

Research Article

Time Series Analysis of Rainfall Distribution in Gambella Meteorological Station

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Abstract

This study conducted on this research on the Time Series Analysis of rainfall distribution in Gambella meteorological station. On this study, we try to see what the rainfall behavior of Gambella meteorological station seems like. In our study we have used time series model and focused on time series component, to deal variation and trend of rain fall distribution in Gambella meteorological station, First, we have seen the actual data of rainfall in mm of the last ten years. The data shows a little change the year. When we see the trend value of the last ten years of the rain it is proportionally a little increasing. From the seasonal indices we have seen there was higher rainfall in the beginning of the years that means the earliest time and it shows proportionally decreasing except 2009 was higher rainfall. Lastly we seen the forecasted value for 2013 based on the rainfall of 2012 rainfall and the forecasted value of rainfall in Gambella meteorological is similar to that of its preceding years, but it will show a little decreasing at the beginning of the year and it will be constant.

Keywords

Rain Fall Distribution, Forecasting, Component of Time Series

1. Introduction

The western part of Ethiopia has one rainfall peak during the year [1]. The length of the rainy period decreases, and the length of the dry period increases as one goes toward the north within this region, as a result of that meridional migration of the occurrence of the dry spell has a particular relevance for rain-fed agriculture, as rainfall water is one of the major requirements for plant life in rain-fed agriculture. As we know, rainfall is very essential for living and non-living things. However, sometimes it may cause to a great disaster, this happens usually from the unexpected floods and unpredictable rainfall in the agriculture area and other places. Considering this, we try to predict the future trend of rainfall to analysis average

variations of rainfall for ten years and to the amount of rainfall distributions in Gambella.

The inter-annual shift of the position of inter-tropical convergence zone causes variation in the wind flow patterns around and over Ethiopia. In its movement to the north and south of the equator alternatively, the ITCZ passes over Ethiopia twice a year and its seasonal migration causes rainfall to variable and seasonal in Ethiopia. The central and most of the eastern half of the country have two rainy periods and one dry period [2]. The two rainy periods are locally known as Kiremt (summer) (June to September) and Belg (Spring) (February

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to May), which are the long and short rainy periods respectively. The annual rainfall distribution over this region shows two peaks corresponding to the two rainy seasons, separated by relatively short dry period. The dry period, which covers the rest of the year (that is October to January), is known as bega [3].

2. Methodology

2.1. Source of Data

Source of the data is secondary providing by Gambella meteorological station. This study was based on the amount of monthly rainfall distributions in Gambella meteorological station for ten years.

2.2. Variable Under Study

Dependent variable: the amount of rainfall in mm Independent Variable: (Time month, seasons, years) In this study, the dependent variable is the amount of rainfall in mm and the independent variable is time (months, seasons and years). To apply Time series analysis, we have to check whether the data is time dependent (random). If the data is non- random, we can apply time series analysis. There are different methods to test randomness of the data such as Rank test, Phase length test and turning point test. However, in this study we see only turning point test [4].

Turning Point Test

The test is based on by counting the number of peaks or troughs, which it exhibits. A “peak” is a value less than its two neighboring values: a “trough”, conversely, is a value less than its two neighbors are? The two together are known as “turning points”. We consider a finite series of n values, $x_1, x_2, \dots, x_n$. The initial value cannot consider (be regarded) as defining a turning point because we do not know x_0 , and similarly, neither can the last value since we do not know x_{n+1} . Three consecutive values are required to determine a turning point [5]. If the series is random, these three values could have arisen in any of $3!$ Possible orders with equal probability. In only three of these would there be a turning point, namely when the greatest or the least of three in the middle. The probability of finding a turning point in any set of three values is then $2/3$.

For the set of ‘ n ’ values, define a counting variable y as 1, $x_i < x_{i+1} > x_{i+2}$ or $x_i > x_{i+1} < x_{i+2}$

1, $x_i < x_{i+1} > x_{i+2}$ or $x_i > x_{i+1} < x_{i+2}$

$$y = \begin{cases} 0 \\ \text{otherwise} \end{cases}$$

The number of turning point p in the series is then if n is large, the distribution of p is approximately normal with mean and variance.

The hypothesis is testing as follow

H_0 : the series is random

H_1 : the series is non-random

We reject H_0 at α level of significance, if $|Z_{cal}| > Z_{\alpha/2}$

2.3. Component of Time Series

When the data was arranged on the basis of their occurrence, we found that the variables under investigation are fluctuating from time to time. The fluctuations are caused by composite force that is constantly at work. This force has four components secular trend, cyclical variation, seasonal component and irregular or random movement [6].

2.3.1. Seasonal Trend

Seasonal variation is short-term oscillation around the trend line. Consumption and production of many commodities, interest rates, bank clearings, etc are marked seasonal swings. Climate and custom together play an important role in giving rise to seasonal movement to all the industries.

2.3.2. Cyclical Variation

It refers to long-term oscillation about trend. In a large number of time series of economic data, it was observed that there was somewhat periodic up and down movement. Cycles in general exhibit semi-regular periodicity as these are neither as regular as are seasonal variations nor as accidental as are accidental as are the random fluctuation [7].

2.4. Models of Time Series

There are two mathematical models, which is commonly used for the decomposition of a time series into component parts. These are additive model and multiplicative model.

Additive model

The data is the sum of the time series components. If the time series data does not contain one of the components the value for that component is equal to zero.

Symbolically

$X_t = M_t + S_t + C_t + E_t$, Where X_t = observation at time t M_t = trend component at time t S_t = seasonal component at time t C_t = cyclical component at time t E_t = random component at time t .

It is an appropriate model if we assume that all components are independent of one another and the magnitude of the seasonal fluctuations does not vary with level of the series [8].

2.5. Estimation of Trend

The study of trend enables us to have a general idea about the pattern of the phenomena under consideration. This helps in forecasting and planning future operations [6]. Trend analysis enables us to compare two or more-time series over different periods of time and draw important conclusions about them. We estimate the trend by using different methods such as free hand method, selected point methods, semi-average method, moving average, method of simple exponential

smoothing and the method of least squares.

2.5.1. The Least Square Point Estimates

Let $b_0, b_1, \dots, b_p$ denote point estimates of the parameters $B_0, B_1, B_2, \dots, B_p$ in the linear regression model. Then the point prediction of (Here, I predict e_i to be zero). next, for $i=1, 2, \dots, n$, the residual $e_i = Y_i - y_i$ and we are also defining the sum of squared residuals to be: Intuitively, if any particular values of $b_0, b_1, b_2, \dots, b_p$ are good point estimates, they will make (for $i=1, 2, \dots, n$) the predicted value y_i fairly close to the observed value Y and thus will make SSE fairly small [9]. We define the least squares point estimates to be the values of $b_0, b_1, b_2, \dots, b_p$ that minimize SSE. It can be shown that the lines regression model can be calculating by using a formula that is expressed by using mathematics called matrix algebra. Rather than present this formula, we rely on computer packages to find the least squares point estimates [8].

2.5.2. Estimation of Seasonal Variation

For additive model (simple moving average) Among all methods of measuring seasonal variation, this method is the most satisfactory and widely used. In this method, we first subtract the trend value obtain by least squares method from the actual data (i. $eY_t - Mt = Ct + St + Et$). When these deviations from trend will average for each month, the cyclic and irregular components is remove to a large extent. The only component left is seasonal which is suitable to adjust so as to be total zero [10].

The adjustment is in the following way: Adjustment=General average with sign reversed.

Seasonal index= Average for each month + Adjustment

2.5.3. Measurement of Cyclical Variation

We can estimate cyclical variation using various methods. But, we consider only residual method. For additive model First depersonalize the data, $X_t - St = Mt + Ct + Et$. Then from the quantity that will obtain subtract trend estimate, $X_t - St - Mt = Ct + Et$. Finally, take an appropriate moving average of the periods to take the effect of irregular component. The remaining data is the estimate of cyclical component [11].

2.6. Forecasting a Time Series Data

Forecasting will be prediction of future values of certain variable. The study of the behavior of variable enables to predict future tendencies [12]. To business executives who are to plan their production program such analysis is, therefore, of great assistance, for it with the help of analysis of this nature that appropriately correct estimates of the future demand will be made. There will be several forecasting methods such as average method, classical model decomposition, exponential smoothing, least squares method, econometric and Box-Jenkins methods. However, in this study we consider classical model decomposition [13].

3. Results

In this chapter we analyze the data of monthly rainfall amount in mm of Gambella meteorological station starting from January 1993 to December 2012.

The data is shown in Table 1 and in Figure 1.

Test of randomness.

H_0 : the series is random. H_1 : the series is not random.

Level of significance $\alpha=0.05$ Test statistics $Z = \frac{P-E(P)}{\sqrt{VAR(P)}}$

Where P is the number of turning points $P = 75$

$n = 120$, n = number of observation

$$E(P) = \frac{2}{3}(n-3) = \frac{2}{3}(120-3)$$

$$E(P) = 7 \quad Var(P) = \frac{16 \cdot 120 - 29}{90} = \frac{16 \cdot 120 - 29}{90} = 21.011$$

$Z = \frac{75-78}{\sqrt{21.011}} = 1.965$ The critical value is $Z_{\alpha/2} = 1.96$ Decision: $|Z_{cal}| > Z_{\alpha/2}$ that is $|1.965| > 1.96$ then reject H_0 . Therefore, we conclude that the data seems to time dependent.

3.1. Model of Time Series

When we plot the time series data shown in Figure 1, the variability of the data is constant through time. Therefore, the appropriate additive model for our data. i.e. $X_t = Mt + St + Ct + Et$, Where Mt = trend component at time t St =seasonal component at time t Ct =cyclical component at time t Et =random component at time.

Table 1. The actual data on monthly rainfall for Gambella meteorological station in mm.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	28.8	61.5	87.4	116	22.3	266.2	186.9	145	239	91.8	30	14.6
2004	51.2	12.4	46.2	130.6	162.2	165.7	216.6	219.2	201	133.3	67.5	81.1
2005	44.5	0.5	193.8	141.7	173	176.8	273.6	237.6	229	68.3	29.7	0.0
2006	16.2	77.2	181.8	110.7	211.7	207.6	327.6	240.3	169.9	91.4	127.9	100.5

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	37.7	51.4	104.3	121.7	226.1	138.4	247.5	177.4	256.3	51	5.9	0.0
2008	34.1	12.3	39.4	108.7	247.2	238.4	221.2	236.9	133.5	191.2	.4	6.3
2009	63.2	29.5	80.1	103.7	244.6	160.3	149.8	304.7	199.5	92.4	78.5	58.2
2010	27.3	88.4	-67.7	101.4	193	394.7	181.3	203.4	186.7	57.9	94.9	7.7
2011	24.4	6.2	34.4	151.1	182.9	311.2	199.9	.190.8	269.7	11	105	25.1
2012	2.2	1.9	55.9	154.5	119	335	223.9	132.8	250.6	32.8	77.4	58

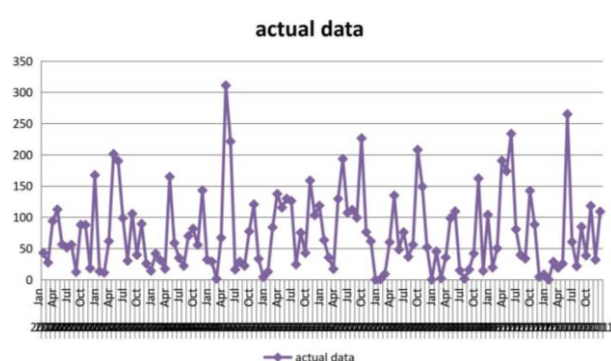


Figure 1. Shows the actual data on monthly rainfall for Gambella meteorological station.

As we see from the graph the amount of rainfall change based on the time because there is variation from time to time. The graph shows as the rainfall is high at the middle of the years and there are very high in summer season.

3.2. Estimation of Trend

We compute the estimated trend value by using least square method. To know the appropriate regression model; we have to compare MAD for linear and quadratic model. The data at hand seems to follow quadratic model because for linear model MAD=50.99, but for quadratic model, MAD=50.81.

Applying the least square method, we fitted linear equation, which is given by $Y_t = b_0 + b_1t + E_t$, where, b_0 and b_1t are intercept and slope of the model respectively; E_t represents the random deviation from the mean. The estimated semiannual trend

value is given by the equation $Y_t = 62.7059 + 0.55t - 4.36t^2$ where, $t = 1, 2, \dots, 40$ Time unit: one-month Origin: Jan 2003 By using the equation and substitute the appropriate time t , we found the estimated trend value for each month of rain fall. It is shown in Table 2 and Figure 2.

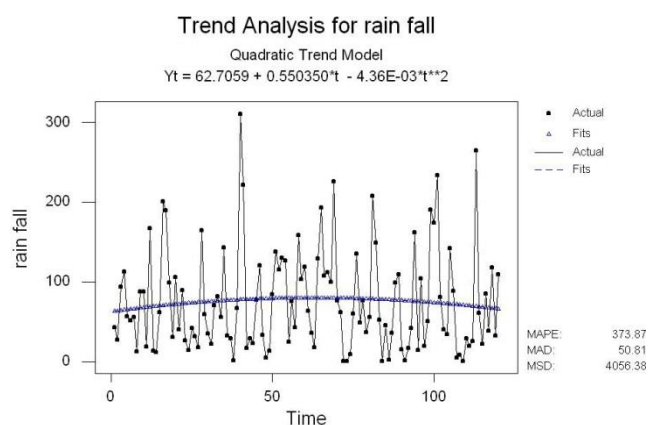


Figure 2. The estimated trend value by using least square method.

From the graph we can see that the trend line shows there is increasing pattern in rain fall with respect to time, but at the end it shows a little decreasing. From the graph we can see that the trend line shows there is increasing pattern in rain fall with respect to time, but at the end it shows a little decreasing. At the middle there are high amount of the rainfall then at the beginning and end. From this we concluded the amount of rain is a little at bega (autumn).

Table 2. The estimated trend value of rainfall in Gambella meteorological station in mm.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	63.25	63.79	64.32	64.84	65.35	65.85	66.34	66.83	67.31	67.77	68.23	68.68
2004	69.12	69.56	69.98	70.39	70.80	71.20	71.59	71.97	72.34	72.70	73.06	73.40
2005	73.74	74.07	74.38	74.69	75.00	75.29	75.57	75.85	76.12	76.37	76.62	76.86
2006	77.09	77.32	77.53	77.74	77.93	78.12	78.30	78.47	78.64	78.79	78.93	79.07

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	79.20	79.31	79.42	79.52	79.62	79.70	79.77	79.84	79.90	79.95	79.99	80.02
2008	80.04	80.05	80.06	80.05	80.04	80.02	79.99	79.95	79.90	79.85	79.78	79.71
2009	79.63	79.54	79.44	79.33	79.21	79.08	78.95	78.81	78.65	78.49	78.32	78.14
2010	77.96	77.76	77.56	77.34	77.12	76.89	76.65	76.40	76.15	75.88	75.61	75.32
2011	75.03	74.73	74.42	74.10	73.78	73.44	73.10	72.74	72.38	72.01	71.63	71.24
2012	70.85	70.44	70.03	69.61	69.17	68.73	68.29	67.83	67.36	66.89	66.40	65.91

This table indicates the estimated value of trend values of rainfall for ten years by using least square method and from the table the distribution of rainfall not so much different in a short period, but it shows a little change through time.

Applying the method of ratio moving average method to the series, we obtain seasonal indices for monthly rainfall amount in mm of Gambella meteorological station.

3.2.1. Estimation of Seasonal Variation

Table 3. The estimated seasonal indices of rainfall in mm.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	-	-	-4.39	.34	-1.38	-18.63	-27.20	--18.76	-18.97	-4.30	5.79	-13.06
2004	-17.17	-7.50	18.80	51.79	58.78	42.88	12.10	-7.86	-9.56	-21.52	-32.66	-39.67
2005	-47.98	-30.19	-9.24	-6.66	-5.62	-16.98	-25.89	-20.42	-2.72	7.65	-3.66	-17.01
2006	-33.27	-7.87	51.07	76.98	74.04	33.16	-20.94	-25.89	-12.26	-13.93	-24.25	-36.91
2007	-28.49	-1.60	26.90	46.80	37.97	18.82	2.94	-3.86	10.07	25.36	33.36	20.54
2008	-5.63	-15.05	2.55	27.76	48.57	56.65	57.01	57.28	47.13	28.43	-12.20	-48.84
2009	-57.42	-40.73	-17.89	-3.54	1.91	-10.89	-.80	28.28	39.29	34.18	6.82	-31.89
2010	-52.23	-41.92	-21.56	-11.94	-14.6	-29.20	-47.94	-37.99	-17.99	-5.43	2.76	-14.00
2011	-5.91	24.90	60.41	90.99	75.93	39.55	10.61	.15	-3.30	-10.87	-31.84	-57.1
2012	-62.76	-58.78	-23.46	13.66	18.01	25.73	4.80	-16.30	-7.81	-3.49	-	-

Seasonal index (1473.84, 8151.477, -350.127, 12075.105, -12387.342, -5969.62, 1489.873, 6448.523, -1007.6, -2721.941, 2618.143, 1159.49)

The table indicates the estimated values seasonal variations of rainfall. The table indicate to us the rainfall is increasing or decreasing with respect to time or its various from seasons to seasons especially in summer and spring (belg). There was proportionally high rainfall at the first three years and the last four years, but at the middle of the years there was relatively low rainfall.

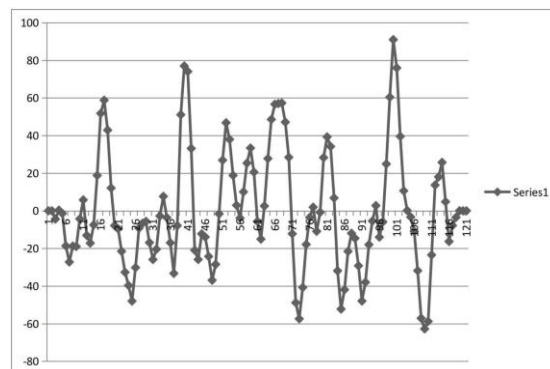


Figure 3. Graph of the seasonal indices of rainfall in Gambella meteorological station.

From the graph and the table, we can see that there was proportionally high rain fall at the first three years and the last four years, but at the middle years there was relatively low rainfall. The figure indicates to us the rainfall is increasing or decreasing with respect to time or its various from seasons to seasons especially in summer and spring (belg) there is high amount of rainfall this is why our graphs are increasing up at

the first three years and at the last of the years.

3.2.2. Estimation of Cyclical Variation

We can estimate cyclical variation using various methods. But, we consider only residual method.

Table 4. The estimated value of cyclical variation.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003					-13.07	-27.00	-48.64	-54.59	-39.44	-32.01	-31.73	-26.60
2004	-4.07	18.35	37.41	41.74	29.26	24.18	22.12	15.81	2.15	-8.03	-9.72	-11.22
2005	-9.05	-5.00	-1.80	3.63	9.48	8.10	4.33	-.27	-3.37	-5.39	-17.43	-20.05
2006	-16.92	-15.3	-10.51	-5.61	-.75	2.69	12.38	6.44	-8.15	-9.50	-8.72	-7.71
2007	-3.32	7.92	15.01	22.18	31.81	33.94	33.76	38.09	40.99	33.36	27.10	24.63
2008	24.30	26.35	30.72	31.96	28.18	20.42	5.07	-4.90	-10.65	-16.20	-23.12	-31.16
2009	-35.72	-31.5	-15.47	-6.07	.15	10.27	13.79	12.46	11.13	9.61	8.26	6.45
2010	.22	-8.06	-12.75	-12.70	-12.02	-7.64	-12.13	-17.28	-15.49	-16.98	-15.71	-14.53
2011	-13.35	-11.10	-.20	9.65	15.38	18.40	13.48	6.85	-.48	-10.89	-25.69	-39.09
2012	-36.62	-23.06	-16.42	-7.27	3.24	6.84	10.53	22.81				

The tables indicate to us the estimated value of rain is increasing or decreasing with the respect to time. The amount of rainfall is high in the middle of 2007 and 2008 and also high at the middle of the last year.

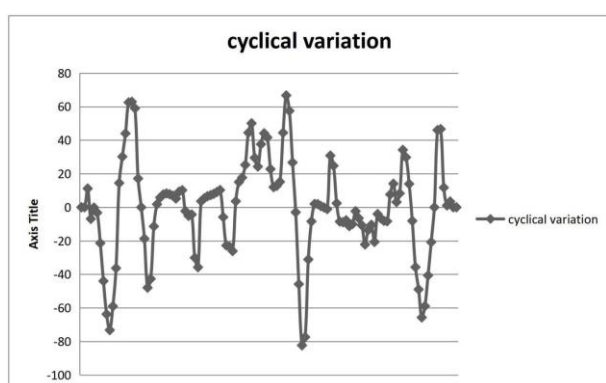


Figure 4. Cyclical variation.

The graph indicates to us the estimated value of rain is increasing or decreasing with the respect to time i.e its graph is cyclically up and down at the beginning, at middle and also near the last it cyclically up and down. The amount of rainfall is high near the beginning, at middle and high at the middle of the last years.

3.3. Forecasting

According to the study we got monthly forecasted rainfall amount of Gambella meteorological station for 2013 [14]. First checking stationarity of the data by using difference method and then we have got stationary time series data we see from the given graph. The graph shows there is no variability between the observation. From the box-Jenkins model we take the mixed model that is ARIMA (autoregressive integrated moving average) method with order of (p,d,q). As we said the observation have no difference (d=0) then the remaining of the model is ARMA(p,q).

3.3.1. Stationarity Checking Graph

$$Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \dots + \Phi_p Y_{t-p} + \epsilon_t - \theta_1 \epsilon_{t-1} - \theta_2 \epsilon_{t-2} - \dots - \theta_q \epsilon_{t-q}$$

That is autoregressive is order two and moving average is order four the difference is zero.

Then our model is given by: $Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \dots + \Phi_p Y_{t-p} + \epsilon_t - \theta_1 \epsilon_{t-1} - \theta_2 \epsilon_{t-2} - \dots - \theta_q \epsilon_{t-q}$

We have the estimated value of the parameters, Final Estimates of Parameters.

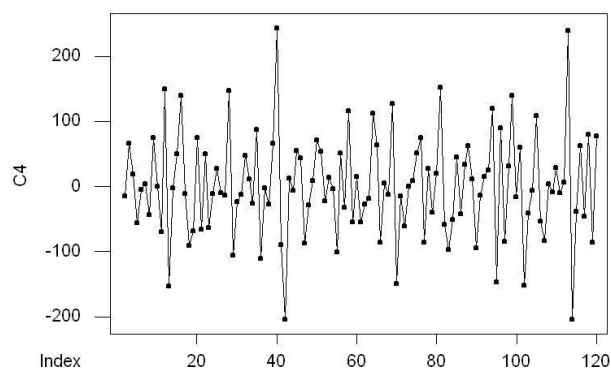


Figure 5. Stationarity checking graph. ARMA(p,q).

Table 5. Estimates of Parameters.

Type		Coef	SE Coef	T	P
AR	1	-0.2129	0.2891	-0.74	0.463
AR	2	0.2550	0.2722	0.94	0.351
MA	1	-0.4690	0.2764	-1.70	0.092

Table 6. Forecasted value of rainfall in Gambella meteorological station in mm.

2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
forecasted value	92.70	81.10	78.43	64.14	78.47	71.77	76.85	74.10	75.95	74.84	75.56	75.12

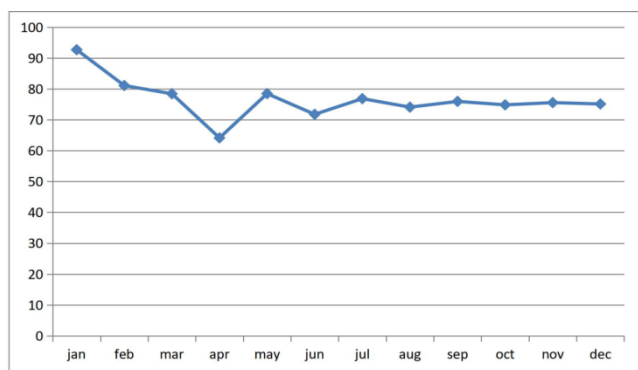


Figure 6. Forecasted value of rainfall in Gambella meteorological station in mm.

From the forecasted data we concluded that there will be a little decreasing at the beginning of the years and then it will be uniform beginning from May, the relation between the forecasted rainfall and the previous rainfall is almost similar behavior that is there is no difference. From the graph of forecasting, the future amount of the rainfall is not so much different from the previous amount of the rainfall. This indicate that there is a little change for rainfall in Gambella.

Type		Coef	SE Coef	T	P
MA	2	0.2709	0.2436	1.11	0.269
MA	3	0.3527	0.1142	3.09	0.003
MA	4	0.3206	0.0992	3.23	0.002

3.3.2. Test of Significance for the ARIMA Parameter

The values of the parameter $\Phi 1$, $\Phi 2$, $\phi 1$, $\phi 2$ are not significance, since α value is less than p-value then we ignored them as a result the model is formed by the remaining parameter [15].

$$Y_t = \varepsilon_t - 0.3527 \varepsilon_{t-3} - 0.3206 \varepsilon_{t-4}$$

The value of parameter $\phi 3$, and $\phi 4$ are significance, since p value is less than α value.

From the given model we forecast the 2013 rainfall of Gambella meteorological station in mm based on 2012 rainfall.

4. Conclusion

In this study, we have discussed time series analysis on monthly amount of rainfall in Gambella meteorological station. Before applying time series analysis firstly, we have tested whether the data is time dependent (not random) or time independent (random) by using turning point test. Moreover, the data seem to be time dependent.

After we measured different components of time series, first we tried to identify the characteristics of trend using the method of least square. Then we measured the seasonal variation by the method of simple moving average. As we see from Figure 3, there was lower rainfall in the middle of the given years and there was relatively higher rainfall. We also measured the cyclical variation of the data by using residual method. Finally, we tried to forecast the next year monthly rainfall amount in mm of Gambella meteorological station.

5. Recommendation

- 1) The rain fed agriculture in Gambella should be supple-

mented by rainfall. These are not sufficient for their development. Therefore, they should have to use irrigation in addition to the rainfall to achieve successive development in a few.

- 2) Since deforestation cause, the decreasing of rainfall every person of the zone should has to plant the trees in order to keep the air condition of their environment from the desert.
- 3) It is better for farmers to construct the terracing to conserve the soil from erosion as well as ploughing horizontally, when high amount of rainfall is raining. By doing this they can support the economy of the region and they can resist drought.

Abbreviations

AR	Autoregressive
MA	Moving Average
ARIMA	Autoregressive Integrated Moving Average

Conflicts of Interest

The authors declare no conflicts of interest.

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