

TREND ANALYSIS OF RAINFALL DATA IN WOLAITA ZONE, SOUTHERN REGIONAL STATE OF ETHIOPIA

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Abstract - The aim of this study was to investigate the monthly, seasonal and annual rainfall variability in Wolaita Zone, Ethiopia. Standard statistical methods were employed to reveal the rainfall departure from the long time mean and its trend was presented using linear regression equations and graphical methods. The result shows the linear trend lines of the monthly rainfall shows decreasing trend in December, January, February and March and increasing trend for other months and annual rainfall data. The p-value computed for the monthly and annual rainfall data shows that, it is greater than significant level $\alpha = 0.05$, so that the null hypothesis, H_0 , that, there is no trend in data, is failed to be rejected. This reveals that there is no statistically significant trend in the data describing the monthly and annual rainfall in Wolaita zone. Also for seasonal rainfall data, the linear regression analysis shows decreasing trend in Belg (FMAM) whereas an increasing trend has been observed for Kiremt (JJAS) and Bega (ONDJ) seasons.

Keywords - Rainfall Variability, Season, Regression, Trend Analysis, Anomaly, ICTZ, El Nino, La Nina

I. INTRODUCTION

Rainfall is one of the most influential and key climate variable its temporal and spatial variability impose immense challenges on the livelihood of nations in many developing countries, specially whose economy's relied on subsistence and small scale farming.

Rainfall is a result of numerous atmospheric and oceanic processes controlling moisture dynamics and circulations, and cause for also hydrological change in the surface of the earth. The Spatio-Temporal distributions of rainfall is being now the main climate agendum in the world and gained the focus from scientific community to be investigated deeply for the societal benefits. These variability are mediated by different factors like topography, atmospheric circulation patterns, land cover, altitude, latitude and elevations. The fluctuation of rainfall from its long range mean value in either side has resulted in a number of catastrophic flood and drought on economically marginalized countries whose coping mechanism is poor.

The countries for which the economy is highly relied on agriculture, investigating the distribution and timing of rainfall based on concise study has paramount importance. In the area where high rainfall fluctuations from its long range mean value is prevalent, society faced serious problem due the extreme events associated rainfall, drought or floods (Amrutha and Shreedhar, 2014).

EPCC (2015) noted that, rainfall is key climatic factor of immense significance for the East African countries like Ethiopia, with extreme occurrences resulting in severe droughts and floods, which are cause for food insecurity, electric power and water scarcity, loss of life and property, and large socio-economic misery. The economy East African

countries like Ethiopia highly relied on subsistence farming, which is highly exposed to the timing, amount and distributions of rainfall. Besides the climate misery on the continent, the people have been hampered by political crisis that has resulted civil war and migrations from the homeland. Even though it is impossible to control the natural events like floods and drought completely, investigating and forecasting the dynamical cause and trend of extreme events has unprecedented value to put in place appropriate adaption and mitigation actions.

Data from National Meteorological Agency depicts, temporal variability of rainfall within a given year is very important for seasonal classifications. Unlike majority of tropical countries, where only two seasons known (wet and dry), in Ethiopia seasons are categorized under three parts based on air mass analysis, dry season (Bega) starts from October and end at January (ONDJ), short rainy season (Belg) which starts from February and ends at May (FMAM) and the last and main rainy season is called kiremt which begins from June and ends at September (JJAS).

Tropical rainfall pattern is known for its seasonality characterized by dry and short rainy period on one side and wet and main (long) rainy season on the other side. The mechanism responsible for the cyclicity of rainfall in tropical regions mainly caused by migration of Inter Tropical Convergent zone across the equator, variations in solar radiation, Indian and African monsoons, Africa Easterly Jet, Low level Somalia Jet and Mascarene and St. Helean high pressure system in South Indian and Atlantic oceans respectively. The magnitude, frequency and location of the meteorological systems impacts the amount, timing and distributions of climatic elements such as; humidity, temperature, precipitation and wind patterns (Diriba Koricha, 2013).

Based on Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), “the global average surface temperature has increased, especially since about 1950. The updated 100-year trend (1906–2005) of $0.74^{\circ}\text{C} \pm 0.18^{\circ}\text{C}$ is larger than the 100-year warming trend at the time of the Third Assessment Report (1901–2000) of $0.6^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ due to additional warm years” (Solomon et al., 2007).

There is a direct influence of global warming on changes in the amount and distributions of precipitation and heavy rain. From the Clausius, Clapeyron relation, moisture holding capacity of atmosphere increase by about 7% per 1°C warming, this shows that the occurrence of global warming contributed to the exacerbation of extreme rainfall as well as the rainfall event (Dindang et al., 2013).

II. STUDY AREA

Wolaita is one of the administrative zones found in South Nations Nationalities Peoples’ Regional State (SNNPRS) of Ethiopia. It is situated b/n latitudes of $6^{\circ}40'$ and $7^{\circ}58'$ N and longitudes of $37^{\circ}14'$ and $37^{\circ}56'$ E, with total area of 4537.5km^2 and inhabited by around 1.8 million people (CSA, 2006).

The altitude of study area ranges from 1200m to 2500m above sea level. Mean annual rainfall in the area varies from 800mm/yr to 1400mm/yr. Average temperature varies from 15°C to 20°C . Rainfall occurs in two distinct rainy seasons ‘kiremt’ rains which is known with larger amount of rain occurs in boreal summer June, July, August and September (JJAS) and the second small rainy season called ‘belg’ occurs y in spring roughly from February to May (FMAM). Kiremt is the main production season but rainfall in ‘Belg’ has also equal importance for agricultural activates in region and other neighboring zones.

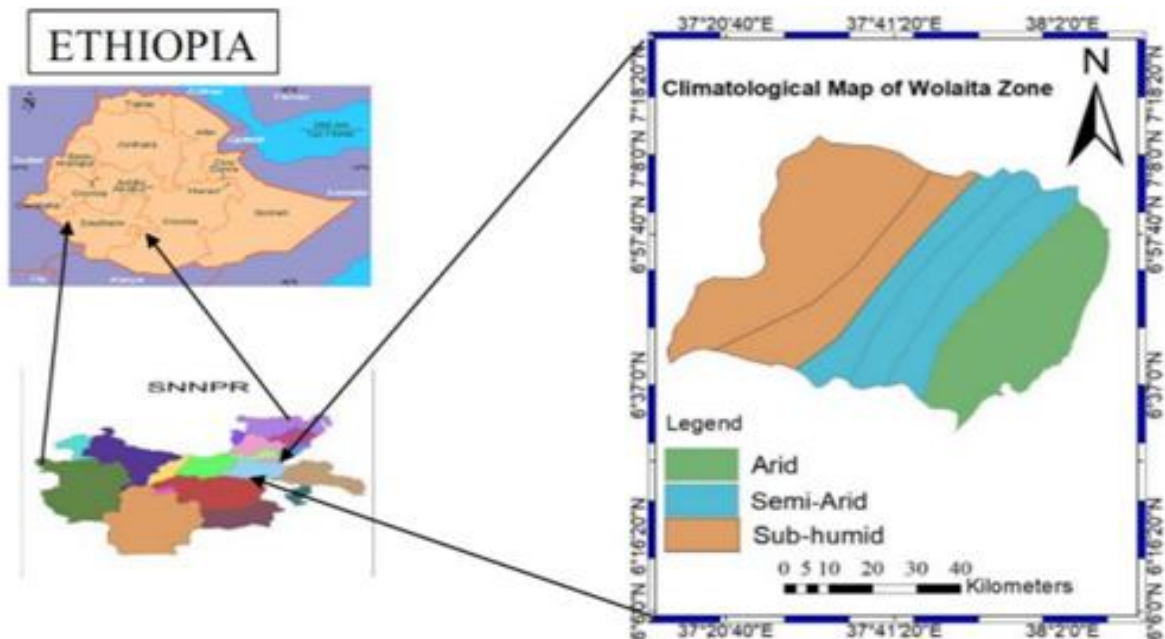


Figure 1; Map of Study Area

III. DATA

The rainfall data for this study extracted from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a 30 + year quasi-global rainfall dataset. Covering 50S to 50N latitudes and all longitudes beginning from in 1981 to 2016, CHIRPS holds 0.05° high resolution satellite imagery with ground station data to make gridded rainfall time series for trend analysis and seasonal drought monitoring schemes. Now from February 12th, 2015, onwards version 2.0 of CHIRPS is accessible online to public (Funk et al., 2015). The link below obtained from the official site of CHIRPS (http://dataviz.vam.wfp.org/seasonal_explorer/rainfall

_vegetation/visualizations) display the data in both graphical and numerical method which is compatible to use in Microsoft Excel and XLSTAT software packages for further detailed analysis.

As noted by CHIRPS, analyzing and predicting rainfall distributions indifferent location and seasons is crucial component of drought early warning and environmental monitoring which helps mitigation and adaptation actions. According to CHIRPS the data derived from satellite imagery at very high resolution has numerous advantages, besides the terrain complexity sometimes make the estimation to bias. In the area where low rain gauges are available, the high resolution satellite data is needed for famine early warning schemes. CHIRPS was established jointly

with scientists at the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Centers in order to provide reliable, up to date, recurrent and more complete datasets for a number of early warning objectives (such as trend analysis and seasonal drought monitoring) to combat the climate change associated problems (Funk et al., 2015).

Having the advantage of the high resolution data mentioned above this study try to depict rainfall variability and trend in Wolaita zone, in order to get valuable information for further detailed and wide area covering analysis.

IV. METHODOLOGY

Various statistical analysis were employed to measure the variability and trend analysis of rainfall data. Mean, range, maximum, minimum, standard deviations, percentage and coefficient of variations were used to measure the central tendency and dispersion of rainfall data in Wolaita Zone. Also simple linear regression methods was employed to extract monthly, seasonal and annual rainfall trend from the data. The data was further displayed in graphical format clarify trend in the rainfall data. The equation of linear regression given below;

$$y = a + bx$$

Where, x is the independent variable and y is the dependent variable. And a is y intercept when ($x = 0$) and b is the slope of regression line. Positive and negative trend on the rainfall data were obtained from the slope of linear equations, which show

increasing and decreasing trend of rainfall in the given time series respectively.

To apply linear regression the data distribution should be normal and smooth. The null hypothesis set is that, there is no trend in the data which means the slope of the linear regression line is zero. PValue of the rainfall statistics shows the significance of the trend. Microsoft Excel and XLSTA were employed to reveal p value of the data. PValue of $\alpha = 0.05$ was set for this study to test significance of the rainfall trend. The square of the correlation coefficient (R^2) from the regression analysis was used to shows the strength of linear relation between dependent (Y) and independent variables(X). The R^2 value ranges from **0** to **1**, where **zero** shows no linear relationship between the variables and **one** shows strong linear relationship between to two variables (Dindang et al., 2016.).

The study mainly focused on examining the rainfall variability and trend analysis besides spatial distribution across the study area. The coefficient of variability shown in equation below used to measure monthly, seasonal and annual variability of rainfall data. It is defined as the ration of standard deviation to its mean value of rainfall.

$$Cv = 100\sigma/x$$

The reliability of annual and seasonal stations rainfall records were examined using method of coefficient of variation. High coefficient of variability means that low reliability of rainfall and vice versa is true as clearly depicted on (Juma, 2012). Reliability (R) is given by the formula;

$$r = 100 - Cv$$

V. RESULT AND DISCUSSION

A. Analysis of Annual and Monthly Rainfall

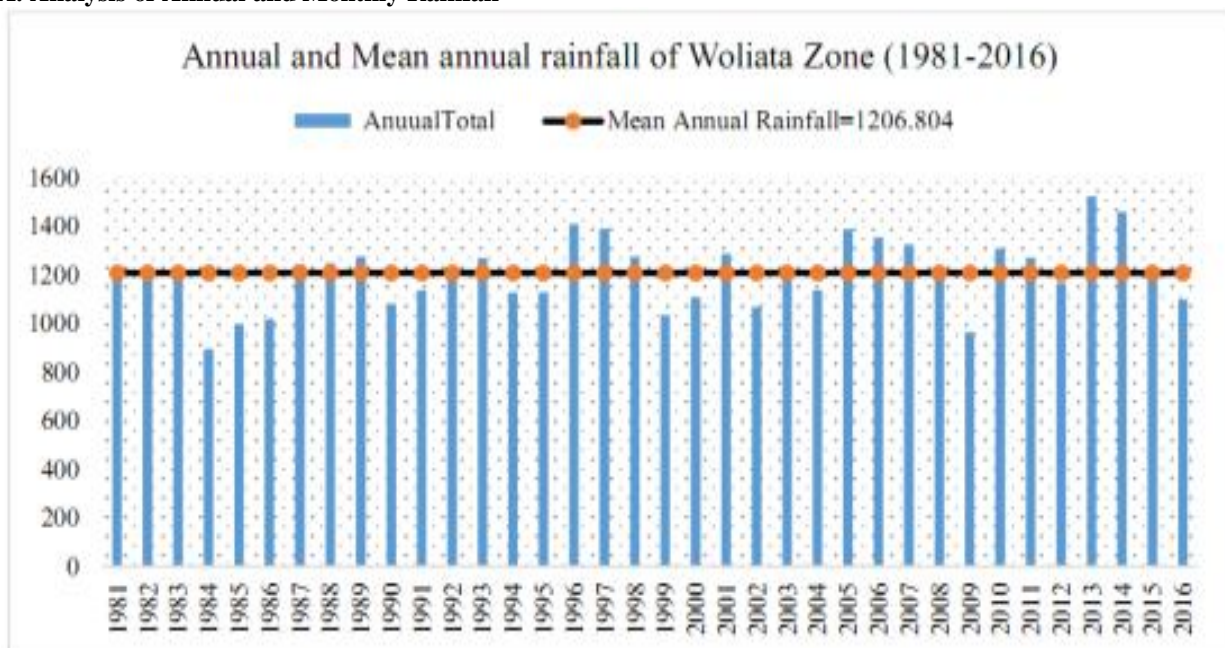


Figure 2: Annual and Mean annual Rainfall of the study area (1981-2016)

Figure 2 above shows the long-term average pattern of the annual rainfall of the study area. The annual mean rainfall over Woliata Zone from 1981 to 2016 is 1206.804mm/yr. The maximum rainfall was recorded in 2013 (1521.92 mm/yr) while the minimum rainfall recorded in 1984(893.36mm/yr). The yellow dotted line shows the average annual rainfall of the study area. The minimum rainfall year 1984 was known for great Ethiopia famine which was occurred due to the failure of average rainfall required for agricultural activities almost all over the country.

But as the fig. 3 below shows the long term annual trend of the study shows positive value, the positive slope values depicts the increment of rainfall during the specified period.

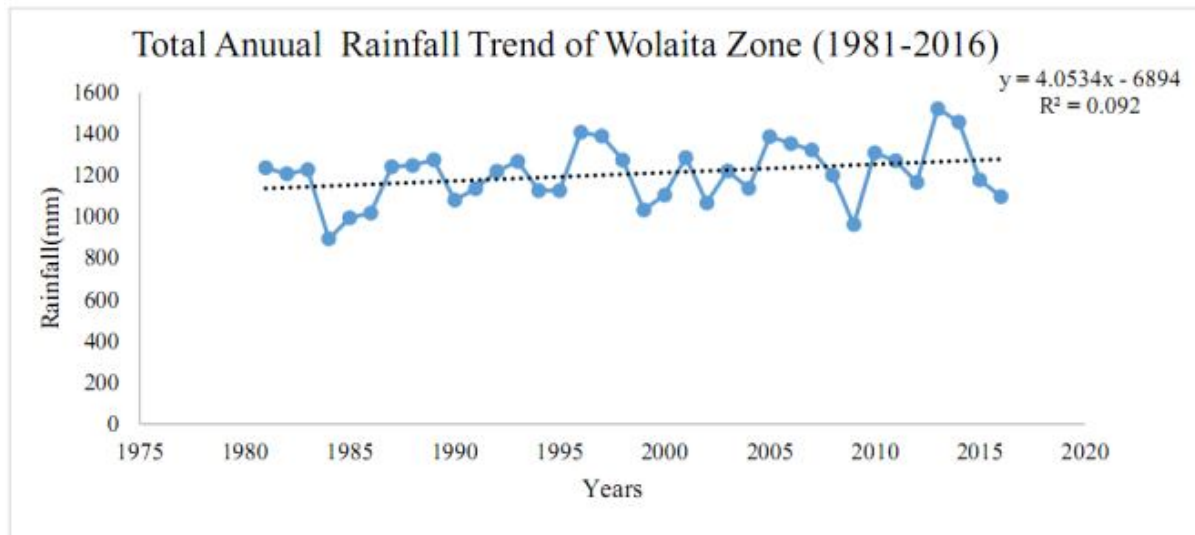


Figure 3: Annual rainfall Trend of the study area (1981-2016)

As fig 4 below shows the departure of annual rainfall from its climatological mean is clear, highly negative departure of the rainfall from the mean was registered at 1984 and the maximum positive departure from the mean was evident on 2013 calendar year. But rainfall fluctuation from the mean on years 1981, 1982, 1994, 2003 and 2008, was very minimum, this result is also well matched to the analysis done by the National Meteorological Agency of Ethiopia, even though the finding was attributed to large geographical area.

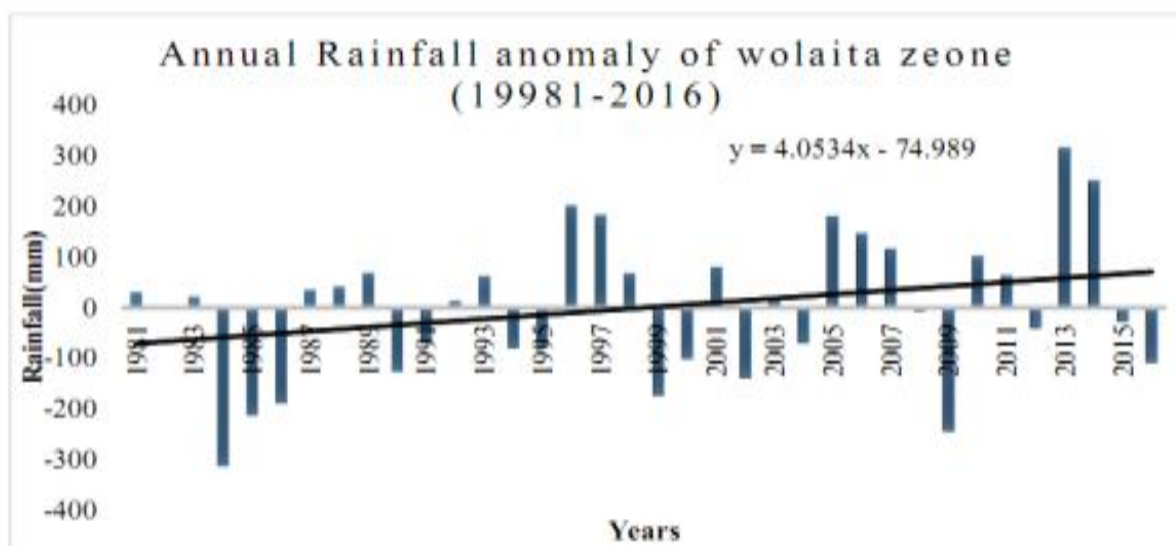


Figure 4: Rainfall anomaly of the study area (1981-2016)

The rainfall pattern in this research area looks uni-modal as can be seen from fig 5 below, starting roughly around March and ending at November, however the maximum rainfall recorded on April, May, July and August. As confirmed by many research work the rainfall in the region bimodal due to rainfall break observed in June, which makes the pattern a bit bimodal. However the highest monthly rainfall recorded on May and the minimum monthly rainfall was recorded on December.

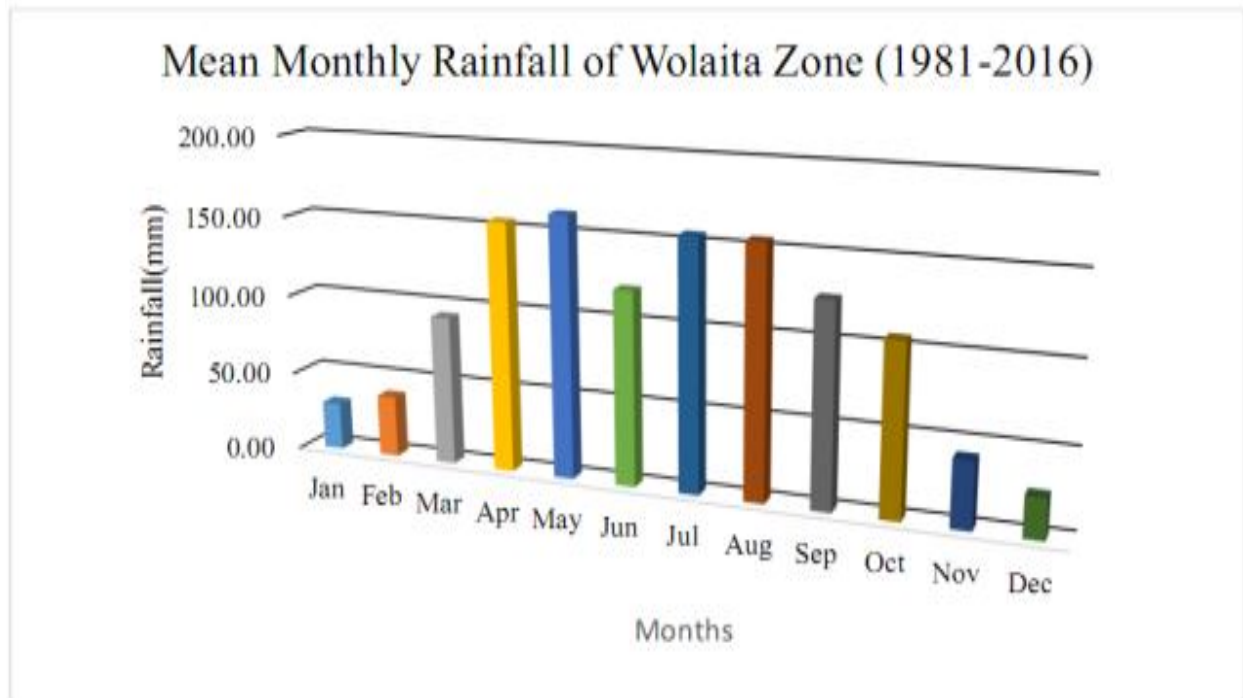


Figure 5: Mean Monthly rainfall of the study area

The coefficient of variation depicted on the fig 6 below shows also the maximum rainfall variability was occurred during December and minimum variability occurred on May. Which is opposite to the reliability of rainfall in respective months, May has high reliability while December is known with low reliability.

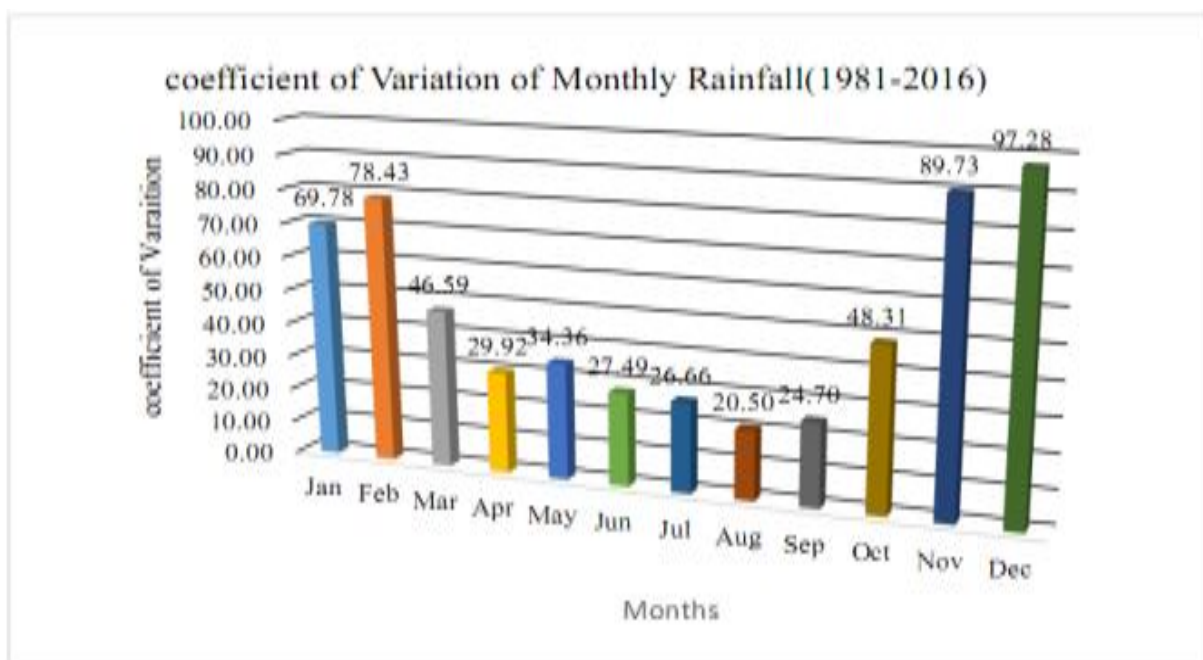


Figure 6: Coefficient of variation of Monthly Rainfall on the study area (1981-2016)

Table 1 shows statistical properties of monthly and annual rainfall on the study area. Generally, the monthly rainfall distribution in Wolaita Zone is variable. Coefficient of variation (ratio of standard deviation and mean) is suitable measure of variability of rainfall. The monthly coefficient of variation (CV) for this area lies between 0.205 and 0.9275. The CV is highest during December (0.9728), followed by November (0.8973) and the least during August (0.205) and September (0.247).

Monthly Rainfall Statistics of Wolaita Zone (1981-2016)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	29.68	38.25	92.97	154.75	161.95	120.11	155.33	155.25	125.47	106.13	41.68	25.23
Maximum	85.23	151.00	212.12	234.03	300.61	233.93	241.75	223.30	199.98	254.38	176.38	101.01
Minimum	5.73	6.54	26.34	63.64	86.92	75.54	90.15	96.39	80.61	39.93	7.28	4.29
Range	79.50	144.46	185.79	170.39	213.69	158.39	151.59	126.92	119.37	214.45	169.10	96.73
Stand Dev	20.71	30.00	43.32	46.30	55.64	33.02	41.42	31.82	30.99	51.27	37.40	24.54
Count	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00
coeff. Var	69.78	78.43	46.59	29.92	34.36	27.49	26.66	20.50	24.70	48.31	89.73	97.28
Reliability	30.22	21.57	53.41	70.08	65.64	72.51	73.34	79.50	75.30	51.69	10.27	2.72
MonthlyTotal	1068.6	1376.9	3347	5570.9	5830.351	4324.05	5592	5588.9	4516.84	3820.6	1500.62	908.2
Percentage	2.46	3.17	7.70	12.82	13.42	9.95	12.87	12.86	10.40	8.79	3.45	2.09

Table 1: Monthly Rainfall Statistics of the study area (1981-2016)

The result of the linear regression is presented in Table 2 below. In these trend test, trend of rainfall for 36 years from January to December has been calculated for each month individually.

Months	Regression Equation	R-Square	P-Value	Statistical Significance	Trend
January	$y = -0.079x + 187.52$	0.0016	0.78	No	Decrease
February	$y = -895x + 1827$	0.0998	0.0568	No	Decrease
March	$y = -0.5815x + 1255.20$	0.002	0.375	No	Decrease
April	$y = 0.6123x - 1069.80$	0.194	0.478	No	Increase
May	$y = 0.4426x - 722.51$	0.007	691	No	Increase
June	$y = 0.9852x - 1848.8$	0.0988	0.079	No	Increase
July	$y = 1.236x - 2290$	0.0969	0.083	No	Increase
August	$y = 0.428x - 700.24$	0.0201	0.5048	No	Increase
September	$y = 0.29x - 464$	0.0101	0.485	No	Increase
October	$y = 1.275x - 2443$	0.0687	0.241	No	Increase
November	$y = 0.5409x - 1039$	0.0232	0.394	No	Increase
December	$y = -0.195x + 414.7$	0.007	0.606	No	Decrease
Annual	$y = 4.053x - 6894$	0.092	0.123	No	Increase

Table 2; Regression Statistics for Monthly and annual rainfall of the study area (1981-2016)

The linear trend lines of the monthly rainfall shows decreasing trend in December, January, February and March and increasing trend for other months and annual rainfall data. As we can see from the tables above the P values for both monthly and annual rainfall trend lines area greater than the $\alpha = 0.05$ which was set to test significance of the trend. This shows that we failed to reject the null hypothesis, which states there is no significant trend in the data. That means, there is no statistical significant trend in the annual and monthly rainfall data in the study area. The R^2 value also signifies that, there is very weak linear relationship between two variables.

B. Analysis of Seasonal Rainfall

EPCC (2015) depicted that, the seasonality in Ethiopia is based on wet and dry condition at different location based on the annual rainfall amount received. As mentioned earlier seasons in Ethiopia are categorized based on air mass analysis, the country is known by three major seasons, these are Belg Season (Feb-May), Kiremt season (June-September) and Bega Season (October-January).

The seasonality is basically the result of the seasonal migration of the Inter tropical Convergence Zone (ITCZ) and the seasonal distribution of the atmospheric pressure systems (both over land and over the nearby Oceans) and the quasi stationary subtropical anticyclones over the Indian Ocean and the Atlantic Ocean (Endalew, 2007).

From the Figure 7, it shows that the highest amount of rainfall in the study area is, in kiremt (JJAS) which is 556.16mm that contributes 46.10% of the annual rainfall. For Belg season (FMAM), and Bega (ONDJ) annual rainfall is 37.10% and 16.80%, respectively. The result shows that Wolaita Zone rainfall is directly influence by the Kiremt and Belg seasons, which are wet season and as can be seen from the fig 7 bega (ONDJ) is dry season in the region.

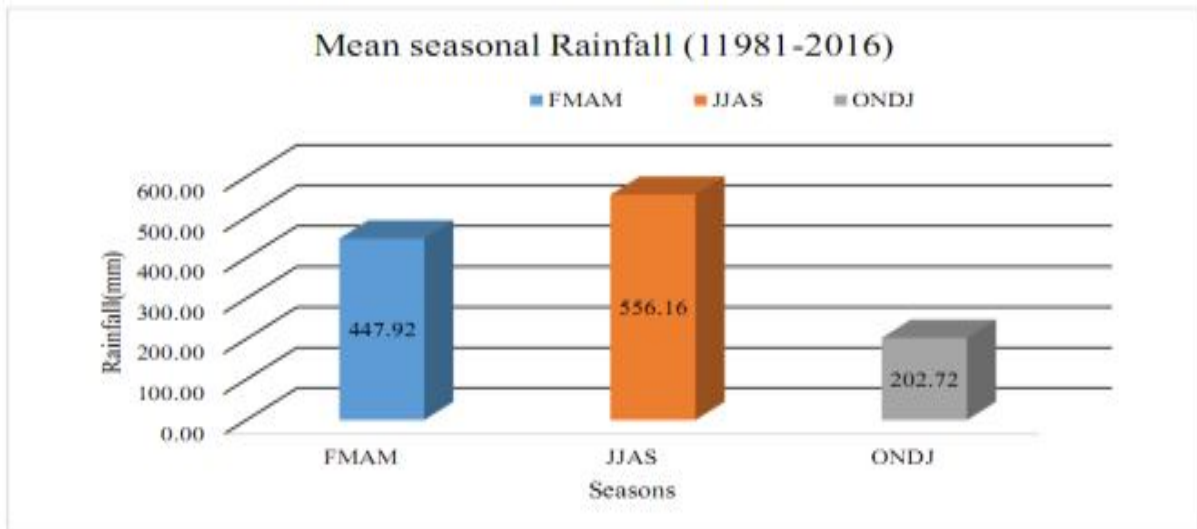


Figure 7: Mean Seasonal Rainfall of the study area (1981-2016)

Figure 8 below shows annual distribution of seasonal rainfall on the study area. As can be seen clearly maximum rainfall amount recorded in Kiremt (JJAS) and Belg (FMAM) whereas minimum rainfall was recorded in Bega (ONDJ) during the specified period.

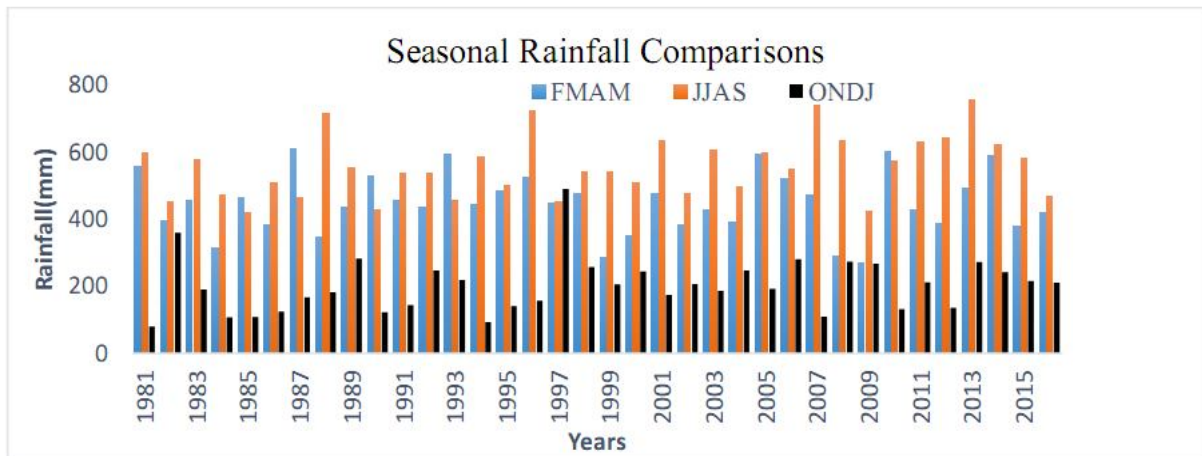


Figure 8: Season rainfall distribution in study period

Also as can be seen from Fig 8 below the Coefficient of variations is high in dry season Bega (ONDJ) and low in the remaining wet season Kiremt (JJAS) and Belg (FMAM).

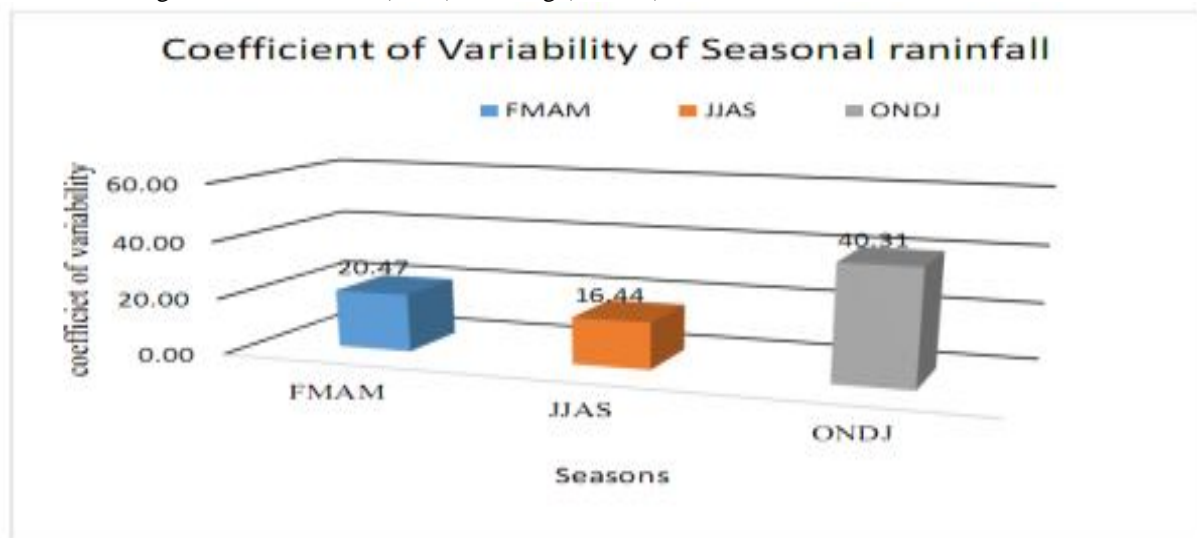


Figure 9: Coefficient of Variability of Seasonal rainfall in the study area(1981-2016)

Table below shows seasonal rainfall statistics of the study area from 1981 to 2016. The minimum rainfall is recorded in dry season (ONDJ) and the maximum rainfall obtained on wet season (JJAS). The JJAS and FMAM rainfall are highly reliable than ONDJ seasons, this shows rainfall in wet seasons are very important for agricultural activities in the region.

National Metrological Agency of Ethiopia (NAM) has categorized rainfall variability under three different levels based on the coefficient of variation (CV) value. Low if CV < 20%, moderate if CV between 20 – 30% and high if CV > 30%, this shows JJAS and FMAM are under low rainfall variability while ONDJ fall under high rainfall variability (Samuel et al, 2017).

Seasons	FMAM	JJAS	ONDJ
Mean	447.92	556.16	202.72
Minimum	271.27	420.98	80.65
maximum	608.61	755.60	490.66
Stand Dev	91.67	91.41	81.72
coeff. Var	20.47	16.44	40.31
Reliability	79.53	83.56	59.69
Range	337.34	334.62	410.01
Percentage	37.10	46.10	16.80

Table 3: Seasonal Rainfall statistics of the study area (1981-2016)

The linear regression analysis shows decreasing trend in Belg (FMAM) whereas an increasing trend has been observed for other seasons (Table 4). Since the p, value for the slope of all seasons is greater than 0.05, there is no statistically significant trend in the rainfall data and year at 95% confidence level. The value of R² also indicates a very weak relationship between dependent (rainfall) and independent (years).

Seasons	Regression Equation	R-Square	P-Value	Statistical Significance	Trend
Kiremt JJAS	$y = 2.92x - 5303$	0.114	0.667	No	Increase
Belg(FMAM)	$y = -0.422x + 1290$	0.0023	0.668	No	Decrease
Bega(ONDJ)	$y = 1.54x - 2880.9$	0.0396	0.275	No	Increase

Table 4: Regression Statistics for seasonal rainfall of the study area (1981-2016)

The following figures below (10, 11, and 12) show the trend of rainfall for each season graphically, JJAS and ONDJ indicate positive trend while FMAM shows negative trend.

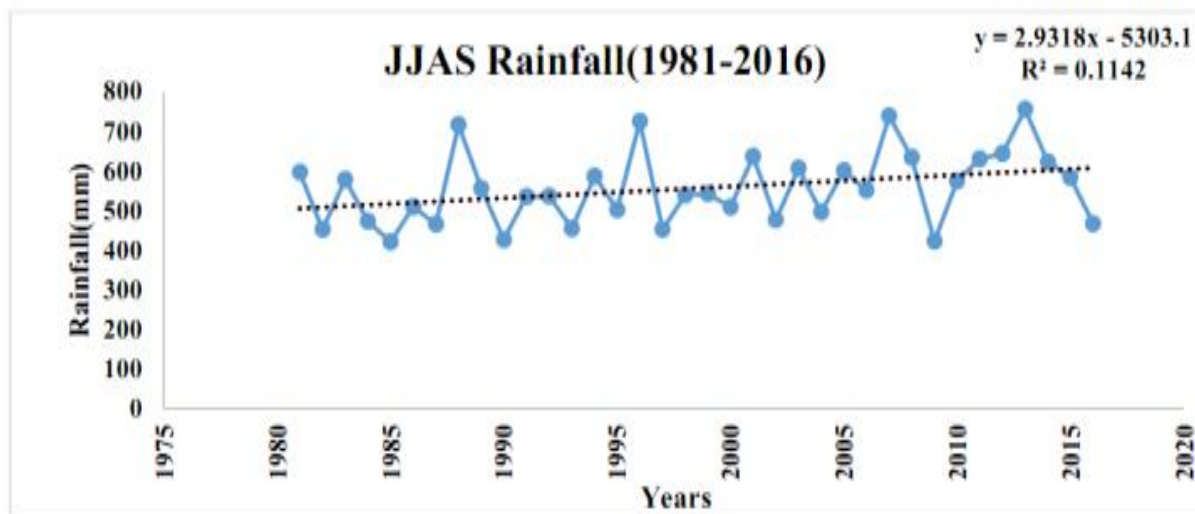


Figure 10: Kiremt (JJAS) Rainfall time series and trend line of the study area (1981-2016)

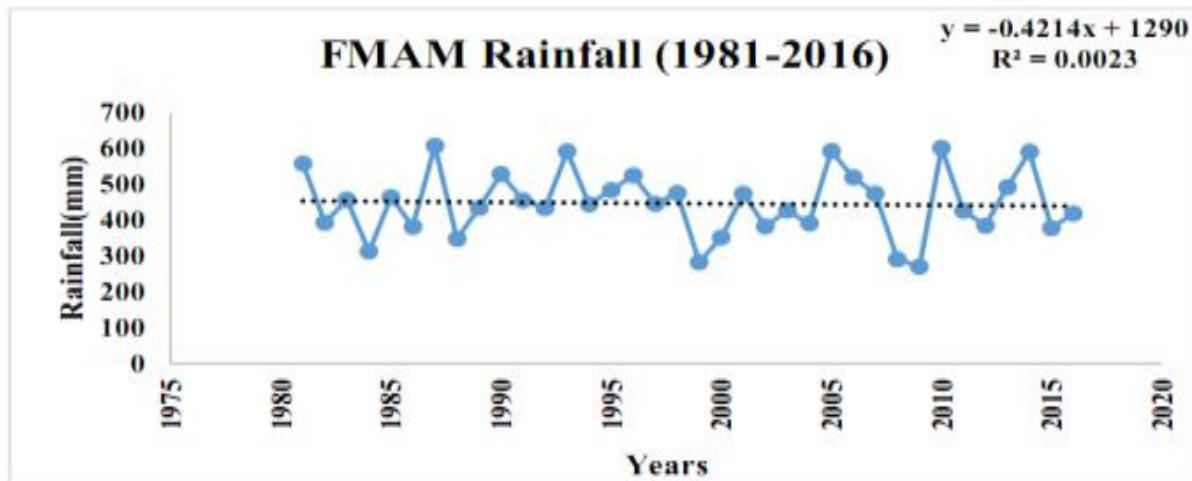


Figure 11: Bega(ONDJ) Rainfall time series and trend line of the study area (1981-2016)

Comparing the slope of the lines for JJAS and ONDJ, we can deduce that JJAS has relatively high positive trend when compared to ONDJ, this in fact shows the important rainy season for agricultural activities (JJAS) had positive trend during 36 year study period. But decreasing trend of FMAM rainfall had its own negative impact on rain fed agriculture of the area. In order to combat the problem appropriate adaptation and mitigation actions should be put in place at, least to alleviate the problem based on the rainfall trend observed in the area.

The variability of seasonal rainfall is associated with a number of different factors. Sea surface temperature fluctuations in the tropical oceans is the dominant factor affecting rainfall variability in the region by inducing cold and warm events called La Nina and El Nino respectively. Also the Indian summer monsoon, Somalia Easterly Jet, high pressure systems in subtropical regions are directly associated with the moisture bearing system of the region, and hence strongly influence the amount and timing of precipitation in the area.

Rainfall anomaly in different seasons and their inter comparison presented graphically in the figures below. Some extreme positive anomaly in the area are linked to the La Nina event, which is associated with low sea surface temperature in eastern Pacific Ocean (Nino 3.4 Region).

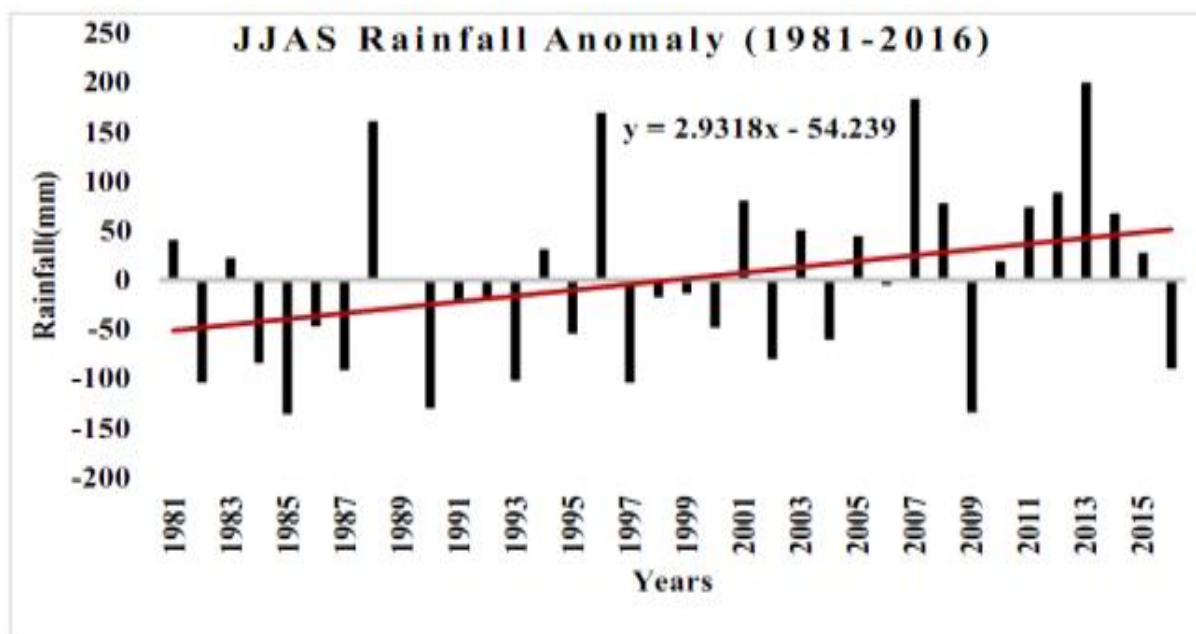


Figure 12: Kiremt (JJAS) Rainfall Anomaly of the study area (1981-2016)

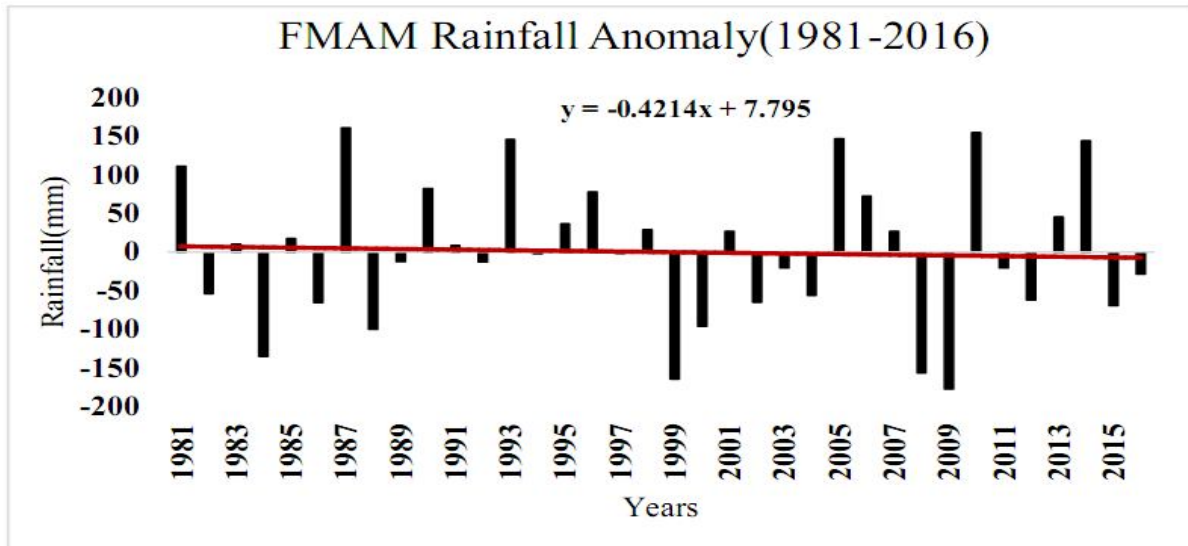


Figure 13: Belg (FMAM) Rainfall Anomaly of the study area (1981-2016)

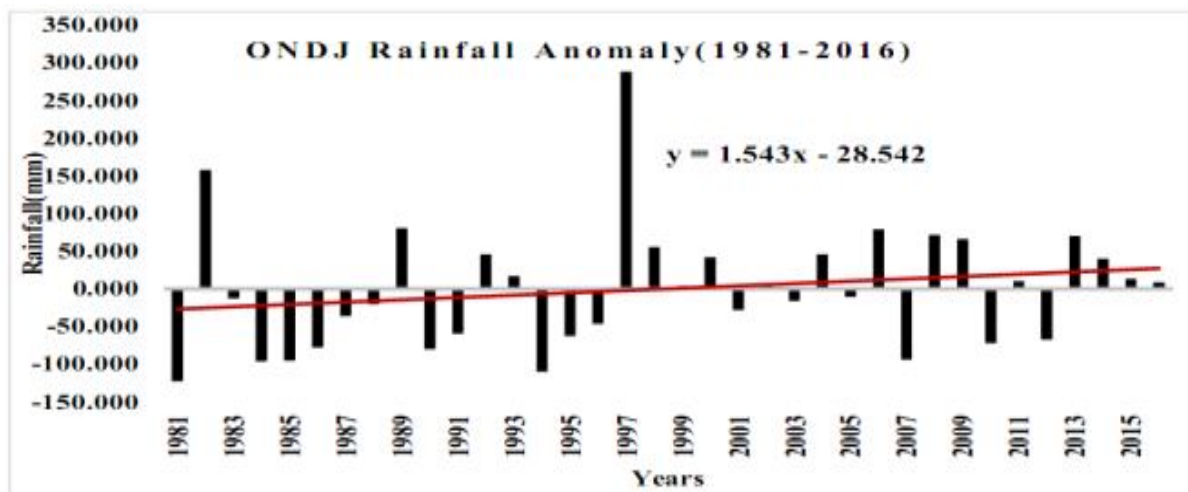


Figure 14: Bega (ONDJ) Rainfall Anomaly of the study area (1981-2016)

As illustrated on the fig 15 above the highly positive anomaly years in 1982 and 1997 are associated with strong La Nina Year. The detailed list of La Nina and El Nino years since 1950 is available on the official web page off Climate prediction center (CPC) "http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php".

The following graph presents the inter comparison of rainfall anomaly for three seasons illustrated individually on fig 13, 14 and 15 respectively.

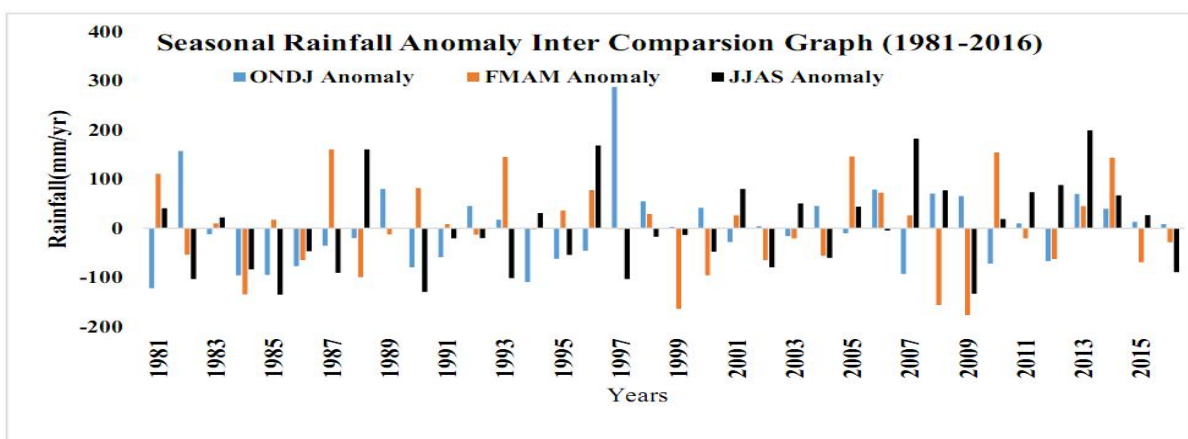


Figure 15: Seasonal Rainfall Inter comparison graph of the study area (1981-2016)

Table below describes “El Niño and La Nina” Years based on the Oceanic Nino Index (ONI) as mentioned on CPC website (<http://ggweather.com/enso/oni.htm>). Which is defined by NOAA climate prediction center as “the running 3-month mean SST anomaly for the Niño 3.4 region (i.e., 5°N-5°S, 120°-170°W).

Events are defined as 5 consecutive overlapping 3 –month periods at or above the +0.5° anomaly for warm (El Niño) events and at or below the –0.5 anomaly for cold (La Niña) events. The threshold is further broken down into Weak (with a 0.5 to 0.9 SST anomaly), Moderate(1.0 to 1.4), Strong (1.5 to 1.9) and Very Strong (≥ 2.0) events. For the purpose of this report for an event to be categorized as weak, moderate, strong or very strong it must have equaled or exceeded the threshold for at least 3 consecutive overlapping 3-month periods” Null, J. (2011).

El Niño Years				La Niña Years		
Weak - 10	Moderate - 7	Strong - 5	Very Strong - 3	Weak - 11	Moderate - 4	Strong - 7
1952-53	1951-52	1957-58	1982-83	1954-55	1955-56	1973-74
1953-54	1963-64	1965-66	1997-98	1964-65	1970-71	1975-76
1958-59	1968-69	1972-73	2015-16	1971-72	1995-96	1988-89
1969-70	1986-87	1987-88		1974-75	2011-12*	1998-99
1976-77	1994-95	1991-92		1983-84		1999-00
1977-78	2002-03			1984-85		2007-08
1979-80	2009-10			2000-01		2010-11
2004-05				2005-06		
2006-07				2008-09		
2014-15				2016-17		
				2017-18		

Table 5: List of “El Nino and La Nina” Years as defined by NOAA.

More clearly data in the table 5, above is graphically shown below to make the comparison of rainfall seasons and El Niño and La Nina years. The red peaks show El Nino (warm) years, the blue ones show La Nina (cold) years and black shows moderate(either) years.

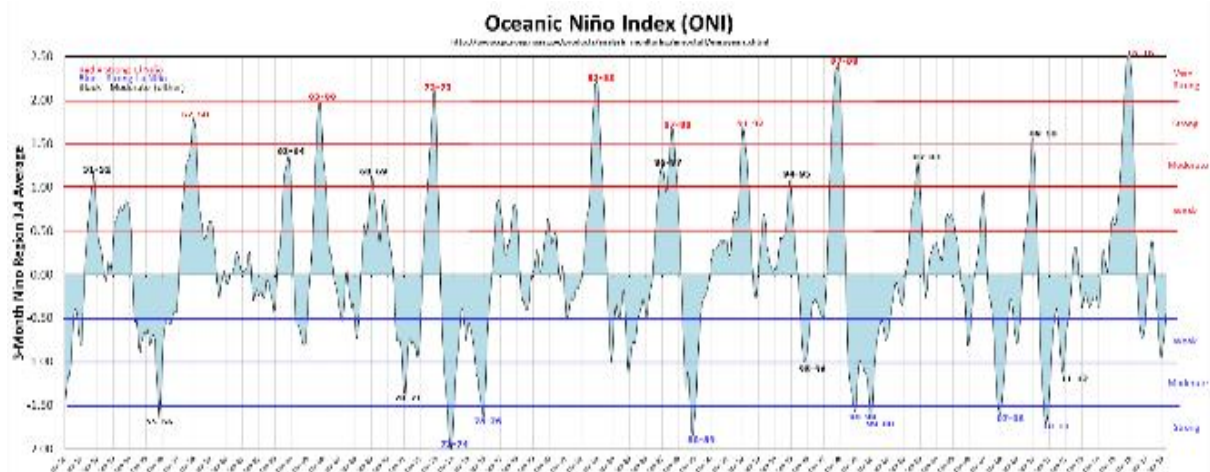


Figure 16: “El Nino and La Nina” Years from 1950 to 2017/18 (adapted from “<http://ggweather.com/enso/oni.htm>”)

For instance, by comparing the seasonal rainfall comparison graph and the list of El Niño and La Nina years we can understand that majority of rainfall anomalies are intertwined with continued fluctuations of sea surface temperature in the tropical eastern Pacific Ocean, besides that the other Oceanic and Atmospheric conditions playing unprecedented role in controlling climate system in the region and vicinity.

If we take Kiremt (JJAS) rainfall, as it is the main important season for agriculture, the positive anomalies in 1988 and 2007 were associated with strong La Niña year, while 2005, 2008, and 2014 were associated with weak La Niña year, and 2011 was linked with moderate La Niña year.

In the cases of negative JJAS anomalies 1982, 1997 and 2015 were associated with very strong El Niño years, while 1987 for strong El Niño year. Also 2009

and 2002 JJAS rainfall anomalies were linked to moderate El Nino years, whereas 1984 and 2004 shows weak association with El Nino years as illustrated on the graph and table.

CONCLUSION

Rainfall trend analysis is very important for countries whose economy's depends on rain fed agricultural activities. Its temporal and spatial variability shall results in catastrophic effect, if appropriate mitigation actions will not be taken timely based on the accurate trend analysis. This study was mainly focused on investigating annual, seasonal and monthly rainfall trend and variability using standard statistical methods recommended by WMO. From the results of coefficient of variability's and linear regressions we inferred that monthly rainfall trend for December, January, February and March shows decreasing trend, while the remaining months show positive trend. Also Kient (JJAS) and Bega (ONDJ) seasons show positive trend, whereas Belg (FMAM) shows negative trend during the study period, but the overall annual rainfall trend in the study area is positive as revealed by this study. The monthly coefficient of variation (CV) lies between 0.205 and 0.9275. The CV is highest during December (0.9728), followed by November (0.8973) and the least during August (0.205) and September (0.247).

One of decisive component triggering rainfall variability and related climate change in the region is, the extreme departure of sea surface temperature in eastern tropical Pacific Ocean from its long range mean based on 30 year's base period. As clearly illustrated on the graph and table above, seasonal rainfall anomalies are associated with the El Nino (warm) and La Nina (cold) events in different years. But further study is required to see the effect of other

Nino indices like Nino 1, Nino 2, Nino 4 other Atmospheric circulation patterns, on the variability of seasonal and monthly rainfall on the study area and the region at large. Though, this study covers, more studies should be done to cover geographically wide area across the region, based on high resolution data and additional climate variability inducing parameters.

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