Long Term Trend Analysis of Precipitation and Temperature for Asosa district, Benishangul Gumuz regional state, Ethiopia)

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Abstract

Background**:** To find and measure the influence of climate change on socio-economic sectors and ecosystems, many worldwide studies have been carried out and policy modifications for mitigation and adaptation were recommended. Though, the time worn made top-down approach, universal study, has little local and regional specificity and has unsuccessful to address the regional and local consequences of climate change. Therefore, this research was conducted in satisfying such awareness gaps in Asosa District, Benishangul Gumuz Regional State.

Methods: The research was designed at addressing the national and local issues of climate change and was done by investigating time series temperature and precipitation trends in Benishangul Gumuz Regional state of Ethiopia, Asosa District in particular. To achieve this objective, both primary and secondary data from different sources were used. The collected data were investigated following quantitative and qualitative analysis methods and Manna Kendall trend test method was used.

Results**:** The main results revealed that the mean, maximum and minimum temperature had a general decreasing annual maximum, minimum and mean annual temperature change from 1993 to 2022. The trend line shows that the average yearly maximum temperature decreased approximately by a factor of -0.0341 and the minimum temperature was decreased by -0.0152 factor respectively. To the average, the annual maximum temperature is found to be 31.4^{0}C (2005 year) and the annual minimum temperature is 14.07 (2011), For the temperature data recorded in the study area, the average values were analyzed usingthe Mann - Kendall test and the results revealed that annual, winter, spring, and autumn season minimum and maximum temperature indicated a decreasing trend but summer season for minimum temperature showed an increasing trend. The Annual minimum temperature result implies that statistically not significant decreasing trend at (P = 0.05) but the annual maximum temperature reveals statistically significant decreasing trend for the annual maximum temperature. Whereas, the annual precipitation amount showed statistically significant increasing trend in Asosa district.

Conclusions**:** To conclude, the concerned body, development planners should design strategies and plans by taking into account a rising summer precipitation and declining temperature impacts on rural livelihoods.

Keywords: Temperature trend, Climate change and variability, Manna Kendall trend test, Precipitation trend, Time series trend analysis.

1. Introduction

Climate change is one of the multiple challenges facing all categories of farmers globally. However, African farmers are the most sensitive in respect of climate variability and change. Climate change impacted negatively on crop production and the livelihoods of the local farmers[1, 2]. Climate change poses a major threat to the semi-arid tropics, which is characterized by scanty and uncertain rainfall, infertile soils, poor infrastructure, extreme poverty and rapid population growth. These conditions present serious environmental, economic and social impacts on the agricultural community[3].

Nowadays climate change is amongst the most critical problems affecting the wellbeing of human beings. In Ethiopia, where the majority of the population rely on agriculture, climate change has adverse effects. In rural areas, low resilient capacity to shocks exacerbates the impacts of climate change such as production failure, which in turn enormously contributed to food insecurity [4].

Small-holder farmers in Ethiopia are facing several climate related hazards, in particular highly variable rainfall with severe droughts which can have devastating effects on their livelihoods [5]. Droughts and floods are very common phenomena in

Ethiopia with significant events occurring every three to five years[6, 7]. The frequency of droughts and floods has increased in many parts of Ethiopia resulting in loss of lives and livelihoods [8]. Other reports also indicate increasing trends in the incidence of meteorological drought episodes, food shortages and climate related human and crop diseases particularly in the northern highland and southern lowland regions of the country [9]. Climate change is expected to exacerbate the challenges of rainfall variability and the accompanying drought and flood disasters in Ethiopia [7].

Climate change is currently a sustainable development issue that requires special attention of governments. Key natural resources and ecological systems (e.g. forests, pastures, water bodies, wetlands and natural habitats), all of which are crucial to sustainable development, are sensitive to changes in climate and climate variability. EPSILON International [10] argued that climate change represents an additional burden on the natural resource base of Ethiopia, which was already affected by increasing resource demands, ineffective management practices and environmental degradation. These stresses are expected to reduce the ability of some environmental systems to provide, on a sustained basis, goods and services needed for effective economic and social development including adequate food and feed supply, decent health, water and energy supplies, employment opportunities and social advancement. It is well recognized that the most vulnerable and marginalized communities and groups are those who will experience the greatest impacts[11], and are in the greatest need of support and adaptation strategies. In this regard the role of government and civil society is crucial for enabling efficient adaptation methods; and development policies and programs having synergy effect with climate change initiatives help adapt with the changing climate better [12].

Environmental issues have been causing debates around the globe. These issues have also got much attention in Ethiopia. Ethiopia has been adversely affected by the environmental crisis. Developing countries and the poor were depicted as unfortunate victims of climate change. The causes of climate change include deforestation, industries, mismanagement of the environment, and utilization of natural resources. One of the effects of climate change brought natural disaster what we call a drought. Drought affected many people, even recently, in Ethiopia. Concerning the environmental problems and issues in Ethiopia, there are beginnings at the policy level[13].

Climate change is one of the most urgent and complex challenges for societies and economies. Left unaddressed it contains the potential to compromise the well-being of the current and future generations. Smallholder farmers who depend on rain-fed agriculture are heavily affected and it is important to understand what they think about the problem and its impacts so that remedial measures can be tailored to address the problem[14].

Global climate change has become an indisputable fact. The effect of climate change on humans has become increasingly serious, especially for the livelihood of farmers. The perception of climate change is the basis of adaptation. Determining the key factors that affect farmers' perception of climate change and clearing the formation mechanisms of farmers' climate change perception are very important for selecting adaptation strategies [15]. Climate change has a serious impact on the farmers' livelihood depending on the natural resources, especially in the ecologically vulnerable alpine region. So it is urgent for us to search for effective strategies to adapt to climate change [16]. Adaptation to climate change is an effective measure at the farm level, which can reduce climate vulnerability by making rural households and communities better able to prepare themselves and their farming to change and support them in dealing with adverse events[17].

Any slight variations in rainfall mount or intensity enforce a severe challenge on the rural community since its main livelihood relays on agriculture which mostly depends on summer monsoon. This is because showing or forecasting climate change influence on mostly subsistent growers at global level is a very challenging duty due to the absence of regular reports, shortage to acquire standard data, exceptional position, and the households' capability to incorporate on-farm and off-farm activities, and finally the farmers' vulnerability to a range of stressors [18]. The overall objective of this study was, so, to fill such research gaps thorough investigating long term trend analysis of precipitation and temperature in Asosa district, Benishangul Gumuz regional state, Ethiopia.

2. Methods

2.1 An overview of the research areas

Asosa district is the district in Western Ethiopia and capital of the Benishangul Gumuz Regional State located in Asosa administrative Zone. The district is geographically lies between 10^{o}04'-10.067^{o} latitude and 34^{o}31'-34.517^{o} longitude. It is 687 km away from Addis Abeba. The total size of the area is about 2317 km2. It is located in 1401-1544 meter above sea level.

Based on 10 years of climatic data (2008–2017) obtained from Ethiopian Meteorology Agency, Benishangul Gumuz Region Service Center, the mean monthly temperature range of the District is 15–28 ◦C and the mean annual rainfall is 1183 mm Wakwoya, Woldeyohannis [19].

This study was carried out in Asosa district which is one of the development corridor in the country and vast investments are being incurred to encourage small scale farmer managed irrigation. The number of agricultural households of the district is 23, 332 and the total rural farmer population of the district is 104,993 (52532 male and 52461 female)[20].

Agriculture is the mainstay of the community. Like in other parts of the country, the farming techniques used by the rural communities are traditional. The study area is characterized as mixed farming system where the livelihood of the rural community depends both on livestock and crop farming. Crop production is almost dependent on rain fed. The dominant crops produced in the district are cereals, pulse, oil seeds and horticultural crops. The major crops grown in the area are Sorghum, Maiz, Teff, Soya bean, Ground nut, Sweet potato, Banana, Mango and others It is estimated the district has livestock population 123,161 of which cattle population 52,585 comprises the major share followed by small ruminants with a population of 61,670 [20]. In addition agricultural extension systems of the study area offers a multitudes of activities such as home-economics, training, visit, arranging field days in cooperation with the district administration officers and NGOs, organizing demonstration trials etc. Since 2004 attempts have been devoted to employ three development agents at each PA in order to offer training on livestock, natural resources and crop sub-sectors at farmer training center.

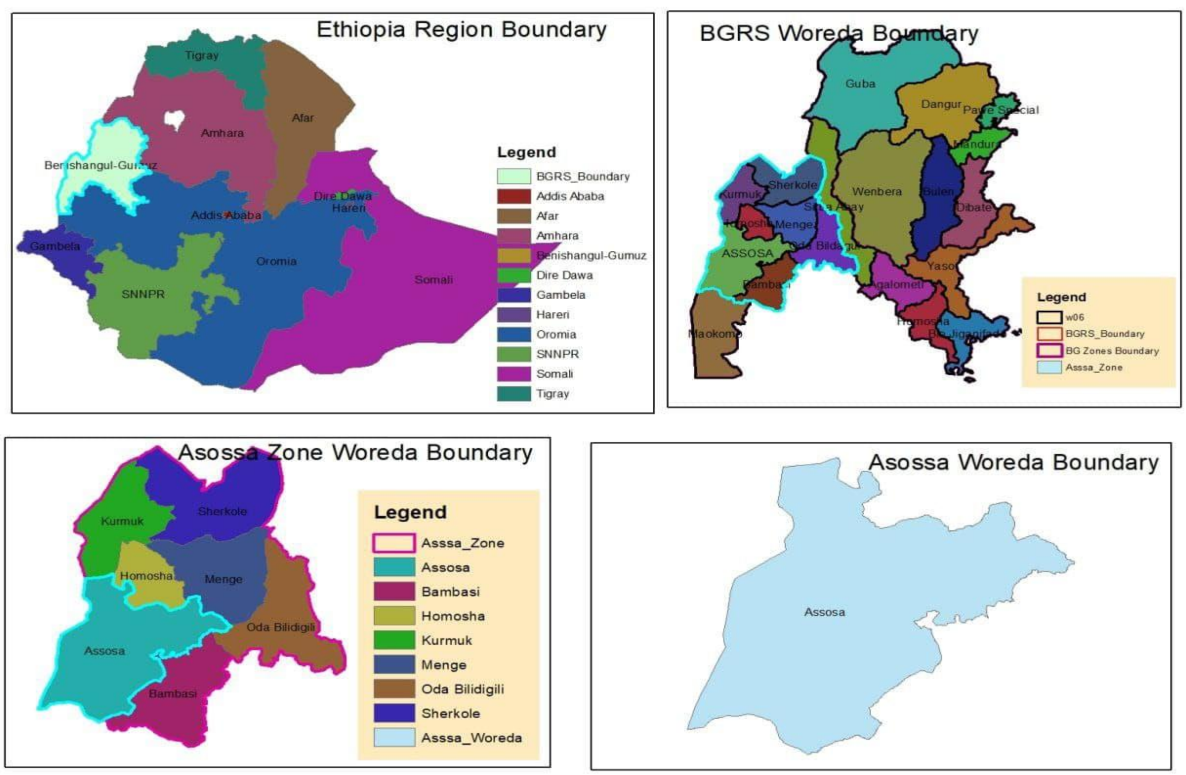

Figure 2.1: Map of the Study area: Source Benishangul Gumuz regional state Bureau of Rural Land Administration

1.2 Data Analysis

The meteorological data was obtained from ground observations of Asosa district Metrological station and the collected data was used for climate trend analysis of the study area. XLSTAT, computer software was used to analyze the trend analysis and to consider the seasonal component of rainfall at the same time. Later, to describe a trend of time series, Mann-Kendall trend test was used to see whether there is a decreasing or increasing trend. Mann-Kendall statistics (S) is one of non-parametric statistical test used for detecting trends of climatic variables. It is the most widely used methods since it is less sensitive to outliers (extraordinary high values within time series data) and it is the most robust as well as suitable for detecting trends in precipitation [21]. Different software such as Origin Pro, and Microsoft excel were used for trend analysis and significant test. As these software are very sensitive to outliers (extraordinarily high values), Mann- Kendall trend test was used to detect the trend and normalized Z-score for significant test.

A mark of +1 is awarded if the value in a time series is larger, or a mark of −1 is awarded if it is reduced. The overall score for the time-series data is the Mann–Kendall statistic which is then compared to a critical value to test whether the trend in rainfall or temperature is increasing, decreasing or if no trend can be observed.

The strength of the trend is proportional to the magnitude of the Mann–Kendall Statistic. Sgn (Xj −X k) is an indicator function that results in the values 1, 0, or −1 according to the significance of Xj − Xk where j > k, the function was calculated as follows:

Sgn (Xj − Xk) = 1 → if, Xj − Xk > 0

Sgn (Xj − Xk) = 0 → if, Xj − Xk = 0

Sgn (Xj − Xk) = −1 → if, Xj − Xk < 0

Where Xj and Xk are the sequential rainfall or temperature values in months J and K (J > k) respectively;

Whereas, a positive value is an indicator of increasing (upward) trend and a negative value is an indicator of decreasing (downward) trend.

In the equation, X1, X2, X3… Xn represents 'n' data points (monthly), where Xj represents the data point at time J. Then the Mann–Kendall statistics (S) is defined as the sum of the number of positive differences minus the number of negative differences, given by:

$$S = \sum_{k=1}^{n-1} * \sum_{j=k+n}^{n} sgn(Xj\ -\ Xk)$$

Where

Sgn (Xj − Xk) = 1 → if, Xj − Xk > 0

Sgn (Xj − Xk) = 0 → if, Xj − Xk = 0

Sgn (Xj − Xk) = −1 → if, Xj − Xk < 0

Trends considered at the study sites were tested for significance. A normalized test statistic (Z-score) is used to check the statistical significance of the increasing or decreasing trend of mean precipitation and temperature values. The trends of temperature are determined and their statistical significance is tested using Mann–Kendall trend significant test with the level of significance 0.05 (Z_α/2 = ± 1.96).

$$Z = \frac{n-1}{\sqrt{var(S)}} \rightarrow \text{If, } S > 0$$

Z = 0 → if, S = 0

$$Z = \frac{n-1}{\sqrt{var(S)}} \rightarrow \text{If, } S < 0$$

Hypothesis testing $H_o = \mu = \mu_o$ (there is no significant trend/stable trend in the data)

$H_a = \mu\_\mu_o$ (there is a significant trend/unstable trend in the data) If −Z1−α/2 ≤ Z ≤ Z 1−α/2 accepts the hypothesis or else reject the null hypothesis. Powerfully increasing or decreasing trends indicate a higher level of statistical significance (Keredin et al. 2013).

3. Results

3.1 Rainfall trend analysis in the Asosa District

The investigation of precipitation and temperature trends in the study area was based on the data obtained from ground observations of meteorological station located in Asosa District, Asosa zone of Benishangul Gumuz regional state.

The results and thoughts provided in the subsequent sections though expressed as Asosa District. The annual and seasonal precipitation trend of Asosa district was analyzed and is presented in (Table 3.1). It was found out that the period from Jun to September is the main rainy season (Kiremet), during which period 70.6% of the annual precipitation is received (Figure 3.1).

The annual minimum, maximum and mean precipitation had of 827.8, 2417.8 and 1,240.75 mm respectively. Among seasons, the mean minimum rainfall of 0.7933 mm has been recorded in winter and the maximum of 653.425 mm in summer. The 314.25 mm annual rainfall has deviated from the average value; among the season, the greater standard deviation was in summer and it followed by autumn, spring and winter. However, moderately sever rain fall variability (CV) was recorded for the annual and summer, highly sever for the spring, winter and autumn. A positive correlation coefficient was found in annual, winter, summer and autumn, a parallel result noticed in regression slope too. This implies that the annual, winter, summer and autumn rainfall had been increasing since 1993. This result has similarity with the findings of [22]. The month of August is with the highest (242.7 mm) average monthly precipitation in the district. After the end of summer (Kiremet) season, the remaining precipitation usually occurs during the autumn (Tsedey) and spring (Belg) seasons (Figure 3.1).

Table 3.1The annual and seasonal rainfall in Asosa district since 1993–2022

Stat.	Annual Total	Winter	Spring	Summer	Autumn
Minimum	827.8	0	100.8	482.8	210
Maximum	2417.8	15.6	558.5	1147.5	710.5
Mean	1240.75	0.7933	204.166	653.425	380.813
SD	314.247	2.911	99.064	147.046	130.935
CV%	25.33	180.46	48.52	22.51	34.38
R	0.12163	0.212	-0.1568	0.1158	0.2736
R Slope	**4.341672**	0.104182	-1.7653	1.933628	4.069188

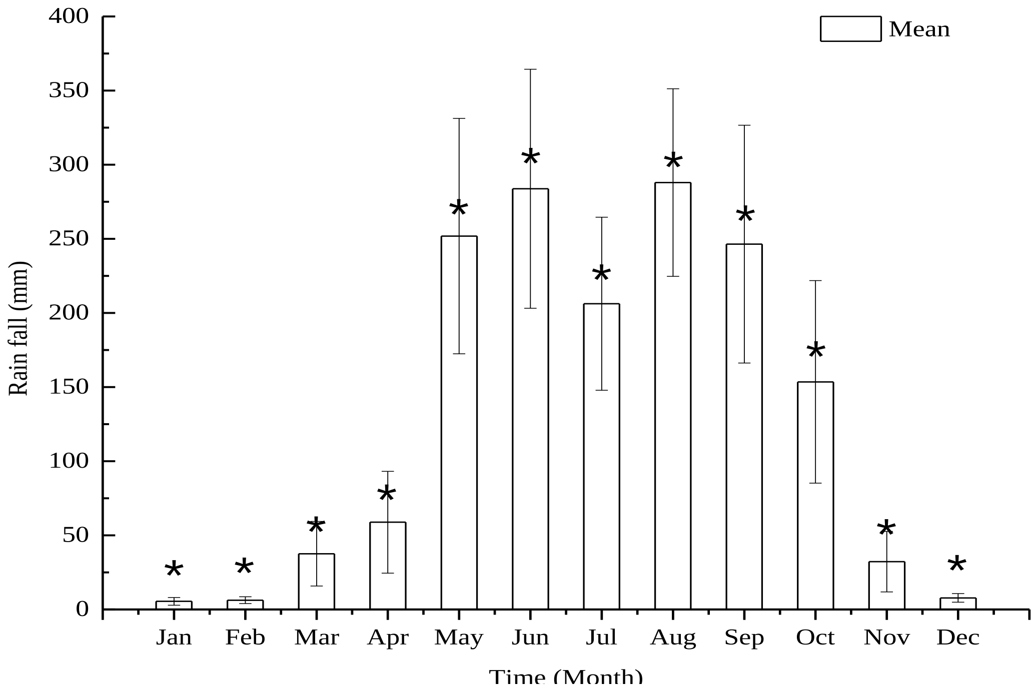

Figure 3.1 Asosa District Monthly rainfall distribution

Analysis of the precipitation record in the study area depicted that there is a general rising trend of the annual rainfall during the last 30 years. The study area station documented minimum yearly rainfall during the second decade and the maximum annual rainfall was recorded in the first decade. The range of yearly rainfall also showed a high variability of annual rainfall in the study area. The minimum yearly rainfall was recorded during 2005(827.8 mm) and the highest annual rainfall was documented in 2000 (2417.8).The annual precipitation of the study area had a range from 827.8 mm in 2005 to 2417.8 mm in 2000. These values indicate that there is high yearly rainfall inconsistency in the study area. For the period of the past 30 years, the precipitation deviated yearly by a maximum of 314.25 mm from the mean (Table 3.1).

In order to identify statistically significant variations in the annual precipitation in the study station, a time series study was undertaken. The parameter estimate of the slope was then tested for statistical significance using the Mann-Kendall trend test at a 0.05 level of significance. As presented in table 3.1 the R-slope of the trendline for figure 3.2 is 4.3417 (positive) which suggests that the long years mean rainfall is increasing.

To clarify the descriptive information, the linear regression was fitted and the slope was determined and paired samples t- test was run to check their correlation. The slope revealed rising trend of precipitation within the stated times. The slope of a line was also used as a measurement of how many units it went up or down for every year to see the change of yearly precipitation conditions.

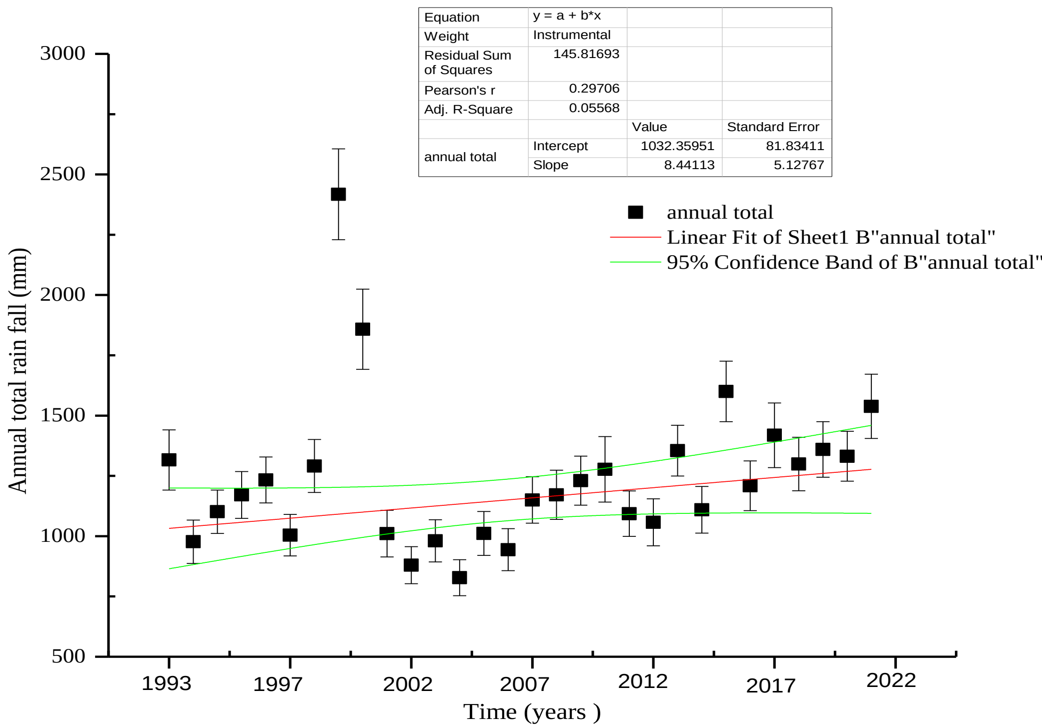

Figure 3.2 Linearity relationship graph of annual total rain fall

The Mann - Kendall test was used to identify the trend of annual and seasonal precipitation between 1993 and 2022; results of which are revealed in Table 3.2. The seasonal and annual rainfall results of both Kendall's tau and the statistic (S) were consistent with one another. A positive trend was observed in annual rainfall, and a mix of negative (spring) and positive (winter, summer and autumn) trends was noticed in seasons; however, it also show statistical significance at 5% for Annual, summer and autumn. The magnitude of the trend was evaluated by the Sen's method which showed an increasing trend annual, winter, summer and autumn (Figures 3.3 and 3.6), and the spring showed the decreasing trend of rainfall in the time series (Table 3.1 and 3.2).The lower bound 5% of the confidence interval demonstrated that the spring season rainfall was negatively influenced, but the upper bound 5% of annul and all seasons and lower bound 5% of annul and the rest seasons except spring found positive.

Table 3. 2. Annual and seasonal rainfall for the Mann - Kendall and Sen's Slope test (19093–2022)

Variabl	Kendall's Tau	S	Var (S)	p-Value	Sen's Slope	95% Interval	Confidence
Annual	0.283	123	3141.667	**0.030**	10.784	0.850	21.023
Winter	0.195	72	2647.333	0.168	0.000	0.000	0.088
Spring	-0.014	-6	3140.667	0.929	-0.118	-4.700	2.740
Summer	0.267	116	3140.667	**0.040**	3.730	0.331	7.971
Autumn	0.297	129	3141.667	**0.022**	5.692	0.726	10.644

As it is depicted in Table 3.3 the monthly average precipitation decreased for April and May but increased for Jun, July, August, September, October and November. Based on the data analysis resulted by Man-Kendall trend test the highest increase was documented at October month with a slope of 2.833 and the lowest increase was recorded at November Month with a slope of (0.540) in the study area station. The positive sign showed that raising from the slope of each average yearly precipitation record.

The coefficient of variability analysis shows that a significant yearly rainfall difference was recorded from weather station with maximum during winter season (180.46%) and minimum During Summer (22.51%) season (see table 3.1). These are also supported by Correlation Coefficient of the yearly precipitation change and variability. All seasons in the study area except spring showed a positive correlation with the time period for the last 3 decades and this was significant at $p<0.05$ for annual, summer and autumn (Table 3.1).

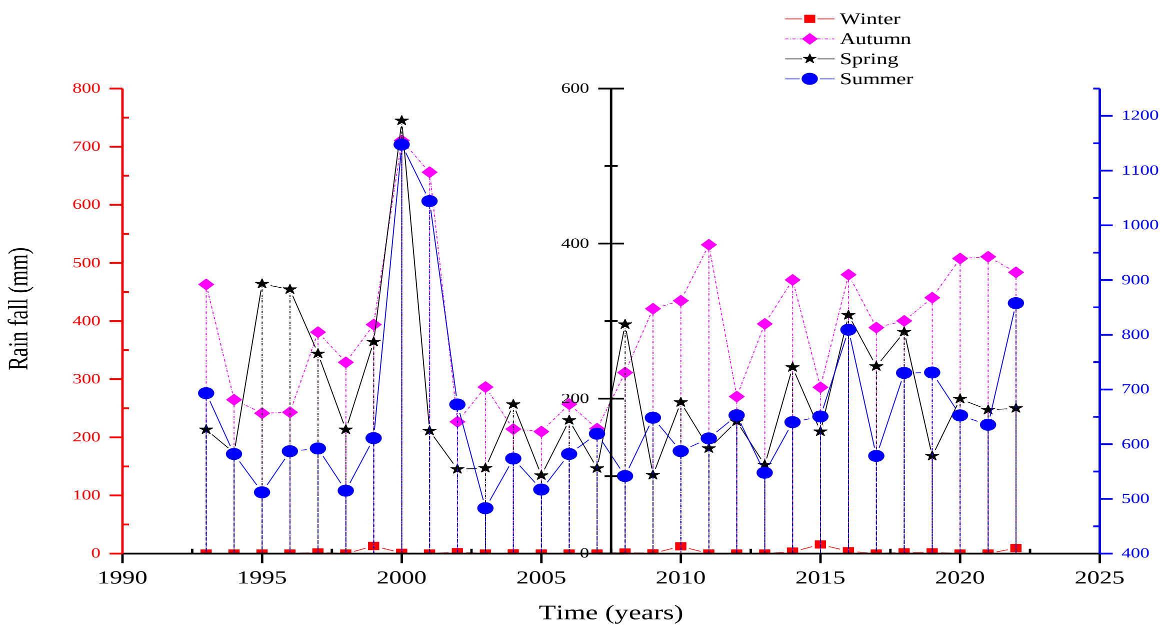

Figure 3.3 Seasonal rain fall variability graph

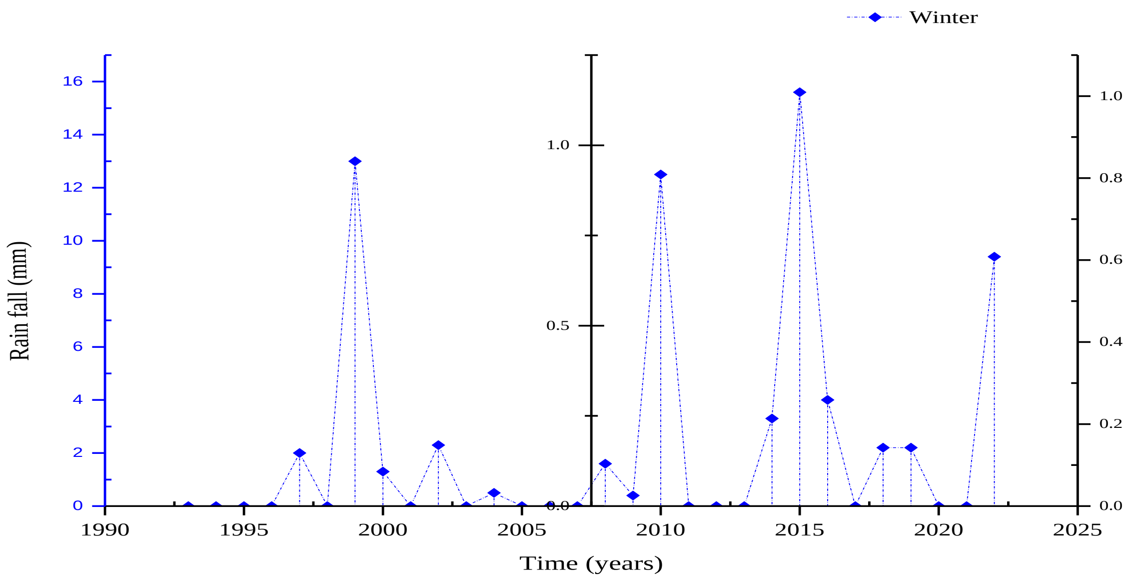

Figure 3.4 Seasonal maximum rain fall variability graph

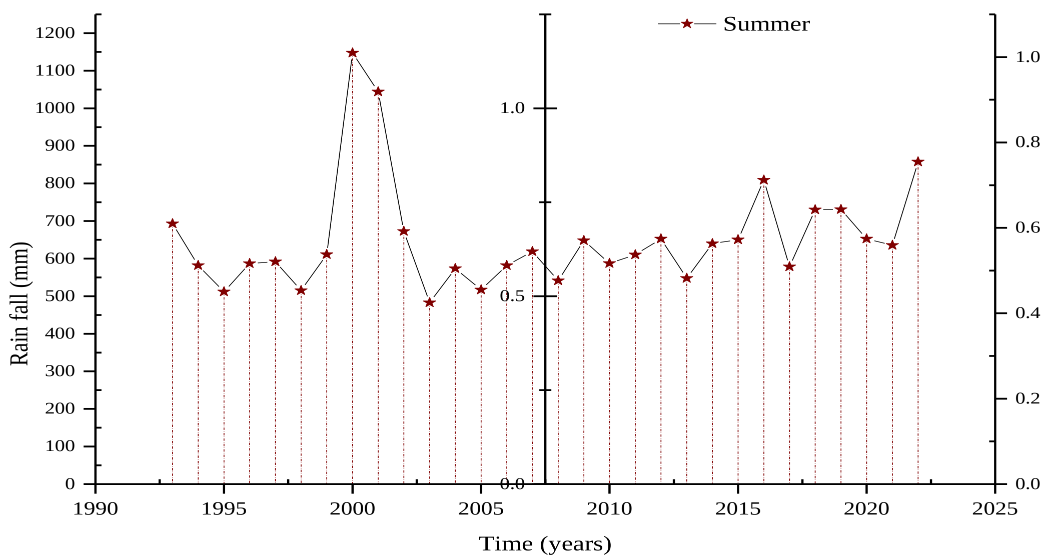

Figure 3.5 Seasonal minimum rain fall variability graph

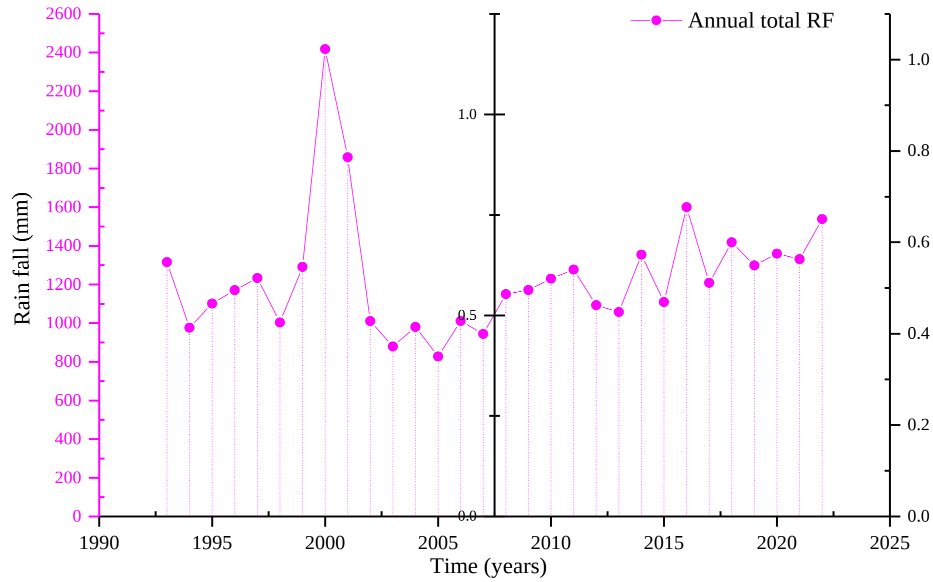

Figure 3.6 Annual total rain fall variability graph

The monthly average precipitation amount for the past three decades from the station was analyzed and mean values were taken for investigation for the study area. Therefore, the mean, minimum and maximum precipitation amount was higher for the months of June, July, August and September (summer season).

..Table 3. 3 Monthly average rainfall statistics for the last 3 decades for Asosa Metrological station (descriptive statistics)

Stat.	Min	Max	Mean	SD	CV%	Kendall's tau	S	Var(S)	p-value	Slop
Jan	0	11	5.5	2.611	47.47	-0.078	-19	1308.333	0.619	0
Feb	0	12.5	6.25	2.304	36.86	0.074	22	1884.000	0.629	0
Mar	0	75.2	37.6	21.805	57.99	0.086	34	2872.000	0.538	0
Apr	0	117.7	58.85	34.359	58.38	-0.030	-13	3137.000	0.830	-0.141
May	61.2	442.5	251.85	79.362	31.51	-0.067	-29	3141.667	0.617	-4.354
Jun	103	464.5	283.75	80.61	28.41	0.053	23	3141.667	0.695	0.679
Jul	88.4	324	206.2	58.374	28.31	0.085	37	3141.667	0.521	0.933
Aug	144	432	288	63.27	21.97	0.214	93	3141.667	0.101	2.025
Sep	94	398.8	246.4	80.185	32.54	0.182	79	3141.667	0.164	2.286
Oct	11	296	153.5	68.323	44.51	0.269	117	3141.667	0.038	2.833
Nov	0	64.5	32.25	20.379	63.19	0.194	83	3112.333	0.142	0.54
Dec	0	15.6	7.8	2.911	37.32	0.351	92	1515.333	0.019	0

Based on the above finding, it is of huge significance to picture the socio economic and environmental effects that could result if increasing precipitation trends last in the future. For rural agriculturalists who are exposed to floods, water logging and consistent nature of precipitation, appropriate adaptation strategies have to be designed and implemented by development planners. The vulnerabilityof rural households might further be worsened if the precipitation continues showing drastic raising trend in the future as this incident results in flood and severe logging of the farm land resources due to heavy precipitation.

3.2. Temperature trends

The average monthly temperature was examined in the study area using the data recorded over the years. The temperature data collected in Asosa Meteorological station was computed and mean, maximum and minimum monthly temperature values were taken for this analysis. Therefore, mean minimum and maximum temperature across all months over the last 30 years in the study area is presented in Table 3.4 and 3.5.

The average yearly minimum and maximum temperature in the district for the last 30 years was 14.067 ^{0}C and 31.442 ^{0}C, respectively. The largest average minimum and maximum temperature was documented in spring than summer season (Tables 3.4). The maximum temperature trend was decreasing at Asosa metrological station in all months except Jun month (Table 3.5). Significant decreasing trend of maximum temperature was observed during July, October and December while the minimum temperature trend was decreasing significantly during February, March and November and increasing during May, July, August and September at study area station. On the other hand, the minimum and maximum temperature trend showed in decreasing trend for annual and throughout the seasons at Asosa district except autumn season for the maximum temperature which shows a positive trend (Table 3.5 and 3.6).The yearly temperature also indicates a decreasing trend; however, there are separate alterations in the tendency for minimum temperature and maximum temperature (maximum temperature decreased more quickly).

The Mann-Kendal trend of yearly, winter, spring, and autumn season minimum and maximum temperature indicated a decreasing trend but summer season for minimum temperature showed an increasing trend. Concerning monthly minimum temperature, May, Jun, July, August, September and October, months revealed a rising trend and Jun, July, August and September were significant at ($p < 0.05$), whereas January, February, March, April, November and December, months revealed a decreasing trend and January, February, March and November were significant ($p < 0.05$) (Table 3.5). On the other hand, monthly maximum temperature, except for Jun, all months indicated a decreasing trend and May, July, October and December were significant at ($p < 0.05$) (Table 3.6). The reason for decreasing of temperature in the study area could be because of change in climate, massive planting of seedlings by the green legacy program of Ethiopian government for the last 10 years, and also it could be because of artificial lake created by great renaissance dam construction at Nile River near to the study area.

Significant rising trends of average minimum temperature particularly in the main growing season, might have damaged crop growth and development as well as yield across the region in Asosa. This is for the reason that the high temperature throughout crop growing season leads to higher evapotranspiration causing in more water demand for the crops.

Table 3.4 Mann Kendall trend test result for annual, seasonal, and monthly Minimum temperature (^{0}C) (from 1993–2022) in Asosa District, Benishangul Gumuz regional state, Ethiopia.

Temperature	Min (◦C)	Max (◦C)	Mean (◦C)	SD	CV%	Kendall's tau	S	Var(S)	p-value	slop
Jan	11.5	16.3	13.224	1.216	9.19	-0.232	-100	3134	0.077	-0.049
Feb	12.021	18.2	14.439	1.517	10.5	-0.372	-161	3137.667	0.004	-0.094
Mar	13.3	20.8	16.061	1.488	9.26	-0.375	-162	3134	0.004	-0.07
Apr	14.2	18.6	16.67	1.177	7.06	-0.185	-80	3136	0.158	-0.04
May	14.5	18.3	16.764	0.867	5.17	0.149	64	3131.333	0.26	0.018
Jun	14.9	17.9	16.162	0.625	3.87	0.247	105	3117	0.062	0.024
Jul	11.9	16.8	15.648	0.895	5.72	0.267	114	3120	0.043	0.022
Aug	13.3	16.465	15.547	0.742	4.77	0.385	165	3127.667	0.003	0.027
Sep	13.3	16.3	15.505	0.677	4.36	0.271	116	3122.667	0.04	0.022
Oct	13	17.6	14.791	0.9	6.08	0.103	44	3126.667	0.442	0.008

Nov	11.6	15.5	13.542	1.039	7.67	-0.303	-131	3135	0.02	-0.06
Dec	10.1	16.3	13.078	1.53	11.7	-0.196	-85	3137.667	0.134	-0.05
Annual	14.067	16.042	15.119	0.521	3.45	-0.172	-75	3141.667	0.187	-0.017
Winter	11.533	16.033	13.58	1.017	7.49	-0.284	-123	3137	0.029	-0.05
Spring	14.8	18.697	16.498	0.904	5.48	-0.184	-80	3140.667	0.159	-0.031
Summer	14.333	16.453	15.786	0.569	3.6	0.277	120	3138.667	0.034	0.021
Autumn	13.067	15.7	14.612	0.652	4.46	-0.025	-11	3139.667	0.858	-0.002

Table 3.5. Mann–Kendall test results for annual, seasonal, and monthly Maximum temperature (⁰C) (from 1993–2022) in Asosa District, Benishangul Gumuz regional state, Ethiopia.

Temperature	Min (◦C)	Max (◦C)	Mean (◦C)	SD	CV%	Kendall's tau	S	Var(S)	p-value	slop
Jan	28.7	34	30.427	1.285	4.22	-0.06	-26	3136.667	0.655	-0.012
Feb	20.838	36.9	31.399	2.47	7.87	-0.042	-18	3131.333	0.761	-0.005
Mar	30.9	35.5	32.386	0.991	3.06	0.086	37	3130.333	0.52	0.01
Apr	27.9	33.9	31.263	1.444	4.62	-0.177	-76	3132	0.18	-0.04
May	25.1	31.9	28.268	1.426	5.04	-0.245	-106	3136.667	0.061	-0.05
Jun	24.1	32.7	25.711	1.748	6.8	0.012	5	3137.667	0.943	0.002
Jul	21.2	29.1	24.349	1.538	6.32	-0.279	-120	3130.667	0.033	-0.048
Aug	23	29.1	24.589	1.506	6.13	-0.16	-69	3135.667	0.225	-0.027
Sep	24.173	29.2	25.538	1.012	3.96	-0.179	-77	3129.667	0.174	-0.021
Oct	25.2	29.4	26.573	1.105	4.16	-0.381	-163	3122.333	0.004	-0.03
Nov	26.3	30.9	27.784	1.045	3.76	-0.188	-81	3135.667	0.153	-0.033
Dec	27.3	33.5	29.621	1.351	4.56	-0.222	-96	3136.667	0.09	-0.03
Annual	26.809	31.442	28.159	0.975	3.46	-0.218	-95	3141.667	0.094	-0.025
Winter	26.549	34.6	30.482	1.36	4.46	-0.224	-97	3139.667	0.087	-0.019
Spring	29	33.667	30.639	1.04	3.4	-0.217	-94	3138.667	0.097	-0.029
Summer	23.362	27.767	24.883	1.249	5.02	-0.147	-64	3140.667	0.261	-0.021
Autumn	25.533	29.733	26.632	0.927	3.48	-0.318	-138	3140.667	0.015	-0.025

Table 3. 6 Monthly mean temperature descriptive statistics (Asosa District 30 years data)

Stat.	Min	Max	Mean	SD	CV %	R	Slope
Jan	11.5	34	22.8	0.864	3.8	-0.27934	-0.03682
Feb	12	36.9	24.5	1.645	6.7	-0.41981	-0.07842
Mar	13.3	35.5	24.4	1.145	4.7	-0.40686	-0.05292
Apr	14.2	33.9	24.1	1.38	5.7	-0.41895	-0.06567
May	14.5	31.9	23.2	0.925	4	-0.09937	-0.01044

Jun	14.9	32.7	23.8	0.929	3.9	0.15312	0.016153
Jul	11.9	29.1	20.5	0.714	3.5	0.03525	0.002857
Aug	13.3	29.1	21.2	0.774	3.7	0.10818	0.009505
Sep	13.3	29.2	21.3	0.524	2.5	-0.07361	-0.00438
Oct	13	29.4	21.2	0.646	3	-0.2569	-0.01884
Nov	11.6	30.9	21.3	0.867	4.1	-0.41524	-0.04088
Dec	10.1	33.5	21.8	0.635	2.9	-0.41434	-0.02986
Annual	14.067	31.442	21.567	0.605	0.0281	-0.36424	-0.02503
Winter	11.533	34.6	22.104	0.938	0.0424	-0.40918	-0.04362
Spring	14.8	33.667	22.511	0.971	0.04431	-0.39003	-0.04301
Summer	14.333	27.767	21.331	0.774	0.0363	0.10818	0.009505
Autumn	13.067	29.733	20.62	0.533	0.0258	-0.35279	-0.02137

As indicated in Figure 3.7 there was a general decreasing annual maximum, minimum and mean temperature change from 1993 to 2022. The trend line shows that the average yearly maximum temperature decreased approximately by a factor of -0.02503 (figure 3.8, table 3.4). This value is indicated by the slope equation given y= -0.02503x + 21.955. To the average, the annual maximum temperature is found to be 31.442^{0}C (2005 year) and the annual minimum temperature is 14.067 (2011 year), however; this value is not kept constant because of the change in climate (Figure 3.7, Table 3.3)

For the temperature data recorded in the study area, the average values were analyzed using the Mann – Kendall test and the results revealed that there is no increasing or decreasing trend for the mean annual temperature in the study area as the calculated p-value is greater than the significance level alpha = 0.05 except April month (table 3.5); one should accept the null hypothesis H0, and reject the alternative hypothesis Ha. It implies that MK test is not statistically significant for the annual mean temperature which shows no trend.

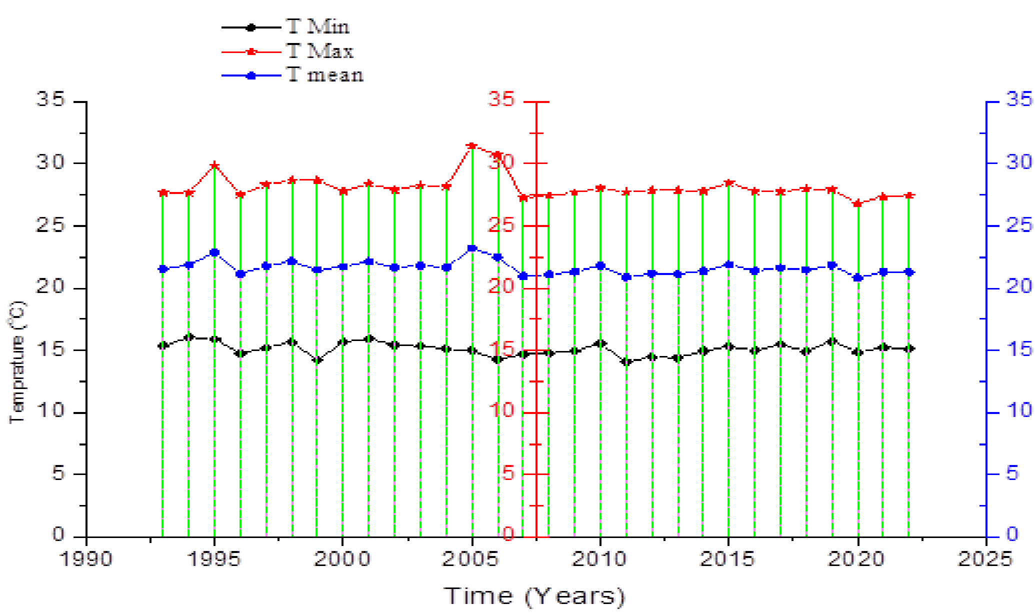

Figure 3.7 Annual minimum, maximum and mean temperature trend in Asosa district

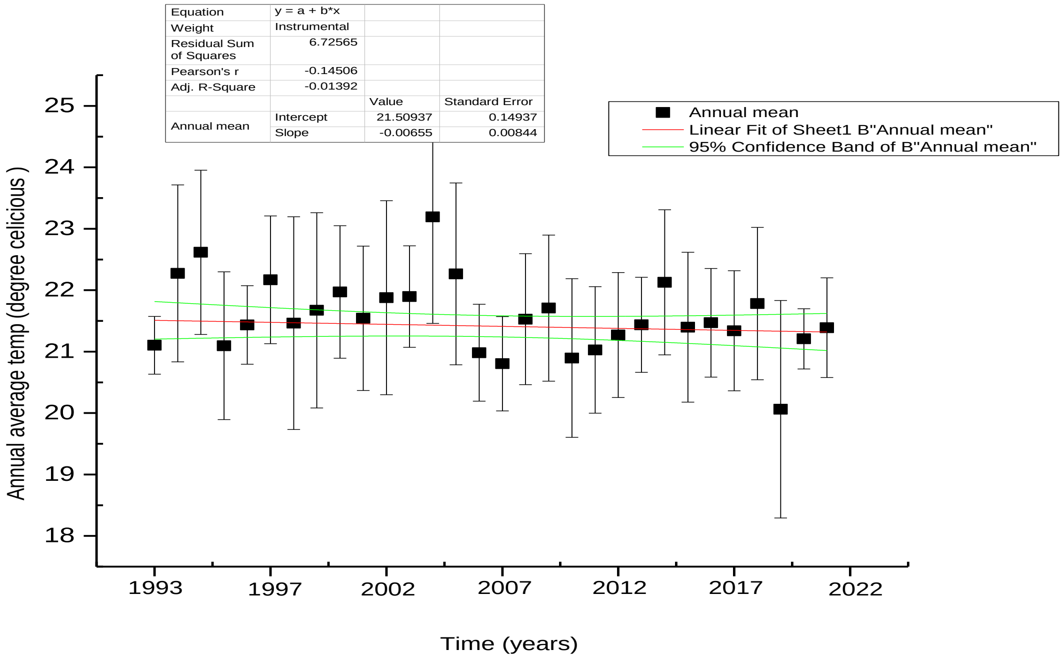

Figure 3.8 Linearity relationship graph of annual mean temperature

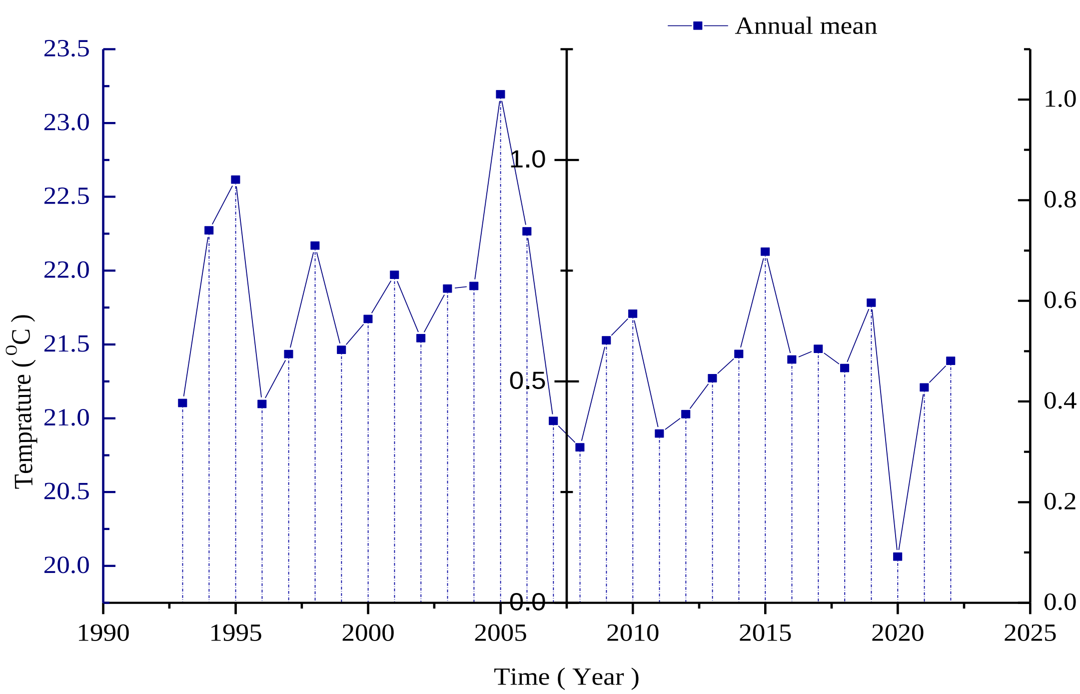

Figure 3.9: Annual mean temperature graph

4. Discussion

Studies have attempted to establish the trend of the climate variability at District and regional level. The seasonal and annual trend in rainfall of Ethiopia has been reviewed from the period 1986 to 2020. The district analysis was carried out considering each meteorological station, while the regional analyses were based on agro-ecological zones (AEZs), using observations from 47 rainfall and 37 temperature stations obtained from the Ethiopian Meteorological Institute (EMI). The district level analysis revealed that Winter (Bega), summer (Kiremt), and annual rainfall showed increasing trend, even though no significant, in most stations, but the rainfall in Spring (Belg) season showed a non-significant decreasing trend at district and regional level[23]. Also, Spring and summer rains in parts of Ethiopia have declined by 15–20 percent since the mid-1970s[24]. The decreasing trend in Spring (Belg) rainfall has been noticed for the southern region of Ethiopia by applying Mann Kendall test [25].

The research District is characterized with maximum precipitation in summer (June to August), some in spring (May) and autumn (September to October), seasons. There is yearly variability of precipitation in the station. Annual and all seasons, in the station exhibited a coefficient of variation (CV > 0.2). The results of this study is commonly consistent with other study findings which reported increased rainfall and non-uniform rainfall changes [23, 26-31]

In the study area, Mann Kendall and Sen's slope estimator test analysis showed that declining and rising trend of precipitation was observed across the seasons. However, there is no statistically significant trend at 95% level for spring and winter seasons Table 3.2). This result is also supported by [23-26, 28, 31-34] that expressed the existence of increasing and decreasing annual and seasonal trends of rain fall in most parts of the country. This disparity may affect the district climate systems as well as the hydrological cycle[35]. It was openly seen that the declining of precipitation in spring season during the study period was probably happened by mainly the reduction of precipitation from April to May ($p < 0.05$) (table 3.3) [35]. The other months showed increasing trend except December, January, February and March.

The unit of variation in the amount of precipitation was greater for spring season allied with annual and summer precipitation in Asosa District. This suggests that related with the summer season, there is more inter annual variability in spring season's precipitation. The present result was comparable to the reports by [22, 36, 37] who found more variability in spring precipitation matched with the summer precipitation in most parts of Ethiopia. Bewket [38] also stated additional precipitation variability in Gondar in spring season with 48% CV value compared with annual and summer precipitation with 17/% and 22%, CV values respectively. In addition, according to the investigation by Abebe [39], the coefficients of variations of precipitation were reported as 23%, 46%, and 35% for annual, spring, and summer precipitations, respectively.

The pattern of precipitation in the study district was not only limited to the various levels of variability and deviation from normal distribution but also indicated ups and downs in the trends. As a result, the total annual, winter, summer, and autumn rainfall exhibits an increasing trend while the spring season rainfall show decreasing trends. On the other hand, winter and spring trends were not statistically significant. The end result of this study is in convergence with the finding of the [40, 41], which says that the expected (21st century) mean annual precipitation trend is likely to be increasing in East Africa. In the same way,[42] stated the truth of both the increasing and decreasing trends of rainfall in the Gamo Gofa zone in southwestern Ethiopia. In covenant with the current study,[43] noted that the yearly total precipitation has revealed an increasing trend of 35 mm per decade; however, it was not statistically significant over the Upper Blue Nile River Basin of Ethiopia. In contrast, the finding of [44] is in opposition to the present study. In their study, they described the existence of a decreasing trend in annual precipitation over the northern, northwestern, and western parts of Ethiopia. In addition, the current study differs with the findings of [45], which indicated decreasing trends in yearly precipitation in the Tana Basin region and the same decreasing trend was detected in the Tigray region of North Ethiopia [46]. Inconsistency could arise from different sources; study period, station data quality, study area location, and the number of years of the data used for the analysis.

Table 3.3 and Fig. 3.1 show the end result of a trend investigation of monthly and seasonal rainfall patterns in the study district. Accordingly, the pattern of precipitation was rising for the majority of the months, except in April and May. However, the pattern of rising trends in rainfall was statistically significant in October and December Months at alpha = 0.05: On the other hand, in the spring season, the precipitation revealed a declining trend of -0.118mm of Sen's slope (Table 3.2). Although, amazingly, the result of the Mann Kendall's tau test result shows negative trends in January Month, the negative sign shows the presence of decreasing trend in the patterns of precipitation. This indicates the strength of Sen's slope test relative to descriptive statistics in detecting each outlier in the data set.

On the other hand, the annual precipitation indicates a rising trend with the Mann Kendall test of 0.283 and by 10.784 mm with Sen's slope (Table 3.2), it was also statistically significant. The result is covenant with findings in the Gurage Zone by Yirga [47]. He reported that the trends of precipitation were declining in Belg and rising in both the annual and summer seasons, but the trends were non-significant. In general, the declining trends of Belg (short rainy season) and the changing trends of Kiremt (long or main rainy season) rain were very detrimental to rain fed mixed farming. The result is in line with the research conducted in the Gubalafto District of North Eastern parts of Ethiopia [48]. The variability is damaging to survival livelihoods because, it influences the rain fed agriculture system in diverse ways, such as through damage to crops and persistent low yields that could lead to household food insecurity[49]. Moreover, the influence of precipitation variability has been found as it was not limited to the effects of subsistence food intake but goes beyond the Ethiopian economy. [50] found that precipitation variability in the state led to a production shortage of 20% and amplified poverty rates by 25%, which cost the economy over one-third of its growth potential. This is because; Ethiopia is highly exposed to climate change and variability and has experienced several food crises during the past decades [37, 51].

The unit of variation in the amount of precipitation was greater for spring season allied with annual and summer precipitation in Asosa District. This suggests that related with the summer season, there is more inter annual variability in spring season's precipitation. The present result was comparable to the reports by [22, 36, 37] who found more variability in spring precipitation matched with the summer precipitation in most parts of Ethiopia. Bewket [38] also stated additional precipitation variability in Gondar in spring season with 48% CV value compared with annual and summer precipitation with 17/% and 22%, CV values respectively. In addition, according to the investigation by Abebe [39], the coefficients of variations of precipitation were reported as 23%, 46%, and 35% for annual, spring, and summer precipitations, respectively.

The results in Table 3.1 and Table 3.3 depict the descriptive analysis of both monthly and seasonal precipitation in the study district for the period 1993 to 2022. The mean annual precipitation of the district from 1993 to 2022 was 1240.75mm, with a standard deviation (SD) of 314.247and 25.33 of the CV. The minimum and maximum records of precipitation were 827.8mm and 2417.8mm, respectively. Summer (locally known as Kiremt season rain) was found to be the season when high amounts of rainfall (M = 653.425mm) were received with moderately severe variation (CV = 22.51%). And it was also the main rainy season (June, July, and August) that had a significant contribution to the total amounts of rainfall received on an yearly basis (M = 1240.8mm). Autumn, locally known as "Tseday rain" (September, October and November), is the season when the 2nd highest amount of average precipitation (380.813) was received. In contrast, winter (locally known as Bega rain, December-February) was the season observed with the least amount of rain (M = 0.7933mm), and the rain at this time was not as demanded as compared to the summer, autumn and spring seasons' rain. The result is in line with the findings of [52, 53]. They stated that summer is the main rainy season contributing the most to the yearly precipitation received in different parts of the country, Ethiopia.

Concerning variability, moderate to extremely high levels of variability were recorded in seasonal and moderate level of variability in annual precipitation was recorded, however moderate to very high levels of variability were observed in the monthly precipitation with the coefficient of variation. The coefficient of variation (CV) is the means of descriptive statistics broadly used to categorize the scale of variability as low (CV < 20%), moderate (20<CV< 30%), high (CV > 30%), very high (CV > 40%), and extremely high (CV > 70%) [54]. Consequently, Jun, July and August were the months with moderate levels of variability, (28.41%, 28.31% and 21.97% of CV), February, May, September and December were the months with high levels of variability (36.86, 31.51, 32.54, 37.32% of CV) and January, March, April, October and November were the months that showed very high levels of variability (47.47%, 57.99%, 58.38%, 44.51% and 63.19% of CV) respectively. Between seasons, summer (Kiremt) was the season with moderate coefficient of variation (22.51% CV), autumn was the season with high coefficient of variation (34.38% CV), spring was the season with very high coefficient of variation (48.52% CV) but winter (Bega) was the season with the extremely high coefficient of variation (180.46%). This suggests that, while the pattern of rainfall was moderately stable during the main sowing season, it was very highly variable during the first sowing season (spring). Kyei-Mensah, Kyerematen [55] noted that the high inconsistency of precipitation in the minor season is repeatedly associated with a decrease in crop production yield. The end result is similar to the situation in Ethiopia's Amhara regional state's south Gonder zone[41, 56]. The authors found that the rainfall pattern in the Kiremt season was less variable compared to the Belg season (March to May) rain.

The average yearly minimum and maximum temperature in the district for the last 30 years was 14.067 ^{0}C and 31.442 ^{0}C, respectively. The largest average minimum and maximum temperature was documented in spring than summer season (Tables 3.4). The maximum temperature trend was decreasing at Asosa metrological station in all months except Jun month (Table 3.6). Significant decreasing trend of maximum temperature was observed during July, October and December while the minimum temperature trend was decreasing significantly during February, March and November and increasing during May, July, August and September at study area station. On the other hand, the minimum and maximum temperature trend showed in decreasing trend for annual and throughout the seasons at Asosa district except autumn season for the maximum temperature which shows a positive trend (Table 3.5 and 3.6).

The yearly temperature also indicates a decreasing trend; however, there are separate alterations in the tendency for minimum temperature and maximum temperature (maximum temperature decreased more quickly). The finding is contrasting with [57] result, who reported a higher increase in minimum temperature than maximum temperature in southwest China. The yearly and seasonal average temperature trend line, studied by [58], showed that in the yearly average temperature series, an increasing trend is detected at 53 stations and a decreasing trend at 17 stations. The average maximum temperature series reveals an increasing trend at 63 stations and a falling trend at 8 stations. The average minimum temperature shows an increasing trend at 33 stations and a declining trend at 31 stations out of 71 total studied stations. A large variability matched with maximum temperature was revealed in coefficient of variation of average yearly, season, and monthly minimum temperature (Figure 3.5 and 3.6). In the same way, [59, 60] described that coefficient of variation is considerably greater for minimum temperature than the maximum temperature in all study regions of western Amhara, Ethiopia between 1979–2008.

The MK trend of yearly, winter, spring, and autumn season minimum and maximum temperature indicated a decreasing trend but summer season for minimum temperature showed an increasing trend. Concerning monthly minimum temperature, May, Jun, July, August, September and October, months revealed a rising trend and Jun, July, August and September were significant at ($p < 0.05$), whereas January, February, March, April, November and December, months revealed a decreasing trend and January, February, March and November were significant ($p < 0.05$) (Table 3.5). On the other hand, monthly maximum temperature, except for Jun, all months indicated a decreasing trend and May, July, October and December were significant at ($p < 0.05$) (Table 3.6). similar to this finding,[60, 61] noted that a non-significant heating trend of minimum temperature was observed in the course of summer season between 1985–2019 in north East Ethiopia.

Significant rising trends of average minimum temperature particularly in the main growing season, might have damaged crop growth and development as well as yield across the region in Asosa. This is for the reason that the high temperature throughout crop growing season leads to higher evapotranspiration causing in more water demand for the crops. This finding is in line with [62] who explained that high temperature damages many cellular developments associated to plant growth and development, which is openly linked to a reduction in photosynthetic efficiency and lastly crop yield. A rise in temperature also causes in a shift from using long duration cultivars to the short maturing ones, which have lower yield potential[63].

Though, documented meteorological data investigation of temperature shows that rising trends detected almost in all parts of the country. According to the Mann–Kendall trend analysis test, the maximum and minimum temperature investigation resulted in a general decreasing with no trend. However, precipitation amount resulted in a general increasing trend based on the average documented values of the Metrological stations from the Asosa district. The reason for increasing rain fall and decreasing of temperature in the study area could be because of change in climate, massive planting of seedlings by the green legacy program of Ethiopian government for the last 10 years and also could be artificial lake created by great renaissance dam construction at Nile River near to the study area. To recommend the concerned body, development planners should design strategies and plans by taking into account a rising summer rainfall and declining temperature without trends impacts on rural livelihoods.

5. Conclusion

Nowadays climate change is amongst the most critical problems affecting the wellbeing of human beings. In Ethiopia, where the majority of the population rely on agriculture, climate change has adverse effects. In rural areas, low resilient capacity to shocks exacerbates the impacts of climate change such as production failure, which in turn enormously contributed to food insecurity. Small-holder farmers in Ethiopia are facing several climate related hazards, in particular highly variable rainfall with severe droughts and floods which can have devastating effects on their livelihoods. Amplified ability to manage upcoming climate change and weather extremes can decrease the magnitude of economic, social and human destructions.

Adverse effects of climate change may degrade current social and economic challenges of the whole country, mainly where people are reliant on resources that are sensitive to climate change and rain fed agriculture. Historical and recent investments and catastrophe interferences in the country are more concentrated on reclamation from a disaster than on the formation of adaptive capacity. Improved ability to manage future climate change and weather extremes can shrink the level of economic, social and human da mage. Among several features of weather and climate in Ethiopia, Precipitation and temperature are the most shared and key for the rural peoples' livelihoods that depend on rain fed agriculture.

Analysis of the rainfall record in the Asosa district meteorological station depicted that there is ageneral rising trend of the annual rainfall during the last 30 years. The range of yearly rainfall also showed a high variability of annual rainfall in the study area. In the Asosa metrological station, the minimum yearly rainfall was recorded during 2005(827.8 mm) and the highest annual rainfall received in 2000 (2417.8).The annual precipitation of the study area had a range from 827.8 mm in 2005 to 2417.8 mm in 2000. These values indicate that there is high yearly rainfall inconsistency in the study area.

For the period of the past 30 years, the precipitation deviated yearly by 314.25 mm from the mean in the study area. The trend on the decadal basis was also investigated to decide the deviations over time within the study periods. In order to identify statistically significant variations in the annual precipitation in the study station, a time series study was undertaken. The parameter estimate of the slope was then tested for statistical significance using the Mann-Kendall trend test at a 0.05 level of significance. The slope of the trendline is 4.3417 (positive) which suggests that the long years mean rainfall is increasing.

The average yearly minimum and maximum temperature in the district for the last 30 years was 14.067 ^{0}C and 31.442 ^{0}C, respectively. The largest average minimum and maximum temperature was documented in spring than summer season (Tables 3.4). The maximum temperature trend was decreasing at Asosa metrological station in all months except Jun month (Table 3.6). Significant decreasing trend of maximum temperature was observed during July, October and December while the minimum temperature trend was decreasing significantly during February, March and November and increasing during May, July, August and September at study area station. On the other hand, the minimum and maximum temperature trend showed in decreasing trend for annual and throughout the seasons at Asosa district except autumn season for the maximum temperature which shows a positive trend (Table 3.5 and 3.6).

Though, documented meteorological data investigation of temperature shows that rising trends detected almost in all parts of the country. According to the Mann–Kendall trend analysis test, the maximum and minimum temperature investigation resulted in a general decreasing with no trend. However, precipitation amount resulted in a general increasing trend based on the average documented values of the Metrological stations from the Asosa district. The reason for increasing rain fall and decreasing of temperature in the study area could be because of change in climate, massive planting of seedlings by the green legacy program of Ethiopian government for the last 10 years and also could be artificial lake created by great renaissance dam construction at Nile River near to the study area. To recommend the concerned body, development planners should design strategies and plans by taking into account a rising summer rainfall and declining temperature without trends impacts on rural livelihoods.

6. Declarations

Author contributions Author contributions T. A.; conceptualized the project; curated the data; conducted the formal analysis; T.A.; and M.M.; developed the methodology and T. A.; and Zhu. H.; supervised the project, while T. A.; wrote the original draft and all authors participated in the subsequent review and editing process.

***Finding*:** Not applicable

I confirm that the data included here is accurate and comprehensive. I hereby certify that this work has not been previously published and has not been submitted for publication to any journal.

Conflict of interest: The authors don't have any competing interests.

***Availability of data**:* The manuscript contains all the data utilized.

Informed consent: Not applicable

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