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PREDICTING SHORT TERM RAINFALL OVER ABUJA USING THE WEATHER PREDICTION MODELS SINGLE MOVING AVERAGE (SMA) AND SIMPLE EXPONENTIAL SMOOTHING (SES).

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Abstract

The study investigated the prediction of rainfall over Abuja using weather prediction models Single Moving Average (SMA) and Simple Exponential Smoothing (SES). In order to achieve the aim of the study, a research objective was used; predict short term rainfall using the SMA and SES models. Secondary data was obtained from Nigerian Metrological Agency (NIMET) Abuja for period of 30years (1990 – 2020) on rainfall over Abuja. From the outcome of the study, it was concluded that there was no significant difference observed rainfall value and SMA(n=2) forecast value in 2006 -2021, and the model predicted the average rainfall of 119.13 mm rainfall value for the year 2021. The result of the study also disclosed that the rainfall forecast of the SMA-model with period 3 within 1990-2021. The trend further reveals that there are no significance differences between the observed rainfall value and SMA(n=3) forecast value within the year 1990-2021, with predicted rain 119.66 mm rainfall value for the year 2021. It could be concluded that the Single Moving Average n=2 predicted better compare to other prediction models. The study hereby recommends among others that; agencies in charge of weather forecast should look into the use of SMA with order n=2 as an alternative model; Government should be encourage to effectively use the models for prediction in term of decision making on issues involving agricultural activities.

Keywords: *Predicting Short, Rainfall, Abuja, Weather Prediction Models, Single Moving Average (SMA) and Simple Exponential Smoothing (SES).*

Introduction

Rainfall has a profound impact on agriculture, air and road transport, hydroelectric power generation, construction, water resources, among others. Normal rainfall is beneficial for agriculture and other economic activities. However, when it is excessive, it may result in flooding and the associated negative impacts. Also the effects of below normal amount of rainfall are also not desirable. The past droughts over West Africa affected the economy, agriculture, livestock and human population (Mahmud *et al*., 2016). The timely information in seasonal rainfall prediction is therefore vital for planning and decision making in these key sectors of the economy. Apart from its relevance to life, tropical rainfall is also important for global climate and weather. Over two thirds of global precipitation falls in the tropics (Semire *et al*., 2012). A notable feature of tropical rainfall is its interannual variability, which on occasions can lead to prolonged dry (drought) and wet (flood) periods. Many studies have established a correlation between SST and rainfall in Africa (Offorha *et al.*, 2018).

Precipitation forecast especially during the onset period is not a very easy task for weather forecasters owing to the fact that rainfall is a dichotomous weather variable. Numerical weather prediction models have been used since 1946 to forecast precipitation and other atmospheric variables. The use of these NWP models has led to a considerable advancement in precipitation forecasting. This is largely due to the horizontal grid spacing of a few kilometers of these NWP models expected to reduce further in the coming years. Accurate precipitation forecast is very important considering the fact that extreme rainfall events could lead to devastating effects such as flooding, aviation hazards amongst others.

The onset dates are the most critical. Reliable prediction of onset time will greatly assist on-time preparation of farmlands, mobilization of seeds/crops, manpower and equipment and will also reduce the risks involved in planting/sowing too early or too late. Predicting the start of the rains in West Africa is a very challenging task because of the irregularities in the rainfall distribution, both in time and in space. Prediction methods have been proposed, some based on rainfall data alone (Sule, 2015; Marel *et al.*, 2018).

Weather forecasting (especially rainfall) is one of the most important and challenging operational tasks carried out by meteorological services all over the world. It is furthermore a complicated procedure that includes multiple specialized fields of expertise. Researchers in this field have separated weather forecasting methodologies into two main branches in terms of numerical modeling and scientific processing of meteorological data. The most widespread techniques used for rainfall forecasting are the numerical and statistical methods. Even though researches in these fields are being conducted for a long time, successes of these models are rarely visible. There is limited success in forecasting the weather parameters using the numerical model (Neelam *et al.*, 2018). The accuracy of the models is dependent upon the initial conditions that are inherently incomplete. These systems are not able to produce satisfactory results in local and short-term cases.

Rainfall prediction is one of the most important and challenging task in the modern world. In general, climate and rainfall are highly non-linear and complicated phenomena, which require advanced computer modeling and simulation for their accurate prediction (Akpanta *et al*., 2015). Rainfall in Nigeria falls within a distinct period (Offorha *et al.*, 2018). These periods vary from the northern part to the southern part of the country because of their relative distance from the Atlantic Ocean.

Rainfall starts earlier and ceases late in the southern parts while it starts late and ceases earlier in the north. The onset month in the south varies between March and April while the cessation month is October. In the North, however, rainfall starts in May and ends in September (Adeniyi, 2014). There is rainfall occurrence all over the country during June to September. However, in August, there is a period of little dry season in the southern part of the country (Oladejo and Abdullahi, 2013). Overall two rainfall peaks occur in the south whereas only one rainfall peak occurs in the north. This makes the climate to be humid in the south with annual rainfall over 2000 mm and semi-arid in the north with annual rainfall less than 600 mm (Offorha *et al.*, 2018)

Generally, agriculture in Nigeria has been receiving unprecedented attention especially with the fall in crude oil revenue in recent years. It is the most important sector of Nigeria's economy providing employment for over 70% of the labour force. In particular, Abuja, which is the Federal Capital Territory of Nigeria. The locals are predominantly farmers and the people usually experience heavy rainfall for the better part of the year (Wiki, 2017). In order to sustain the tempo and ensure that food is on the table of the average Nigerian, adequate scientific measures should always be put in place. In this regard, the effect of a good knowledge of not only the amount but also the frequency of rainfall cannot be overemphasised since over 80% of the farmers still rely on rainfall.

It is apparent that many studies have been carried out on rainfall prediction in Nigeria (Olatayo and Taiwo, 2014; Christian and Ikpang, 2015; Akinbobola *et al*., 2018). Also based on the literatures reviewed, no research work has compared the single moving average and simple exponential smoothing models, and determined the suitability of single moving average model to rainfall prediction of over Abuja. This present study intends to bridge these gaps. It is therefore to close this gap that this work sets out to juxtapose the single moving average and simple exponential smoothing method on the updated data on the frequency of rainfall in Abuja.

Methods

The method of this study involved numerical prediction of rainfall data over Abuja. The study relied mainly on secondary data. Therefore, rainfall data that spanned 30 years from (1990 -2020) were sourced from the archival records of the Nigerian Meteorological Agency (NIMET), Abuja, Nigeria. The methods of data analysis used to achieve the objective of the study is both moving average model and simple exponential smoothing models. The data was analyzed by testing for the presence of unit root in the time series data, presentation of the trend line equation, i.e., linear trend equation, quadratic trend equation and their related graphs with the use of R Statistical Software.

Single Moving Average Model: The moving average method involves calculating the average of observations and then employing that average as the predictor for the next period. The moving average method is highly dependent on n, the number of terms selected for constructing the average (Kitani *et al*., 2012). The equation is as follows:

$$F_{t+1} = (Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3} + \cdots Y_{t-n+1})/n \quad (1)$$

Where:

F_{t+1} = the forecast value for the next period

Y_t = the actual value at period t

n = the number of term in the moving average

The optimal n value can be determine by interactive model that the smallest error. In some method the general approach has been to use MSE (Ismail and Shabr, 2014). In this study, the value of n taking 2, 3 and 4.

Simple exponential smoothing model: The exponential smoothing method is a technique that uses a weighted moving average of past data as the basis for a forecast. This method keeps a running average of demand and adjusts it for each period in proportion to the difference between the latest actual demand figure and the latest value of the average (Atsalakis and Valavanis, 2011). The equation for the simple exponential smoothing model is:

$$F_{t+1} = \alpha Y_t + (1-\alpha)F_{t-1} \quad (2)$$

Where:

F_{t+1} = the new smoothing value or the forecast value for the next period

α= the smoothing constant ($0 < \alpha < 1$)

Y_t = the new observation or actual value of the series in period t

F_t = the old smoothed value or forecast for period t

The accuracy of the simple exponential smoothing method strongly depended on the optimal value of (α). The preferred range for α is from 0.1 to 0.3. In this study, the value of α taking 0.1, 0.2 and 0.3.

Results

The organization of data for the study was achieved with the collection of 30 years' monthly rainfall distribution data range from (1990 -2020), from the archival records of the Nigerian Meteorological Agency (NIMET), Abuja, Nigeria. The data was sorted and presented in an excel sheet before being processed and subjected to time series analysis.

Prediction of short-term rainfall using the single moving average model and simple exponential smoothing models

Single Moving Average (SMA) Model of Rainfall Distribution Over Abuja

The moving average method involves calculating the average of observations and then employing that average as the predictor for the next period. The optimal n value of n taking are 2, 3 and 4. The SMA forecast trend of the rainfall distribution over Abuja, taking n= 2, 3 and 4 are shown in Figure 2.1 -2.3 respectively.

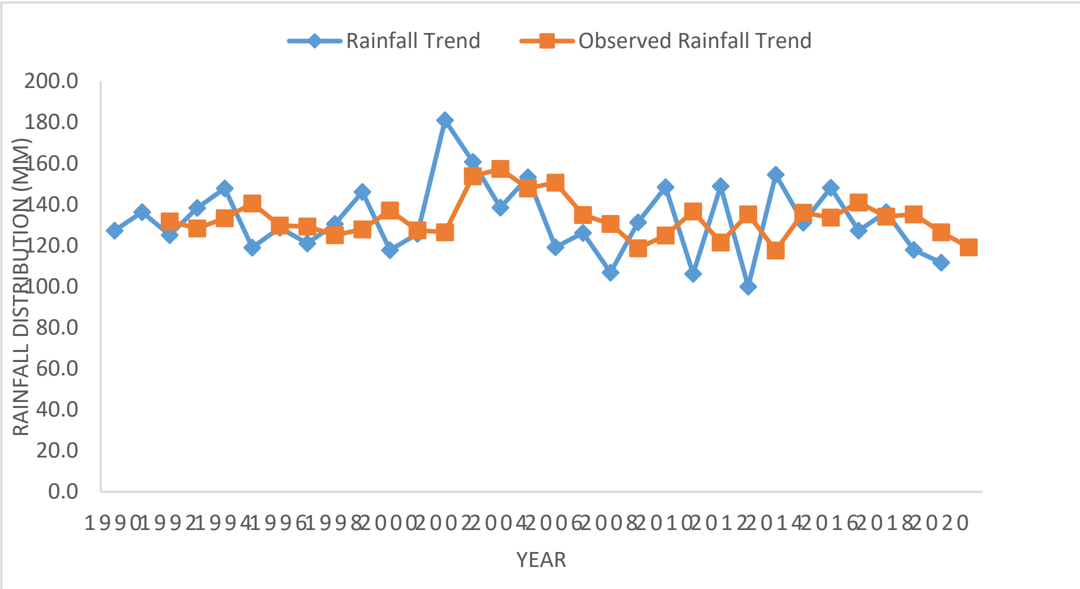


Figure 2.1: SMA- (2ma) Forecast Trend of Rainfall Distribution Trend Over FCT Abuja (1990-2020)

The figure 2.1 disclosed that rainfall forecast of the SMA- model with periods within 1990-2021. The trend further reveals that there are significance differences between the observed rainfall value and SMA(n=2) forecast value within the year 1990 – 2005; while there are no significance difference observed rainfall value and SMA(n=2) forecast value in 2006 -2021. The SMA(n=2) model further predicted the average rainfall of 119.13 mm rainfall value for the year 2021.

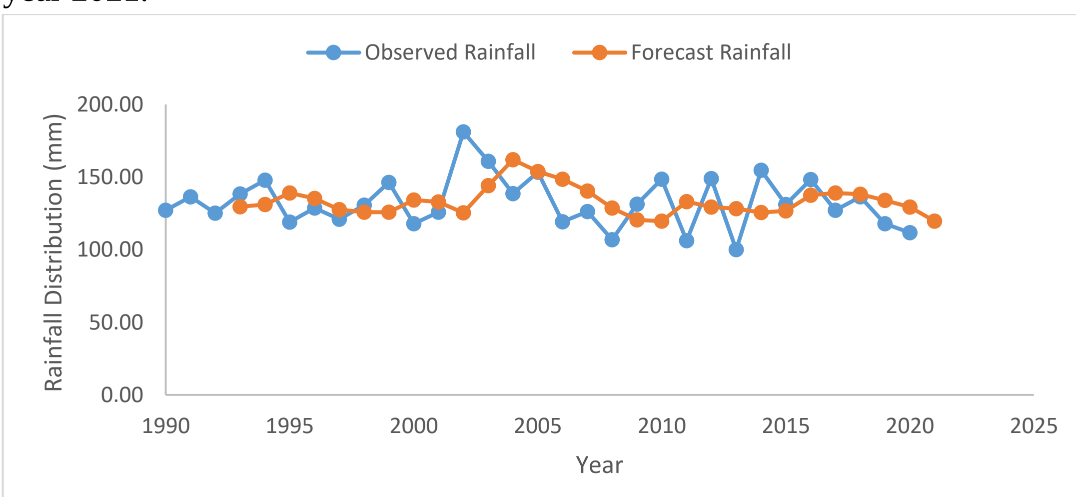
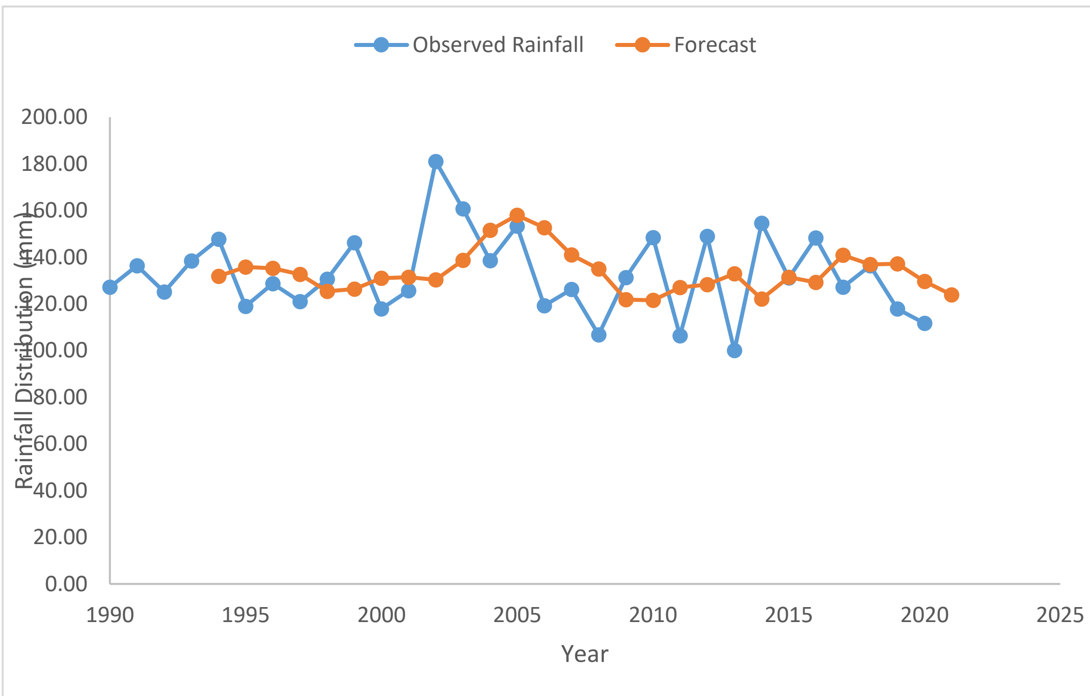


Figure 2.2: SMA- (3ma) Forecast Trend of Rainfall Distribution Trend Over FCT Abuja (1990-2020)

The figure 2.2 unveiled the rainfall forecast of the SMA- model with period 3 within 1990-2021. The trend further reveals that there are no significance differences between the observed rainfall value and SMA(n=3) forecast value within the year 1990-2021, although the correlation value of 0.018 indicate a weak relationship trend. The SMA(n=3) model further predicted the rain 119.66 mm rainfall value for the year 2021.

Figure 2.3: SMA- (4ma) Forecast Trend of Rainfall Distribution Trend Over FCT Abuja



(1990-2020)

The figure 2.3 disclosed the rainfall forecast of the SMA- model with period 4 within 1990-2020. The trend further reveals that there are significance differences between the observed rainfall value and SMA(n=4) forecast value within the year 2012-2014, while between 2015 – 2020 there are no significance difference. The correlation value of - 0.046, shows that on average the SMA (n = 4), weak negative relationship. The SMA(n=4) model further predicted the rain 123.89 mm rainfall value for the year 2021.

Simple exponential smoothing model of Rainfall Distribution Over Abuja

The accuracy of the simple exponential smoothing method strongly depended on the optimal value of (α). The preferred range for α used in this study, are 0.1, 0.2 and 0.3. The SES forecast trend of the rainfall distribution over Abuja, taking α = 0.1, 0.2 and 0.3are shown in Figure 2.4 -2.6 respectively.

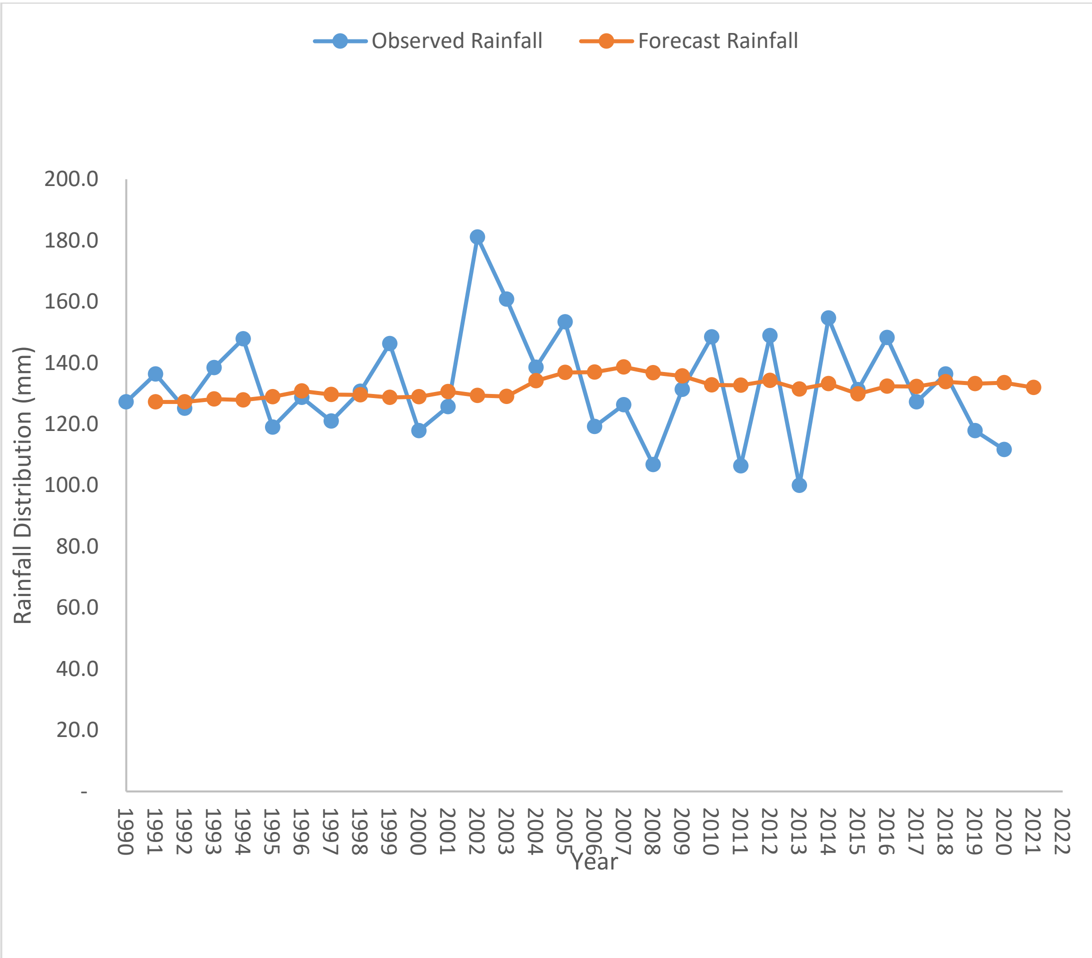


Figure 2.4: SES- (α-0.1) Forecast Trend of Rainfall Distribution Trend Over FCT Abuja (1990-2020)

The figure 2.4 disclosed the rainfall forecast of SES- model with α-0.1. The trend further reveals that there are no significance differences between the observed rainfall value and SES- (α-0.1) forecast value within the year 1900-2001, while between 2015 – 2021 there are significance difference. The SES-(α-0.1) model further predicted the rain 129.89. mm rainfall value for the year 2021.

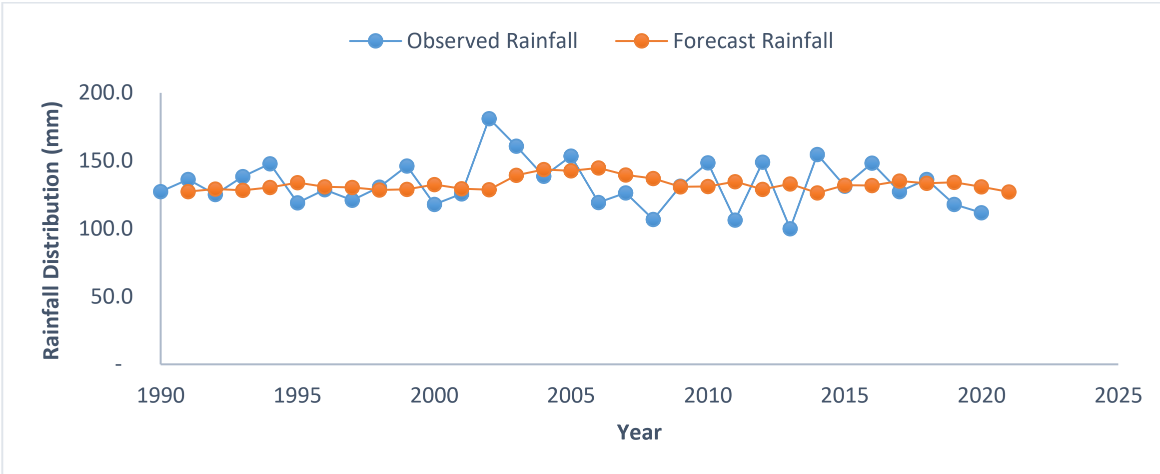


Figure 2.5: SES- (α-0.2) Forecast Trend of Rainfall Distribution Trend Over FCT Abuja (1990-2020)

The figure 2.5 disclosed the rainfall forecast of the SES- model with α-0.2 within 1990-2020 respectively. The trend further reveals that there are significance differences between the observed rainfall value and SES- (α-0.2) forecast value within the year 2009-2014, while between 2015 – 2020 there are no significance difference. The SES- (α-0.2) model further predicted the rain 101.61 mm rainfall value for the year 2021.

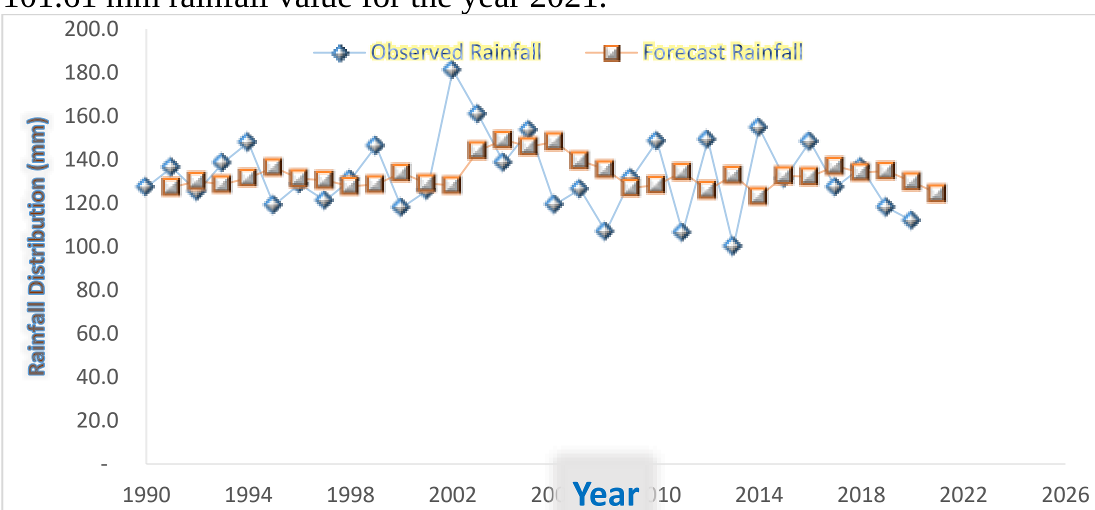


Figure 2.6: SES- (α-0.3) Forecast Trend of Rainfall Distribution Trend Over FCT Abuja (1990-2020).

The figure 2.6 disclosed the rainfall forecast of the SES- model with α-0.2 within 1990 – 2020. The trend further reveals that there are significance differences between the observed rainfall value and SES- (α-0.3) forecast value within the year 1990 – 2014, while between 2015 – 2021 there are no significance differences. The SES- (α-0.3) model further predicted the average rainfall of 124.278 mm rainfall value for the year 2021.

Discussion of Results

The results of the study unveiled that the rainfall forecast of the SMA- model with period 2 within 1990-2021, and the results revealed that there are no significance difference observed rainfall value and SMA(n=2) forecast value in 2006 -2021. And the model predicted the average rainfall of 119.13 mm rainfall value for the year 2021.

The trend further reveals that there are no significance differences between the observed rainfall value and SMA(n=3) forecast value within the year 1990-2021, with the correlation value of 0.018 indicate a weak relationship trend. The SMA(n=3) model further predicted the rain 119.66 mm rainfall value for the year 2021.

The trend further reveals that there are significance differences between the observed rainfall value and SMA(n=4) forecast value within the year 2012-2014, while between 2015 – 2020 there are no significance difference. The SMA(n=4) model further predicted the rain 123.89 mm rainfall value for the year 2021. Similarly, the trend further reveals that there are no significance differences between the observed rainfall value and SES- (α-0.1) forecast value within the year 1900-2001, while between 2015 – 2021 there are significance difference. The SES- (α-0.1) model further predicted the rain 129.89. mm rainfall value for the year 2021.

The trend further reveals that there are significance differences between the observed rainfall value and SES- (α-0.2) forecast value within the year 2009-2014, while between 2015 – 2020 there are no significance difference. The model further predicted the rain 101.61 mm rainfall value for the year 2021. It was obtained that the rainfall forecast of the SES- model with α-0.2 within 1990 – 2020. And also the SES- (α-0.3) model further predicted the average rainfall of 124.278 mm rainfall value for the year 2021.

The outcome of the study also unveiled the comparism between the forecast trend of the rainfall distribution over Abuja, models SMA(n=2) with each forecast of SES α-0.1,0.2, 0.3. The result disclosed that the rainfall forecast of the SMA- 2 and SES- (α-0.1) forecast value within the year 1991-2021. A p-value of 0.46 indicate that there is no significant difference between SMA- 2 and SES- (α-0.1) forecast value within the year 1991-2021. Similarly, the rainfall forecast of the SMA- 2 and SES- (α-0.2) forecast. A p-value of 0.86 indicate that there is no significance difference between SMA- 2 and SES- (α-0.2) forecast value within the year 1991-2021. The result also disclosed that the rainfall forecast of the SMA- 2 and SES- (α-0.3) within 1991-2021 respectively.

P-value of 0.93 indicate that there is no significant difference between SMA- 2 and SES- (α-0.2) forecast value within the year 1991-2021.
The result disclosed that the rainfall forecast of the SMA- A and SES (α - 0.1) within 1991-2021 respectively, p-value of 0.55 indicate that there are no significance difference between SMA- 2 and SES- (α-0.2) forecast value within the year 1991-2021. Similarly, p-value of 0.89 indicate that there are no significance difference between SMA- 2 and SES- (α-0.2) forecast value within the year 1991-2021. Outcome of the study also revealed p-value of 0.97 indicate that there are no significance difference between SMA- 2 and SES- (α-0.3) forecast value within the year 1991-2021. Outcome of the findings on that the rainfall forecast of the SMA- 3 and SES- (α-0.3). The differences between the SMA- 4 and SES- (α-0.3) forecast value. P-value of 0.47 indicate that there are no significance difference between SMA- 2 and SES- (α-0.3) forecast value within the year 1991-2021.
The outcome of the result of the rainfall forecast of the SMA- 3 and SES- (α-0.3). The p-value of 0.83 indicates that there are no significance differences between SMA- 2 and SES- (α-0.3) forecast value within the year 1991-2021. Also the findings disclosed that the rainfall forecast of the SMA- 4 and SES- (α-0.3). A p-value of 0.74 indicates that there are no significance differences between SMA- 2 and SES- (α-0.3) forecast value within the year 1991-2021.
Finally, the result revealed that error of the forecast model results. The Mean Absolute Percentage Error (MAPE), are 12.93, 12.88, 13.43, 11.08, 11.56 and 12.03 for Single Moving Average n-2, Single Moving Average n-3, Single Moving Average n-4, Simple exponential smoothing α - 0.1, Simple exponential smoothing α - 0.2 and Simple exponential smoothing α - 0.3 respectively.

Conclusion

From the outcome of the study, it could be concluded that there is no significance difference observed rainfall value and SMA(n=2) forecast value in 2006 -2021, and the model predicted the average rainfall of 119.13 mm rainfall value for the year 2021
From the outcome of the findings on the ranking of each error estimators it could be concluded that single moving average n = 2 was ranked 1st with total error rank 11. Simple exponential smoothing 0.1, 0.2, was ranked 2nd with total error ranked 12. Single Moving Average n=3, was ranked 3rd total error ranked 13. Single Moving Average n=4 and Simple exponential smoothing α = 0.3 was ranked 4th with total error ranked value 18. Hence single moving average n = 2 predicted better as compared to other prediction model.

Recommendations

Based on the conclusion of the study, the following recommendations were made:

1. Agencies in charge of weather forecast should look into the use of SMA with order n=2 as an alternative model.
2. Government should be encouraged to effectively use the models for prediction in term of decision making on issues involving agricultural activities.

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