Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.8, No.21, 2018

Spatial and Temporal Rainfall Trend Analysis: A Case Study of South Western, Ethiopia

Barana Babiso Badesso
Senior Lecturer, Department of Geography & Environmental Studies, Wolaita Sodo University, Ethiopia
PO Box: 138 Wolaita Sodo, Ethiopia

Abstract
Based on the 31 year period rainfall record, analysis was carried out to extract the trends of seasonal and annual rainfall in south western Ethiopia. Eventhough, Nekemte and Jima are found in the same rainfall regime called single maxima; the analysis demonstrates that Nekemte stations are shown a slight decreasing trend in rainfall magnitude. Cross-correlation of annual rainfall between the two stations in the period of 1971-2002 is around 11.07, which is low. Though they are in the same rainfall regime, the correlation shows that they may not be subjected to the same climatic change influence. The coefficient of variation and standard deviation for 1951 to 1990 ranged from 0.32 to 0.2, and 60 mm to 90.4 mm, respectively, confirming the moderate variability of the mean monthly rainfall over the two stations. This shows that outside of the 4-months rainy period, there is little rainfall during the rest of the year and are highly variable. Even though the data was inadequate for the analysis of rainfall series, the temporal rainfall distribution shows that the dry spells are more frequent than the wet spells. In this regard, hence, the mean annual rainfall coefficient of variability (CV) clearly indicated moderate to high rainfall variability.
Keywords: Trends, Climate change, Rainfall Variability, South Western Ethiopia

1. Introduction

Climate Change should be taken as a main agenda at all levels as its impact is very devastating and affecting almost everything. Global temperature is rising and it is projected that the global mean temperature will rise between 1.4 and 5.8 °C by the year 2100 (IPCC, 2007; Locky and Mackey, 2009). The rising temperature affects all major components of hydrological systems: it induces change in precipitation pattern, enhances melting of snow and ice, and increases evaporation, altering soil moisture and runoff (Nijssen, 2001; Xu, *et al*., 2011). The relationship between the climate system and the hydrologic cycle underlies the risk of floods and drought and possible future influences of global warming on water resources (Shelton, 2009).

Climate variability and change are major threats for developing countries, especially for the people of sub-Saharan Africa (SSA). Higher temperatures throughout SSA are causing increased evapotranspiration, shorter growing periods, drying of the soil, increased pest and disease pressure, shifts in suitable areas for growing crops and livestock, and other problems for agriculture (Cline, 2007; Lobell et al., 2008). Climate change is also expected to cause increased variability of rainfall in much of SSA, and increased intensity and frequency of extreme events, including droughts, floods and storms.

In a country like Ethiopia where irrigation schemes are not yet widely applied the dependence of agricultural practices on seasonal rains is very high. Not only the agriculture sector but also other sectors like hydro power generation, water supply and the like are highly controlled by seasonal rains performance. For the purpose of reasonable planning and avoiding risk, the country needs to know the performance of the rainy season ahead of time. The *Bega* season occurs from October to January, *Belg* form February to May and *Kiremt* from June to September (NMSA, 1996). Hence, *Bega* rainfall amount of a given year is the sum of October-December rainfall amount of the given year plus rainfall amount of January of the coming year. Similarly the seasonal rainfall amount of *Kirem*t and *Belg* seasons defined as the sum of rainfall amount of each month rainfall in the season respectively.

Previous time-series studies of rainfall patterns in Ethiopia have been carried out at various spatial (e.g. regional, national) and temporal (e.g. annual, seasonal, monthly) scales. Osman and Sauerborn (2002) determined that summer rainfall (known as Kiremt) in the central highlands of Ethiopia declined in the second half of the 20th century, while Seleshi and Zanke (2004) failed to find such a trend over central, northern, and northwestern Ethiopia. Instead, they found a decline of annual and Kiremt rainfall in eastern, southern, and southwestern Ethiopia since 1982. Verdin *et al*. (2005) confirmed the Seleshi and Zanke (2004) findings of annual rainfall decline in southwestern and eastern Ethiopia, but argued that while rainfall has been declining in the Northeast since 1996, Kiremt rain has been consistent (i.e. no trends) for the entire nation since the 1960s. In contrast to Verdin *et al*. (2005), Conway (2000) reported that there are no recent trends in rainfall over the northeastern Ethiopian highlands.

Thus, understanding the variations in rainfall both spatially and temporally and improving the ability of forecasting rainfall may help in planning crop cultivation as well as in designing water storages, planning drainage channels for flood mitigation, etc. Thus, the paper focuses on the trends and seasonal patterns of rainfall on a set of selected weather stations by utilizing statistical techniques. The work was considered monthly and annual rainfall data recorded on 2 stations within a time span of nearly 50 years. Emphasis was given to find out whether there is any significant change in the rainfall time series records over the years. The study would also address the temporal climate change trend of precipitation and its variation over the two stations.

2. Objective

This study investigated the temporal (annual, seasonal, monthly) dynamics of rainfall and its spatial distribution within Jima and Nekemte stations. Changes in rainfall were examined using data from both stations in between 1952-2004 and 1971-2002 respectively. The variability and trends in seasonal and annual rainfall were analyzed with data from all available years.

3. Materials and Methods

3.1. Study Area

Nekemte ("*Naqamtee*" in Afan Oromo language; also called Lekemt) is a market town and separate woreda in western Ethiopia. Located in the Eastern Welega *Zone* of the Oromia Region, Nekemte has a latitude and longitude of 9°5′N 36°33′E (Fig.1) and an elevation of 2,088 meters. **Jima** is located in south western Ethiopia. The center is located at 7° 46' N latitude and 36° E (Fig.1) longitude at an altitude of 1,753 meters above sea level. The area receives an average annual rain fall of 1,532 mm with average maximum and minimum temperature of 26.8 and 11.8°C, respectively.

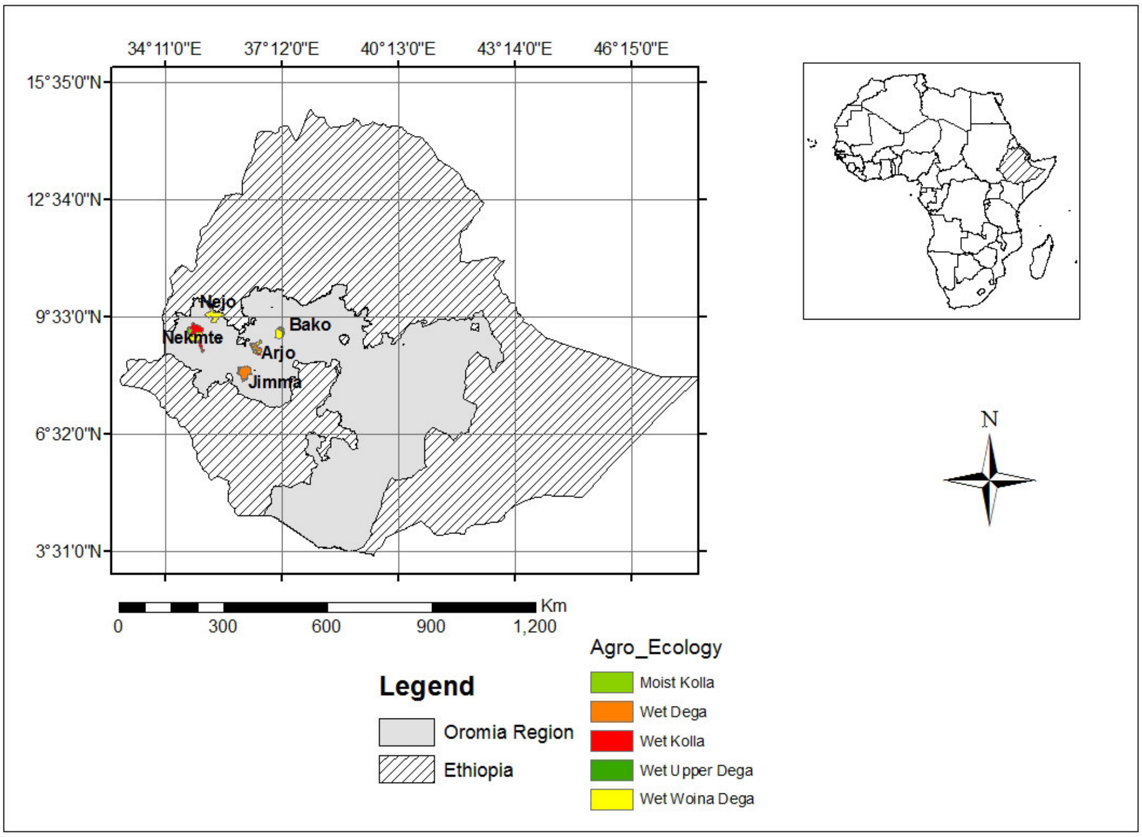


Figure 1: Location Map (Source: Extracted from Ethio-GIS)

3.2. Methods

For the study of rainfall variation (trend detection) in annual and seasonal basis with available data for both stations are selected and used in the analysis, which have less number of missing data and which have continuous record compared to the other station. The record period 1971-2002 are taken as the common period where statistical test is applied to detect and measure trend. This 31 year period is selected to see change of rainfall variation recently in the areas.

Among the stations, Jima station has monthly missing data for continuous two complete years (1961 and 1962), and both Jima and Nekemte have monthly missing data of randomly distributed in the study period. In these stations, missed months are estimated by using **arithmetic mean method** from the **preceding years** using simple average method and through interpolation. The above procedure is prepared on MS-Excel worksheet and the computation is finished on the worksheet.

4. Results and Discussion

4.1 Rainfall Regimes in Ethiopia

The rainfall regime in Ethiopia is characterized as uni-modal and bi-modal systems influenced by topographical variation in the country, seasonal cycles and opposing responses to regional and global weather systems, consequently, three rainfall regimes are commonly identified (NMSA, 1996; Bekele,1997; Seifu A., 2004).

Regime A that comprises the central and the eastern part of the country has a **bi-modal** (Quasi-double maxima) rain classified as the long rainy season (June –September) and short rains (March-May) locally referred as ***Kiremt*** and ***Belg*** rains respectively. The rest of the months (October to February) are dry period.

Regime B in the western part of the country (from southwest through to northwest) has a **mono-modal** rainfall (Single maxima) pattern (June – September), and the rainy period ranges from February through November mainly in the western and south-western part of the country, and decreases northwards (See Figure 4.1c).

Regime C that comprises the south and south-eastern part of Ethiopia has two distinct wet and dry seasons. The main rain season is from February through May, and short rains from October to November, and the dry periods are June to September and December to February.

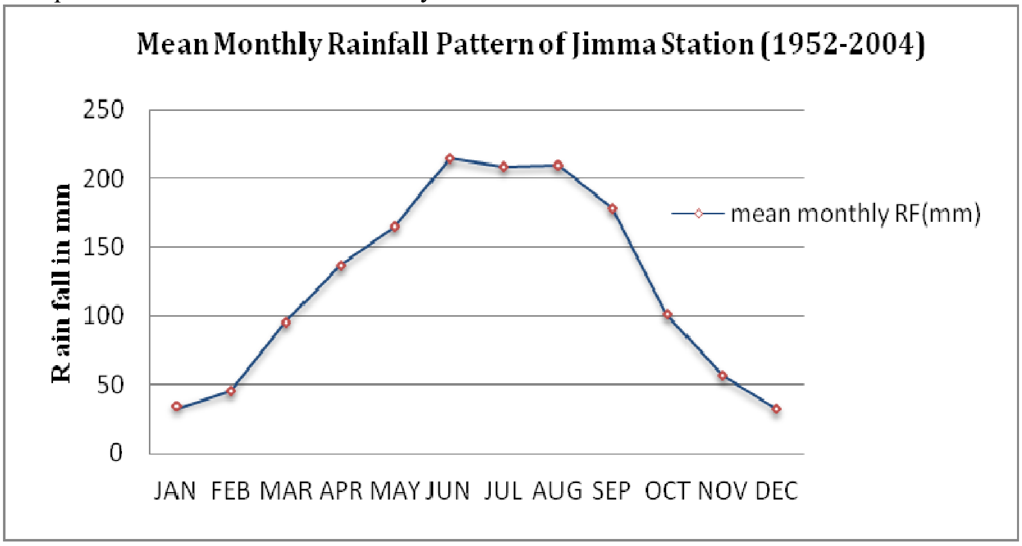


Figure 4.1a. Mean monthly rainfall distribution for the stations

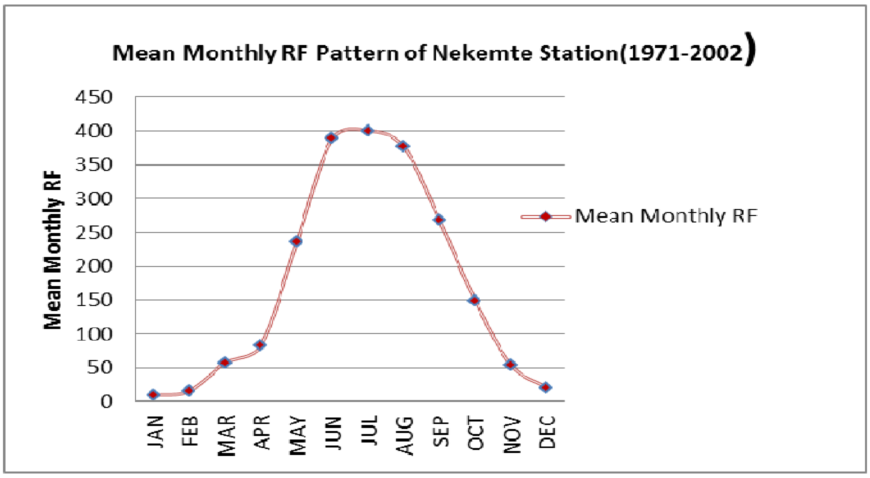


Figure 4.1b. Mean monthly rainfall distribution for Nekemte Station

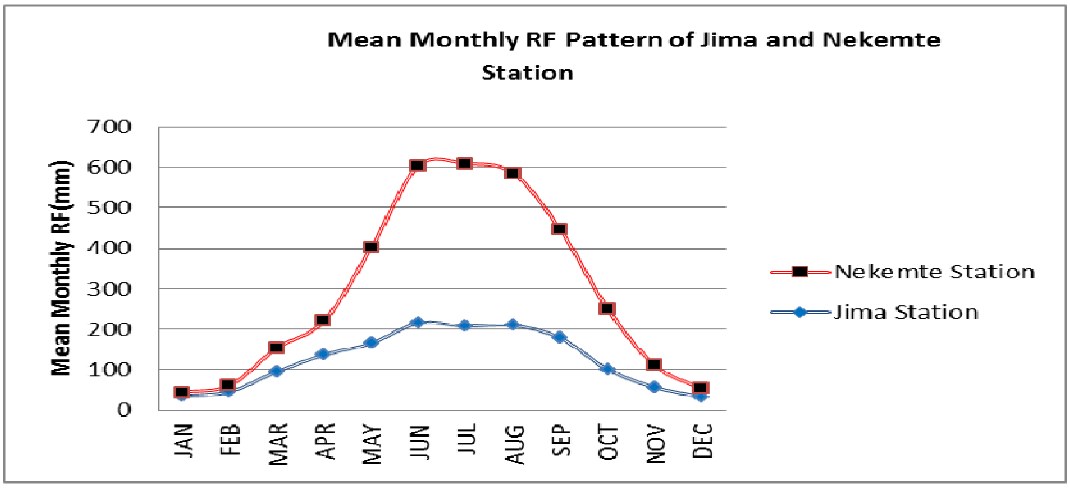


Figure 4.1c. Comparison of Mean monthly rainfall distribution for both Stations

When we compare each stations, July had more rainfall distribution than the rest months. In particular, stations recorded total mean monthly rainfall greater than 400mm in Nekemte and 210 in Jima. When monthly rainfall was mapped over the areas, it was found to vary from one location to another and the total Monthly rainfall recorded in Nekemte is much greater in amount than Jima. Generally, Kiremt (JJAS) rainfall condition was satisfactory and of single maxima type for both of the stations temporally or spatially.

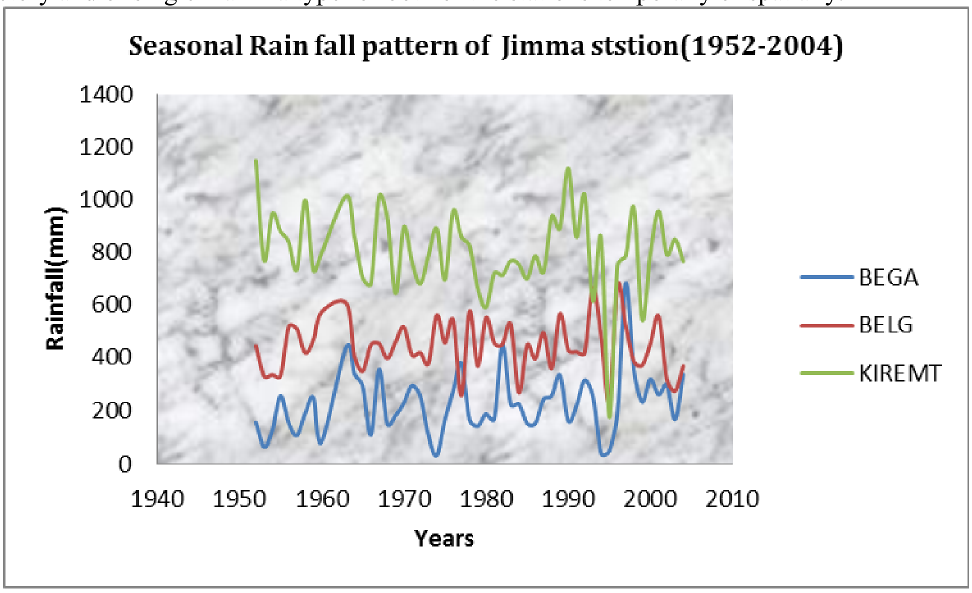
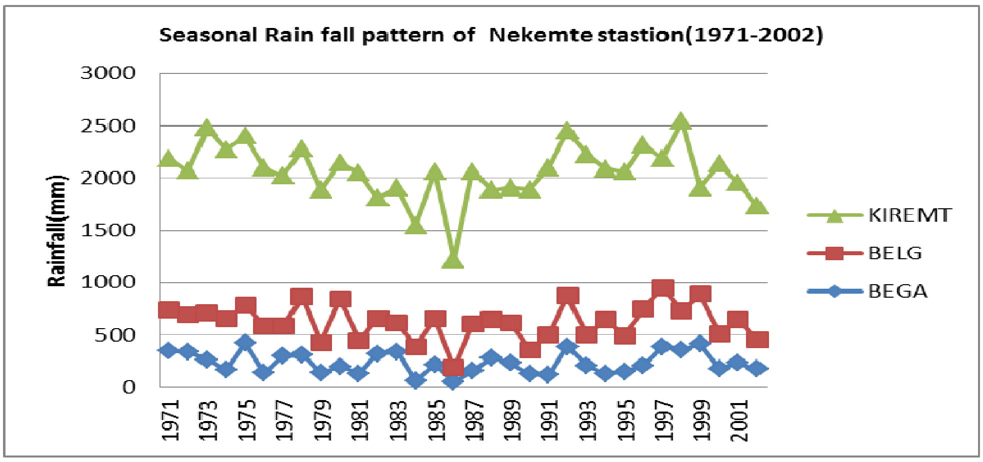


Fig. 4.1d. Observations of mean spatial distribution of seasonal Kiremt (JJAS), Belg (FMAM) and Bega (ONDJ) precipitations for the different rainfall regimes.



Most precipitation occurs in the wet Kiremt season (June through September), and the remaining precipitation occurs in the mild Belg season (February or March through May) and in the Bega (October through January or February). The annual precipitation increases towards the Kiremt and has been found to range from 200 to 1500 mm for Jima and 700 to 2000 and above for Nekemte.

The Kiremt rain in Nekemte station shows that there is high variability since CV is greater than 0.30. Jima station has less variability in the annual and Kiremt rainfall. However, the variability levels have been less as compared with that of Belg and Bega season.

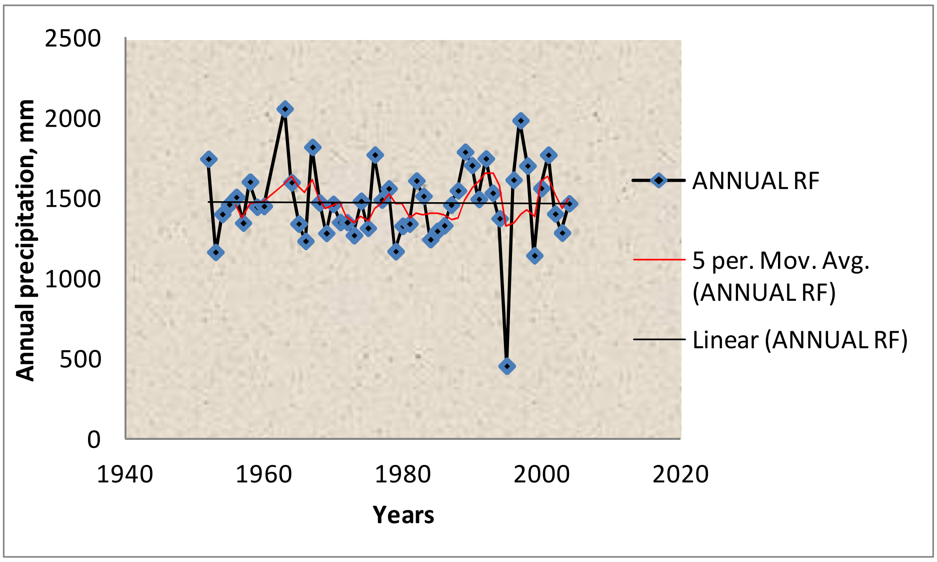


Fig 4.1e. Five Year Moving Average Plot of Annual Rainfall for Jima Station

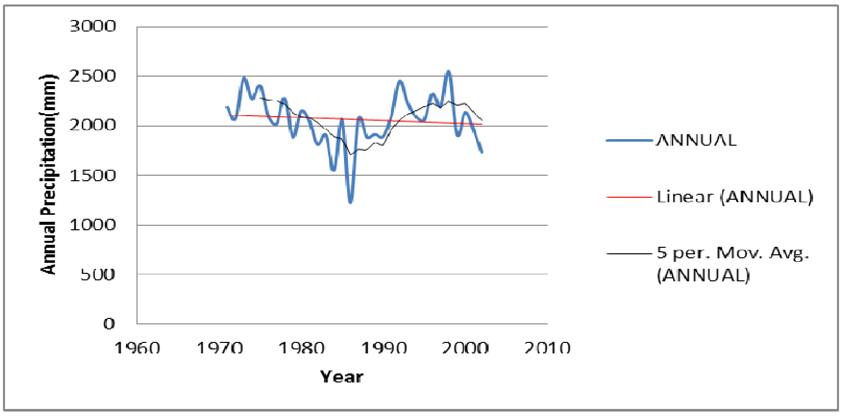
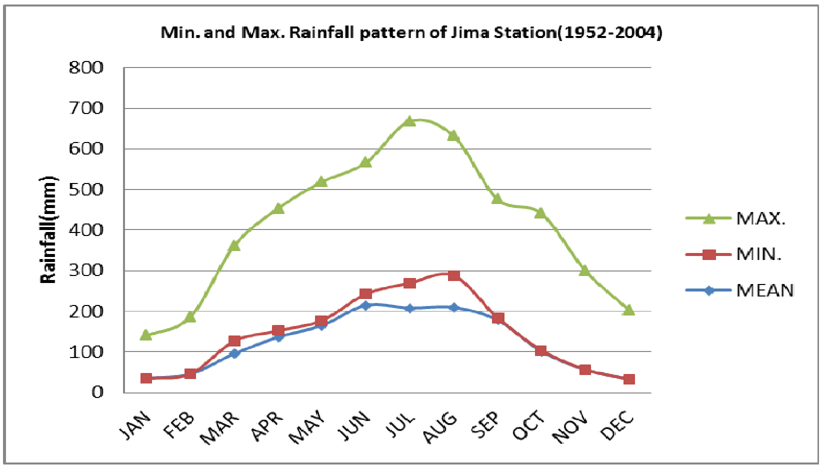


Fig.4.1f. Five Year Moving Average Plot of Annual Rainfall for Nekemte Station

Figure shows the cyclic component of the time series. The cyclic nature of the monthly rainfall follows systematic down ward or upward turn. However, years like 1985-86 for Nekemte and 1995-1997 for Jima are marked by high cyclic index values. It seems that there is short time oscillations embedded in long time oscillations in the cyclic components. As the time step in the data is annual and have to be calculated 5-years moving averages.

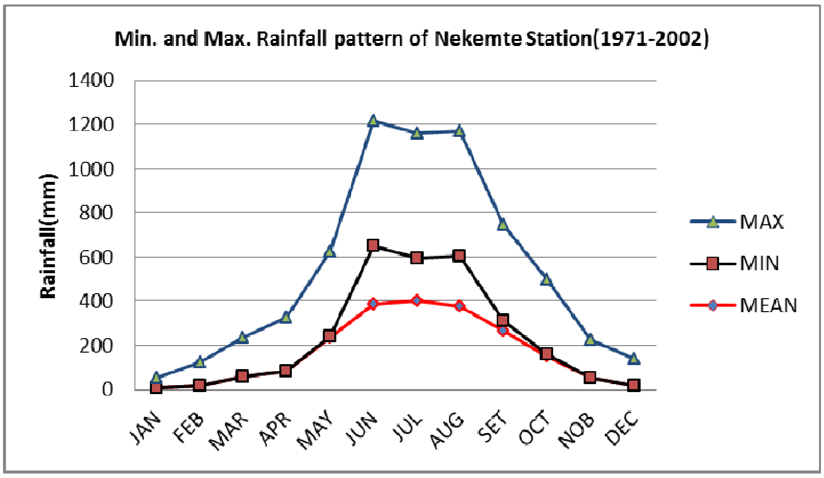
Table 4.1a&b Climatological data as total monthly rainfall in millimetres (mm) and monthly minimum and maximum RF in mm the above mentioned for the years

Jima	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN	34.6	45.6	95.5	136.4	165.2	214.6	208.1	209.4	178.5	101.3	56.4	32.7
MIN.	0	0	30.9	15.6	12.2	27.7	61.3	78.6	5.4	2.8	0	0
MAX.	105	140.2	234.6	301.3	341.2	323.5	398.6	343.7	291.9	336.7	243.4	170



F.g 4.1g. Climatological data as total monthly rainfall in millimetres (mm) and monthly minimum and maximum RF in mm the above mentioned for the years

Nekemte	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOB	DEC
MEAN	9.7	15.6	57.8	83.5	235.4	388.7	400.4	376.2	267.6	149.5	54.5	20.3
MIN	0	0	0.6	0	4.9	263.2	194.9	226.6	45.4	10.9	0	0
MAX	42.4	110.2	178.2	244.2	383.7	567.2	563.5	567.9	432.5	338.7	170.1	120.8



As can be depicted from the fiigure, monthly minimum RF had been recorded in Bega and Belg months about 0 mm in the both stations. Monthly maximum RF recorded in Kiremt months of both stations of the highest is that of Nekemte about 567 mm. The lowest rainfall of the stations implies the period of great drought & famine that affected all the communities of people and resulted its effect to the national level.

4.2 Analysis of Annual Data

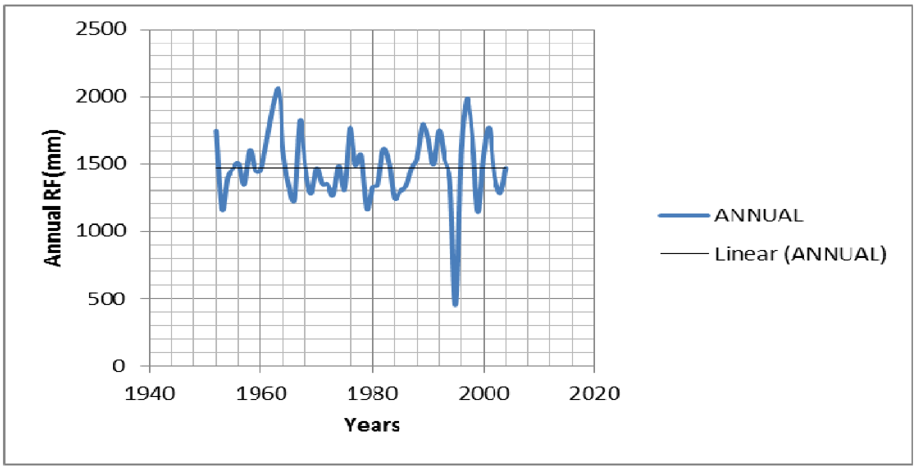


Figure 4.2a Analysis of Annual RF data for Jima station

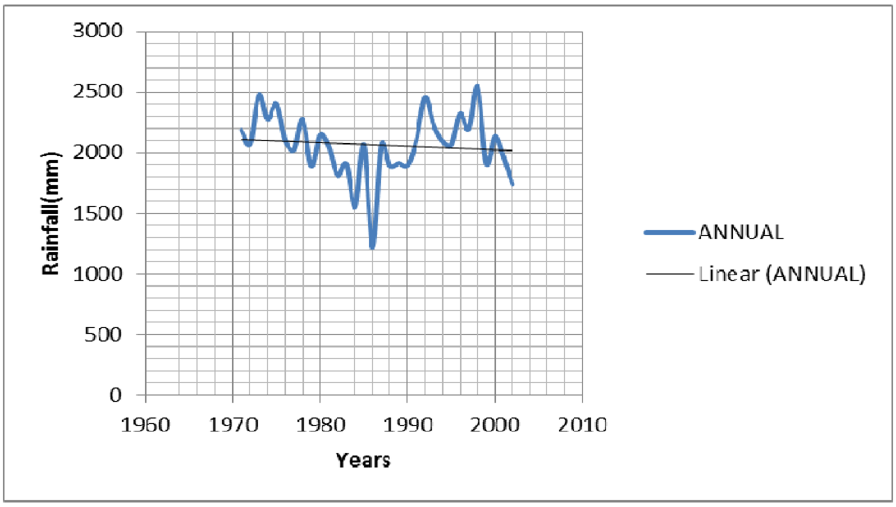


Figure 4.2b Analysis of Annual RF data for Nekemte station

Eventhough, Nekemte and Jima are found in the same rainfall regime called Monomodal(single maxima); the analysis demonstrates that Nekemte stations are shown slight decreasing trend in rainfall magnitude as shown in the Fig. above. Cross-correlation of annual rainfall between the two stations in the period of 1971-2002 is around 11.07, which is low. Though they are in the same rainfall regime, the correlation shows that they may not be subjected to the same climatic change influence.

NB- the researcher used Pearson Product moment to calculte the cross-correlation of the annual rainfall of both stations. i.e.,

$$R = \frac{N\sum xy-(\sum x \sum y)}{\sqrt{N\sum x^2-(\sum x)^2}\ (N\sum y^2-(\sum y)^2)}$$

=11.07 though there is positive relationship b/n them there is covarance in climatic variables that affect the trend.

Table 4.2a Statistical summary of areal rainfall data (1971-2002)

Station		January	February	March	April	May	June	July	August	September	October	November	December	Annual
Jimma Jima	Mean	34.6	45.6	95.5	136.4	165.1	214.5	208.1	209.4	178.4	101.3	56.4	32.7	1468.5
	Stdv	29.3	34.6	44.1	60.6	66.2	60.1	57.1	56.5	57.5	67.2	64.6	36.2	250.2
	CV	0.85	0.75	0.46	0.44	0.4	0.28	0.274	0.27	0.32	0.66	1.14	1.1	0.17
	Skew	0.81	0.73	1.18	0.5	0.52	-0.35	0.43	-0.04	-0.60	1.08	1.53	1.88	-0.84
Nekemte	Mean	9.7	15.6	57.7	83.4	235.4	388.7	400.4	376.1	267.6	149.5	54.5	20.3	2059.5
	Stdv	12.2	22.2	36.9	63.4	93.3	67.3	81.2	90.4	75.4	84.9	40.3	23.7	268.4
	CV	1.25	1.42	0.64	0.76	0.39	0.17	0.2	0.24	0.28	0.56	0.74	1.16	0.13
	Skew	1.65	2.68	1.00	1.09	-0.55	0.94	-0.68	0.47	-0.47	0.49	0.95	2.62	-0.82

The above table 4.1 shows the statistical summary of rainfall data from 1952 to 2004 considering monthly mean (mm), standard deviation and coefficient of variance of aerial rainfall data of the selected stations. From this table we can identify the stations which have high variation of rainfall data by comparing the values of coefficient of variance (CV) which is calculated, dividing the standard deviation by the mean of the areal rainfall data.

This provides a measure of year-to-year variation in the data series. NMSA (1996) documented that CV less than 0.20 is less variable, CV between 0.20 and 0.30 is moderately variable and CV greater than 0.30 is highly variable. During the rainy season, there is moderate variability in rainfall from one month to another, as observed from both station. The coefficient of variation and standard deviation for 1951 to 1990 ranged from 0.32 to 0.2, and 60 mm to 90.4 mm, respectively, confirming the moderate variability of the mean monthly rainfall over the two stations. This shows that outside of the 4-months rainy period, there is little rainfall during the rest of the year and are highly variable.

For a normally distributed random series, its skew-ness and kurtosis should be equal to 0. It is evident from analysis, the data are positively skewed and the relative peaked-ness is large for the stations. Most of the data could not be represented by normal distribution.

5. Conclusions

This study focused on analyzing the trends of rainfall recorded in 2 meteorological stations over the last three decades. The following conclusions are drawn from this study:

- Belg rainfall totals in the areas didn't show any significant change (trend).
- Kiremt rainfall totals show slight change at Nekemte station. The mean of Wet month's rainfall total shows less significant change at both stations.
- Annual rainfall totals also show no significant change at Jima and Nekemte station.

In addition, the moving average plot shows that there appears to be cyclic tendency in annual rainfall. The cyclicity of rainfall should be checked on more number of stations and its effect on detection of rainfall trend was studied. The total annual precipitation trend shows slight increase for the one and decrease for another, but only as an artifact of a period of high precipitation averages in the late 1980's and 1990's. Therefore, Data will have to be collected over a longer period of time prior to concluding whether the average annual precipitation is actually decreasing.

Acknowledgements

I would like to thank the staffs of Nekemte, Jimma, Arjo, Nejo and Bako Meteorological station for making raw data available. The author declares no conflict of interest.

References

Bekele F. 2000. *Ethiopian Use of ENSO Information in its Seasonal Forecasts*. National Meterological Services Agency: Addis Ababa.

Conway D. 2000. Some aspects of climate variability in the Northeast Ethiopian Highlands – Wollo and Tigray. *SINET – Ethiopian Journal of Science* **23**: 139–161.

Cline, W. 2007. Global Warming and Agriculture: Impact Estimates by Country. Washington, DC: Peterson Institute.

Funk, C., Michaelsen, J., and Marshall, M., in press, Mapping recent decadal climate variations in precipitation and temperature across Eastern Africa and the Sahel, chap. 14 of Remote sensing of drought—Innovative monitoring approaches: Wardlow, B., Anderson, M., and Verdin, J., eds., New York, CRC Press, 484 p.

H.K.W.I. Jayawardene1, D.U.J. Sonnadara1, and D.R. Jayewardene. 2005. Trends of Rainfall in Sri Lanka over the Last Century. *Sri Lankan Journal of Physics*, Vol. **6** (2005) 7-17.

IPCC. Summary for Policymakers, in Climate Change. 2007: Impacts, Adaptation and Vulnerability; Cambridge University Press: Cambridge, UK, 2007; p. 1000.

Lobell, D. B., M. B. Burke, C. Tebaldi, M. D. Mastrandrea, W. P. Falcon, and R. L. Naylor. 2008. Prioritizing climate change adaptation needs for food security in 2030. Science 319 (5863): 607-610.

Locky, H.; Mackey, B. 2009. The nature of climate change: Reunite international climate change mitigation efforts with biodiversity conservation and wilderness protection. Int. J. Wilderness 2009, 15, 7–14.

Monthly Rainfall data of Jima station (1952-2004).

Monthly Rainfall data of Nekemte Station (1971-2002).

Monthly Meteorological Bulletin for September 2008. Monthly Weather Report. Jimma sub branch meteorological office. (Also available online at ftp://chg.geog.ucsb.edu/pub/pubs/SatelliteRainfallApplications_2010.pdf.)

NMSA, 2012. The Use of Seasonal Climate Prediction in Reducing Livestock Death during Drought in Borena Zone Oromia regional State, Ethiopia. *Journal of the Ethiopian Meteorological Society*, 1-85.

National Meteorological Services Agency (NMSA), 1996: Assessment of drought in Ethiopia. Meteorological Research Report Series, Vol. 1, No. 2, Addis Ababa, Ethiopia.

Nijssen, B.; O'Donnell, G.M.; Hamlet, A.F.; Lettenmaier, D.P. 2001. Hydrologic sensitivity of global rivers to climate change. *Climate Change* 2001, 50, 143–175.

Osman M, Sauerborn P. 2002. A Preliminary Assessment of Characteristics and Long Term Variability of Rainfall in Ethiopia – Basis for Sustainable Land Use and Resource Management. In Challenges to Organic Farming and Sustainable Land Use in the Tropics and Subtropics, Deutscher Tropentag 2002: Witzenhausen.

Seleshi Y, Zanke U. 2004. Recent changes in rainfall and rainy days in Ethiopia. *International Journal of Climatology* **24**: 973–983, DOI:10.1002/joc.1052.

Seifu A. 2004. Rainfall Variation and its Effect on Crop Production in Ethiopia. Unpublished Thesis, Adis Ababa, Ethiopia.

Shelton, M.L. 2009. Hydro-climatology Perspective and Applications; Cambridge University Press: Cambridge, UK, 2009; p. 436.

Verdin J, Funk C, Senay G, Choularton R. 2005. Climate science and famine early warning. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences* **360**: 2155–2168.

Xu, H.; Taylor, R.G.; Xu, Y. 2011. Quantifying uncertainty in the impacts of climate change on river discharge in sub-catchments of the yangtze and yellow river basins. Hydrol. Earth Syst. Sci. 2011, 15, 333–344.