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Development of Rainfall Empirical Models for Osun Watershed, Nigeria

J. J. Musa[1*] and M. A. Abubakar[1]

[1]*Department of Agriculture and Bioresources Engineering, Federal University of Technology, P.M.B 65, Minna, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to conduct a sequential detection for the possible trends in seasonal rainfall data series using various statistical packages. Farmers in Osun basin lack adequate planning with respect to agricultural activities for its maximum productivity as rainfall trends are often cited as one of the causes of socio-economic problems such as food insecurity. The available rainfall records provide information on monthly basis as obtainable from other meteorological stations nationwide. Rainfall records from 1980 to 2009 which were most consistent required for the development of rainfall models were used. A time series analysis was used to develop various models. The volume of rainfall within the study location was observed to fluctuate with December having the lowest amount of rainfall of 1.10 mm. The average rainfall was observed to be on the increase from the month of February through to the month of November with the highest amount of rainfall recorded in the month of September with an average rainfall of 556.60 mm. The polynomial equation was used to develop a best line of fit of $y = 1.4227x^3 - 29.502x^2 + 154.72x + 9.2348$ with a R Square value of 0.7541. A double maxima of June and September was observed while April which is used to be the beginning of the raining season tends. October which used to be the beginning of dry season was also observed to tend towards raining month. The linear, exponential growth and s-curve equation models of the forms $Y_t = 16141 + 84.5t$; $y_t = 15557.6 * (1.00676^t)$;

*Corresponding author: E-mail: johnmusa@futminna.edu.ng;

and $y_t = \frac{10^5}{\left(5.77969+3.26815(0.6591^t)\right)}$ were developed respectively. The data set were further decomposed and it was observed that there was a seasonal effect. The seasonal indices show the average downward movement within the first 3 months and the last 2 months of the season and average upward movements from the 4th to the 10th month. In conclusion the Linear model from this study proved to be the best for predicting rainfall events for the Osun watershed. It is therefore recommended that the Linear model be used to predict rainfall for the Osun watershed.

Keywords: Dry; empirical; rainfall; season; watershed; wet.

1. INTRODUCTION

Over decades now, the study of climate change has gained much importance because of its dynamic, complex nature and its influence on various sectors of our environment which includes the threat to global climate change. [1] stated in their finds that any change in any component or sector of the environment leads to change in the whole system and a fundamental component of the environment is climate. Thus, a change in the climate of an environment will affect every other component of that environment. Therefore, climate change can therefore no longer be described as a thing of the future but a process that is currently ongoing. It can therefore be said unequivocally that climate change is now a reality, and the adversities of this transformations will cause the greatest challenge facing the world today. To this end, scientists have shown that due to the increase in the concentration of greenhouse gases in the atmosphere, the climate is changing which affects its major components such as temperature, relative humidity and the amount of rainfall distribution. The report of [2,3] stated the last 100 year (1906 – 2005), a linear trend of average global surface temperature was in the range of 0.56 to 0.92℃ which is larger than the corresponding trend range of 0.4 to 0.8℃ for the years between 1901 and 2000. [4] stated that between the years 1900 and 2005, the world precipitation was found to either be increasing or decreasing in different parts of the world globally.

For accurate and good quality results, change in time and space requires long-term trend analysis which is dependent upon the available homogeneous data. Such data set are also affected by non-climatic factors such as changes in instruments, station location, station environment and so on make climate data unrepresentative of temporal climate variability [5].

There is a growing awareness across the world today as it concerns global warming with respect to changes in the various hydrological parameters as temperatures are increasing and will continue to increase for the next century. Different parts of the world are currently experiencing this change; the case of Osun watershed is therefore not an exception as such changes are responded to differently.

Weather forecasting in the last two decades has experienced a strong pattern towards probabilistic forecasts. This takes the form of probability distribution over future weather conditions [6]. Changes in weather conditions (such as temperature, quantity of rainfall, relative humidity, etc) has made weather forecasting paramount to every sector of the world. Some researchers have identified in their study the use of the multimodel analysis in probabilistic climate projections stated that complex models have been developed by several scientist to represent nonlinear climate systems through the use of computer simulations to forecast climate variables such as temperature, relative humidity, and precipitation over a given location or country [7,8,9,10]. Such developed models are known to have different level of uncertainties which are majorly grouped into three; this includes initial conditions, boundary conditions, and parameter uncertainties. To attend to these uncertainties can be complex and almost impossible.

Soft Computing and Statistical Techniques has been identified by some researchers that Multiple Linear Regression (MLR) can be to develop models for forecasting weather parameters which can forecast the weather condition for a particular area using the data collected from such areas [11]. From such data, statistical information is extracted in the time series. Inputs to the models to be developed are chosen based on the correlation of the statistically analyzed data from where the regression equations are developed. The data set are usually divided into two parts; one set to develop the MLR equations and the other set is used to test the developed model.

With the current turn of the Nigerian government from the production of crude oil as source of revenue to agriculture, the success or failure of harvest and water scarcity in any period of any year in the future must be considered greatly. Rainfall is an important sector of any economic in the development of a country's economy that mostly depend on agriculture. An integral percentage of the rural populace requires rain as a key for the growth of their agricultural activities. Osun basin whose economy is heavily dependent on productive rain fed agriculture, rainfall trends are often cited as one of the causes of socio-economic problems such as food insecurity. Consideration for irrigation activities in this part of the world is not prominent as most agricultural activities depend mainly on rain. A dry period is usually experienced as a result of good rainfall which can be for a long or short period of time which may affect the crop yield which take its turn on the economy of the nation.

The aim of this study is to conduct a sequential detection for the possible trends in seasonal rainfall data series using the various statistical packages. To also statistically establish the trend and distribution pattern of the annual rainfall regime for the study area and to develop empirical model which can be used for predicting rainfall and some other hydro-metrological information in the study area.

2. MATERIALS AND METHODS

2.1 Study Location

Osun State is located in the tropical rain forest zone of Nigeria which has a total land mass of approximately 14,875 sq km and lies between latitude 7°30′0″ and 7° 50' 0"N and longitude 4°30′0″ and 4°50' 0" E at an altitude of 353 meters above sea level. Though a landlocked State, it is has many rivers and streams which runs through her and serves the water needs of the State. The State is located within the tropical rain forest which in most cases experiences rainfall from March ending to November of the same year while the dry season starts from the month of January to the month of February. Thus, making the people in the area predominantly farmers.

2.2 Data Used

The most consistent and available rainfall records of 1980 to 2009 were collected from the Osun meteorological station. This record provided information on monthly rainfall amounts only, as is obtainable in most of the other meteorological stations nationwide. Older records before 1980 were not available as most had missing data from the Metrological Services Departments of the Federal Ministry of Aviation Oshodi Lagos State.

2.3 Rainfall Analysis

The analysis of the Osun 30 year rainfall data were sorted on monthly basis. The sorting of the data was made possible based on the identification and selection of all the annual rainfall values for the various selected durations (months). Rainfall amounts on monthly basis were calculated in millimeters.

2.4 Linear Regression (LR) Model

The linear regression (LR) model shows the variable Y which is thought to be a linear combination of one or more variables which is measured using the same unit [12]. Simple linear regression model are mostly of the form:

$$Y = b_0 + b_1 X \tag{1}$$

where X is the predictor variable and b_0 and b_1 is the unknown constant variables while the multi-linear regression model are mostly of the form. This equation is also called the mathematical model for linear regression.

2.5 Multi-linear Regression (MLR) Model

The MLR model is used to develop empirical equations for forecasting weather and other parameters which are known to have observed data set. This developed equation is capable of forecasting conditions for which the data set are provided for. The data is cleaned up to have the same statistical indicators which will be used to extract all hidden information which are present in the time series. [13] stated that these hidden information includes moving average (MA), exponential moving average (EMA), rate of change (ROC), oscillator (OSC), moments and coefficients of skewness and kurtosis can be determined over a certain period of time. The obtained empirical equations for the observed data set are then used to forecast the expected target of the modeler. The data is usually divided into two parts with the first used to obtain the equation and the remaining parts used to data are used to test the developed model. The MLR model consist of predictors which are expressed in powers of first, second and third orders to form the third-order polynomial model with the predictor variable.

The MLR model is mostly of the form

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \cdots \ldots \ldots \ldots \ldots + e \qquad (2)$$

where b_0, b_1, b_2 ,b_3 are regression coefficient and X_1, X_2 X_3 are the predictor or independent variable and e is unexplained part of the dependent variable with a zero mean and constant variance which is also called the error level of the equation.

According to [14], preliminary analysis of regression analysis for 30 year data was carried out to determine characteristics like moments and dependence structure of the data set. This was carried out to be able to evaluate randomness and trend pattern. In this regard, the time series plot was examined to establish whether there is any relationship as well as seasonal characteristics like trend and moments. The objective here is to evaluate seasonality in the moments. Analysis of dependence structure was done in time and frequency domains; basically through autocorrelation and spectral density, respectively. Building MLR model is an iterative process which involves finding effective independent variable to explain the process we are trying to model or understand.

2.6 Model Validation

The evaluation of the computer model involved in carrying out statistical analysis recommended by [15] to validate the model. These validations are:

2.7 Model Development

The rainfall data collected was from 1980 to 2009. The data collected were used to generate linear, quadratic, exponential growth and S-curve models of trend analysis modeler. The models were used to forecast data for years 2000 to 2009 and compared with the observed data. The best data that best compared with the original (observed) was used to forecast to the year 2030. The various models were developed using Minitab 16.0 software which is in line with the studies of [11].

3. RESULTS AND DISCUSSION

3.1 Rainfall Data Analysis

In this region of Nigeria, the fact that rain falls almost throughout the year, agricultural activities has been observed to be relatively slow and unrewarding. To make this a profitable venture, the rainfall data for the period of 1980 and 2009 years for Osun watershed was obtained from the metrological station at Oshogbo. It was observed that average annual rainfall for the period of study ranged between 926.33 mm and 1995.17 mm. Table 1 presents the average monthly and yearly rainfall for a period of 30 years. It can be seen from the table that the rainfall period per year spans through the months of February to November with the actual heavy down pour starting from April to October. This is typical of the zone and similar to the observations made by [16]. Though, within the years of observation some of the months had missing values. This rainfall pattern is influenced by the proximity of the study area to the Atlantic Ocean which is believed to bring in the rains into the inter-lands of Nigeria. The further away from the ocean the study location is the reduced the rain fall impact.

It was also observed from the table that the dry and wet season periods were carefully outlined to be between the months of February and November for the wet season while the months of December of the previous year to the January of the following year as the dry season. This also shows the seasonal cycle of the series which is not stationary. This is similar to the works of [17,18]. They studied the time series analysis for rainfall data of Jordan which they used as a case study for using time series. In their study, they tried to fit an ARIMA model stationary data in both variance and the required mean. In the case of [19], it was observed from their study which was centered on Statistical Study of Annual and Monthly Rainfall Patterns in Ekiti State, Nigeria showed that the monthly rainfall increased progressively from the months of February and decreased from the month of November-December paving way for the dry season to set in. A double maxima of June and September was observed while April which is used to be the beginning of the raining season is tending towards dry month and October that used to be the beginning of dry season is also tending towards raining month. This was also observed in this study most especially towards the later part of the years of study for the Osun basin. This shift according to [19] is known to have a significant impact on the ecosystem of the area and also its agricultural activities. It was observed from the table also that from the months of April, there was gradual increase in the amount of rainfall until it got to the pick where it was again observed to be declining in a gradual mode from the month of October. This can be stated as the general trend of rainfall pattern in the study area. From the Table 1, a trend was also observed over the 30 years data period that the volume of rain fall within the study location was observed to be fluctuating. In some of the years, it was observed that there were rainfalls during the early part of the year. Such years includes 1982, 1986, 1988, 1990, 1994, 1997, 2001, 2003, 2006, and 2009. This is similar to the works of [20]. Though not heavy, it was also observed from that the some of the years recorded some amount of rainfall during the month of January. Nineteen eighty two was observed to have recorded the lowest average rainfall of 926.33 mm while 1985 had the highest rainfall amount of 1995.17 mm. The average rainfall was observed to be on the increase from the month of February through to the pick months of between July and September after which a recession was observed to start occurring. The polynomial equation was used to develop a best line of fit of $y = 1.4227x^3 - 29.502x^2 + 154.72x + 9.2348$ with a R Square value of 0.7541. This result is similar to the works of [21]. Fig. 1 shows the best line of fitness for the average monthly rainfall data for the study period of 30 years.

3.2 Statistical Analysis

Several statistical method are currently being employed by researchers to enable them determine some basic information from data sets. Some of which have employed such methods to forecast several hydrological parameters, such researchers include [22,23,16, 24,25,26,20,14] etc.

The observed total annual rainfall data was statistically analyzed using Minitab 16.0 and Microsoft Excel 2013 to determine the Mean, Median, Standard Deviation (SD), Minimum, Maximum and the Skewness values of the observed data. The Mean, Median, Standard Deviation (SD), Minimum, Maximum and the Skewness values are presented in Table 1. The Minitab 16.0 was used develop the Linear, Exponential Growth and S-curve models. The data were trained for the first twenty year for a period of 1980 to 1999 to develop the models. Table 2 shows the developed empirical models for the average yearly rainfall.

The developed empirical models were used to develop new sets of corresponding forecasted values, a forecast for the ten years of 2000 to 2009 was developed and the values compared with the actual observed data. Figures 2 and 3 show compression of the determined various values of the developed model for both average annual rainfall and average monthly rainfall.

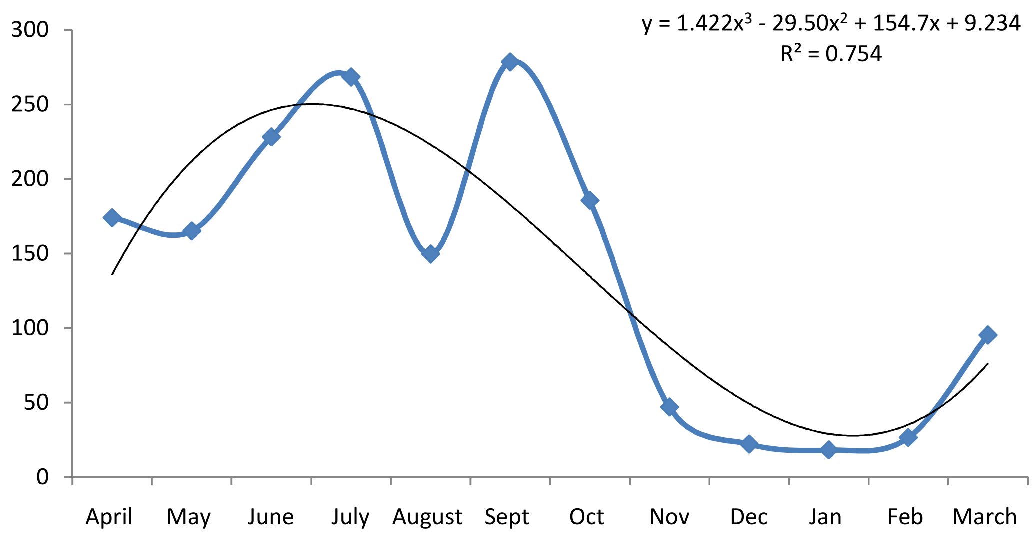

Fig. 1. Graph of annual rainfall against the average total numbers of months under consideration for a period of 30 years

Table 1. Average yearly rainfall distribution for Osun watershed (mm)

Year	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	March	Annual rainfall
1980	188.50	133.70	278.20	186.00	404.90	348.20	303.80	52.00	21.90	4.30	50.50	127.00	2099.00
1981	140.20	165.90	253.20	209.90	150.30	183.00	132.60	49.70	22.00	4.20	5.10	98.50	1414.60
1982	28.50	165.40	158.90	156.10	44.70	185.60	186.40	14.50	22.00	9.60	101.40	60.50	1133.60
1983	74.90	158.50	282.60	129.40	45.30	312.10	80.20	46.90	22.00	4.10	17.80	38.70	1212.50
1984	121.20	284.60	271.00	232.40	165.20	156.10	40.10	39.50	11.00	4.20	1.40	171.20	1497.90
1985	513.30	410.70	259.80	335.40	285.00	206.50	86.20	32.00	6.50	4.10	41.90	212.80	2394.20
1986	41.60	211.10	271.90	170.60	102.20	256.90	132.30	23.40	6.10	4.60	125.40	190.70	1536.80
1987	91.20	86.60	140.80	244.40	355.10	230.70	263.20	0.80	6.60	4.20	32.10	145.40	1601.10
1988	193.80	240.40	223.40	141.70	101.40	301.70	244.80	27.70	29.70	3.70	92.30	93.90	1694.50
1989	200.70	245.10	230.00	300.30	210.50	158.90	124.20	23.60	42.80	4.10	46.80	115.00	1702.00
1990	140.90	121.00	197.20	210.40	115.50	277.30	150.00	76.00	55.80	12.10	1.20	143.10	1500.50
1991	295.30	204.20	281.30	552.20	223.60	309.60	204.90	71.60	12.60	6.10	55.30	171.20	2387.90
1992	96.70	196.10	223.90	185.00	52.00	488.20	131.40	67.10	9.10	6.20	4.90	74.90	1535.50
1993	100.10	152.40	195.30	477.00	219.40	351.20	88.30	90.30	5.60	18.80	34.60	121.00	1854.00
1994	186.20	192.70	263.30	584.20	269.40	219.10	165.90	39.20		31.30	50.90	74.50	2076.70
1995	130.70	124.60	407.50	251.30	319.40	348.80	344.30	36.60		18.40	49.80	101.00	2132.40
1996	187.20	187.40	236.00	236.80	190.90	302.20	175.00	1.60		5.40	93.20	141.30	1757.00
1997	219.40	219.50	276.40	71.90	76.20	230.10	187.70	23.70	23.70	27.60	58.20	70.80	1485.20
1998	180.90	228.50	254.60	210.90	14.80	241.40	332.30	63.80		15.40	23.20	36.20	1602.00
1999	132.00	120.50	236.10	335.10	170.20	253.20	259.30	63.80		3.20	21.20	69.20	1663.80
2000	187.60	124.80	384.30	169.40	196.00	216.30	176.30	23.40		7.20	16.50	87.20	1589.00
2001	253.30	219.40	199.00	333.20	91.10	274.80	66.40	56.60	1.10	11.10	14.10	84.70	1604.80
2002	175.40	98.80	264.90	294.40	237.60	148.40	125.20	89.90		13.70	11.70	124.30	1584.30
2003	297.50	111.10	193.20	61.00	81.40	556.60	184.00	123.20		16.30	12.70	53.80	1690.80
2004	173.90	171.60	207.90	171.90	170.40	354.10	197.40	37.40		4.80	78.20	49.20	1616.80
2005	108.60	248.20	298.30	314.60	30.10	278.20	142.40	38.40	17.00	21.80	12.10	161.40	1671.10
2006	119.20	161.00	153.10	188.80	237.60	300.50	153.20	24.00		38.80	32.80	120.90	1529.90
2007	86.50	133.00	164.20	306.50	201.20	255.00	186.10	16.80		32.10	26.50	90.00	1497.90
2008	221.60	122.50	175.20	424.20	164.80	209.40	218.90	9.50	48.40	28.70	31.80	136.20	1791.20
2009	151.50	242.90	207.10	411.30	201.20	255.00	186.10	16.80		25.30	37.10	130.00	1864.30
MEAN	174.00	165.19	228.16	268.44	149.70	278.58	185.63	46.97	22.17	18.20	26.49	95.26	1690.71
MEDIAN	173.90	133.00	207.10	306.50	170.40	255.00	184.00	37.40	17.00	16.30	21.20	90.00	
S. D	61.24	55.40	65.27	108.45	76.62	101.01	66.79	34.09	24.07	11.28	18.49	39.28	
MIN	86.50	98.80	153.10	61.00	14.80	148.40	66.40	9.50	1.10	3.20	11.70	36.20	
MAX	297.50	248.20	384.30	424.20	237.60	556.60	332.30	123.20	48.40	38.80	78.20	161.40	
SKEWNESS	0.61	0.47	1.30	-0.35	-0.71	2.02	0.57	1.10	0.92	0.41	2.21	0.08	

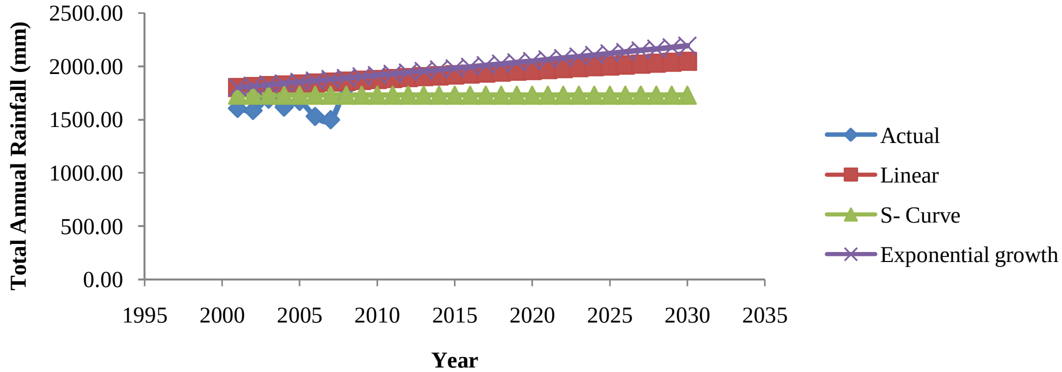

Fig. 2. Compression of the various forecasted values with the actual observed average annual rainfall

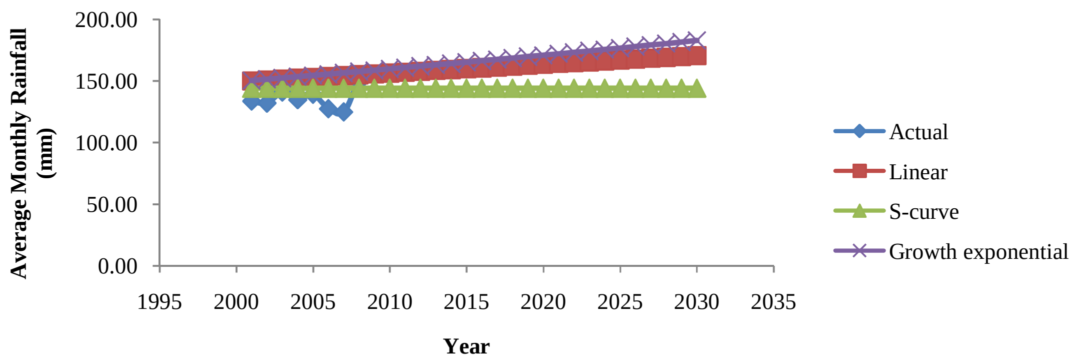

Fig. 3. Compression of the various forecasted values with the actual observed average monthly rainfall

The data set were further decomposed and it was observed that there was a seasonal effect. This was discovered because of the cyclic nature of the graph as presented in the appendix. Thus the de-trended data and seasonally adjusted data were observed to be different the original observations from the data set. This is in conformity with the works of [14].

For the rainfall data, the chart of the seasonal indices shows the average downward movement within the first 3 months and the last 2 months of the season and average upward movements from the 4th to the 10th month. The chart of percent variation by season shows that the 1st month has the least variation and the 3rd month has the most variation. This is similar to the works of [1]. When the data was de-trended by season, it was observed that the 1st, 2nd, 6th, 9th, 11th and 12th months where the absolute value of the seasonal effect was largely felt while the 3rd, 4th, 5th, 7th and 8th months had less variation.

It was also observed that because of the de-trended data and also the seasonally adjusted data which looked slightly different from the original observations, it can be conclude that a trend component and a seasonal component were present in the data. The residuals graph shows that the fitted values are under predicted in part of the second and last annual cycle (the graph exhibits large positive residuals in these regions) this similar to the works of [27].

The linear model was observed to have a steadily increasing predicted value which in real life may not be visible as rainfall values do not increase geometrically. The S-Curve model gave an almost steady and common value (amount) of rainfall for the study area. The exponential growth model had the predicted values for thirty years to be cyclical in nature which is a clear reflection of the study area. Tables 3 and 4 show the comparison of the average measured and forecasted values for the various empirical models developed for a period of ten years.

Table 2. Developed average yearly rainfall empirical model

S/no	Name of equation	Developed empirical model
1	Linear	$y_t = 16141 + 84.5t$
2	Exponential growth	$y_t = 15557.6 * (1.00676^t)$
3	S-curve	$y_t = \frac{10^5}{(5.77969 + 3.26815(0.6591^t))}$

Table 3. Observed and forecasted values for a period of thirty years for total annual rainfall

Year	Actual	Linear	Exponential growth	S- curve
2001	16048	18000.10	18041.52	17300.95
2002	15843	18084.60	18163.41	17301.30
2003	16908	18169.11	18286.12	17301.53
2004	16168	18253.61	18409.65	17301.68
2005	16711	18338.11	18534.03	17301.78
2006	15299	18422.61	18659.24	17301.84
2007	14979	18507.12	18785.30	17301.88
2008	17912	18591.62	18912.21	17301.91
2009	18643	18676.12	19039.98	17301.93
2010		18760.62	19168.61	17301.94
2011		18845.13	19298.11	17301.95
2012		18929.63	19428.48	17301.96
2013		19014.13	19559.74	17301.96
2014		19098.63	19691.88	17301.96
2015		19183.14	19824.92	17301.97
2016		19267.64	19958.85	17301.97
2017		19352.14	20093.69	17301.97
2018		19436.64	20229.44	17301.97
2019		19521.15	20366.11	17301.97
2020		19605.65	20503.70	17301.97
2021		19690.15	20642.22	17301.97
2022		19774.65	20781.67	17301.97
2023		19859.16	20922.07	17301.97
2024		19943.66	21063.42	17301.97
2025		20028.16	21205.72	17301.97
2026		20112.66	21348.98	17301.97
2027		20197.17	21493.21	17301.97
2028		20281.67	21638.42	17301.97
2029		20366.17	21784.60	17301.97
2030		20450.68	21931.78	17301.97

Table 4. Observed and forecasted values for a period of thirty years for average monthly rainfall

Year	Actual	Linear	S-curve	Growth exponential
2001	1337.33	1500.01	1441.75	1503.46
2002	1320.25	1507.05	1441.78	1513.62
2003	1409.00	1514.09	1441.79	1523.84
2004	1347.33	1521.13	1441.81	1534.14
2005	1392.58	1528.18	1441.82	1544.50
2006	1274.92	1535.22	1441.82	1554.94
2007	1248.25	1542.26	1441.82	1565.44
2008	1492.67	1549.30	1441.83	1576.01
2009	1553.58	1556.34	1441.83	1586.66
2010		1563.39	1441.83	1597.38
2011		1570.43	1441.83	1608.18
2012		1577.47	1441.83	1619.04
2013		1584.51	1441.83	1629.98
2014		1591.55	1441.83	1640.99
2015		1598.60	1441.83	1652.08
2016		1605.64	1441.83	1663.24

Year	Actual	Linear	S-curve	Growth exponential
2017		1612.68	1441.83	1674.47
2018		1619.72	1441.83	1685.79
2019		1626.76	1441.83	1697.18
2020		1633.80	1441.83	1708.64
2021		1640.85	1441.83	1720.18
2022		1647.89	1441.83	1731.81
2023		1654.93	1441.83	1743.51
2024		1661.97	1441.83	1755.28
2025		1669.01	1441.83	1767.14
2026		1676.06	1441.83	1779.08
2027		1683.10	1441.83	1791.10
2028		1690.14	1441.83	1803.20
2029		1697.18	1441.83	1815.38
2030		1704.22	1441.83	1827.65

4. CONCLUSION

The trend analysis of rainfall for Osun basin for the different season were elaborated by the various statistical methods employed. The results showed that in 30 years there had been a gradual increase in the amount of rainfall within the study location. The difference observed in the monthly data showed that there was composite nature in some of the years which was mixed with the wet and dry years which occurred in all seasons. The time series data were examined for fluctuations and trends which depended on the data collected for the 1980 - 2009 period. It was established from the results of the analysis that there was a shift in the beginning and ending of the various seasons that were identified.

Three statistical models of linear, exponential growth and S-Curve were developed, of which the exponential growth equation proved to be the model which forecasts rainfall for the study area best. The delay in rainfall till March has supported the actions of the cattle nomads in engaging in grazing activities and incessant bush burning while the farmers in most local areas do not help matters as they are also involved in the uncontrolled bush burning thereby setting most of the tree crop plantations ablaze causing deforestation and environmental degradation. The high rainfall amount in October might have serious agricultural implications as late grains (e.g. maize, beans), early yam planting, cocoa pods and other farm products are adversely affected by heavy rainfall of August.

The developed model will be very useful if put to use by the relevant agencies in predicting rainfall for the study area most especially in the redesigning of seasonal management of agricultural activities, flood control, constructions and water resources design and maintenance. Thus it is paramount to educate the local farmers on the need to be informed on about rainfall activities and proposed government intervention programmes on reducing dependence on rain-fed agriculture and as they are also known to take into cognizance the recent changes in climate. In conclusion the linear model from this study proved to be the best for predicting rainfall events for the Osun basin.

It is therefore recommended that the Linear model developed can be used to predict rainfall for this watershed as it was found to be most adequate in its prediction.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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