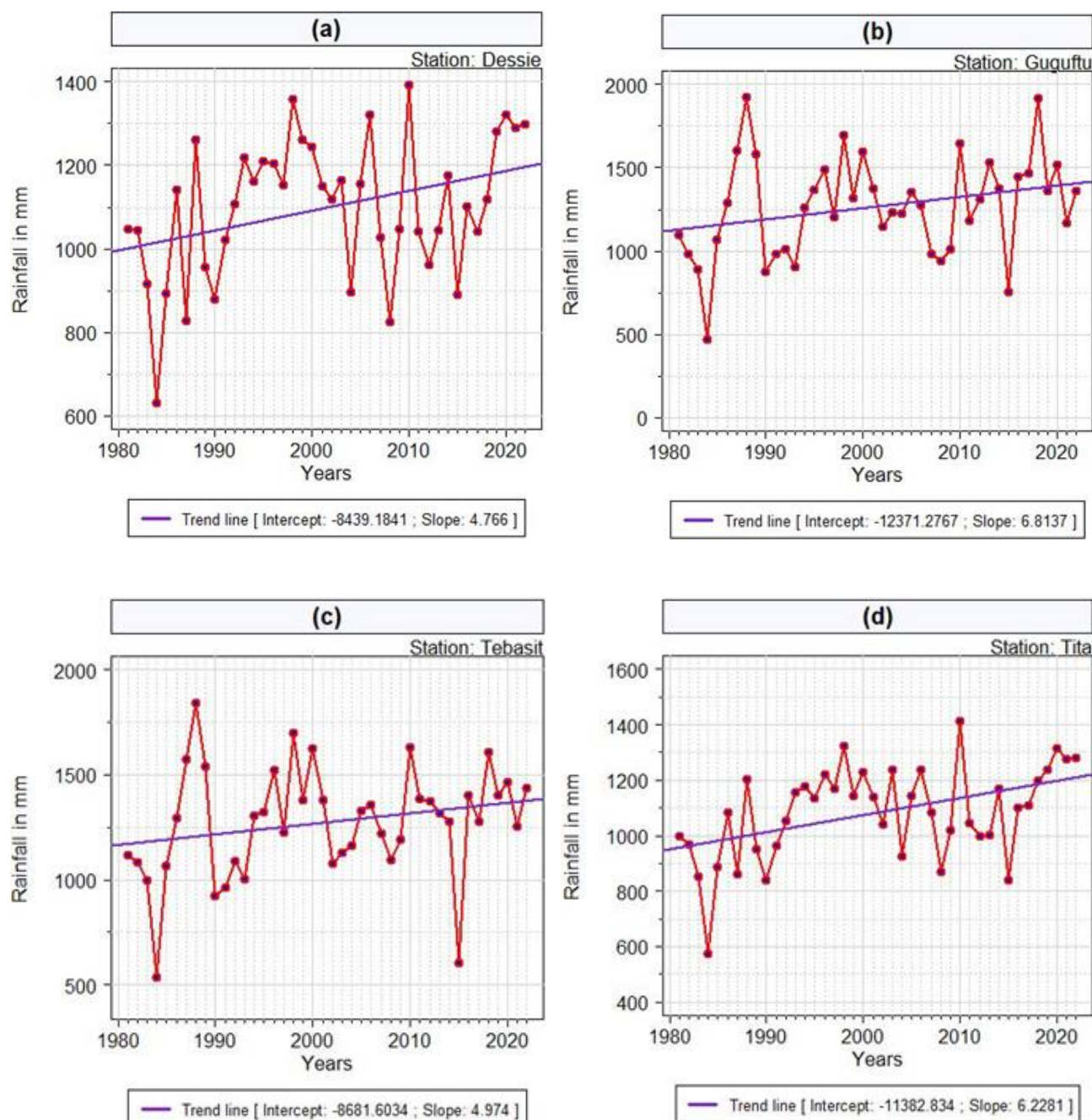
Source: Station based ENACT rainfall data from Ethiopian Meteorology Institute from 1981-2022.

The annual rainfall trend was conducted from 1981-2022, how rainfall changes over time, typically displayed on a line graph as shown Figure 4. This indicated to identify the long-term situation of increase, decrease or stability in rainfall above four decades. According to this a linear regression

model, the slope line change of the annual rainfall was an increasing trend of 4.766mm, 6.8137mm, 4.974mm and 6.2281mm per 42-year period at Dessie, Gugufu, Tebasit and Tita respectively. This long-term increase in annual rainfall across the four Dessie zuria stations was shown over the

studied 42-year periods. In Gugufu station was shown as the strongest upward trends, while at Dessie station shown as the lowest still the entire trends positive. This information is important for water resource monitoring, agricultural management and advanced knowledge for local climate change

effects. Over the past forty-two year period, the ranges of amount of rainfall were recorded in 630.7mm to 1391.5mm, 466.4mm to 1924.5mm, 536.3mm to 1841.2mm and 575.6mm to 1415.2mm at Dessie, Gugufu, Tebasit and Tita respectively.



Source: Station based ENACT rainfall data from Ethiopian Meteorology Institute from 1981-2022.

Figure 4. Annual Rainfall Trend over a= Dessie, b= Gugufu, c= Tebasit and d= Tita.

The Kendall's tau (ZMK) and Sen's slope values were used to assess trends in yearly and monthly rainfall series at Dessie zuria station. The monthly Mann-Kendall's test was used to analyze that the monthly rainfall at Dessie station was increasing trend in May, June, July, August, October and November

because sen's slope and kendall's tau (ZMK) values were both positive while at Gugufu station revealed statistically decreasing trends in January, February, March and December this indicated that both sen's slope and kendall's tau (ZMK) values were negative (Table 6). The monthly rainfall

at Tita station showed statistically decreasing trends in January, February, March, September, and December. On the other hand, monthly rainfall at Tebasit station showed statistically decreasing trends in January, February, March and December. There were significant trends at Dessie in June, August and December (p-value=0.02, 0.001 and 0.04) and at Guguftu station in June, July, October and November as p-value (0.02, 0.02, 0.01 and 0.02) lower than the 5% level of significance. There were statistically significant trends at Tita station only in June, July and August as their p-value was less than the significance level of $\alpha=0.05$. There were statistically significant trends at Tebasit station in March, June and July as their p-value (0.03, 0.009 and 0.03) lower than the

significance level of $\alpha=0.05$, others were non-significant. The annual rainfall was a non-significant increasing trend as the computed p-value (0.05 and 0.07) greater than or equal to the significance level of $\alpha=0.05$ at Dessie and Guguftu station respectively. While annual rainfall was statistically significant, increasing trend as the computed p-value (0.003 and 0.04) lower than the significance level of $\alpha=0.05$ at Tita and Tebasit station. The slopes of annual rainfall were changed at 4.7mm, 7.4mm, 6.2mm and 6.1mm per year at Dessie, Guguftu, Tita and Tebasit station respectively. This slope values represent the amount of rainfall increasing trend rate per year.

Table 6. Monthly Rainfall Mann-Kendall and Sen's Slope Trend Test from 1981-2020.

statistics		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dessie	P-value	0.2	0.3	0.1	0.9	1.00	0.02	0.05	0.001	0.7	0.5	0.09	0.04	0.05
	ZMK	-0.1	-0.1	-0.2	-0.003	0.001	0.3	0.2	0.4	-0.04	0.07	0.2	-0.2	0.2
	Slope	-0.1	-0.2	-0.9	-0.01	0.01	0.8	2.9	3.5	-0.4	0.2	0.05	-0.3	4.7
Guguftu	P-value	0.2	0.2	0.1	0.7	0.5	0.02	0.02	0.06	0.7	0.01	0.02	0.3	0.07
	ZMK	-0.1	-0.1	-0.2	0.04	0.08	0.3	0.2	0.2	0.04	0.3	0.3	-0.1	0.2
	Slope	-0.1	-0.4	-0.8	0.2	0.3	1.2	4.0	3.0	0.2	0.7	0.1	-0.03	7.4
Tita	P-value	0.5	0.2	0.1	0.6	0.6	0.01	0.03	0.002	0.8	0.4	0.08	0.06	0.003
	ZMK	-0.07	-0.1	-0.2	0.05	0.06	0.3	0.2	0.3	-0.02	0.09	0.2	-0.2	0.3
	Slope	-0.04	-0.2	-0.8	0.3	0.4	0.7	3.1	3.5	-0.2	0.3	0.1	-0.3	6.2
Tebasit	P-value	0.09	0.07	0.03	0.9	0.7	0.009	0.03	0.06	0.6	0.07	0.05	0.09	0.04
	ZMK	-0.2	-0.2	-0.2	0.01	0.04	0.3	0.2	0.2	0.06	0.2	0.2	-0.2	0.2
	Slope	-0.3	-0.5	-1.1	0.08	0.2	1.1	3.7	3.2	0.4	0.5	0.1	-0.05	6.1

Source: Station based ENACT temperature data from Ethiopian Meteorology Institute from 1981-2022.

4. Conclusion

In Ethiopia agriculture, vegetation cover and water sector is dependent on rain, since rainfall and temperature were the main climatic conditions in the study area. The temperature and rainfall data analysis was carried out using a non-parametric Mann-Kendall's test and Sen's slope estimator test, which used to conducted monthly and yearly trend analysis. The monthly and yearly rainfall, maximum temperature, and minimum temperature data were presented from 1981-2022. The ranges of coefficients of variation at Dessie, Guguftu, Tita and Tebasit for monthly maximum temperatures were shown from 3.7% to 5.2%, 5.3% to 7.7%, 3.0% to 5.7% and 5.0% to 7.6% respectively. The average yearly maximum temperatures were 22.4 °C and 22.2 °C at Dessie and Tita stations respectively. Then the average yearly maximum

temperature coefficient of variation was varied from 1.9% (Tita) and 4.5% (Guguftu). The slope of average annual maximum temperature was increased at 0.006 °C, 0.03 °C, 0.005 °C and 0.01 °C per year at Dessie, Guguftu, Tita and Tebasit stations in the study area respectively. The average yearly maximum temperature was a non-significant increasing trend at Dessie, Tita and Tebasit station respectively while significant increasing trend at Guguftu station. Average annual minimum temperature showed at 8.7 °C, 4.5 °C, 9.3 °C and 5.6 °C at Dessie, Guguftu, Tita and Tebasit respectively. The annual minimum temperature coefficient of variation was 13.9%, 19.1%, 10.6% and 15.4% at Dessie, Guguftu, Tita and Tebasit stations respectively. The average yearly minimum temperature was a non-significant increasing trend at Guguftu and Tebasit station but a non-significant decreasing trend at Dessie and Tita station. The slope of average annual minimum temperature at Dessie, Guguftu, Tita and Tebasit stations was

changed at -0.02°C , 0.01°C , -0.004°C and 0.014°C per year respectively. The monthly rainfall coefficients of variation were moderate variability in July and August, but other months were high variability. The slope line change of the annual rainfall was an increasing trend of 4.766mm, 6.8137mm, 4.974mm and 6.2281mm per 42-year period at Dessie, Gugufu, Tebasit and Tita respectively. The annual rainfall was a non-significant increasing trend at Dessie and Gugufu station but significant increasing trend at Tita and Tebasit station. The slopes of annual rainfall were changed at 4.7mm, 7.4mm, 6.2mm and 6.1mm per year at Dessie, Gugufu, Tita and Tebasit stations respectively. Hence, information generated by this study could be beneficial to agricultural and water resources planning and management, especially in urban environments where adaptability to climate variability and change is still low. Therefore, the results obtained in this work showed temperature increment, and the concerned stakeholders should take policymakers, which will help with climate change mitigation and adaptation strategy.

Abbreviations

CDT	Climate Data Tool
CV	Coefficient of Variation
MK	Mann-Kendall
ZMK	Mann-Kendall Test Statistics

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Wendimnew Getachew Alemu is the sole author. The author read and approved the final manuscript.

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Conflicts of Interest

The author declares no conflicts of interest.

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