Variability and trends of climate in east Wollega zone, Western Ethiopia

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Abstract. Climate change is a major concern for the environmental, social and economic sectors of our world. The purpose of the study was to examine climate variability and trends in East Wollega Zone, Western Ethiopia. Daily precipitation and temperature information for 37 years (1981-2017) were gathered from the Ethiopian National Meteorological Agency. Mann-Kendall trend test, Sen Slope, linear regression model, and coefficient of variation were used to analyze data. The result found that monthly, seasonal and annual rainfall observed an insignificant declining trend except for May, November, and spring and the change was only significant for August at a significance level of 0.05. Maximum and minimum temperature revealed upward warming trends on a monthly, seasonal and yearly basis. The outcome of the linear regression model indicated an insignificant relationship between monthly, seasonal, and annual rainfall and time at a confidence level of 0.05. A statistically significant relationship has been detected between annual maximum, minimum, and mean temperature and year at 0.05 significance level. With the exception of winter minimum temperature, the result found a statistically significant relationship for seasonal temperature. The variation of seasonal rainfall was moderate for summer (23%) and autumn (29%) while it was high for spring (33%) and winter (65%) and it was also moderate for annual (23%). In view of the fact that crop production is affected by rainfall and temperature variability, adaptation to its adverse effect is imperative. Cropping system decisions and adaptation plans in the area should better accommodate for fluctuations in rainfall and temperature.

Keywords: rainfall, temperature, Mann-Kendall (MK), trend, linear regression

1. Introduction
Climate change is among the greatest environmental, social, and economic issues locally, regionally, and globally. An agreement amongst researchers on human-induced warming of the planet has increased to 100% [1]. Climate change is an unavoidable reality that has already begun to happen [2]. Because of economic and population growth, human activities impacted the climate by increasing the amount of greenhouse gases in the atmosphere [3]. Agriculture and climate change are linked in two ways: agriculture cause climate change by emitting greenhouse gases, and climate change have a negative impact on agriculture in general [4].
Despite increases in certain crops, climate change is anticipated to have a negative effect on agriculture, jeopardizing global food security [5]. Extreme weather events, notably severe flooding and droughts, have adversely impacted crop productivity, widened yield gaps, and threatened agricultural sustainability in emerging and vulnerable parts of the world [6]. Because of their direct impact on agriculture, temperature and rainfall are the significant climate variables highly examined in climate studies [7]. Variations in rainfall patterns and soil erosion, both of which are critical for agricultural production, can be influenced by rising temperatures, which increase evapotranspiration and lower soil moisture [8].

Africa is the most susceptible continent on the planet, with frequent droughts, severe temperatures, and rains causing devastation on crop and food supplies [9]. Ethiopia is one of the most sensitive countries to climate change, and natural disasters such as drought and flooding occur on a regular basis [10], (Gashaw et al., 2017), and [12]. Ethiopia has suffered climate change and fluctuation, as well as other environmental challenges [13]. Climate change and unpredictability disproportionately affect subsistence farmers, who endure unpredictable and geographically diverse impacts [14]. In Ethiopia, where rain-fed agriculture is the norm and exposure is worsened by widespread poverty and rapid population expansion droughts are the most devastating climatic hazard [15]. Though Ethiopia's influence of global warming has been minimal in recent decades, the temperature has risen at a rate of about 0.2°C per decade [16]. Rainfall was unpredictable in terms of both space and time [17]. From 1961 to 2015, mean temperature showed a considerable upward trend, whereas summer season rainfall showed a downward tendency from 1901 to 2015 [18].

Climate research is needed to quantify local effects and vulnerabilities, identify adaptation alternatives, and guide regional and national climate policies and initiatives [19]. The knowledge of climate variability and trends is very crucial for panning adaption decision and ensuring agricultural sustainability among small-scale farmers. Increased localized climate risks and extremes, including floods, changing rainfall patterns, and cropping season changes, are already affecting agriculture. Crop productivity in the area was negatively impacted by such catastrophic events and constant climate changes, posing a challenge to the country's efforts to achieve food security in a changing environment. In general, climate research in Ethiopia is restricted at the national level, and it is almost always missing at the local level. Climate studies must be locally relevant in order for their findings to be used. As a result, the purpose of this research was to fill this gap by examining climate variability and trends in Western Ethiopia's East Wollega Zone.

2. Materials and methods

2.1 Description of the study area

The research was carried out in the Oromia National Regional State's East Wollega Zone in Western Ethiopia. It is one of the Oromia National Regional State's Zones, which includes 17 rural districts and 289 rural peasant associations. It is located 328 kilometers west of Ethiopia's capital, Addis Ababa. The zone's entire land area is around 14,102.5km², accounting for about 3.88% of the Oromia National Regional State's overall area.

2.1.1 Location

East Wollega Zone is found on Northing 8°31'20"N to 10°22'30"N and Easting 36°06'00"E to 37°12'00"E. It is bordered on the North by Amhara National Regional State, on the South by Jimma zone, on the East by Horo Guduru Wollega and West Shewa zone, on the North-West by Benishangul Gumuz National Regional State, on the West by West Wollega zone, and on the South-West by Buno Bedelle zone. Figure 1 depicts a map of the research area.
2.1.2 Topography and climate
The altitude of the zone ranges between 718 to 3163 meters above sea level. It consists primarily of low plateaus with isolated ranges, such as in the Jima Arjo district. The zone's climate is classified into three categories: highland (20.50%), midland (50.90%), and lowland (28.60%). The daily temperature ranges from 15 to 27°C [20]. Long summer rainy seasons (June to September), brief rainy seasons (March to April), and winter dry seasons alternate (December to February). The main rainy season in Ethiopia is from June to September, as is the case in much of the country's highlands [21].

2.1.3 Farming system
The dominant source of livelihoods in the study area is crop production and livestock rearing. Crop and livestock production are used for both domestic use and as a source of revenue. Maize, sorghum, teff, millet, wheat, and barley are the principal cereal crops farmed in the area. Crop production is an important livelihood activity for farmers and is mainly rain-fed subsistence agriculture. Cattle rearing rely on natural grasses and crop wastes that are retained in the traditional management approach [22]. The research areas soils have been severely eroded because of these environmentally unfriendly farming methods and excessive rainfall levels, resulting in nutrient loss, soil acidity, and overall land and natural resource degradation. As a result, most soil acidity-sensitive crops such as barley, bean, and wheat have been forced out of cultivation in some places [23].

Figure 1. Location map of the research area
2.2 Data type and sources
Historical time series climate data (temperature and rainfall) for 37 years (1981-2017) was collected from National Meteorology Agency (NMA). The study included both dependent and independent (explanatory) variables. In this case, the independent variable was time, while the dependent variables were temperature and rainfall.

2.3 Analytical materials and methods

2.3.1 Mann-Kendall trend test
Mann-Kendall (MK) test was employed for trend analysis. Kendall’s tau, S statistics, Z statistics, and P-value were used to detect variation in rainfall and temperature. The P-values used to determine whether any apparent patterns are statistically significant or not. The decision was made based on level of significance (α =0.05) which compared against the p-value. There is no significant trend if the p-value is above the significance level (α =0.05); there is a significant trend if the p-value is below the significance threshold. The negative of MK Stat (S), Kendall’s tau, and Z statistics value represents the declining trend while the positive value represents the increasing trend or change. Mann-Kendall discrimination is the most usually interest non-parametric experience for detecting climatic shifts and run the analysis [24]. The MK S Statistic is calculated as equation (1).

\[ S = \sum_{j=1}^{n-1} \sum_{i=i+1}^{n} sign(G_j - G_i) \] (1)

Where \( G_j \) and \( G_i \) are the time series' successive data values in the years \( j \) and \( i \) \((j > i)\) and \( n \) is the time series length. Positive S importance particularizes an increasing strike and negative importance depicts a falling trend in the data course and sign \((G_j - G_i)\) calculated as equation (2):

\[ sign(G_j - G_i) = \begin{cases} 1 & (G_j - G_i) > 0 \\ 0 & (G_j - G_i) = 0 \\ -1 & (G_j - G_i) < 0 \end{cases} \] (2)

The S-variance statistic's \((\sigma^2)\) is defined as equation (3).

\[ \sigma^2 = \frac{n(n-1)(2n+5)-\sum t_i(i-1)(2i+5)}{18} \] (3)

Where, \( t_i \) represents the count of fasten to extent \( i \) that have been completed. If the data sequence holds tied values, the numerator summation term is used. Equation (4) is to compute the standard test statistic \((Z_s)\):

\[ Z_s = \begin{cases} \frac{s-1}{\sigma} & for S > 0 \\ 0 & for S = 0 \\ \frac{s+1}{\sigma} & for S < 0 \end{cases} \] (4)

The result of the test statistic trend's significance is measured in \(Z_s\). In reality, the null hypothesis, Ho, is tested using this test statistic. The null guess is rejected if \(|Z_s|\) is bigger than \(Z_{\alpha/2}\), where \(\alpha\) is the selected significance threshold, meaning that the trend is significant.

2.3.2 The test of Sen's slope estimator
Sen's slope estimator was used to estimate the average changes in a variable over time (increasing or decreasing) per period (monthly, seasonally, or annually) [25]. The slope of Sen is defined as equation (5):

\[ Sen's\ Slope = Median \left( \frac{x_j - x_i}{j-i}; i < j \right) \] (5)
Where, \( x_j \) and \( x_i \) are data values at time \( j \) and \( i \) \((i < j)\). A positive number of denotes an upward trend, whereas a negative value denotes a downward trend.

2.3.3 Model of linear regression
This model was fitted to historical rainfall and temperature data in order to describe a link between the dependent variables (rainfall and temperature) and the independent variable (time). It is a useful technique for examining the links between variables by linking one variable to a group of variables [26]. A linear regression equation defined as equation (6).

\[
Y = c + dx 
\]

Where the response variable is \( y \), the slope is \( d \), the explanatory variable is \( x \), and the intercept is \( c \).

2.3.4 Coefficient of variation
The temporal variability of temperature and rainfall was calculated using the coefficient of variation (CV). The coefficient of alteration is a spread measure that expresses the amount of variance compared to the mean. A higher CV appraise directs greater variability, whereas a lower CV indicates less variability, and is calculated as equation (7).

\[
CV = \frac{\sigma}{\mu} \times 100 
\]

Where \( CV \) stands for coefficient of variation; \( \sigma \) is standard error and \( \mu \) is mean of rainfall and temperature.

3. Discussion of the findings
3.1. Rainfall patterns and trends
The two-sided Mann-Kendall test was performed to examine whether there is a statistically significant monotonic increasing or decreasing trend in monthly, seasonal, and yearly rainfall data sequence, as shown in Table 1. The results demonstrated that, except for August, no significant trend could be detected at the 0.05 significance level on a monthly, seasonal, or annual basis. Except for May, November, and the Spring season, the S statistics, Z statistics, and Kendall’s tau all exhibit negative values, indicating a decreasing trend in monthly, seasonal, and annual rainfall. The Sen's slope of a trend line displays a declining magnitude in rainfall per month, seasonal, and yearly, except for May, November, and spring, which have a positive slope. The findings of a research done in Northwest Ethiopia were similar, with rising temperatures and decreasing rainfall amounts [27]. Figure 2 and Figure 3 show Sen's slope for monthly and seasonal rainfall.

| Period    | MK Stat (S) | Kendall’s tau | Z Statistic | P-value | \( \alpha \) | Sen’s Slope | Sig. at \( \alpha = 0.05 \) |
|-----------|-------------|---------------|-------------|---------|-----------|-------------|------------------|
| January   | -70         | -0.1051       | -0.9024     | 0.3668  | 0.05      | -0.171      | Insignificant    |
| February  | -82         | -0.1231       | -1.0594     | 0.2894  | 0.05      | -0.272      | Insignificant    |
| March     | -106        | -0.1592       | -1.3733     | 0.1697  | 0.05      | -0.574      | Insignificant    |
| April     | -144        | -0.2162       | -1.8703     | 0.0614  | 0.05      | -1.287      | Insignificant    |
| May       | 96          | 0.1441        | 1.2425      | 0.2141  | 0.05      | 1.857       | Insignificant    |
| June      | -34         | -0.0511       | -0.4316     | 0.6660  | 0.05      | -0.898      | Insignificant    |
| July      | -54         | -0.0811       | -0.6932     | 0.4882  | 0.05      | -0.941      | Insignificant    |
| August    | -212        | -0.3183       | -2.7596     | 0.0058  | 0.05      | -3.125      | Significant      |
| September | -64         | -0.0961       | -0.8239     | 0.4100  | 0.05      | -1.256      | Insignificant    |
| October   | -16         | -0.0240       | -0.1962     | 0.8445  | 0.05      | -0.262      | Insignificant    |
| Season  | Month | P-value | Slope   | Std. Error | t-value | Significance  |
|---------|-------|---------|---------|------------|---------|--------------|
| November | 44    | 0.0660  | 0.5624  | 0.5738     | 0.05    | 0.206        |
| December | -44   | -0.0661 | -0.5624 | 0.5738     | 0.05    | -0.107       |
| Winter   | -62   | -0.0930 | -0.7978 | 0.4250     | 0.05    | -0.470       |
| Spring   | 4     | 0.0060  | 0.0392  | 0.9687     | 0.05    | 0.067        |
| Summer   | -96   | -0.1441 | -1.2425 | 0.2141     | 0.05    | -4.414       |
| Autumn   | -36   | -0.0541 | -0.4578 | 0.6471     | 0.05    | -1.140       |
| Annual   | -94   | -0.1411 | -1.2163 | 0.2239     | 0.05    | -6.449       |

Note: P-value of less than or equal to 0.05 is significant, while one more than 0.05 is not

**Figure 2.** Sen's monthly rainfall slope

**Figure 3.** Sen's seasonal rainfall slope
3.2 Trend of temperature

3.2.1 Minimum monthly temperature trend. Table 2 displays the monthly average minimum temperature for the period of 1981-2017, which demonstrates a warming trend. The Mann-Kendall test found a significant warming tendency for the months of April, May, July, August, September, and October at the 0.05 significance level. A notable trend has not been observed for the months of January, February, March, June, November, and December. The direction of change in minimum temperature for all months was increased, as evidenced by positive Mann-Kendall Stat (S), Kendall's tau, and Z Statistics. The presence of positive change per month was also demonstrated by Sen's slope. Sen's slope for monthly minimum temperature is shown in Figure 4.

Table 2. Mann-trend Kendall's test findings for monthly minimum temperatures

| Months | MK Stat (S) | Kendall's tau | Z Statistic | P-value | Sen's Slope | Sig. at α =0.05 |
|--------|-------------|---------------|-------------|---------|-------------|-----------------|
| Jan    | 94          | 0.1414        | 1.2165      | 0.2238  | 0.023       | Insignificant   |
| Feb    | 109         | 0.1640        | 1.4129      | 0.1577  | 0.020       | Insignificant   |
| Mar    | 97          | 0.1458        | 1.2557      | 0.2092  | 0.015       | Insignificant   |
| Apr    | 258         | 0.3880        | 3.3618      | 0.0008  | 0.040       | Significant     |
| May    | 186         | 0.2801        | 2.4206      | 0.0155  | 0.022       | Significant     |
| Jun    | 146         | 0.2202        | 1.8974      | 0.0578  | 0.011       | Insignificant   |
| Jul    | 181         | 0.2728        | 2.3552      | 0.0185  | 0.013       | Significant     |
| Aug    | 172         | 0.2594        | 2.2378      | 0.0252  | 0.008       | Significant     |
| Sep    | 312         | 0.4699        | 4.0689      | 0.00004 | 0.015       | Significant     |
| Oct    | 180         | 0.2707        | 2.3415      | 0.0192  | 0.033       | Significant     |
| Nov    | 107         | 0.1608        | 1.3865      | 0.1656  | 0.023       | Insignificant   |
| Dec    | 16          | 0.0240        | 0.1962      | 0.8445  | 0.005       | Insignificant   |

Note: P-value of less than or equal to 0.05 is significant, while one more than 0.05 is not.

Figure 4. Sen's slope for monthly minimum temperature
3.2.2 Trend of monthly maximum temperature. The monthly maximum temperature for the period of 1981-2017 shows a warming trend, as shown in Table 3. The Mann-Kendall test has indicated a significant warming tendency at the 0.05 significance level for all months except January, May, November, and December. For all months, the positive Mann-Kendall Stat (S), Kendall's tau, and Z Statistic demonstrated an increasing trend in maximum temperature. The presence of positive change was also observed by Sen's slope for all months. Sen's slope for monthly maximum temperature is shown in Figure 5.

| Months   | MK Stat (S) | Kendall's tau | Z Statistic | P-value | Sen's Slope | Sig. at α =0.05 |
|----------|-------------|---------------|-------------|---------|-------------|-----------------|
| January  | 146         | 0.2195        | 1.8968      | 0.05786 | 0.036       | Insignificant   |
| February | 229         | 0.3446        | 2.9828      | 0.00286 | 0.077       | Significant     |
| March    | 286         | 0.4294        | 3.7275      | 0.00019 | 0.077       | Significant     |
| April    | 244         | 0.3664        | 3.1782      | 0.00148 | 0.101       | Significant     |
| May      | 22          | 0.0330        | 0.2747      | 0.78360 | 0.010       | Insignificant   |
| June     | 177         | 0.2664        | 2.3025      | 0.02131 | 0.029       | Significant     |
| July     | 161         | 0.2419        | 2.0928      | 0.03637 | 0.017       | Significant     |
| August   | 152         | 0.2286        | 1.9752      | 0.04824 | 0.016       | Significant     |
| September| 220         | 0.3308        | 2.8648      | 0.00417 | 0.028       | Significant     |
| October  | 187         | 0.2810        | 2.4329      | 0.01498 | 0.029       | Significant     |
| November | 139         | 0.2092        | 1.8053      | 0.07102 | 0.013       | Insignificant   |
| December | 83          | 0.1249        | 1.0727      | 0.28340 | 0.011       | Insignificant   |

Note: P-value of less than or equal to 0.05 is significant, while one more than 0.05 is not

![Figure 5. Sen's slope for monthly maximum temperature](image)
3.2.3 Seasonal and yearly temperature trends. Table 4 displays the results of the Mann-Kendall trend test, which revealed an increasing warming trend for seasonal and yearly maximum and minimum temperatures. Except for the winter minimum temperature, the tendency of maximum and minimum temperatures on both a seasonal and annual basis demonstrated a statistically significant warming trend at the 0.05 significance level. The presence of seasonal and annual temperature increment is further confirmed by the Sen's slope. Seasonal and yearly maximum and minimum temperatures have increased throughout the period of 1981-2017, according to positive MK test Statistics (S), Kendall's tau, and Z Statistics. Sen's slope is shown in Figure 6 and Figure 7 for the minimum and maximum seasonal temperatures, respectively. A study of the upper Blue Nile River Basin found a similar trend in yearly minimum and maximum temperatures from 1981 to 2010 [28].

Table 4. Mann-Kendall trend test results for seasonal and yearly temperatures

| Variable | Seasons | MK Stat (S) | Kendall's tau | Z Statistic | P-value | Sen's Slope | Sig. at α =0.05 |
|----------|---------|-------------|---------------|-------------|---------|-------------|----------------|
| Tmax     | Winter  | 253         | 0.3414        | 3.0484      | 0.00230 | 0.044       | Significant    |
|          | Spring  | 264         | 0.3565        | 3.1817      | 0.00146 | 0.062       | Significant    |
|          | Summer  | 182         | 0.2458        | 2.1897      | 0.02855 | 0.019       | Significant    |
|          | Autumn  | 255         | 0.3448        | 3.0733      | 0.00212 | 0.020       | Significant    |
| Tmin     | Winter  | 107         | 0.1444        | 1.2823      | 0.19970 | Insignificant | Significant    |
|          | Spring  | 284         | 0.3835        | 3.4237      | 0.00062 | 0.025       | Significant    |
|          | Summer  | 209         | 0.2824        | 2.5165      | 0.01185 | 0.010       | Significant    |
|          | Autumn  | 281         | 0.3797        | 3.3876      | 0.00071 | 0.025       | Significant    |
| Annual   | Tmax    | 262         | 0.3934        | 3.4136      | 0.00064 | 0.035       | Significant    |
|          | Tmin    | 226         | 0.3393        | 2.9427      | 0.00325 | 0.018       | Significant    |

Note: P-value of less than or equal to 0.05 is significant, while one more than 0.05 is not.

Figure 6. Sen's slope for seasonal minimum temperature
3.3 Summary of the fitted linear regression Model

3.3.1 Annual rainfall and temperature in relation to time. The findings of the fitted linear model to analyze the relationship between rainfall, temperature, and time are shown in Table 5. At the 95% confidence level, the results showed that there was no significant association between annual rainfall and time. The fitted model's R-Squared score suggests that 4.52% of the variability in annual rainfall is explained by the fitted model, while the correlation coefficient of -0.21 indicates a weak relationship. At the 95% confidence level, there was a statistically significant association between annual maximum, minimum, and mean temperature and year. The R-squared data revealed that the variability in annual maximum, minimum, and mean temperatures was 21.30%, 20.34%, and 26.33%, respectively. The correlation coefficients for maximum, minimum, and mean temperature were 0.46, 0.45, and 0.51, respectively, indicating a moderate link between the variables. Figure 8 and Figure 9 show annual rainfall and temperature time series plots, respectively.

Table 5. Annual rainfall and temperature results from the fitted linear regression model

| Variable | Linear Regression Equation | R² (%) | correlation coefficient | P-Value | Relationship |
|----------|-----------------------------|--------|-------------------------|---------|--------------|
| Rainfall | $y = -8.18x + 18179.1$      | 4.52   | -0.21                   | 0.2065  | Not significant |
| Tmax     | $y = 0.04x -56.9448$        | 21.30  | 0.46                    | 0.0040  | Significant |
| Tmin     | $y = 0.02x -21.5948$        | 20.34  | 0.45                    | 0.0051  | Significant |
| Tmean    | $y = 0.03x -40.4901$        | 26.33  | 0.51                    | 0.0012  | Significant |

Note: P-value of less than or equal to 0.05 is significant, while one more than 0.05 is not.
Figure 8. Annual rainfall actual, fitted and residual plot using linear regression model

Figure 9. Yearly temperature time series plot
3.3.2 Seasonal rainfall and temperature in relation to time. The findings of the fitted linear regression model to explore the association between seasonal temperature and rainfall with time are shown in Table 6. Except for the winter minimum temperature, the results demonstrated a statistically significant link between seasonal minimum and maximum temperatures and time at the 95% confidence level. The fitted model exhibited 14.68%, 22.29%, 15.29% and 12.66% of variability in winter, spring, summer and autumn maximum temperature respectively. Winter, spring, summer, and autumn minimum temperatures varied by 2.22%, 26.63%, 18.48%, and 21.04%, respectively. At the 95% confidence level, there was no statistically significant association between winter, spring, summer, and autumn rainfall and time. The fitted model's R-squared statistics indicated that rainfall variability in winter, spring, summer, and autumn was 8.41%, 0.14%, 7.143%, and 0.79%, respectively. Figure 10 depicts a seasonal rainfall time series plot.

| Season | Variable | Linear Regression Equation | $R^2$ (%) | Correlation coefficient | P-Value | Relationship |
|--------|----------|-----------------------------|----------|------------------------|---------|--------------|
| Winter | Tmax     | $y = 0.05x -73.62$          | 14.68    | 0.3832                 | 0.0192  | Significant  |
|        | Tmin     | $y = 0.01x -9.51$          | 2.22     | 0.1489                 | 0.3791  | Insignificant |
| Spring | Tmax     | $y = 0.07x -103.72$        | 22.29    | 0.4721                 | 0.0032  | Significant  |
|        | Tmin     | $y = 0.03x -34.73$         | 26.63    | 0.5160                 | 0.0011  | Significant  |
| Summer | Tmax     | $y = 0.02x -18.83$         | 15.29    | 0.3911                 | 0.0167  | Significant  |
|        | Tmin     | $y = 0.01x -7.18$          | 18.48    | 0.4299                 | 0.0079  | Significant  |
| Autumn | Tmax     | $y = 0.03x -31.51$         | 12.66    | 0.3558                 | 0.0307  | Significant  |
|        | Tmin     | $y = 0.02x -35.16$         | 21.04    | 0.4587                 | 0.0043  | Significant  |
| Winter | Rainfall | $y = -1.02x + 2089.94$     | 8.41     | -0.2900                | 0.0817  | Insignificant |
| Spring | Rainfall | $y = -0.40x +1149.4$       | 0.14     | -0.0375                | 0.8258  | Insignificant |
| Summer | Rainfall | $y = -5.74x +12464.6$      | 7.143    | -0.2673                | 0.1098  | Insignificant |
| Autumn | Rainfall | $y = -1.02x + 2475.14$     | 0.79     | -0.0889                | 0.6007  | Insignificant |

Note: P-value of less than or equal to 0.05 is significant, while one more than 0.05 is not.

Figure 10. Time series plot of seasonal rainfall
### Table 7. Coefficient of variation of rainfall and temperature

| Month    | Rainfall (mm) | Tmax (°C) | Tmin (°C) |
|----------|---------------|-----------|-----------|
|          | Mean          | SD        | CV (%)    | Mean          | SD        | CV (%)    | Mean          | SD        | CV (%)    |
| January  | 17.45         | 21.30     | 122       | 27.15         | 1.57      | 6         | 13.03         | 1.15      | 9         |
| February | 22.49         | 20.53     | 91        | 29.08         | 1.87      | 6         | 14.62         | 1.12      | 8         |
| March    | 56.18         | 36.72     | 65        | 30.30         | 1.56      | 5         | 16.17         | 0.65      | 4         |
| April    | 90.83         | 41.44     | 46        | 29.67         | 1.94      | 7         | 16.58         | 0.78      | 5         |
| May      | 199.70        | 87.36     | 44        | 27.28         | 2.19      | 8         | 16.56         | 0.63      | 4         |
| June     | 296.39        | 95.91     | 32        | 23.83         | 0.79      | 3         | 15.70         | 0.36      | 2         |
| July     | 342.36        | 96.66     | 28        | 22.00         | 0.68      | 3         | 14.85         | 0.35      | 2         |
| August   | 353.61        | 92.28     | 26        | 22.15         | 0.49      | 2         | 14.94         | 0.24      | 2         |
| September| 277.61        | 74.52     | 27        | 23.05         | 0.63      | 3         | 15.01         | 0.28      | 2         |
| October  | 116.06        | 75.72     | 65        | 24.31         | 1.00      | 4         | 13.46         | 0.94      | 7         |
| November | 32.88         | 22.66     | 69        | 24.83         | 1.17      | 5         | 12.20         | 1.11      | 9         |
| December | 18.70         | 19.86     | 106       | 25.57         | 1.41      | 5         | 11.99         | 1.51      | 13        |
| Winter   | 58.63         | 37.93     | 65        | 27.27         | 1.43      | 5         | 13.21         | 0.83      | 6         |
| Spring   | 346.71        | 116.05    | 33        | 29.09         | 1.52      | 5         | 16.44         | 0.54      | 3         |
| Summer   | 992.36        | 232.43    | 23        | 22.66         | 0.57      | 3         | 15.17         | 0.28      | 2         |
| Autumn   | 426.55        | 124.73    | 29        | 24.06         | 0.85      | 4         | 13.56         | 0.57      | 4         |
| Annual   | 1824.25       | 416.60    | 23        | 25.77         | 0.97      | 4         | 14.59         | 0.43      | 3         |

Note: SD stands for Standard Deviation, and CV is for Coefficient of Variation

#### 3.4 Rainfall and temperature variability

Table 7 illustrates the coefficient of variation values based on [29] as (CV < 20) low variability, (20 < CV < 30) modest variability, and (CV > 30) significant variability in rainfall. Accordingly, the seasonal variation of rainfall was moderate for summer (23%) and autumn (29%) whereas it was high for spring (33%) and winter (65%), and yearly rainfall variation was moderate (23%). The temperature variation was classified as (steady < 5°C; modest 5 ≤ 10°C; and excessive, ≥10°C) according to [30]. Seasonal maximum temperature was stable for summer (3%) and autumn (4%) while it was moderate for winter and spring (5%). The seasonal minimum temperature was stable in the spring (3%), summer (2%), and autumn (4%), but moderate in the winter (6%). The annual maximum and minimum temperatures remained stable. Except for the severe variability in the minimum temperature in December, the temperature variation in the area was classified as stable and moderate. Monthly, seasonal, and yearly rainfall coefficients of variation are shown in Figure 11.
4. Conclusion
Climate change is one of the world’s most pressing environmental, social, and economic issues. The purpose of this study was to investigate the trend and variability of rainfall and temperature in the East Wollega Zone of Oromia National Regional State. The result of the study found that, except for May, November, and spring, the monthly, seasonal, and yearly rainfall all showed an insignificant declining trend. In the monthly, seasonal, and annual time scales, maximum and minimum temperatures revealed an increasing warming trend. At the 0.05 significance level, the results of the linear regression model revealed an insignificant connection between monthly, seasonal, and yearly rainfall and time. There was a statistically significant link between annual maximum, minimum, and mean temperature and year at 0.05 significance level. With the exception of the winter minimum temperature, a statistically significant connection between seasonal temperature and time was identified at the 0.05 significance level. The variance of monthly, seasonal, and annual minimum and maximum temperatures ranged from stable to moderate, with the exception of the December minimum temperature, which showed severe variability. Summer and autumn had a moderate seasonal fluctuation in rainfall, whereas spring and winter had a significant variation. The fluctuation in annual rainfall was moderate. Because crop production is influenced by rainfall and temperature variability, smallholder farmers must learn to adapt to their negative repercussions. It is better to consider this variability when deciding a cropping system and planning adaptation in the area. Despite the fact that the climate system is complicated and has many variables, the current study only considers rainfall and temperature. As a result, future research should take into account more climate parameters for more in-depth investigations in the area.

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