Climate Variability and Trend in Andracha, Southwest Ethiopia

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Abstract

A good characterization of time series rainfall and temperature trends, variability, and prediction is necessary for many studies in climatology, hydrology, agriculture, and forestry. It provides input for policymakers and practitioners that help to make informed decisions and allows the identification of deviations due to global climate change. This study quantified trends and variability in monthly, seasonal, and annual rainfall and temperature in Andracha district, Southwestern Ethiopia, over 31 years (1987-2017). The Mann-Kendall test and Sen's slope estimate were applied to identify the trends and magnitude over the time series. A pre-whitening approach was applied to eliminate serial correlations in the rainfall and temperature data.The analysis revealed the highest inter-annual variability for December-February rainfall, with a Coefficient of Variation (CV) of 33.46%, followed by September-November and March-May rainfall, with CVs of 17.44% and 15.76%, respectively. The temperature did not show a significant trend through the observed time series at the 95% confidence level, while a mix of positive and negative trends was observed for rainfall. The findings indicate that May monthly rainfall exhibits a statistically significant rising trend, whereas August month and June-August (main rain season) rainfall exhibit statistically significant declining trends. The test did not show a statistically significant trend in annual rainfall and rainfall in the remaining seasons and months. The rates of change in rainfall were found to be 2.88 mmyr^{-1}, -2.91 mmyr^{-1}, and -4.66 mmyr^{-1} for the May, August, and June-August season, respectively, during 1987-2017. The study indicates that the district is less sensitive to temperature changes but has a decline in rainfall in the main rainy season. The information obtained from this research can help practitioners and policy-makers understand patterns and trends of climate variables for better planning and management of the district.

Keywords: Mann-Kendall test • Pre-whitening, Rainfall • Sen's slope estimate • Temperature

Introduction

Climate can be explained as the average state of the atmosphere as well as the underlying land or water on time scales of seasons and longer [1]. Precipitation and temperature are two of the most essential variables in the field of climate sciences and hydrology and are commonly applied to detect the degree and intensity of climate change and variability [2]. Precipitation is a crucial constituent of rainfall-runoff interactions and affects flood/drought evaluation and alleviation measures. Temperature plays a significant role in evaporation, transpiration, and water demand and thus considerably influences both water accessibility and management approaches [3]. The industrial revolution that evolved in the middle of the past century brought about the release of greenhouse gases into the atmosphere [4].

Climate change, global warming, and global energy imbalance are regarded as the main outcomes of the substantial rise in greenhouse gas concentration largely due to industrialization, burning of fossil fuels, and land use land cover changes [5]. The average global surface temperature has increased by approximately 0.74°C over the past 100 years, although the largest portion of the increase (0.55°C) has appeared over the past 30 years [6]. Future projections mostly indicate pronounced warming over many land areas. Future climate change will bring about a rise in the average mean temperature and variations in annual and seasonal rainfall [4]. The warming in Africa is anticipated to be more than the gl obal annual mean warming all over the continent and in all seasons [7]. Climate models projected that Ethiopia will have more warming of 0.7°C-2.3°C by the 2020s and 1.4°C-2.9°C by the 2050s [6,8]. Extended variations in temperature appear to exist at comparatively small spatial and temporal scales [3].

Temperature variation has an impact on evapotranspiration and rainfall patterns, which in turn have consequences on the stream flow rate, hydrologic cycle, and water demand [9]. Temperature, solar radiation, wind, rainfall, and evapotranspiration are the main climatic variables influencing agricultural production [10]. Climate change can interrupt food availability, decrease access to food and impact food quality [4]. The impacts of climate change are more extreme in poor developing countries since many developing countries highly depend on rain-fed agriculture [6] and are least provisioned socially, technologically, and financially to encounter climate change effects [5]. Africa is anticipated to experience generally adverse climate change impacts about existing inflated high temperatures and dwindling and irregular rainfall together with far-reaching poverty and underdevelopment [11]. Ethiopia is cited as one of the most susceptible countries to climate change and frequently denotes greater probabilities of droughts that have historically affected millions of farmers [4]. Extended climate-associated changes in rainfall patterns and variability and temperature are most likely to enhance the incidence of floods and droughts in Ethiopia [11]. Prevailing climate variability is already making a significant impact on Ethiopia by affecting food security, water and energy supply, poverty reduction, and sustainable development efforts, as well as by degrading natural resources and initiating natural disasters [1]. Climate change is expected to diminish the gross domestic product growth of the country by 0.5%- 2.5% yearly [12].

A proper analysis of temperature and precipitation trends, variability, and forecasting is basic in evaluating the state of the climate of a region and gives a general estimate of the changes in the climatic variables [5]. Studying the spatiotemporal dynamics of climatic variables because of a changing climate, specifically in countries where rain-fed agriculture is prevalent, is crucial to evaluate climate-induced changes and infer appropriate adaptation and mitigation strategies [11]. Long-term assessment of trends in temperature and rainfall and an understanding of the numbers of rainy days are vital for subsistent farmers, which usually rely on rainfall situations [12-13]. Climate trend analysis is also an important construct for the prediction of future climate scenarios [14]. Precise prediction of climate variables is imperative for policymakers and planners and development workers dealing with mitigation and adaptation measures to cope with climate change [5].

It is critical, therefore, to better understand temporal trends, patterns, and variability in temperature and rainfall from records for predicting future impacts. Accurately identifying and characterizing climatic trends to acquire important information on what has been changing in the past few decades is thus an important beginning step in climate studies. Different studies have been reported to explore climate variability, trends, and predictions in Ethiopia [3, 4, 7, 9]. However, no studies on climate trends and predictions have been reported in Andracha district, Southwestern Ethiopia. This study fills this research gap.

Material and Methods

Study area description

The study was conducted in Andracha district, Sheka Zone, Southwest Ethiopia (Figure 1). It lies between latitudes 7°13'57"N-7°59'64" N and longitudes 35°13'25"E–35°49'27"E with a geographical area of approximately 102,000 ha [15-17]. The area receives rain for approximately 9 months with an average annual rainfall of 1770 mm-2240 mm, while the annual mean temperature is approximately 17.3°C-17.9°C (Figure 2). It is one of the areas in Ethiopia with high forest cover. The forests in Andracha district are very rich in plant species composition and have both global and national importance for conservation. It has been included in the Eastern Afromontane Biodiversity Hotspot and UNESCO Biosphere Reserve [18, 19]. The district has a total population of 26,449 people, out of which 13,291 are male and 13,148 are female [20-22].

Historical climate dataset

Historical time series data of daily precipitation and minimum and maximum air temperatures of Andracha district for 31 years (1987 - 2017) were obtained from the National Meteorology Agency of Ethiopia. These data were derived from a hybrid of observed climate datasets at the Gecha meteorological station and satellite data. The study duration was selected owing to the availability of climate data. Four distinct seasons are recognized in the study area:

(1) December–January–February(DJF)-dry-season

(2) March-April-May (MAM) - short rain season,

(3) June-July August (JJA) - the main rainy season, and

(4) September–October–November (SON) - wet season.

The short rainy season is caused by moist easterly and southeasterly winds from the Indian Ocean, while the main rainy season is a result of convergence in low-pressure systems and the Intertropical Convergence Zone [11].

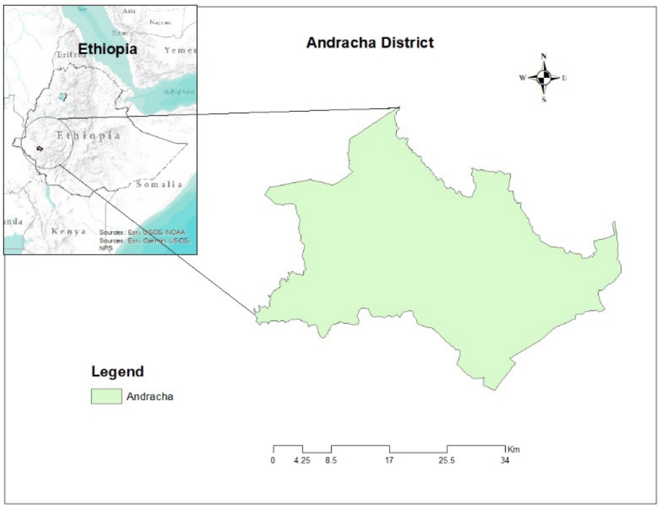

Figure 1. Map of the study area

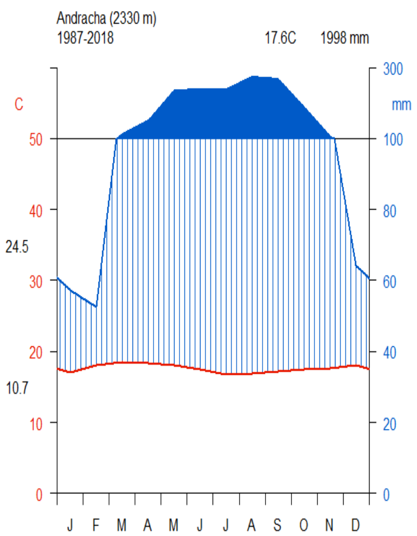

Figure 2. Walter Leith climo diagram for Andracha district.

Statistical tests and analysis

Variability analysis

Temperature and rainfall time series data variability in the study area was computed using the Coefficient of Variation (CV) [11,14]. The coefficient of variation is the measure of the dispersion of data points in the data series around the mean [13]. A higher value of CV is an indicator of larger variability, and vice versa, which is computed as [11]:

$$CV = \frac{\delta}{\mu} \times 100$$

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

CV is used to classify the degree of variability of rainfall events as less $(CV < 20)$, moderate $(20\ CV < 30)$, and high $(CV > 30)$ [11].

Trend detection and characterization

Different statistical test methods are used to detect trends in climate variables; these are broadly classified0020as parametric and nonparametric tests [23,24]. Parametric methods assume an underlying distribution (typically Normal) for the variables of interest, whereas nonparametric methods do not [3,25]. The advantage of nonparametric statistical tests over parametric tests is that the former is more suitable for no normally distributed, outlier, censored, and missing data, which are frequently encountered in climate time series data [11,26]. The most common and effective nonparametric test for working with time series trends is the Mann-Kendall (MK) test [10,11,16,26]. The Mann-Kendall test eliminates the effect of serial dependence on auto-correlated data, which modifies variance in datasets [11,16,27]. The time series data in this study were investigated for trends using the Mann-Kendall test. The magnitude of the statistically significant trend was determined using Sen's slope estimator [11-13]. Before applying the MK test, all the time series data were tested for serial correlation using Lag-1 autocorrelation at the 5% significance level to make the series serially independent otherwise, trends might be incorrectly estimated [3,13].

Pre-Processing of time series data

The 31 years of daily rainfall and temperature data were reduced to monthly and annual series of total rainfall and average temperature. These series were subsequently tested to determine whether pre-whitening was appropriate. Removing serial dependence is one of the main problems in testing and interpreting time series data. The MK test requires that a time series be serially independent. The Trend-Free Pre-Whitening (TFPW) approach was applied to eliminate serial correlations in the time series data if they existed to conform to this requirement. The serial correlation coefficient (r_1) was calculated as [11-14]:

$$r_1 = \frac{\frac{1}{n-1}\sum_{i=1}^{n-1}(x_i - \overline{X})(x_{i+1} - \overline{X})}{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{X})^2}$$

No significant serial correlation was judged present if the value of r_1 fell inside the bounds given by:

$$\frac{-1-1.645\sqrt{(n-2)}}{n-1} \le r_1 \le \frac{-1+1.645\sqrt{(n-2)}}{n-1}$$

If, however, the significant serial correlation was detected, then a pre-whitened series x* (with one fewer data point than the original) was created for subsequent analysis from:

$$x_i^* = x_{i+1} - r_1 x_i$$

Mann-Kendall (MK) test

The Mann-Kendall test is used to detect statistically significant trends in variables such as rainfall, temperature, and stream flow. In the MK test, parameters such as Kendall's tau, S statistic, and Z statistic were considered to identify the increasing or decreasing trend in the time series of climatic parameters. For a time series $x_1, x_2, x_3, \ldots, x_n$, with n>10, the MK test statistic (S), the variance of MK test statistic V(S), and the associated standard normal test statistic (Z) are calculated as follows [3, 13, 11, 14]:

$$Z = \begin{bmatrix} \frac{S-1}{\sqrt{V(S)}} \; for\ S > 0 \\ 0 \quad for\ S = 0 \\ \frac{S+1}{\sqrt{V(S)}} \; for\ S < 0 \end{bmatrix}$$

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

$$\operatorname{sgn}(x_j - x_i) = \begin{bmatrix} 1 \ for(x_j - x_i) > 0 \\ 0 \ for(x_j - x_i) = 0 \\ -1 \ for(x_j - x_i) < 0 \end{bmatrix}$$

$$V(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5) \right]$$

Where *q* represents the total number of tied groups. A set of the same values in a dataset is referred to as a tied group. Each tied group is denoted by *tp*. Z_{MK} follows a normal distribution, a positive Z_{MK} depicts an upward trend and a negative Z_{MK} depicts a downward trend for the period. Trends are then tested against some critical values ($Z1\text{-}\alpha$) to show that either is statistically significant or not. If $|Z|>Z1\text{-}\alpha$ (taken as 0.05 in this study), the null hypothesis of a no-trend is rejected, and the alternative hypothesis of a significant trend is accepted [5].

Sen's slope estimator

The direction and magnitude of the trend in time series data were quantified using Sen's slope [27]. Sen's slope estimator was used to estimate the magnitude of trends in the time series data [10,28]. This method assumes that the trend line is a linear function in the time series. The advantage of using Sen's slope is that it is not affected when outliers and single data errors are present in the dataset [13]. To derive an estimate of Sen's slope *b*, the slopes of all data pairs are calculated by [14]:

$$b_i = \frac{X_J - X_i}{j - i}, i = 1, 2...., N, \ j > i$$

Sen's estimator of the slope is the median of these *N* values of b_i:

$$b = \begin{Bmatrix} b_{(N+1)/2} \\ 0.5[b_{N/2} + b_{(N+2)/2}] \end{Bmatrix} \quad \begin{matrix} if\ N\ is\ odd \\ if\ N\ is\ even \end{matrix}$$

The sign of *b* reflects the direction of the trend in the time series data, and its value represents the steepness of the trend.

Results

Preliminary analysis of climate variables

The historical time series for climatic variables in the observed years (1987-2017) is shown in Figure 3A-3H. The annual average temperature of Andracha for the 31 years studied was 17.6 ± 0.26 °C and 1.49% CV (Table 1). The minimum and maximum recorded average temperatures were 17.2°C (in 2007-coldest year) and 18.1°C (in 2003-warmest year), respectively. The average temperature for the different seasons ranged from 17.1°C (JJA) to 18.3°C (MAM), and the monthly average temperature varied from 16.8°C (July) to 18.5°C (March). The minimum temperature has a relatively higher variability (CV 6.18%) than average and maximum temperatures, but generally, the temperature had less variability than rainfall.

Accordingly, the mean annual rainfall of the area for the 31 years studied (1987-2017) was 2005.2 ± 235.8 mm and had an 11.76% CV (Table 1). The minimum and maximum recorded rainfalls were 1468.6 mm (in 1987 -the driest year) and 2736.8 mm (in 1992 - the wettest year)

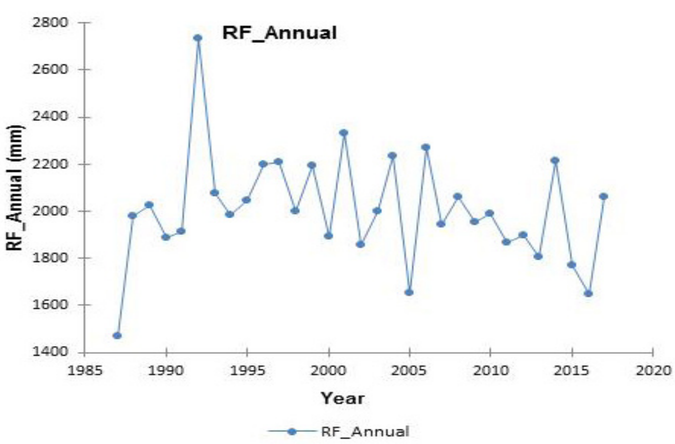

Figure 3A. Historical Time Series for 1985-2800

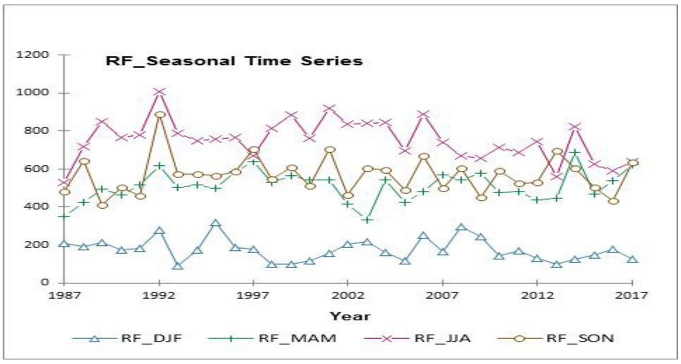

Figure 3B. Seasonal Time series 1987-2017

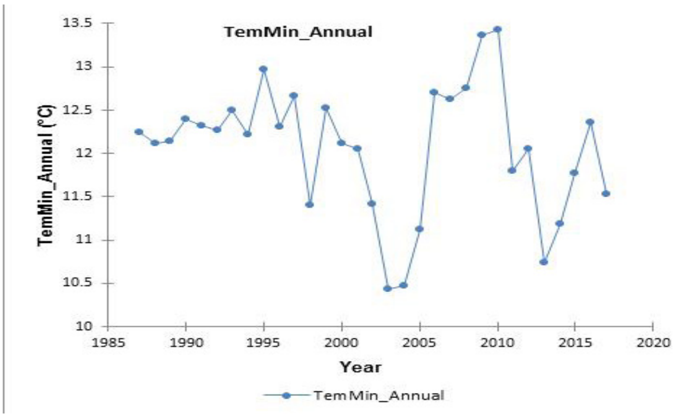

Figure 3C. 1985-2020 Minimal Annual temperature from 1985-2020.

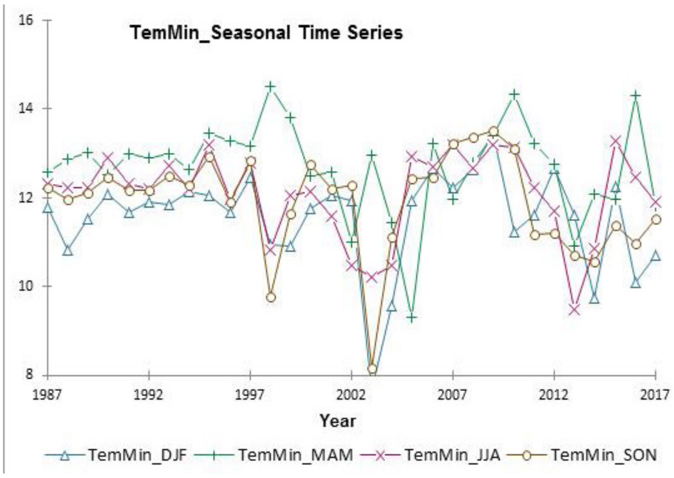

Figure 3D. Minimal Temperature 1987-2017

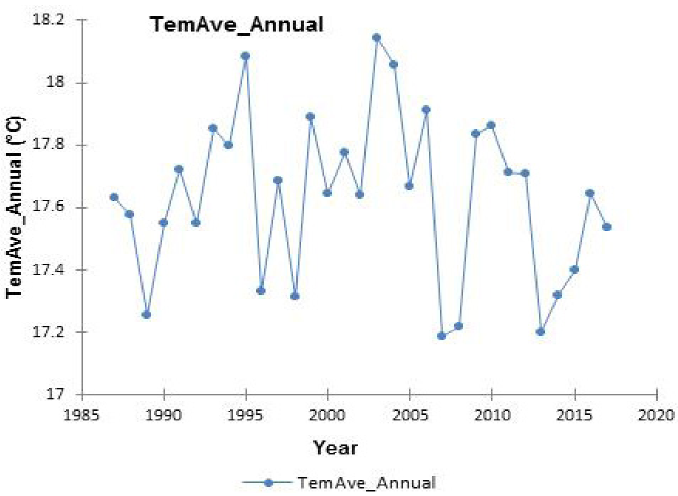

Figure 3E. Average Annual Temperature 1985-2020

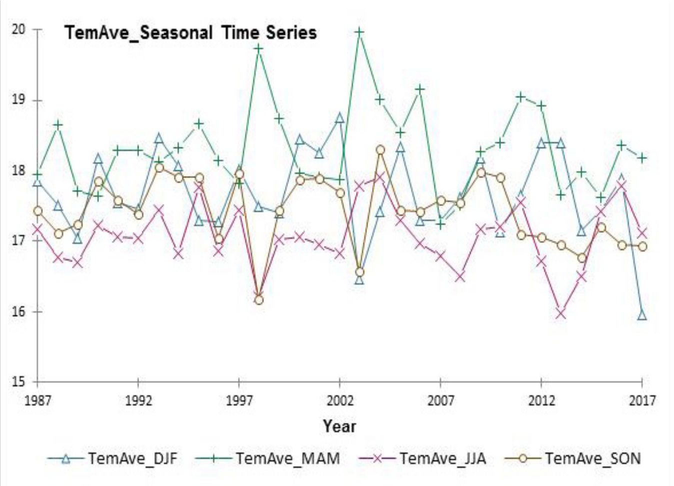

Figure 3F. Average Temperature Time Series 1987-2017

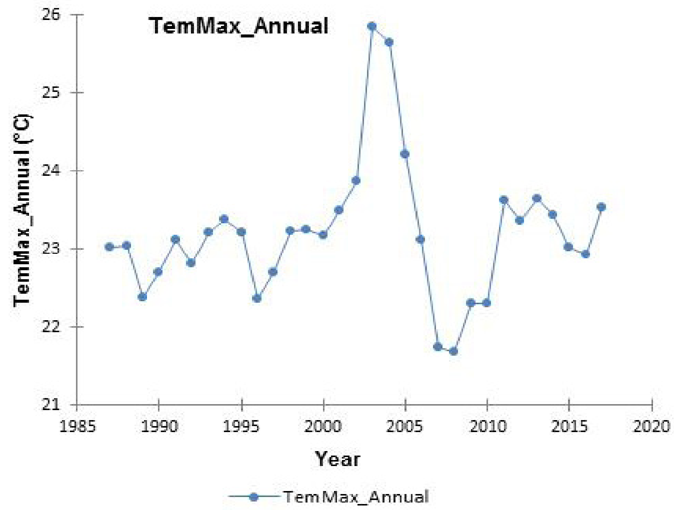

Figure 3G. Maximum Annual temperature from 1985-2020

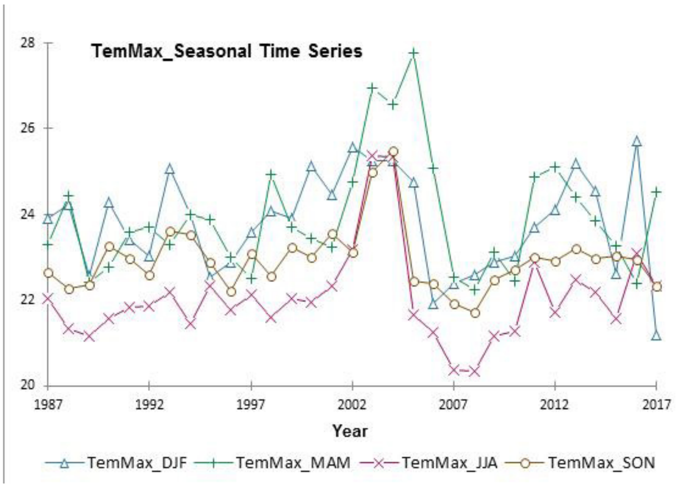

Figure 3H. Historical Time Series for Climatic Variables.

per year, respectively. Mean rainfall for the different seasons ranged from 175.6 mm (DJF) to 751.8 mm (JJA), and monthly average rainfall varied from 52.6 (February) to 274.1 mm (August). As portrayed in Table 1, JJA is the major rainy season in the study area, which contributes approximately 37.5% of the total rainfall. The SON and MAM seasons also contributed much of the total rainfall in the area, with amounts of 28.4% and 25.4%, respectively. Rainfall variability was highest for the DJF season, with a CV of 33.46%, followed by the SON and MAM seasons, with CVs of 17.44% and 15.76%, respectively. The rainfall anomaly also revealed the existence of inter-annual variability, and rainfall was prominent below the long-term average, mainly since 2007 (Figure 4).

'RF' stands for rainfall, 'TemMin' for minimum temperature, 'TemAve' for average temperature, 'TemMax' for maximum temperature; values after the lower dash represent the four seasons.

Historical time series trend characteristics

Temperature trends: Significant autocorrelation was detected for minimum temperature (in August, September, JJA and Annual) and maximum temperature (in April, May, July, August, November, MAM, JJA, SON, and Annual). The autocorrelations were removed using the pre-whitening method. As shown in Table 2, the MK trend test results revealed that the minimum, average and maximum temperatures showed no statistically significant trend through the observed time series at the 95% confidence level. Even though there was no significant trend in temperature, from Sen's slope estimator, we observed that minimum temperature had an increasing trend tendency in January and a decreasing trend tendency in August and September, while maximum temperature indicated an increasing trend tendency in February, March, and June and a decreasing trend tendency in November (Table 2).

Rainfall trends: Similar to temperature, autocorrelation was present for the December month of rainfall. Therefore, the pre-whitening method was applied to eliminate serial correlations before applying the MK test and Sen's slope estimator. The results of the trend analysis MK test and Sen's slope estimator are presented in Table 2. The findings indicate that May rainfall exhibits statistically significant rising trends, whereas August month and JJA seasonal rainfall exhibit statistically significant declining trends for the observed time series (at the 95% confidence level). The test

Table 1. Summary of Time Series Climate Data of Andracha District (1987 - 2017)

Climate Variable	Obser. Years	Minimum	Maximum	Mean	Std. Deviation	CV (%)
RF_DJF	31	90.01	318.65	175.63	58.77	33.46
RF_MAM	31	331.47	686.89	509.70	80.31	15.76
RF_JJA	31	528.10	1007.66	751.84	108.07	14.37
RF_SON	31	412.56	886.83	569.09	99.26	17.44
RF_Annual	31	1468.57	2736.78	2005.20	235.78	11.76
TemMin_DJF	31	7.65	13.45	11.54	1.12	9.70
TemMin_MAM	31	9.30	14.51	12.69	1.06	8.37
TemMin_JJA	31	9.48	13.29	12.08	0.98	8.07
TemMin_SON	31	8.17	13.51	11.91	1.11	9.35
TemMin_Annual	31	10.44	13.43	12.06	0.75	6.18
TemAve_DJF	31	15.96	18.76	17.67	0.62	3.49
TemAve_MAM	31	17.24	19.96	18.31	0.63	3.44
TemAve_JJA	31	15.97	17.92	17.07	0.45	2.65
TemAve_SON	31	16.18	18.30	17.43	0.49	2.81
TemAve_Annual	31	17.19	18.14	17.64	0.26	1.49
TemMax_DJF	31	21.19	25.72	23.80	1.16	4.88
TemMax_MAM	31	22.24	27.77	23.94	1.36	5.69
TemMax_JJA	31	20.35	25.36	22.06	1.09	4.95
TemMax_SON	31	21.71	25.48	22.95	0.77	3.34
TemMax_Annual	31	21.68	25.85	23.21	0.88	3.81

'RF' stands for rainfall, 'TemMin' for minimum temperature, 'TemAve' for average temperature, 'TemMax' for maximum temperature; values after the lower dash represent the four seasons.

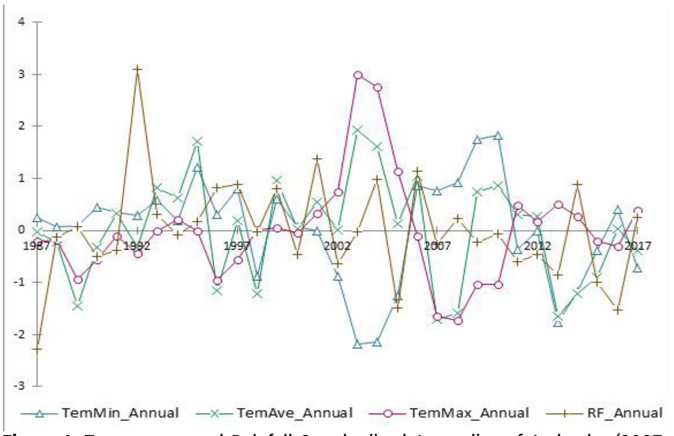

Figure 4. Temperature and Rainfall Standardized Anomalies of Andracha (1987 - 2017)

Table 2. Mann-Kendall Trend Test and Sen's Slope Estimator Results of Monthly, Seasonal and Annual Rainfall and Temperature (1987 - 2017) Bold values indicate statistically significant results at the 0.05 alpha level

Climate Variables	Rain Fall				Minimum Temperature				Average Temperature				Maximum Temperature			
	MK (S)	Kendall's tau	p value	Sen's slope	MK (S)	Kendall's tau	p value	Sen's slope	MK (S)	Kendall's tau	p value	Sen's slope	MK (S)	Kendall's tau	p value	Sen's slope
January	-75	-0.161	0.208	-0.701	85	0.183	0.153	0.023	-13	-0.028	0.838	-0.003	23	0.049	0.708	0.007
February	-11	-0.024	0.865	-0.153	31	0.067	0.61	0.01	49	0.105	0.415	0.013	77	0.166	0.196	0.034
March	-71	-0.153	0.234	-1.108	-13	-0.028	0.838	-0.008	23	0.049	0.708	0.007	75	0.161	0.208	0.028
April	17	0.037	0.786	0.56	8	0.017	0.905	0.002	19	0.041	0.76	0.006	-17	-0.037	0.786	-0.011
May	171	0.368	0.004	2.884	-27	-0.058	0.659	-0.009	-19	-0.041	0.76	-0.002	-31	-0.067	0.61	-0.015
June	-27	-0.058	0.659	-0.848	-47	-0.101	0.434	-0.01	19	0.041	0.76	0.003	86	0.185	0.148	0.027
July	-21	-0.045	0.734	-0.447	1	0.002	1	0	9	0.019	0.892	0.003	33	0.071	0.587	0.007
August	-137	-0.295	0.021	-2.909	-53	-0.114	0.377	-0.022	-10	-0.022	0.878	-0.002	3	0.006	0.973	0.001
September	7	0.015	0.919	0.097	-95	-0.204	0.11	-0.041	-83	-0.178	0.163	-0.02	27	0.058	0.659	0.005
October	-13	-0.028	0.838	-0.243	-17	-0.037	0.786	-0.009	-27	-0.058	0.659	-0.005	26	0.056	0.671	0.009
November	37	0.08	0.541	0.65	-21	-0.045	0.734	-0.014	-66	-0.142	0.269	-0.016	-81	-0.174	0.174	-0.017
December	-51	-0.11	0.395	-0.726	1	0.002	1	0.001	-43	-0.092	0.475	-0.011	-33	-0.071	0.587	-0.012
DJF	-87	-0.187	0.144	-1.901	7	0.015	0.919	0.003	-25	-0.054	0.683	-0.005	23	0.049	0.708	0.006
MAM	63	0.135	0.292	1.904	-49	-0.105	0.415	-0.012	11	0.024	0.865	0.002	-41	-0.088	0.497	-0.017
JJA	-119	-0.256	0.045	-4.66	-57	-0.123	0.341	-0.017	5	0.011	0.946	0.001	-9	-0.019	0.892	-0.002
SON	15	0.032	0.812	0.719	-49	-0.105	0.415	-0.028	-99	-0.213	0.096	-0.018	-35	-0.075	0.563	-0.012
Annual	-49	-0.105	0.415	-4	-53	-0.114	0.377	-0.011	-23	-0.049	0.708	-0.002	-9	-0.019	0.892	-0.001

did not show a statistically significant trend in annual rainfall and rainfall in the remaining seasons and months. Using Sen Slop's estimator, the rate of change of rainfall was found to be 2.88, - 2.91, - 4.66 mm per year for the May, August, and JJA seasons, respectively, from 1987 to 2017. Although DJF seasonal rainfall did not depict a significant trend, the CV (33.46%) was the highest of all the seasons, which indicated the presence of inter-annual variability in the DJF rainfall.

Discussion

The detection, estimation, and prediction of trends and related statistical and physical significance are necessary characteristics of climate research [29]. Precisely predicting trends of precipitation and temperature can play a crucial role in irrigation scheduling, water-resource distribution planning and optimization, soil and water conservation, and cropping system design [14,30]. Many studies, representing a wide range of locations and scales, have investigated trends in climatic variables [3,10,12,14].

Annual and seasonal rainfall and temperature pattern

The Andracha district can be considered one of the most precipitated areas in Ethiopia that receive rainfall in almost all of its seasons. It receives most of its rainfall in JJA season. The area also receives much rainfall in the SON and MAM seasons. This result is in agreement with reports that high rainfall normally occurred in the JJA seasons in most places of the country with more consistency than the other seasons [4,11,25,30]. The coefficient of variation for annual rainfall was low, but the coefficient for the DJF season was highly variable in accordance with the classification stated in [31]. Variability was also observed in the SON season, which is a period where crops started flowering and/or ripening and require more water for maturation, indicating that the season's rainfall is a highly variable climatic factor. Slight perturbations such as temperature fluctuations at critical points in crop growth can have considerable effects on later productivity [11]. Cheung, Senay, and Singh (2008) stated that in countries such as Ethiopia, where their economy is heavily dependent on low-productivity rain-fed agriculture, rainfall trends and variability are frequently mentioned factors in explaining various socioeconomic problems, such as food insecurity.

Very low values of rainfall anomalies correspond to drought-prone periods. Lower anomaly values were recorded in Andracha district in 1987, 2005, and 2016. These years are linked either with drought occurrence or El Nino effects in the country. On the other hand, temperature variability was found to be very low (CV<10%) in the district. The maximum difference between the mean and median values was less than 13.6 mm and 0.27°C for rainfall and temperature, respectively, suggesting that there were few outliers in both climate variables [1,4,11].

Trends in air temperature and rainfall

Given a time series of temperature and rainfall, a trend is a rate at which temperature changes over a time period [25]. Spatial and temporal analyses of temperature and precipitation trends are necessary to distinguish regions that are exposed to floods and droughts and to enable responsible bodies to comply with these regions by generating more appropriate adaptation and mitigation strategies [5]. Currently, meteorologists and climate researchers worldwide have given notable consideration to analyzing temperature and precipitation time series trends [11].

The temperature trend was nearly constant in the district even though an increase in temperature is among the manifestations of global climate change. This is probably because the region is one of the few remaining areas in the country with high forest cover [32]. Studies in other parts of Ethiopia, however, indicated a rising trend in air temperature [3,12,14,33, 34]. It is generally difficult to directly compare climate trend findings to those from similar studies due to differences in data aggregation, trend detection methodology, and preprocessing techniques [3, 8].

The present study revealed that the main rainy season (JJA) rainfall was reduced in the study area for the study period of 1987-2017. Supportive results on the declining trends in JJA rainfall were reported by Benti and Abara (2019), which were studied in closer proximity to our study area, Masha, and by Wagesho et al. (2013), who disclosed July–September seasonal and annual rainfall data that exhibited significant decreasing trends in northern, northwestern and western parts of Ethiopia. Osman and Sauerborn (2002) also reported a noticeable decreasing trend in annual and summer rainfall that started at the end of the 1910s. IPCC (2014) indicated that precipitation amounts are likely to decrease in most parts of Sub-Saharan Africa (SSA), while rainfall variability is expected to increase. Other findings in the country showed varying results. Studies by Cheung et al. (2008), Asfaw et al. (2018), Mekonnen et al. (2018) and Marie et al. (2021) reported a falling trend in JJA rainfall, while Mengistu et al. (2014) and Alemayehu and Bewket (2017) found an insignificant trend of rainfall in the season. Asfaw et al. (2018) reported trend analysis studies conducted in Ethiopia at different spatiotemporal scales and came up with mixed results.

In general, the results of the study show that the study area is not much affected in the case of changing temperature in comparison to precipitation. Relative to temperature, the long-term behavior of precipitation is characterized by greater spatial variability, indicating a proportionately higher dependence on regional and local variables (Chattopadhyay & Edwards, 2016). Because the JJA season is the main cropping season, sound soil and water management, short season seed supply and irrigation practices should be implemented to reduce future crop failure in the area [4]. A small change in precipitation can have greater impacts on water resources and agriculture and biodiversity. Asfaw et al. (2018) also pointed out that the major problem as far as rainfall distribution is concerned is not only the amount but also the variability and change in onset and cessation periods. The same study also indicated that what farmers have experienced for the last three decades has been a paradox: little or no rain when needed and more than enough when rain is not actually necessary. Possible causes of changing precipitation trends are global climate shifts, changes in sea surface temperature, dwindling global monsoon circulation, land and vegetation degradation and increasing aerosols from anthropogenic activities [11]. Among them, anthropogenic climate change is considered the most influencing factor because it also controls the other three factors [5].

Conclusion and Recommendations

This study quantified temperature and rainfall variability and trend in Andracha district, Southwestern Ethiopia. The main rainfall is concentrated in the JJA season and the SON and MAM seasons. The highest variability was detected in the DJF season rainfall. There were no clear trends in temperature over the period 1987–2017, while a mix of positive and negative trends was observed for rainfall. May monthly rainfall exhibits rising trends, and JJA seasonal rainfall exhibits a declining trend. The main findings of the present study can serve development workers and field researchers in the district for better planning and management of the area and to policymakers for directing appropriate adaptation and mitigation measures to deal with anticipated climate variability and climate change. It is imperative to scheme an approach in the agricultural and forestry sectors to take into consideration the declining and variable nature of rainfall in the district. Similar studies involving weather stations in adjacent districts with advanced GCM and RCM tools are also recommended for adequately contextualizing the processes responsible for those trends and gaining a comprehensive understanding of how these variables are performing in a larger context.

Data Availability

The datasets used and analyzed during the current study are available from the corresponding author upon request.

Conflicts of Interest

The authors report that there are no competing interests to declare.

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