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LONG TERM ANALYSIS TRENDS OF RAINFALL AND TEMPERATURE OF ANDIT WATERSHED

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Abstract:
The impacts of climate change and climate variability on human life led the scientific community to monitor the behavior of weather and climate variables. As a responsible body in the present study, trends and variations in climatic variables (i.e., rainfall, air temperature, and soil temperature) were analyzed on monthly, seasonal (Belg, summer, spring, and winter) and annual time scales for And it tid watershed, central highland of Ethiopia. It was done using non-parametric statistical techniques, i.e., the Mann–Kendall (MK), over 24 years. To detect the inhomogeneity of the data, autocorrelation has been taken into account using the Hamed and Rao method. The trend analysis revealed that monthly, seasonal and annual rainfall did show a statistically insignificant decreasing trend at ($P<0.05$) level of significance. Annually, a noticeable trend increase was found in maximum air temperature and a noticeable decrease in minimum air temperature from the non-parametric statistical tests at a ($P<0.05$) significance level. With this circumstance, the mean temperature showed an insignificant increasing trend at ($P<0.05$). This type of analysis of several climatic variables at the watershed level is helpful for the planning and management of water resources and the development of adaptation strategies in adverse climatic conditions.

Keywords: Climate change, Andiit tid, Mann–Kendall, Hamed, and Rao

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INTRODUCTION

The world's environment is in a transition phase, and one of the major concerns of today's world is climatic change due to natural and anthropogenic influences. Climatic change can be described as a decadal or even longer period of variation in weather conditions (Beg et al., 2002). Nationally in Ethiopia, climate variability is imposing significant challenges, especially on efforts put for poverty reduction and sustainable development. Due to high dependence on rain-fed agriculture, low adaptive capacity, and a higher reliance on natural resources base for livelihood, Ethiopia is ranked as the most vulnerable county for the adverse effects of climate change (NMA, 2007; World Bank, 2010). These challenges further impact regional, social, environmental, and economic systems (Eriksson et al., 2009), whereas they make uncertain future water supply, storage, and hazards, like a flood (Orlove, et al. 2008).

These impacts of climate change and climate variability on human life led the scientific community to monitor the behavior of weather and climate variables (Weldegerima et al., 2018). Any change of mean global and regional temperature will impact rainfall's spatial and temporal distribution (Tesfahunegn, et al., 2016). The variations occurred in precipitation directly or indirectly affect floods, droughts, and water resources (Wen, X. et al. 2017). De Luis et al., 2010 stated that; precipitation affects the availability of water resources and is one of the most important climatic factors and hydrological parameters. Therefore, investigating the temporal variations of precipitation in previous periods is critical for making reliable predictions of future climate changes. According to Desalegn et al., (2018), the relationship between monthly rainfall and river discharge in Andit tid watershed is 90.7%.

And it tid watershed is one of the soil conservation research project (SCRP) experimental watersheds maintained by the water and land resource project (WLRC). The watershed has long-term records of rainfall and temperature data stretched back from 1994. So in this study, we investigated a holistic, long-term (1994 to 2017) trends and variations in rainfall and temperature over time at Andit tid watershed central Ethiopian highlands, using the Mann-Kendall test. This study provides a broad overview of all mentioned parameters statistics, including monthly, seasonal and annual variability at the watershed level. The nature of rainfall in Ethiopia is sporadic and irregularly distributed, and the agro-ecological zone is varied within a few kilometers (25-30km). That is why we conducted watershed-based local trend analysis to use the output for decision making and early preparedness at the local level. The availability of long-term observed data on the study area also initiated us to convert the data into information through conducting this research.

METHODS

Andit tid watershed is one of the soil conservation research project (SCRP) sites. It is situated on 39°43′E longitudes and 9°48′N latitudes (Figure1) 180 km northeast of capital city Addis Ababa. The altitude of the catchment ranges between 3040 to 3550 m.a.s.l. The mean annual rainfall is 1585.2 mm, the minimum and maximum temperatures are 7°C and 17°C, respectively. The minimum and maximum average soil temperatures are 8°C and 20°C, respectively. The agro-climatic zone of the watershed is most humid. And it Tid has been administered by the Amhara Regional Agricultural Research Institute (ARARI) under the supervision of the Debre Brihan Agricultural Research Center (DBARC). In the study watershed, there is a huge amount of collected and available data such as river discharge, sediment yield, climatic data, crop production, and land use/cover data for the last since 1982.

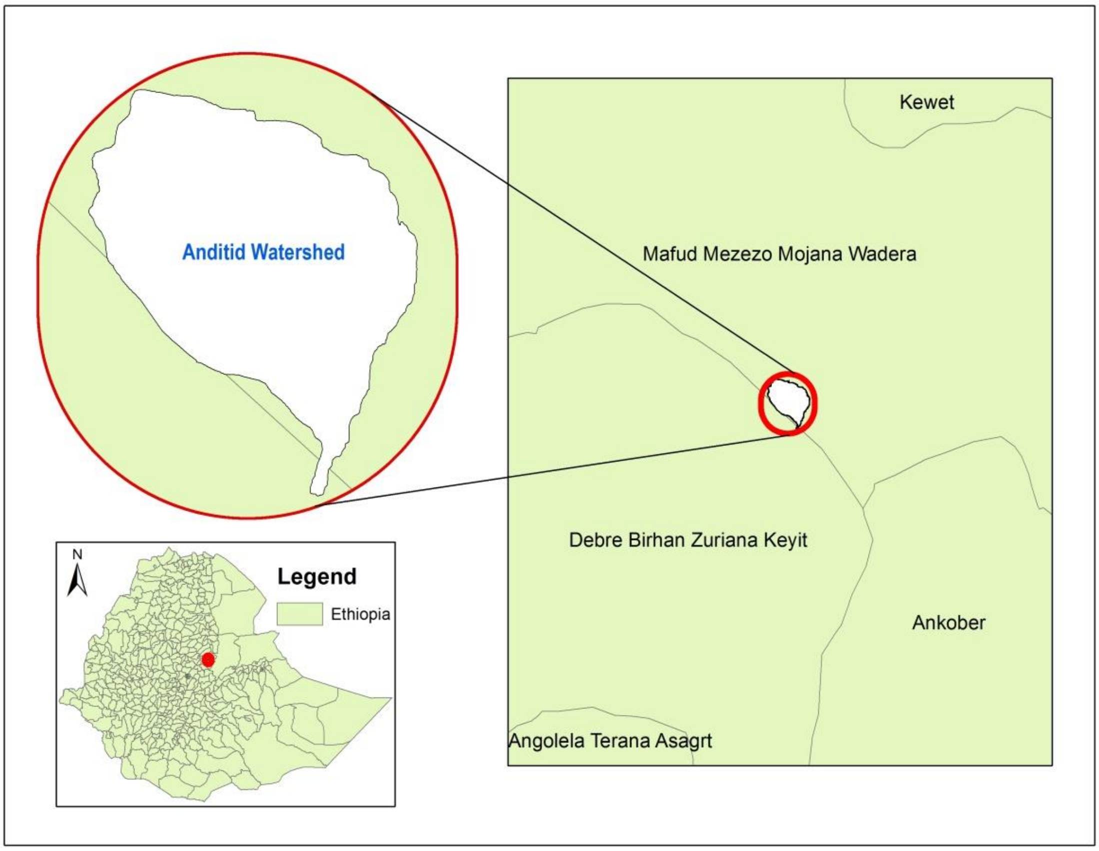

Figure1. The location map of the study watershed

The rainfall, air, and soil temperature records are available for the period from 1994 to 2017 at Andit tid watershed in daily time series. For the seasonal analysis, the data have been divided into four seasons based on the local situation, like winter (Bega) (December–February), Belg (March-May), summer (kiremt) (June–September), and spring (Tsedey) (October–November). Collected time series data has some missing values. The missing value is interpolated during data processing. We used the ARIMA function for filling the missing value of the data. Auto-Regressive Integrated Moving Average (ARIMA) model is considered as a powerful and extensively used statistical tool to analyze and predict time series data. The main advantages of the model are that it can detect seasonal changes and consider serial correlation within the time series(Yurekli K, et al., 2007).

MK test is a non-parametric test method, has been widely used to detect whether trends exist in meteorological or hydrologic time series (Wang et al., 2006). Since there are chances of outliers to be present in the dataset, the non-parametric MK trend test is less affected by the outliers (Birsan, et al., 2005). Mann–Kendall test has been applied to the monthly, seasonal, and annual rainfall and temperature series to investigate the trends. The Mann–Kendall (MK) test (Kendall, 1975; Mann, 1945; Hirsch 1992) has been widely used in hydrological studies. This test evaluates whether outcome values tend to increase, decrease, or be fussy over time. For making a statistical decision, the test statistics are evaluated at ($p < 0.05$) significance level.

Mann–Kendall test statistic is denoted by *S* and is computed using each pair of the observed values *xi* and *xj* of the random variable under consideration. Each pair is then inspected to find out whether *xi* > *xj* or *xi* < *xj*. The MK test statistic 'S' is calculated based on Mann, (1945), Kendall, (1975) and Yue, et al. (2002) using the formula:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where sgn is the signum function and *xi,* and *xj* are the annual values in the years *i* and *j*, *i* > *j*, respectively,

The application of the trend test is done to a time series Xi that is ranked from i = 1, 2…n-1 and Xj, which is ranked from j = i + 1, 2…. n. Each of the data point Xi is taken as a reference point which is compared with the rest of the data point's Xj so that:

$$sgn(x_j - x_i) = \begin{Bmatrix} +1\ if (x_j - x_i) > 0 \\ 0\ if\ (x_j - x_i) = 0 \\ -1\ if\ (x_j - x_i) < 0 \end{Bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Under the null hypothesis of no trend, the statistic *S* follows the approximately normal distribution with mean zero and variance (Kendall, 1975) statistic is given as:

$$var(S) = \frac{n(n-1)(2n+5) - \sum_{t=1}^{m} t_1(t_1 - 1)(2t_1 + 5)}{18} \ldots\ldots\ldots\ldots (3)$$

Where: n is the number of observations, and it is the ties of the sample time series. And m is the number of tied groups, and *tk* is the number of data points in the group *k*.

When the sample size *is n* ≥ 10, as used in this study, the test statistic Z is calculated (Kendall, 1975).

$$Z = \begin{Bmatrix} \frac{S-1}{\sigma}\ if\ S > 0 \\ 0\ if\ S = 0 \\ \frac{S+1}{\sigma}\ if\ S < 0 \end{Bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Z follows a normal distribution; a positive Z and a negative Z depict an upward and downwards trend for the period, respectively.

Sen's Slope estimation test is also another non-parametric trend analysis method for climatic and hydrologic studies (Sen, 1968). According to Sen's method, it computes both the slope (i.e., the linear rate of change) and intercepts. The magnitude of the trend is predicted by (Sen, 1968; Theil, 1950) slope estimator methods. A positive value of β indicates an 'upward trend' (increasing values with time), while a negative value of β indicates a 'downward trend'. Here, the slope T_i of all data pairs is computed as (Sen, 1968). In general, the slope T_i between any two values of a time series x can be estimated from:

$$Ti = \frac{x_k - x_j}{j - k} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (5)$$

Where: x_j and x_k are considered as data values at time j and k (j >k) correspondingly. The median of these N values of T_i is represented as Sen's estimator of the slope, which is computed as:

$$Q = \begin{cases} T_{\frac{N+1}{2}} & \text{if } N \text{ is odd and} \\ \left[\frac{T_{\frac{N}{2}} + T_{\frac{(N+1)}{2}}}{2}\right] & \text{if } N \text{ is even} \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

A positive value of Qi indicates an upward or increasing trend, and a negative value of Qi gives a downward or decreasing trend in the time series.

Sometimes, Mann–Kendall gives incorrect or too large rejection rates when applied to an autocorrelation time-series data(Bayazit M, 2008). Autocorrelation within a time series data, also known as a serial dependency, is always considered one of the main problems of time series data analysis and trend detection. Since the Mann–Kendall test statistic variance increases with the magnitude of serial correlation, positive serial correlation increases the Type I error when the time series has no trend(Yue, et al., 2002). If autocorrelation value (r) falls between the upper and lower bound of the confidence interval, then data are considered serially correlated. Several methods were used to remove serial dependency like DE trending, first-order differencing, pre-whitening, variance correlation (Hamed KH, 1998), and trend-free pre-whitening (TFPW) approach (Yue et al. 2002b). In this research, autocorrelation has been taken into account using the Hamed and Rao method.

We used XLSTAT 2020 software to calculate the MK test and Sen's slope, including the homogeneity and normality tests.

CV is calculated to evaluate the variability of the rainfall. A higher value of CV is the indicator of larger variability, and vice versa. According to Hare, (2003), CV is used to classify the degree of variability of rainfall events as less (CV< 20), moderate (20 < CV <30), and high (CV >30). CV (%) computed as:

$$CV = \frac{\sigma}{\mu} * (100) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (7)$$

Where CV is the coefficient of variation, σ is the standard deviation, and μ is the mean precipitation.

We used precipitation concentration index (PCI), which is the ratio of the square of the rainfall amount of the specific month to the square of the total rainfall to show the rainfall distribution in the watershed. It can also follow similar procedures for calculating seasonal precipitation concentration indices. According to the (Oliver, 1980), the PCI value of less than 10% represents a uniform rainfall distribution (i.e., low rainfall concentration); PCI values between 11-15 denote a moderate rainfall concentration; values from 16-20 denote irregular rainfall distribution, and values above 20% represent the irregularity(i.e., high rainfall concentration) of rainfall distribution (De Luis et al., 2010). PCI is calculated using the equation:

$$PCI_{annual} = \frac{\sum_{i=1}^{12} P^2{}_i}{(\sum_{i=1}^{12} p_i)^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (8)$$

Where: P_i is the rainfall amount of the i^{th} month.

It is calculated as the ratio between the mean monthly rainfall and one-twelfth of the mean annual rainfall. When the PC is greater than one, the month is the wet month that can contribute more than one-twelfth of the mean annual rainfall and dry months contribute less than one-twelfth of the mean annual rainfall (Tena A, et al. 2018). A month is rainy if the rainfall coefficient is greater than 0.6. The expression "small rains" refers to months with a rainfall coefficient of 06-0.9, and the expression "big rains" refers to months with a rainfall coefficient of 1 and above. Big rainy months are further classified into three groups: months with "moderate concentration" (coefficient of 1 to 1.9); months with "high concentration" (coefficient of 2-2.9); and months with "very high concentration" (coefficient of 3 and above)(Tena A, et al. 2018).

RESULT AND DISCUSSION

Trends and variability of rainfall based on the coefficient of variation (CV)

The mean annual rainfall of the area during the study period was 1585.2mm with a 201.5 mm standard deviation and 12.7% CV. In 1999 rainfall was 1894.1 mm, which was the highest among the study period. However, the lowest rainfall was seen in 2015, which was 1193.9mm. As described in Table1, summer is the major rainy season in the Andit tid watershed, contributing about 61.8% of the total rainfall. From 61.8%, July and August cover 45.8%; this clearly revealed the presence of a high concentration of rainfall in July and August. In the study area, 19.4% of the total rainfall was occurred in another rainy season, March to May (Belg). The total amount of annual rainfall had shown no significant change (CV=12.7) over time. Based on the CV value, spring gets inter-annually variable rainfall than the other seasons. When we compared to summer and Belg with their CV, higher inter-annual variability occurred in the Belg season with CV (31.2%) than summer CV (17.7%). The result agrees with the findings of (Asfaw et al., 2018), where more variability in Belg rainfall than the summer rainfall in most parts of Ethiopia was disclosed. Camberlin & Philippon, (2002) also found a strong inter-annual variability over the last four decades in equatorial East Africa instead of the long summer rains.

Trends and variability of rainfall based on PCI

The PCI value of the watershed is 13.87% which means the rainfall in the watershed has a moderate rainfall concentration, as shown in Table1. In fact, the rainfall distribution can also be verified by the rainfall recorded from four different rain gauges distributed in different watershed locations. Based on the recorded rainfall from these four rain gauge sites of the watershed, there was insignificant variation among the rainfall amount. In contrast with this study, the precipitation concentration index in the Woleka sub-basin revealed the presence of a high and very high concentration of rainfall (Asfaw et al., 2018). Another study also reported a high concentration of rainfall in the central highlands of Ethiopia by (Arragaw, A., Woldeamlak, 2017).

Trends and variability of rainfall based on precipitation coefficient (PC)

The precipitation coefficient (%) value of the watershed indicates that July (PC=2.86) and August (PC=2.65) have big rain with high concentration; September (PC=1.12) have big rain with moderate concentration, and these three months could contribute more than one twelve of total rainfall amount. On the other hand, the month of March, April, May, June, and October have small rain with PC values of 0.69, 0.84, 0.8, 0.79, and 0.67, respectively. The month of January, February, and November are dry months as verified from the precipitation coefficient values mentioned in Table1. In agreement with our finding, the rainfall coefficient of Maybar in July and August, is about 3 and 3.1 respectively, which is a 'very high concentration," while September with a rainfall coefficient of 1.1 is regarded as a moderate concentration (Tena A et al., 2018).

Table 1. Basic statistics and MK trend analysis of rainfall of Andit tid watershed (1994–2017)

Month	Min	Max	Mean	Std. deviation	CV (%)	%	PC	PCI (%)	MK test	Sen's slope
Jan	0.0	165.2	48.8	41.0	84.1	3.1	0.37	0.09	0.007	0.000
Feb	0.0	126.0	45.7	35.9	78.5	2.9	0.35	0.08	0.208	1.591
Mar	3.5	206.4	91.2	50.6	55.5	5.8	0.69	0.33	-0.072	-1.459
Apr	8.5	208.3	111.0	56.1	50.5	7.0	0.84	0.49	-0.116	-1.569
May	40.6	267.0	105.8	57.7	54.5	6.7	0.80	0.45	0.210	2.118
June	25.3	213.5	104.5	44.8	42.9	6.6	0.79	0.43	0.080	0.350
July	143.6	609.9	377.7	96.1	25.5	23.8	2.86	5.68	-0.232	-4.203
Aug	211.7	526.4	349.4	87.3	25.0	22.0	2.65	4.86	-0.196	-3.468
Sept	3.4	317.6	148.4	71.2	48.0	9.4	1.12	0.88	-0.196	-3.206
Oct	18.0	334.2	88.7	80.0	90.1	5.6	0.67	0.31	-0.152	-1.270
Nov	0.0	178.7	63.9	48.7	76.1	4.0	0.48	0.16	-0.065	-0.294
Dec	0.0	122.9	50.0	38.2	76.4	3.2	0.38	0.10	0.011	0.105
Belg	90.2	478.1	308.1	96.3	31.2	19.4	0.78	3.78	0.007	0.206
Summer	681.6	1412.5	980.0	173.0	17.7	61.8	1.85	38.22	-0.261	-9.574
spring	21.2	364.6	152.6	98.6	64.6	9.6	0.58	0.93	-0.145	-4.326
Winter	20.4	353.9	144.5	91.4	63.3	9.1	0.36	0.83	0.152	2.223
Annual	1193.9	1894.1	1585.1	201.5	12.7	100.0		13.87	-0.239	-12.0

→Min: minimum; Max: maximum; std.: standard; CV: coefficient of variation; %: percent of contribution of each months; PC: precipitation coefficient; PCI: precipitation concentration index; MK: Mann Kendall

Trends and variability of rainfall based on MK test and Sen's slope estimator

The MK test and Sen's slope estimator were applied to the time-series data from 1994 to 2017 for Andit tid watershed. The results of the MK test and Sen's slope for trend analysis are presented in Table1. The trend analysis has been done for all months, seasons, and the whole year. The results of the MK test for monthly, seasonal and annual precipitation data revealed a statistically insignificant trend. The monthly trend analysis revealed that the main rainy months (July, August, and September) show decrement but are statistically insignificant. The decreasing trend of the main rainy months affects the rainy season and even the annual rainfall to have a decreasing trend. From the analysis, we see an insignificant increment of rainfall in the Belg season and an insignificant decrement of rainfall in the summer; this implies shifting rainfall from the main rainy season of the watershed to Belg. In our study, the variable but insignificant increasing trend of Belg rain through time was in contrast with (Arragaw, A., Woldeamlak, 2017) they reported that, Belg rainfall showed a significant decreasing trend. But the result confirmed that, the rainfall trend of the Andit tid watershed is in decreasing pattern. However, it is insignificant; the output of this analysis is in agreement with Negash, et al., (2013), where statistically significant declining summer rainfall at watershed level was reported in a different part of Ethiopia, including the central highland. The results are in contrast with the findings of Daniel, et al., (2014), where the statistically non-significant increasing trend was recorded in all seasons (including annual time scale) and (Arragaw, A., Woldeamlak, 2017), where statistically significant increasing trends in July and November in dega and woina-Dega agro-ecologies of central highlands of Ethiopia. Sen's Slope test (Table1), which gives a magnitude of the slope, also shows a decreasing trend for each month, season, and year over the period from 1994–2017 except dry months and seasons.

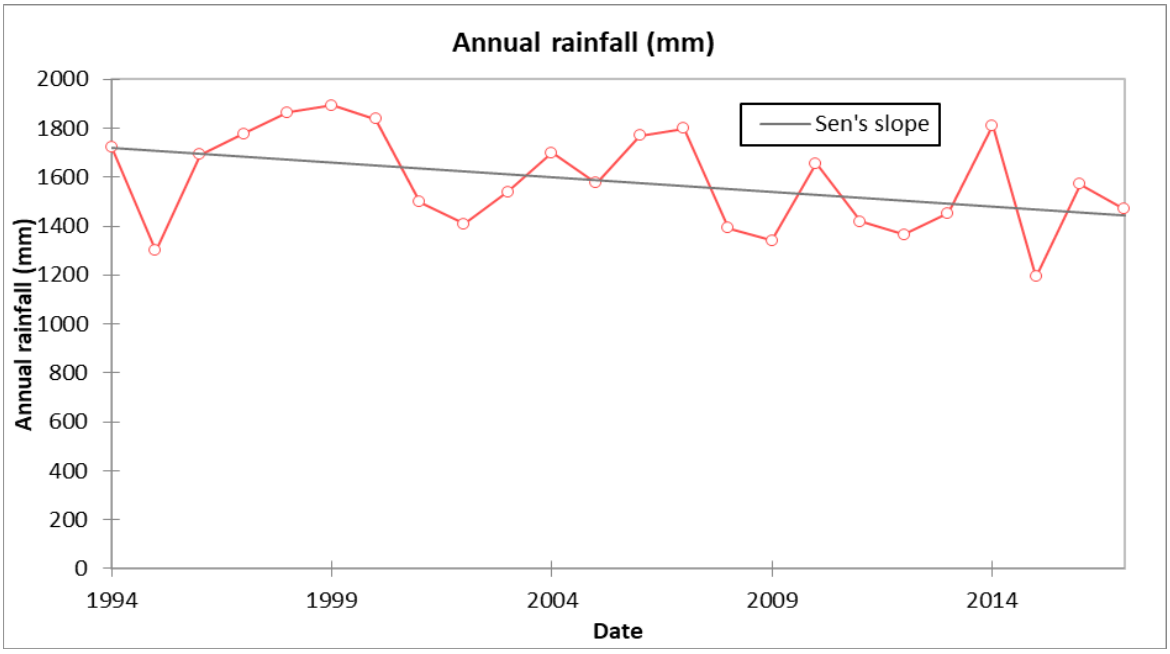

Figure 2. The annual rainfall and Sen's slop of Andit tid watershed (1994-2017)

Air and soil temperature variability and trend analysis

The mean daily minimum and maximum air temperature of the watershed were 7.5° and C 17.6° C, respectively. The mean daily air temperature of the watershed was 12.6 °C. The watershed's mean minimum and maximum soil surface temperatures were 8° and 20.5° C, respectively. The mean soil surface temperature of the watershed was 14.2 °C. Based on the long term time series air temperature data November and December were the coldest months with an average value of 10.8 °C and 10.6°C, respectively; whereas May and June are the hottest months with an average value of 14.2°C and 14.4°C, respectively. In more than 99% of the records, daily soil surface temperature was higher than the daily air temperature.

Table 2. Extreme temperature measurements and average temperature summary table

	Extreme temperature(^{o}C)records and date of events			
Events	Minimum air temp	Maximum air temp	Minimum soil temp	Maximum soil temp
Lowest record	**-9** ^{o}C (22/7/2017)	**2** ^{o}C (11/22/2010)	**-6** ^{o}C (07/01/2012) &09/01/2012)	**1** ^{o}C (02/01/2014) &(16/06/2010)
highest record	**23** ^{o}C (01/31/2008)	**26** ^{o}C (08/06/2006) &01/01/2017)	**22** ^{o}C (03/05/2004)	**34** ^{o}C (06/01/2015)
Average (^{o}C)	7.5	17.6	8	20.5
Annual Average(^{o}C)	12.6		14.2	

Analysis of annual, seasonal, and monthly temperature data was undertaken to detect the variability and trend of temperature change in the study area for the periods of 1994–2017. As demonstrated in (Table 3), the annual MK trend test result revealed that maximum temperatures have significantly increased at a 95% confidence level through time. The trend for mean temperature showed a non-significant increasing trend except May, June, and August (they showed an insignificant decreasing trend). In contrast with mean and maximum annual temperature, the annual minimum temperature shows highly significant (P<0.01) decreasing trends with Sen's slope of -0.044. Seasonal trend analysis indicated that, except the spring, the maximum temperature of all seasons showed significantly (P<0.05) increasing trends. The mean temperature also showed a significant increase in the winter and spring seasons. Contractually, the seasonal minimum temperature showed highly significant (P<0.01) decrement trends in Belg and summer. Except for some months (insignificant increment), the maximum temperature showed statistically significant increasing trends. The mean temperature showed insignificant increasing trends except for January, April, and November (they showed significant increasing trends). The monthly minimum temperature showed a significantly decreasing trend in April, May, June, July, August, and September; the remaining months showed an insignificant decreasing trend. The overall trend analysis result revealed a significant increase in maximum temperature and a significant decrement in minimum temperature with an insignificant increase in mean temperature (Table 3). The result contrasts with the findings of Asfaw et al., (2018), where the increasing trends in the minimum temperature series were higher than those in the maximum temperature series.

Table 3. MK trend test and Sen's slope result of air temperature of Andit tid

	Maximum temperature (^oC)		Mean temperature (^oC)		Minimum temperature (^oC)	
	MK test	Sen's slope	MK test	Sen's slope	MK test	Sen's slope
January	0.478*	0.133	0.355*	0.052	-0.007	-0.002
February	0.362*	0.091	0.297	0.031	-0.076	-0.009
March	0.478*	0.108	0.275	0.040	-0.145	-0.022
April	0.435**	0.110	0.304*	0.041	-0.356**	-0.022
May	0.072	0.030	-0.181	-0.029	-0.439**	-0.068
June	0.188	0.040	-0.043	-0.005	-0.496**	-0.049
July	0.5**	0.122	0.116	0.013	-0.492**	-0.095
August	0.398*	0.071	-0.188	-0.022	-0.667**	-0.137
September	0.41**	0.081	0.171	0.019	-0.475**	-0.061
October	0.181	0.065	0.051	0.014	-0.175	-0.031
November	0.435	0.118	0.384**	0.064	0.156	0.025
December	0.348	0.070	0.152	0.024	-0.116	-0.028
Belg	0.427*	0.096	0.196	0.018	-0.478**	-0.033
Summer	0.558*	0.091	0.065	0.006	-0.543**	-0.076
Spring	0.188	0.084	0.159*	0.027	-0.094	-0.011
Winter	0.485*	0.092	0.399*	0.035	-0.167	-0.015
Annual	0.435*	0.086	0.181	0.019	-0.399**	-0.044

*: statistically significant at (P<0.05) and **: statistically significant at (P<0.01)

Based on the soil surface data, the coldest and the hottest months are November (11.1 ^oC) and June (17.3 ^oC), respectively. The seasonal soil surface temperature tells the wettest and driest season of the study area: spring (11.5 ^oC) and Belg (16.7 ^oC), respectively. Maximum monthly soil temperature showed insignificant increasing trends except for May and June (they showed insignificant decreasing trends). Except for May, June, July, and November, the mean monthly soil temperature showed significant (P<0.05) increasing trends. Similarly, the minimum monthly soil surface temperature showed significantly increasing trends except for May. The seasonal maximum soil temperature showed an insignificant increasing trend. In the agreement, the seasonal mean and minimum soil temperature also showed a significant increasing temperature trend. Similar to the seasonal soil temperature, the annual mean and minimum soil temperature showed statistically significant, whereas maximum soil temperature showed an insignificant increasing temperature trend.

Table 4. MK trend test and Sen's slope of soil temperature of Andit tid

	Maximum temperature (°C)		Mean temperature (°C)		Minimum temperature (°C)	
	MK test	Sen's slope	MK test	Sen's slope	MK test	Sen's slope
January	0.058	0.03	0.333*	0.060	0.313*	0.073
February	0.036	0.01	0.338*	0.068	0.312*	0.12
March	0.138	0.054	0.367*	0.086	0.342*	0.115
April	0.072	0.034	0.326*	0.065	0.338*	0.095
May	-0.120	-0.041	0.072	0.016	0.275	0.068
June	-0.171	-0.094	0.101	0.021	0.356*	0.082
July	0.065	0.032	0.232	0.049	0.407**	0.107
August	0.065	0.031	0.319*	0.083	0.456*	0.111
September	0.130	0.055	0.377*	0.088	0.439*	0.095
October	0.236	0.081	0.304*	0.078	0.3376*	0.082
November	0.134	0.05	0.171	0.035	0.254	0.079
December	0.275	0.074	0.37*	0.092	0.304*	0.085
Belg	0.022	0.016	0.326*	0.069	0.333*	0.092
Summer	0.080	0.025	0.37*	0.072	0.456**	0.113
Spring	0.188	0.054	0.268	0.055	0.304*	0.08
Winter	0.138	0.035	0.384**	0.071	0.442*	0.093
Annual	0.123	0.034	0.377*	0.076	0.398*	0.097

*: statistically significant at (P<0.05) and **: statistically significant at (P<0.01)

Regression between rainfall, air temperature, and soil temperature (To)

The regression analysis determined the relationship between the parameters of each other. The graph below indicates the indirect relation of air and soil temperature with rainfall, while the air temperature can be defined by 14.7%. The result of regression analysis has confirmed the result of the MK non-parametric trend test results.

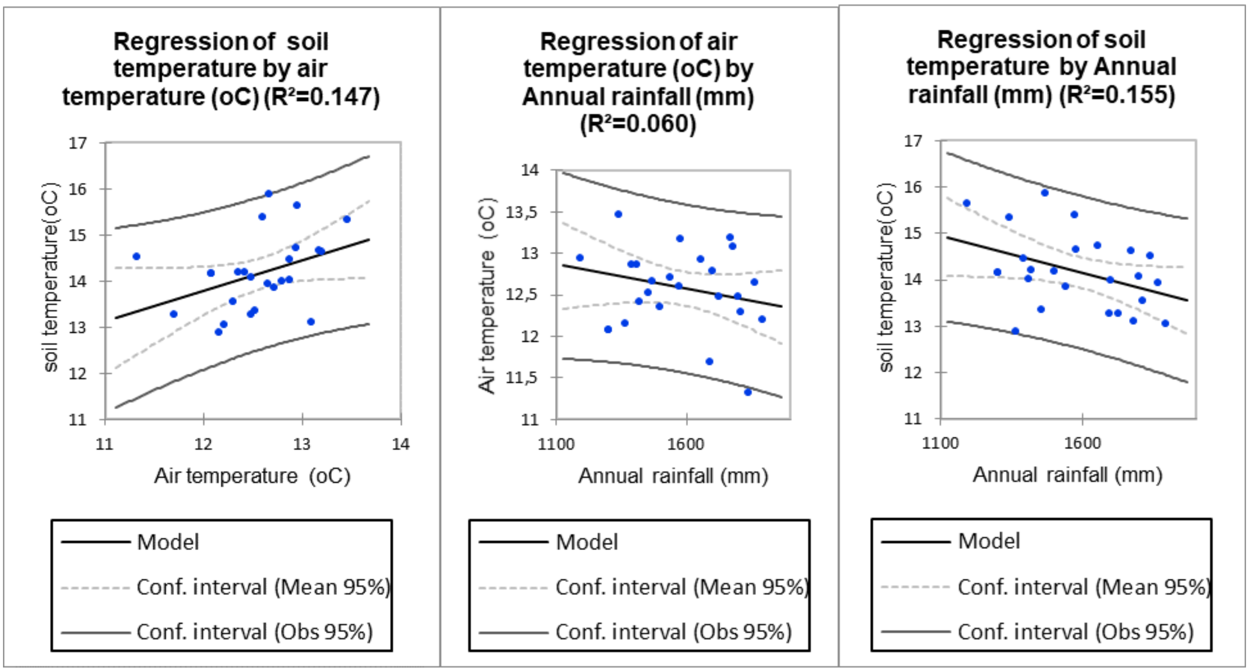

Figure3. The regression (R^2) between mean annual rainfall, air T° and soil T°

CONCLUSION

This study analyzed trends of rainfall air temperature and soil temperature in the Andit tid watershed for the study period from 1994 to 2017 using a non-parametric statistical Mann Kendall trend test. During the test, the autocorrelation was taken into account using the Hamed and Rao method. Additional basic rainfall characteristics such as precipitation concentration index (PCI), precipitation coefficient (PC), and coefficient of variation (CV) were computed to analyze the variability and trend of rainfall. The Sen's slope or magnitude of change in climatic variables was also estimated over the study period. The result of this long-term trend analysis revealed that the mean annual rainfall of the watershed is 1585.1mm with a 201.5mm standard deviation and 12.7% coefficient of variation. Even though it was insignificant, except for the driest months and winter season, the trend analysis of rainfall revealed an overall decreasing trend was observed for the monthly, seasonal, and annual scales. The PCI and CV indicated that the watershed has a moderate concentration (PCI=13.87) of rainfall with lower inter-annual variability (CV=12.7). From the precipitation coefficient, we could conclude that, July, August, and Septembers have big rain with high concentrations.

The monthly scale trend showed the maximum and mean air temperature showed an increasing trend, with some months showing statistically increasing at ($P<0.05$) level of significance. In contrast with this trend, the minimum monthly air temperature showed decreasing trends, with some months showing a significant decreasing trend. Except for spring (insignificant increasing trend), the maximum seasonal air temperature showed a statically significant increasing trend at ($P<0.05$) level of significance. A statistically significant increasing trend of mean temperature was shown in spring and winter with the insignificant increasing trend of Belg and summer air temperature. Contractually, in Belg and summer statistically significant decreasing trend of the minimum air temperature was shown with an insignificant decreasing trend in spring and winter. Annually, maximum (statistically significant ($P<0.05$)) and mean (insignificant ($P<0.05$)) air temperature were showed an increasing trend, while the minimum annual air temperature showed a statistically significant decreasing trend at ($P<0.01$) level of significance. Except for May and June (insignificantly decreasing), all the monthly maximum soil temperatures showed a statistically insignificant increasing trend. Except for some months (insignificant increasing trends), all the monthly mean and minimum soil temperatures showed a statistically increasing trend (P<0.05). On the seasonal scales; a noticeable increase was revealed in soil surface temperature (i.e., minimum and mean temperature) based on the results of Mann Kendall non-parametric statistical tests at (P<0.05) level of significance, similarly the seasonal maximum soil temperature showed an increasing trend, but statistically it was insignificant (P<0.05) based on the Mann Kendall test. In a similar situation with the seasonal trend, except the maximum soil temperature (statistically insignificant increasing trend), the annual mean and minimum soil temperature also showed a statistically increasing trend at (P<0.05) level of significance. Local watershed-based trend analysis is expected to help facilitate a transition to the more precise recommendation and policymaking. The information generated with this research helps the Andit tid community to adopt sustainable water resources planning and management. Eventually, this will help policymakers and researchers to focus on local-scale planning measures for climate change adaptation and mitigation, by considering watershed-based local-scale variability in trends.

REFERENCES

Arragaw, A., Woldeamlak, B. (2017). Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia. Geogr. Ann. Phys. Geogr. https://doi.org/10.1080/04353676.2017.1289460.

Asfaw, A., Simane, B., Hassen, A., & Bantider, A. (2018). Variability and time series trend analysis of rainfall and temperature in north-central Ethiopia: A case study in Woleka sub-basin. Weather and Climate Extremes, 19(June 2017), 29–41. https://doi.org/10.1016/j.wace.2017.12.002

Bayazit M, O. no¨z B. (2008). To whiten or not to whiten in trend analysis? Hydrol Sci J, 52(4), 611–624.

Beg, N., Morlot, J. C., Davidson, O., Afrane-Okesse, Y., Tyani, L., Denton, F., Sokona, Y., Thomas, J. P., La Rovere, E. L., Parikh, J. K., Parikh, K., & Rahman, A. A. (2002). Linkages between climate change and sustainable development. Climate Policy, 2(2–3), 129–144. https://doi.org/10.3763/cpol.2002.0216

Birsan, M., Molnar, P., Burlando, P., Pfaundler, M. (2005). Streamflow trends in Switzerland. Journal of Hydrology, 314, 312–329.

Camberlin, P., & Philippon, N. (2002). The East African March-May rainy season: Associated atmospheric dynamics and predictability over the 1968-97 period. Journal of Climate, 15(9), 1002–1019. https://doi.org/10.1175/1520-0442(2002)015<1002:TEAMMR>2.0.CO;2

Daniel, M., Woldeamlak, B., Lal, R. (2014). Recent spatiotemporal temperature and rainfall variability and trends over the upper Blue Nile river basin, Ethiopia. Int. J. Climatol., 34(2278–2292).

De Luis, M., González-Hidalgo, J. C., & Longares, L. A. (2010). Is rainfall erosivity increasing in the Mediterranean iberian peninsula? Land Degradation and Development, 21(2). https://doi.org/10.1002/ldr.918

Desalegn, A., Tezera, A., & Tesfay, F. (2018). Developing GIS-Based Soil Erosion Map Using RUSLE of Andit Tid Watershed, Central Highlands of Ethiopia. Journal of Scientific Research and Reports, 19(1). https://doi.org/10.9734/jsrr/2018/40841

Eriksson, M., Jianchu, X., Shrestha, A. B., Vaidya, R. A., Nepal, S., & Sandström, K. (2009). The Changing Himalayas Impact of climate change on water resources and livelihoods in the greater Himalaya. May 2014.

Hamed KH, R. R. A. (1998). A modified Mann–Kendall trend test for autocorrelated data. Hydrol, 204(1–4), 182–196.

Hare, W. (2003). Assessment of Knowledge on Impacts of Climate Change, Contribution to the Specification of Art, 2 of the UNFCCC. WBGU.

Kendall, M. G. (1975). Rank Correlation Methods, 4th ed. Charles Griffin, London.

Mann, H. B. (1945). Non-parametric test against trend. Econometrica, 13, 245–259.

Negash, W., Goel, N.K., Jain, M. . (2013). Temporal and spatial variability of annual and seasonal rainfall over Ethiopia. Hydrol. Sci. J, 58(2), 354–373. https://doi.org/10.1080/02626667.2012.754543

NMA. (2007). Climate Change National Adaptation Programs of Action (NAPA) of Ethiopia, Addis Ababa, Ethiopia.

Oliver, J. E. (1980). Monthly precipitation distribution: A comparative index. Professional Geographer, 32(3). https://doi.org/10.1111/j.0033-0124.1980.00300.x

Orlove, B., E. Wiegandt, and B. L. (2008). The place of glaciers in cultural and natural landscapes: Environment, history, and culture as influences on perceptions of glacier dynamics. In Darkening peaks: Mountain glacier retreat in social and biological contexts. Berkeley: University of California Press, 3–19.

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. J. Am. Stat. Assoc., 63, 1379–1389.

Tena Alamirew, Daniel Berhanu, Hans Hurni, and G. Z. (2018). 'Longterm agro-climatic and hydro-sediment observatory report: The case of Maybar micro-watershed, Awash River Basin, North-eastern Ethiopia'. In WLRC Research Report II.

Tesfahunegn, G.B.; Mekonen, K.; Tekle, A. (2016). Farmers' perception on causes, indicators and determinants of climate change in northern Ethiopia: Implication for developing adaptation strategies. Appl. Geogr., 73, 1–12.

Theil, H. (1950). A rank-invariant method of linear and polynomial analysis, part 3. Nederlandse Akademie van Wettenschappen. Proceedings, 1397–1412.

Wang, X. L., Swail, V. R., & Zwiers, F. W. (2006). Climatology and changes of extratropical cyclone activity: Comparison of ERA-40 with NCEP-NCAR reanalysis for 1958-2001. Journal of Climate, 19(13), 3145–3166. https://doi.org/10.1175/JCLI3781.1

Weldegerima, T. M., Zeleke, T. T., Birhanu, B. S., Zaitchik, B. F., & Fetene, Z. A. (2018). Analysis of Rainfall Trends and Its Relationship with SST Signals in the Lake Tana Basin, Ethiopia. Advances in Meteorology, 2018. https://doi.org/10.1155/2018/5869010

Wen, X.; Wu, X.; Gao, M. (2017). Spatiotemporal variability of temperature and precipitation in Gansu Province (Northwest China) during 1951–2015. Atmos. Res., 197, 132–149.

WorldBank. (2010). The World Bank Annual Report 2010 Year In Review. World Bank Annual Report.

Yue, S., Pilon, P., Phinney, B., Cavadias, G. (2002). The influence of autocorrelation on the ability to detect trend in hydrological series. Hydrol. Proc, 16, 1807–1829.

Yurekli K, Simsek H, Cemek B, K. S. (2007). Simulating climatic variables by using stochastic approach. Build Environ, 42, 3493–3499.