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TIME SERIES TREND ANALYSIS OF PRECIPITATION AND TEMPERATURE: THE CASE OF ARBA MINCH TOWN, SOUTHERN ETHIOPIA

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ABSTRACT

Long-term climate averages changes are the result of significant annual climate variability. This study aimed at analyzing trends and variability of Temperature and precipitation of Arba Minch Town, in Southern Ethiopia. Temperature and precipitation data were collected from Arba Minch meteorology station from 1987-2014 and 1982-2014, respectively. Summary descriptive statistics, regression analysis and Mann Kendall trend test method were used to analyze the long-term data. Regression analysis for the trends and Mann-Kendall rank statistic test were used for the examination of their significance. Statistically significant abrupt deviations and trends have been identified. The mean maximum temperature ranges between 27.27ºC and 33.37ºC, while, the mean minimum temperature varies between 16.25ºC and 18.3ºC. The mean annual average precipitation result has been also found 881.16. Overall, the main findings revealed that the minimum and maximum temperature had generally warming trend likewise the precipitation amount showed long range variability

KEYWORDS: Climate Variability, Manna Kendall, Precipitation, Temperature

INTRODUCTION

Precipitation and temperature trend analyses, on different spatial and temporal scales, have been of great concern during the past century because of the attention given to global cli-mate change. Climate is important for development but natural climate fluctuations from autonomous climate cycles disrupt ecological, economic and social systems. However, human factors have impact on local and global climate patterns. Continued rates of high population growth, increasing reliance on fossil fuel-driven growth technologies, and land use effects, (particularly urbanization, agriculture and deforestation) cause global climate change, largely due to increases in concentrations of atmospheric greenhouse gases and aerosols [1].

The issue of climate change and variability has become more threatening to food security, sustainable development of any nation, and also to the totality of human existence [2]. There is a substantial concern over the global problem of climate change and it is described as the most universal and irreversible environmental problem facing the planet Earth [3]. The effects of climate variability such as rising temperature and changes in precipitation are undeniably clear with impacts already affecting ecosystems, biodiversity and people. These conditions determine the carrying capacity of the biosphere [3].

Climate change is a global problem, but it has national, regional and local manifestations which need to be addressed. Ethiopia is one of the most vulnerable countries to the impacts of climate change. Climate change threat is greater in Ethiopia because of the country's less adaptive capacity and deepened poverty [4]. The negative impacts associated with climate change are also confounded by many factors, including widespread poverty, human diseases, and high population density, which is estimated to double the demand for food, water and livestock forage within the next 30 years [5].

Climate refers to long-term weather patterns, over periods of 30 years or more, that are typical of a region. When changes occur in the climate that a region experiences over a long period of time, it is called "Climate Change". Scientific research has documented that the earth's atmosphere has been warming since the pre-industrial period of the mid-18thcentury due to increasing concentrations of GHGs in the atmosphere. Naturally, the earth absorbs a portion of the sunlight it receives, which then heats the plan-et, and reflects some of the sunlight back into space. As the earth is heated by the sunlight, it also radiates a portion of this heat back into the atmosphere in the form of infrared radiation. Greenhouse gases warm the earth system by absorbing a portion of the outgoing radiation from the planet and re-radiating some of the absorbed radiation back towards the Earth's surface. As the overall energy of the system increases, the Earth surface and lower atmospheric temperatures increase, as well. Many greenhouse gases occur naturally, and without them the earth surface would be on average 60 degrees Fahrenheit colder [6].

Ethiopia is located in a tropical region where temperature differences are strongly modulated by elevation [7]. It has unusual eco-environmental settings ranging from extreme heat at one of the lowest places in the world (Dallol in Ethiopia) to one of the coolest summits in Africa (Mt. Ras Dashan). The lowlands, below 1500m above sea level, constitute about 61% of the total land mass of the country and are generally warmer and drier than the highlands and mountains [8]. The warm and drier lowlands, particularly extensive in the south east, eastern and north eastern parts of the country, are inherently areas of low and erratic precipitation not suitable for reliable crop production and are used for extensive pastoral livestock production [9]. The cool and moist highland plateau and mountains, on the other hand, are under extensive crop production. In between the two systems, there are transitional areas that share the properties of both. These are referred to as agro-pastoral systems and are characterized by a livestock-dominated crop production system. Agro-pastoralism is common particularly in the great East African Rift Valley region of the country. These varied eco-environmental settings in Ethiopia offer unique opportunities to study climate change in the tropics.

MATERIALS AND METHODS

1. Study Area

Arba Minch town is one of the emerging towns of Ethiopia which is found in Southern Nations, Nationalities and Peoples regional state of Ethiopia. The name Arba Minch was derived from the "forty springs" which means a collection of more than forty springs which are located in the Arba Minch natural forest. Astronomically Arba Minch is located at 6°04′ North Latitude and 36°40′ East Longitude; Mean Annual Temperature 21ºC-26ºC; Mean Annual Rainfall is 929 mm and the prevailing wind direction is from southeast to northwest. It is found in Gamo Goffa zone and used as a zonal capital of the zonal administration in Southern Nation's Nationalities and Peoples Regional State of Ethiopia. It is located at about 505 km south of Addis Ababa, the capital city [10] [11]. According to the National Meteorology Agency /NMA/, Ethiopia, Arba Minch's climate condition has been classified into Dry Season and Main Rainy Season, which is described monthly based below in Table1[12].

Table1. Climatic Conditions of Arba Minch Town

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Season	Dry	Dry	Dry	Wet2	Wet2	Wet2	Wet2	Wet2	Wet2	Dry	Dry	Dry

Wet2 =Main Rainy Season, Dry = Dry Season

Arba Minch Location

Fig1. Location of Arba Minch ***Source: Googlemaps.com***

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2. Data Collection and Analysis Methods

The data was collected from Arba Minch meteorology station which is located in Arba Minch Town. It includes daily rainfall data from 1982 to 2014 and maximum and minimum daily temperature recorded from 1987 to 2014. Daily precipitation and temperature data were first calculated as monthly and annually on the excel spreadsheet. Then the average precipitation amount was computed over the 33-year period to be able to examine precipitation statistics which is commonly or generally defined as distance from the average. The trend detection methods were applied to annual and monthly precipitation and temperature data. The Thom test resulted homogenous and statistically significant at 95% confidence limit for precipitation and temperature. Thus, time series can be taken as homogeneous during the study period. Firstly, regression models were created in order to detect linear trends of precipitation and temperature data. Secondly, statistical trend detection methods are applied to detect inconsistencies and non-homogeneities (both gradual trends and abrupt changes/shifts) in the data series of climatic variables. Therefore, the determination of abrupt changes or shifts (based on the mean values) in the data series is emphasized in the statistical trend analyses. In this paper, standard monthly and annual precipitation and temperature data were analyzed for trends using Mann Kendall (MK) and Sen's slope (SS) estimator none parametric tests. This test has been widely used climatologic data analysis [13] [14]. The technique is based on the detection of trends and change point(s) and attaching to it a probability significance level in a time series. The test examines whether a random response variable monotonically increases or decreases with time. It is a rank based procedure, resistant to the influence of extremes, and useful for skewed data and has a higher power than many other commonly used linear tests [15][16].

RESULTS AND DISCUSSION

1. Precipitation

Monthly and annual rainfall variability was analyzed by variability indices. For variability analysis, the coefficient of variation (CV)

The CV has been classified as: low variability (CV<20%), moderate rainfall variability (between 20% and 30%), high variability (CV>30%), very high (CV>40%) and extremely high inter-annual (CV>70%) variability [17] [18]. Accordingly from the statistical analysis from table 1 showed November, December, January and February have recorded very high Variability of rainfall from 1982-2014 which is 98.2%, 124%, 117% and 102% respectively. The degree of Skewness was very close to normal in May and June (0.045 and 0.08) respectively. The rest of the months have recorded a positive rain distribution.

Table2. Statistical summary of monthly precipitation for Arba Minch station

	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	33	33	33	33	33	33	33	33	33	33	33	33	33
Mean	881.16	29.8	33	59.9	153.3	151.8	60.1	43.9	50	89.06	114.7	60.4	35.2
StE	28.70	6.08	5.84	7.19	12.2	11.04	5.93	4.53	5.2	9.567	10.03	10.3	7.63
Median	866.2	18.6	27.4	56	139.4	140.2	59.9	39.7	43.1	78.4	117.4	51.7	22.8
StD	164.90	34.9	33.5	41.3	70.1	63.42	34.1	26	29.9	54.96	57.64	59.3	43.8
CV (%)	18.71	117	102	69	45.71	41.78	56.7	59.3	59.7	61.71	50.25	98.2	124
Skewness	0.1847	2.54	1.22	1.47	0.68	0.045	0.08	0.68	0.21	1.074	0.171	2.5	1.85
Kurtosis	-0.5057	9.32	0.6	2.39	0.344	-0.87	-0.4	0.25	-1.2	0.362	-0.37	6.79	2.77
Range	673.86	178	121	175	293.8	223.7	132	110	101	197.8	235	269	168
Minimum	580.08	0	0	15.4	25.7	43.2	0	1.4	4.2	28.6	10	4.5	0
Maximum	1253.94	178	121	191	319.5	266.9	132	112	106	226.4	245	273	168

StD = Standard Deviation, StE = Standard Error

The coefficient of kurtosis record was more than the normal index in November and January and it becomes lower in August. Monthly precipitation of Mean distribution in the study area is shown in Table 1; most precipitation occurs during March, April, May and June months with annual average 881.16 mm, and April, May and October were commonly the months with the highest observed precipitation.

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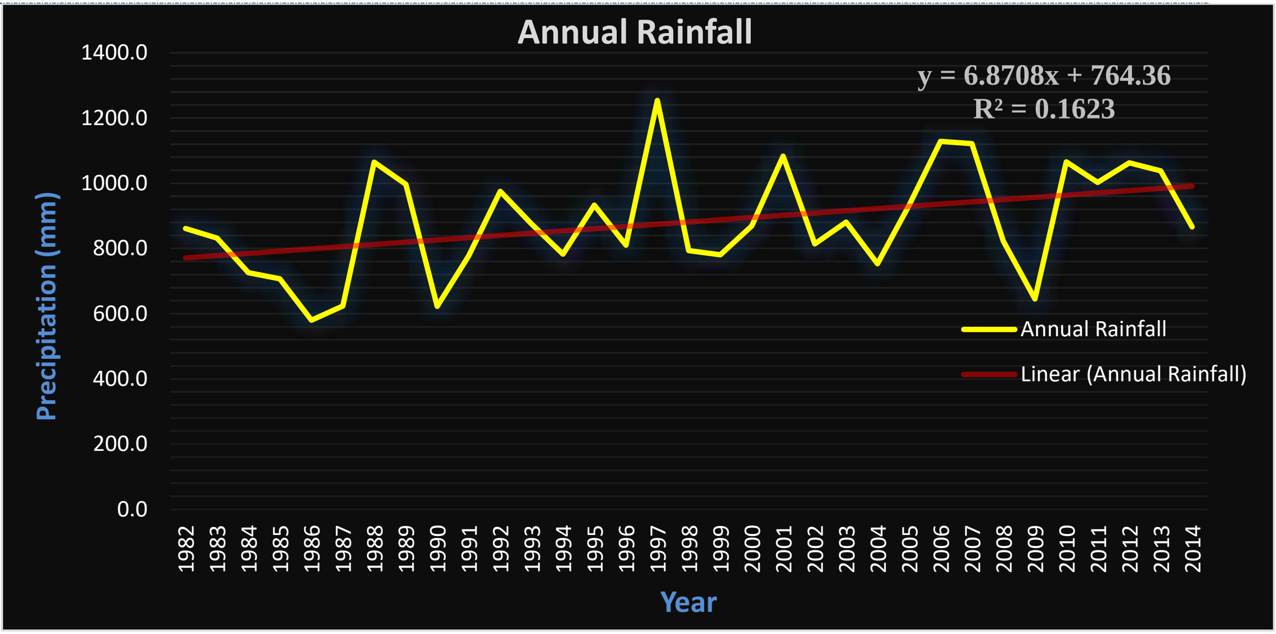

Fig2. Annual Rainfall trend for the period 1982-2014

A description of the applied statistical test procedure has given in Table 2. Statistically, significant trends are not found for precipitation on monthly basis, but the negative trend on February, May, July, August and December were (-0.187, -0.421, -0.579 and -0.095) respectively. But this result was not statistically significant at 95 % confidence limit during the period of 1982-2014. On the other hand, annual precipitation trend was positive but the result was not statistically significant at 95 % confidence limit during the period of 1995-2014. Here, Trend analyses were also conducted on monthly precipitation data.

Table3. Monthly Mann-Kendall results of precipitation for the study area

Months	Minimum Temperature			Maximum Temperature			Precipitation		
	Test Z	Signific.	Sens's Slope	Test Z	Signific.	Sens's Slop	Test Z	Signific.	Sens Slop
January	-0.77081		-0.0299	2.13	*	0.047	0.64		0.106
February	-0.45458		-0.01509	1.60		0.043	-0.51		-0.187
March	-0.05929		-0.00488	1.38		0.044	0.24		0.158
April	-0.51397		-0.00934	1.23		0.036	0.83		1.093
May	0.533634		0.008333	2.61	**	0.049	-0.32		-0.421
June	1.20609		0.013178	1.15		0.040	0.84		1.018
July	0.513971		0.007419	3.04	**	0.077	-1.11		-0.579
August	0.217407		0.002859	0.51		0.016	-0.39		-0.362
September	0.770805		0.01106	0.20		0.007	0.92		0.833
October	0.770805		0.012823	1.60		0.037	1.44		2.058
November	1.067477		0.031119	0.75		0.018	0.64		0.409
December	0.11867		0.001161	0.43		0.010	-0.26		-0.095

Z is Mann–Kendall trend test, Slope (Sen's slope) is the change (days)/annual; **,* is statistically significant at 0.05 and 0.1 probability level; ns is non-significant trend at 0.1

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2. Temperature Trends

In fig1 the annual maximum temperature trend showed the temperature was increasing by 0.0939 ºC per year or 0.939 ºC per decade. This result is far greater than (9.3 times) the national level annual maximum temperature change (0.1 ºC per decade) between 1960-2006 studies by FDRE [19]. The reason for this could be urban island heat effect such as population density, deforestation, construction of roads and buildings due to their emissivity potential as it can be shown easily in Stefan-Boltzmann radiation law (since a black body like roads have an emissivity of 1. Soil, Asphalt and human skin have emissivity of about 0.95).Beyond to this, the geographical location of Arba Minch is in the rift-valley which has an opportunity for increasing of the temperature trend.

So that analysis of trends in annual and monthly temperature data conducted for the periods of record 1987-2014. Table 3 represents the statistical summary of the mean annual maximum temperature and its trend in the period of under examination; the year 2009 has recorded the maximum annual temperature with 32.3 ºC throughout 28 years (1987-2014); on the other hand 1992 was the coldest year with annual minimum temperature 11.5 ºC. Using a linear regression model, the rate of change is defined by the slope of regression line which in this case is about 0.0939 ºC/28 yrs. during the period of 1987-2014. This finding is not similar to global warming rate which is estimated 0.6 ºC for the past century. This result shows that approaching to global warming study has important impact on the regional climate in the study area for the last three decades.

Table4. Statistical summary of monthly Maximum temperature for Arba Minch station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	28	28	28	28	28	28	28	28	28	28	28	28
Mean	32.15	33.28	33.37	31.09	29.12	27.27	27.9	28.805	28.99	28.83	29.58	30.11
StE	0.207	0.229	0.222	0.234	0.177	1.031	0.223	0.1893	1.097	1.081	1.115	1.135
Median	32.37	33.47	33.29	31.25	29.23	28.27	27.87	28.729	30	29.86	30.49	31.39
StD	1.095	1.21	1.175	1.237	0.937	5.455	1.181	1.0014	5.803	5.718	5.899	6.004
CV (%)	3.406	3.635	3.522	3.978	3.217	20	4.232	3.4766	20.02	19.83	19.94	19.94
Skewness	-0.46	-0.66	0.034	0.502	-0.03	-4.95	0.507	-0.175	-4.94	-5.09	-4.989	-5
Kurtosis	-1.07	1.175	-1.05	1.025	-0.49	25.56	-0.13	-0.498	25.46	26.54	25.9	25.9
Range	30.23	29.82	31.22	29.11	27.17	0	26.02	26.732	0	0	0	0
Minimum	33.71	35.49	35.33	34.6	30.93	31.26	30.5	30.845	32.64	31.5	34.5	34.4

StD = Standard Deviation, StE = Standard Error

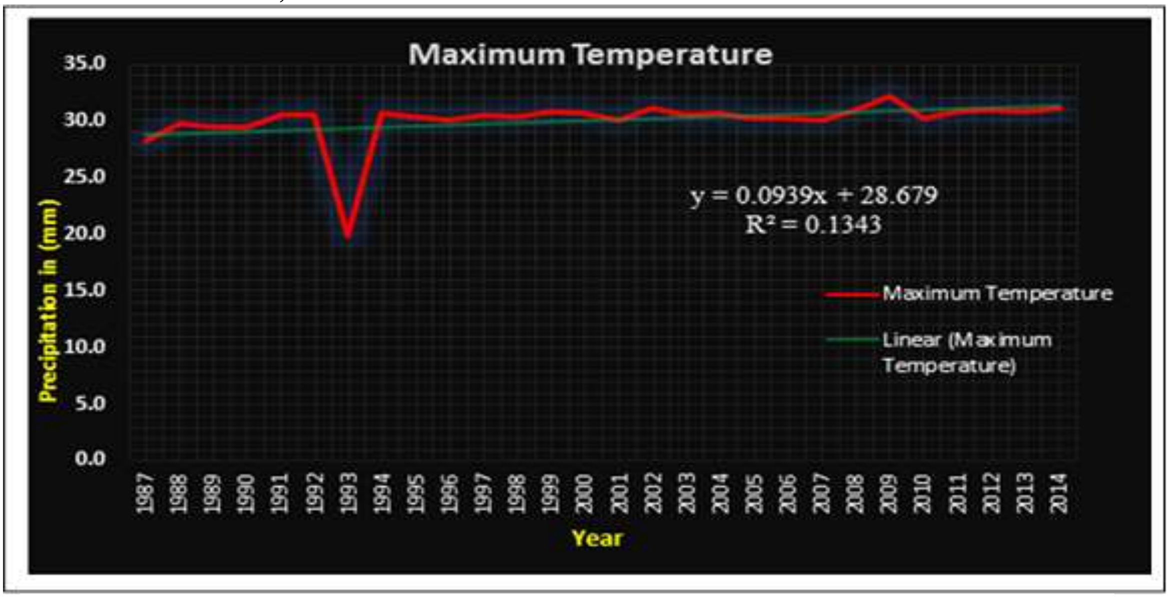

Fig3. Maximum Annual temperature trend for the period 1987-2014

Statistically, the January, May and July has significant trends for maximum temperature data on annual and monthly basis, with a positive trends for period of record (1987-2014) considered. Overall, annual maximum temperature trend is positive (increases) and this result is statistically significant at 95 % confidence limit during the period of 19987-2014.

Table5. Statistical summary of monthly Minimum temperature for Arba Minch station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	28	28	28	28	28	28	28	28	28	28	28	28
Mean	16.25	16.88	18.39	18.26	18.14	17.31	17.88	18.04	17.50	16.70	14.81	13.67
StE	0.24	0.28	0.24	0.15	0.11	0.64	0.10	0.096	0.688	0.629	0.816	0.960
Median	16.48	16.73	18.20	18.18	18.20	17.98	17.94	17.88	17.88	17.31	16.23	14.53
StD	1.302	1.52	1.30	0.83	0.59	3.43	0.55	0.50	3.642	3.33	4.32	5.08
CV (%)	8.01	9.04	7.07	4.59	3.26	19.82	3.10	2.81	20.81	19.92	29.16	37.16
Skewness	0.02	0.30	-0.17	0.92	0.03	-5.09	-0.13	0.27	-4.19	-5.01	-3.15	-2.19
Kurtosis	-0.24	-0.31	0.17	1.49	-1.12	26.57	0.212	-1.14	21.72	25.97	9.468	4.025
Range	14.12	14.61	15.04	16.84	17.29	0	16.81	17.26	0	0	0	0
Minimum	19.30	20.02	20.89	20.36	19.19	19.07	19.05	18.89	23.87	18.66	17.46	18.7

StD = Standard Deviation, StE = Standard Error

Many studies about minimum temperature trend over Ethiopia showed that the minimum temperature trend over the country is significantly increased faster than the maximum temperature trend. For example, according to FDRE [19] NAPA (National Adaptation Program of Action) reported that average annual minimum temperature trends rising by 0.2-0.4 ºC per decade and average annual maximum temperature by 0.1 ºC per decade during 1960-2006. According to the annual minimum temperature of the town is increasing by 0.388 ºC per decade.

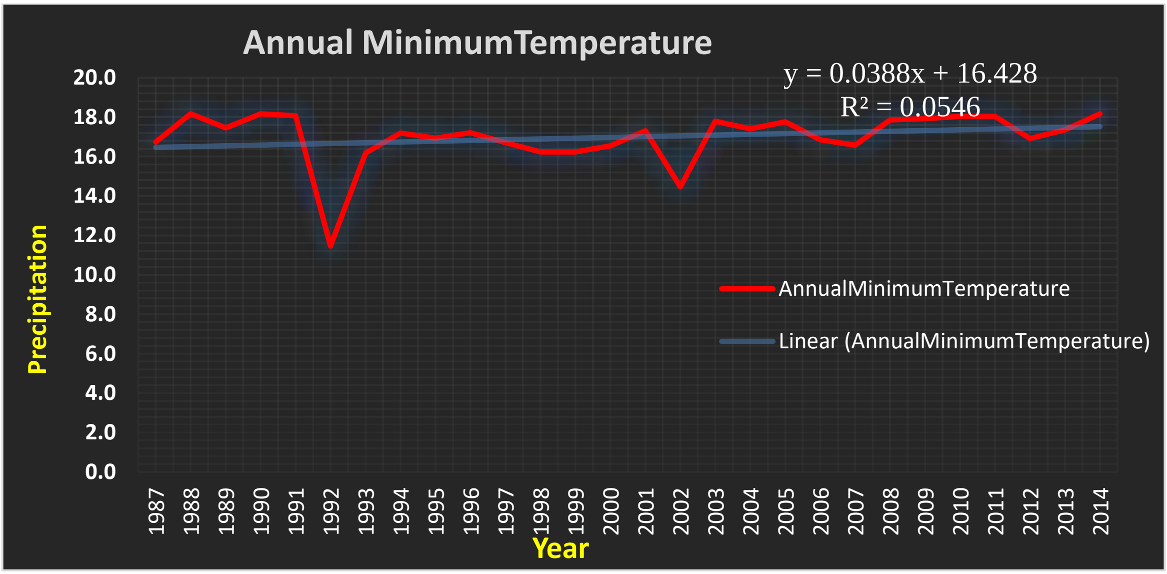

Fig4. Minimum Annual temperature trend for the period 1987-2014

CONCLUSION

The study was inspected rainfall and temperature trend analysis of 33Years, from 1982-2014) and 28 Years, from 1987-2014 respectively in the Arba Minch meteorological station, Arba Minch Town. According to both the statistical summary and Mann-Kendal time series analysis result; the annual rainfall and temperature trend showed statistical significance at $p < 0.05$ or $p < 0.01$ It was found that there was an increasing trend in the annual rainfall and also an increasing trend or a positive trend in both the maximum and minimum temperature as well. It was discovered that, the temperature trend analysis has showed significance, but the annual and the monthly rainfall was not statistically significant.

The months, December and January have recorded the highest annual rainfall variation (CV %), which was 124 and 117 respectively. On the other hand, for the maximum and minimum temperature the coefficient of variation were found in September (CV=20%) and December (CV=37%) respectively. the monthly Mann-Kendall precipitation results were found negative at the months February, May, July, August, and December while the rest are positives. In both the maximum and minimum temperatures were found all most all having a positive. As a recommendation for prediction of future climate conditions, level of variability of these two weather elements must be examined and understood. Temperature were slightly increasing when we compare to the global average temperature and the rainfall also increased, shorten the length of growing period. And we were also observing irregularity of onset and cessation of rainfall. Hence Arba Minch is one of the tourist sites of the country, it is important to mitigate and experience weather adaptation strategies for the time to time changing climatic condition.

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REFERENCES

[1] Seth, D.2007. “Climate change and risk management in Africa”, World economic forum on Africa, Cape Town.
[2] Gadgil, S., Seshagiri, P. and Sridhar, S.1998. “Modeling impacts of climate variability on rain-fed groundnut”, Indian institute of Science, Bangalore, India. 11p. 70.
[3] IPCC (Intergovernmental Panel on Climate Change). (2001).”Climate change impacts, adaptation and vulnerability, Contribution of working group II to the third assessment”, Cambridge University Press, Cambridge.
[4] Michael, C. (2006). “WWF (Worldwide Fund) for nature climate change scientist” Gland, Switzer-land.
[5] Davidson, O., Halsnaes, K., Huq, S., Kok, M., Metz,B., Sokona,Y. and Verhag, J.2003. “The development and climate nexus: The case of sub Saharan Africa. Clim. Policy”, 31:97-113.
[6] Wallace, J. M. and Hobbs, P.V. (2006).Atmospheric science: “An Introductory Survey” 2nd Edition. Academic Press, London, UK.
[7] Kreyling J, Wana D, Beierkuhnlein C. 2010. “Potential consequences of climate warming for tropical plant species in high mountains of southern Ethiopia”, Divers. Distrib. 16: 593–605.
[8] McSweeney C, New M, Lizcano G. 2010. UNDP climate change profile for Ethiopia. Retrieved on June 03, 2011. http://countryprofiles. geog.ox.ac.uk.
[9] Coppock L. 1994. The Borana Plateau of Southern Ethiopia: Synthesis of pastoral research, development and change, 1980–91 ILCA (International Livestock Center for Africa) Systems study 5. Addis Ababa: Ethiopia.
[10] Arba Minch Municipal City-“Physical Characteristic of the Arba Minch Town” http://www.mwud.gov.et/web/arbaminch/physical-characterstic) [18th Accessed January 2017)
[11] Esayas D., Engida E. (2013) “Urban Planning and Land Management Challenges in Emerging Towns of Ethiopia: The case of Arba Minch”, Journal of Urban Environmental Engineering.
[12] National Meteorological Agency/NMA/, Ethiopia, (http://www.ethiomet.gov.et/climates/climate_of_city/2467/Arba%20Minch[Accessed24thJanuary, 2017)

ISSN: 2277-9655
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CODEN: IJESS7

[13] Awetahegn N. (2015). “Precipitation and Temperature Trend Analysis in Mekelle City, Northern Ethiopia, the Case of Illala Meteorological Station” Journal of Environment and Earth Science.
[14] Libiseller C., Grimvall A (2002) “Performance of partial Mann-Kendall test for trend detection in the presence of covariates”, Environmetrics 13: 71-84.
[15] Kahya E., Kalaycı S (2004) “Trend Analysis of Stream flow in Turkey”, Journal of Hydrology 89, 128-144.
[16] Önöz B., Bayazıt M (2003) “the power of statistical tests for trend detection”, Turkish Journal of Engineering and Environmental Sciences 27, 247-251.
[17] Martha K., R. Negeswara R. (2016). “Observed and Projected Rainfall Trends and Variability: A Case Study in Gama Gofa Zone, Ethiopia”, Imperial Journal of Interdisciplinary Research (IJIR).
[18] Hadju, G., Tesfaye, K., Mamo, G., & Kassa, B. (2013). “Trend and variability of rainfall in Tigray, Northern Ethiopia: Analysis of meteorological data and farmers’ perception”, Academia Journal of Environmental Sciences, pp.1-13.
[19] Federal Democratic Republic of Ethiopia /FDRE/. (2008). “Environmental policy”, environmental protection authority in collaboration with the ministry of economic development and cooperation. Addis Ababa.