Scientific African 18 (2022) e01404

Contents lists available at ScienceDirect

Scientific African

journal homepage: www.elsevier.com/locate/sciaf

Modelling and forecasting new cases of Covid-19 in Nigeria: Comparison of regression, ARIMA and machine learning models

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ARTICLE INFO

Article history:
Received 2 April 2022
Revised 17 August 2022
Accepted 19 October 2022

Editor: DR B Gyampoh

Keywords:
ARIMA
Machine learning
Forecasting
Time series

ABSTRACT

Covid-19 remains a global pandemic threatening hundreds of countries in the world. The impact of Covid-19 has been felt in almost every aspect of life and it has introduced globally, a new normal of livelihood. This global pandemic has triggered unparalleled global health and economic crisis. Therefore, modelling and forecasting the dynamics of this pandemic is very crucial as it will help in decision making and strategic planning. Nigeria as the most populous country in Africa and most populous black nation in the world has been adversely affected by Covid-19 pandemic. This study models and compares forecasting performance of regression, ARIMA and Machine Learning models in predicting new cases of Covid-19 in Nigeria. The study obtained data on daily new cases of Covid-19 in Nigeria between 27th February, 2020 and 30th November, 2021. Graphical analysis showed that Nigeria had witnessed three waves of Covid-19 with the first wave between 27th February, 2020 and 23rd October, 2020, the second wave between 24th October, 2020 and 20th June, 2021 and the third wave between 21st June, 2021 and 30th November, 2021.The second wave recorded the highest spikes in new cases compared to the first wave and third wave. Result reveals that in terms of forecasting performance, inverse regression model outperformed other regression models considered as it shows lowest RMSE of 0.4130 compared with other regression models. Also, the ARIMA (4, 1, 4) outperformed other ARIMA models as it reveals the highest R^2 of 0.856 (85.6%), least RMSE (0.6364), AIC (-8.6024) and BIC (-8.5299). Result reveals that Fine tree which is one of the Machine Learning models is more reliable in forecasting new cases of Covid-19 in Nigeria compared to other models as Fine tree gave the highest R^2 of 0.90 (90.0%) and least RMSE of 0.22165. Result of 15 days forecasting indicates that Covid-19 pandemic is not over yet in Nigeria as new cases of Covid-19 is projected to increase on 15/12/2021 with predicted new cases of 988 compared with that of 14/12/2021, where only 729 new cases was predicted. This therefore emphasizes the need to strengthen and maintain the existing Covid-19 preventive measures in Nigeria.

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https://doi.org/10.1016/j.sciaf.2022.e01404

Introduction

Coronavirus is a virus associated with the respiratory system which often causes the common cold across all ages. It has crown-like spikes on the exterior surface. The size of the virus ranges between 65 to 125mm in diameter and has a single-stranded ribonucleic acid (RNA). The first case of isolation resulting from Coronavirus was in 1965, Tyrell and Bynoe [1]. The current and popular version of coronavirus disease named "Covid-19" was first reported in China in Wuhan city [1]. Due to the speed of spread and high mortality rate associated with the virus, the World Health Organization (WHO) declared it as a global health emergency [1,2]. Covid-19 virus mitigated from Bats to human and the pandemic was declared by the WHO as the most aggressive disease that has affected more than 90% of the countries in the world with European Continent being the most affected continent in the world [3,4]. The virus is believed to have been transmitted from wild animals to man with unknown optimal time of disappearance [4]. The Covid-19 pandemic spread within fifty to sixty days to the whole globe and the implementation of suitable mitigating measures for Covid-19 globally has been quite challenging [5]. One of the major factors that drive the spread of this virus is the issue of immigration of the infected people from one place to another [2] and countries around the world have to come up with different Covid-19 protocol to curtail further spread of the disease.

Africa has shared in the global pandemic and Nigeria is not an exemption. The Infectious Disease Centre, Yaba, Lagos state, reported the first confirmed case on February 27th, 2020. This confirmed case was a foreigner from Milan, Italy, who came into Nigeria, and ever since, there has been a rapidly increasing spread of the infection within Nigeria [6]. The Covid-19 pandemic resulted in a severe adverse socio-economy and was felt in all sectors of the African economy. Most countries experienced loss of jobs, reduced income, and increased corruption (as some countries used the opportunity to leverage the gaps in the system). The consumer price index also rose, and imported goods became very expensive as most African countries that depend solely on China and other developed economies faced enormous challenges [7]. Covid-19 has been identified as the biggest global threat of 2020 and 212 countries and territories in the world have been affected [8]. The severity of this disease has attracted the attention of scientist and researcher all over the world. This disease can be spread across a short distance by air through the droplets from the nose of an infected persons when the infected person sneezes or coughs, and its clinical manifestations include; dry cough, fever, tiredness, headache, aches, nasal congestion, and breathing difficulty among others [8] . The spread of Covid-19 virus can best be prevented through social distancing [8] and other measures such as regular washing of hands with soap and water or with alcohol- based sanitizer, wearing of face mask, self-isolation, and, currently, the use of vaccine against the infection [9]. However, significant progress has also been recorded due to the enforcement of these preventive measures by relevant regulative bodies [10].

As captured in a study by [6], The Federal Government of Nigeria closed all non-essential services (businesses and industries) in the country. It restricted the movement of people across states in Nigeria, including the commercial capital of Nigeria, Lagos state, Ogun state, and the Federal Capital Territory, Abuja, effective from March 30th, 2020. The inter-state movement was banned and restricted to the barest minimum. Consequently, the gradual easing of lockdown started on May 4th, 2020. In collaboration with some ministries, the Federal Government of Nigeria devised a way of fighting the pandemic. The Covid-19 pandemic disrupted social relations among people globally due to the social distancing that people are forced to practice. Social distancing limits how people relate to colleagues, family, and friends [11].

Covid-19 is a global pandemic and requires the collective effort of every citizen to fully combat the spread of the disease, hence, developing a predictive model for the pandemic is very crucial and this will assist in policy formulation that will help in controlling the spread of Covid-19 pandemic. Since the advent of the first reported case of Covid-19 in Nigeria, several attempts have been made to forecast its future values. For instance, [12] proposed a time series model for predicting Covid-19 confirmed cases in Nigeria. Also, [13] developed a predictive model for confirmed cases in Nigeria using regression approach. Similarly, [14] carried out a study on modelling Nigerian Covid-19 cases with comparative analysis of different regression models. Similarly, [15] modeled and forecasted new cases of Covid-19 in ten countries in Africa. In another study, [16] analysed the patterns of the spread of Covid-19 in Nigeria using the Box-Jenkins approach while [17] modeled the effect of confirmed cases and critical cases on the fatality rate using multiple linear regression. Similarly, [18] applied ARIMA model to both confirmed and Covid-19 mortality in Nigeria within the period of eight months. A study by [19] compared the performance of single forecasting artificial intelligence with the Variational Mode Decomposition (VMD) with empirical demonstration with Covid-19 cases in Brazil and America. Result as obtained by [19] indicated that the hybridized VMD artificial intelligence forecasting models outperformed the single forecasting models. Other predictive models such as the Bayesian sequential data assimilation [20], regression [21], ARIMA models [22], combination of regression, ARIMA and Machine Learning models [23], Interpretable Temporal Attention Network [24], Artificial Neural Network [25] have also been applied to Covid-19 data. Similarly, state neural based framework [26], ensemble learning models coupled with urban mobility information [27], space time ARIMA [28] among other predictive models have been proposed for forecasting cases of Covid-19. Most of these studies were carried out during the first wave of the pandemic and before the advent of Covid-19 vaccine. To the best of the researcher's knowledge, most of the research carried out so far in Nigeria focused more on the confirmed cases using either the time series approach or the regression approach. In this present study, the research will focus on comparative analysis of the performance of the regression models, ARIMA models and Machine Learning models with primary focus on the daily new cases of Covid-19 in Nigeria. Therefore, this study focuses on modelling and forecasting new cases of Covid-19 in Nigeria. The primary aim of the study is to compare the performance of regression, ARIMA and Machine Learning models and use the best of these models to forecast new cases of Covid-19 in Nigeria.

Table 1
Descriptive statistics for Covid-19 new cases in Nigeria between27th February 2020 and 30th November 2021.

Statistic	Values
Mean	332.303
Standard Error	14.706
Median	189
Standard Deviation	372.895
Variance	139050.688
Kurtosis	4.788
Skewness	2.007
Range	2464
Minimum	0
Maximum	2464
Sum	213671
Number of observations	643

Methods

This section presents data set description and the models used in analysing the data.

Data set description

The data used in this study comprises daily new cases of Covid-19 in Nigeria between 27th February 2020 and 30th November 2021 as obtained from the official website of the Nigeria Centre for Disease Control (NCDC). The summary descriptive analysis of the data presented in Table 1. Table 1 show that the cumulative cases of Covid-19 was 213671 with the maximum case of 2464 which was reported on 23rd January, 2021. The skewness was 2.007 which shows that it is positively skewed, meaning that the reported new cases of Covid-19 in Nigeria increased more than it decreased in values within the period of study. The minimum and maximum new cases of Covid-19 were 0 and 2464 respectively. The data were transformed by taking the log transformation.

Regression models

The regression models used in this study are the simple linear regression, quadratic regression, cubic regression and inverse regression as defined below:

The simple linear regression model is defined as:

$$Y_i^1 = \beta_0 + \beta_1 D_i + \varepsilon_i \tag{1}$$

The quadratic regression model is defined as:

$$Y_i^1 = \beta_0 + \beta_1 D + \beta_2 D_i^2 + \varepsilon_i \tag{2}$$

For cubic regression, the model can be specified as:

$$Y_i^1 = \beta_0 + \beta_1 D + \beta_2 D_i^2 + \beta_3 D_i^3 + \varepsilon_i \tag{3}$$

For inverse regression, the model specification is:

$$Y_i^1 = \beta_0 + \beta_1 \frac{1}{D_i} + \varepsilon_i \tag{4}$$

where, β_0, β_1,β_2 andβ_3 are the parameters of the regression models and $\mathrm{D_i}$ are the transformed reported daily new cases of Covid-19 in Nigeria.

Autoregressive integrated moving average (ARIMA) models

In this study, six different tentative ARIMA models were fitted to the data. These ARIMA models are ARIMA (4,1,2), ARIMA (4,1,3), ARIMA (4,1,4), ARIMA (4,1,5), ARIMA (5,1,4) and ARIMA (5,1,5). Autoregressive Integrated Moving Average model [ARIMA (p,d,q)] can be defined in terms of B operator as follows:

$$\lambda_p(B)(1-B)^d Y_i^1 = \Psi_q(B)\varepsilon_t \tag{5}$$

$$where,\ \lambda_p(B) = 1 - \lambda_1 B - \lambda_2 B^2 -_{\dots} \lambda_p B^p \tag{6}$$

$$\Psi_q(B) = 1 - \Psi_1 B - \Psi_2 B^2 -_{\dots} \Psi_q B^p \tag{7}$$

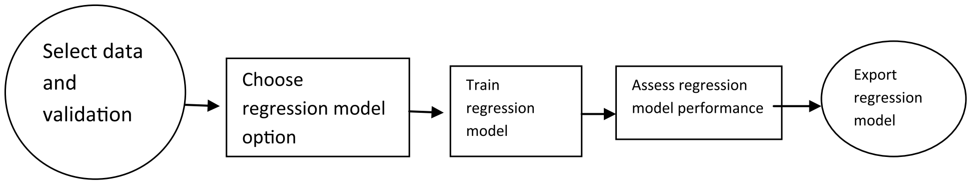

Fig. 1. Flowchart for training the machine leaning models.

where, p is the order of AR, d is the order of differencing and q is the order of MA The number of difference required is the number d.

For ARIMA (4,1,2): $p = 4,\ d = 1, q = 2$

$$(1 - \lambda_1 B - \lambda_2 B^2\ - \phi_\lambda B^3\ - \lambda_4 B^4)(1 - B)Y_i^1 = (1 - .\Psi_1 B - .\Psi_2 B^2)\varepsilon_t \tag{8}$$

where, $\phi_1, \phi_2, \phi_3, \phi_4, \theta_1, \theta_2$ are the parameters of ARIMA (4,1,2).

For ARIMA (4,1,3): $p = 4,\ d = 1, q = 3$

$$(1 - \lambda_1 B - \lambda_2 B^2 - \lambda_3 B^3 - \lambda_4 B^4)(1 - B)Y_t = (1 - .\Psi_1 B - .\Psi_2 B^2 - .\Psi_3 B^3)\varepsilon \tag{9}$$

where, $\lambda_1, \lambda_\lambda, \lambda_3, \lambda_4, \theta_1, \theta_2, \theta_3$ are the parameters of ARIMA (4,1,3).

For ARIMA (4,1,4): $p = 4,\ d = 1, q = 4$

$$(1 - \lambda_1 B - \lambda_2 B^2 - \lambda_3 B^3 - \lambda_4 B^4)(1 - B)Y_i^1 = (1 - \Psi_1 B - \Psi_2 B^2 - \Psi_3 B^3 - \Psi_4 B^4 \tag{10}$$

where, $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \Psi_1, \Psi_2, \Psi_3, \Psi_4$ are the parameters of ARIMA (4,1,4).

For ARIMA (4,1,5): $p = 4,\ d = 1, q = 5$

$$(1 - \lambda_1 B - \lambda_2 B^2 - \lambda_3 B^3 - \lambda_4 B^4)(1 - B)Y_t = (1 - \Psi_1 B - \Psi_2 B^2 - \Psi_3 B^3 - \Psi_4 B^4 - \Psi_5 B^5)\varepsilon_t \tag{11}$$

where, $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \Psi_1, \Psi_2, \Psi_3, \Psi_4, \Psi_5$ are the parameters of ARIMA (4,1,5).

For ARIMA (5,1,4): $p = 5,\ d = 1,\ q = 4$

$$(1 - \lambda_1 B - \lambda_2 B^2 - \lambda_3 B^3 - \lambda_4 B^4 - \lambda_5 B^5)(1 - B)Y_t = (1 - \Psi_1 B - \Psi_2 B^2 - \Psi_3 B^3 - \Psi_4 B^4)\varepsilon_t$$

Where, $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \Psi_1, \Psi_2, \Psi_3, \Psi_4$ are the parameters of ARIMA (5,1,4).

For ARIMA (5,1,5): $p = 5,\ d = 1,\ q = 5$

$$(1 - \lambda_1 B - \lambda_2 B^2 - \lambda_3 B^3 - \lambda_4 B^4 - \lambda_5 B^5)(1 - B)Y_t^1 = (1 - \Psi_1 B - \Psi_2 B^2 - \Psi_3 B^3 - \Psi_4 B^4 - \Psi_5 B^5)\varepsilon_{tt} \tag{12}$$

where, $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \Psi_1, \Psi_2, \Psi_3, \Psi_4, \Psi_5$ are the parameters of ARIMA (5,1,5).

To determine the goodness of fit of the ARIMA model, the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots of the ARIMA model were used. The performances of these ARIMA models were compared both in terms of fitness using R^2, AIC and BIC and forecasting performance using Root Mean Square Error (RMSE). The Ljung-Box statistics was used to assess the goodness of fit of these ARIMA models while the normality of residuals was tested using Jacque Bera test. If the p-value of the The Ljung-Box is greater than 0.05, it means that the ARIMA model is of good fit while p-value of Jacque Bera test greater than .05 indicates that the residuals are normally distributed.

Machine learning models

This study considered the following machine learning models: Fine tree, Bagged tree, Exponential GPR, Medium tree, Boosted Trees, Trilayered Neural Network, Wide N.N., Matern 5/2 GPR, Squared exponential GPR and Rational Quadratic GPR. The flow chart in Fig. 1 shows the workflow used in training these machine learning models.

The performance of these machine leaning models was compared using R^2, Mean Square Error (MSE), Root Mean Square Error (RMSE) and Mean Absoluate Error (MAE). Machine learning model with the highest R^2, least MSE, RMSE and MAE was considered as the best among the competing models.

Results

The graphical representation of the data is as shown in Fig. 2 which shows that between 27th February, 2020 and 30th November, 2021, Nigeria has experienced three waves of Covid-19 pandemic during the period under study. The first wave occurred between 27th February, 2020 and 23rd October, 2020 with the highest number of daily new case of 790 which was recorded 1st July, 2020. The second wave occurred between 24th October, 2020 and 20th June, 2021 and the highest case recorded during this period is 2464 on 23rd January, 2021. The second wave recorded the highest number of new cases amongst the three waves. The third wave of the pandemic happened between 21st June 2021 and 30th November, 2021. 1149 new cases were reported on 18th August, 2021 and it was the highest case for the period of the third wave.

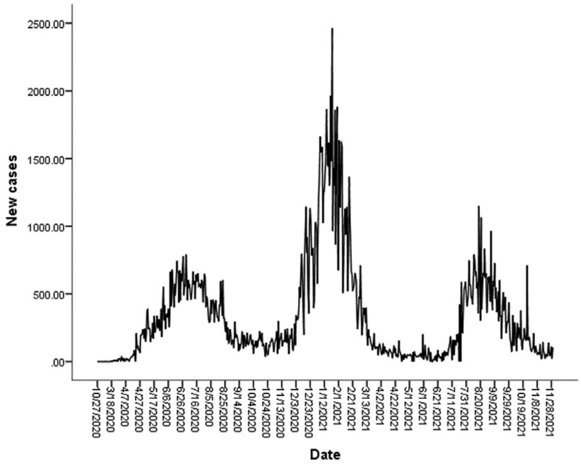

Fig. 2. New cases of COVID-19 in Nigeria between 27th February, 2020 and 30th November, 2021.

Table 2
Summary result of the Augmented Dickey Fuller (ADF) for stationarity of the new cases of Covid-19 in Nigeria.

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.92574	0.0000**
Test critical values:	1% level	-3.444691	
	5% level	-2.867757	
	10% level	-2.570145	
**			

** $p < .05$, stationary after first differencing

Table 3
Summary of the results of regression models.

Models	R^2	R^2_{adj}	F	RMSE	Model Equations
Linear	0.048	0.046	22.679	0.6263	$Y_i^{'} = 2.450 - 0.001D_i$
Quadratic	0.328	0.325	110.393	1.7588	$Y_i' = 1.648 + 0.007D_i - 1.508 \times 10^{-5}D_i^2$
Inverse	0.066	0.064	31.978	0.4130	$Y_i' = 2.373 - 20.593(\frac{1}{D_i})$
Cubic	0.364	0.360	86.177	0.9111	$Y_i' = 1.216 + 0.015D_i - 5.029 \times 10^{-5}D_i^2 + 4.378 \times 10^{-8}D_i^3$

The stationarity of the series was examined using Augmented Dickey Fuller test and the p-value of 0.0000 ($p < .05$) was obtained after first differencing meaning that the series is stationary after first differencing (Table 2). In terms of forecasting performance, the inverse regression outperformed other regression models with the least RMSE of 0.4130 while among the ARIMA models considered, ARIMA (4,1,4) gave the highest R^2 ($R^2 = 0.856$) and the least AIC (-8.6024), BIC (-8.5299) and the least RMSE (0.6364) compared with other ARIMA models. This indicates that the ARIMA (4,1,4) is the best performing ARIMA model for forecasting new cases of Covid-19 in Nigeria. The acf and pacf plots as shown in Fig. 3 indicate that the residuals are within the acceptable confidence level, which implies that the model is a good fit.

This is also supported by the result of Ljung-Box statistics with p-value of 0.099 ($p > 0.05$), meaning that the residuals are independent (Table 3). As a way of also diagnosing the model, the normality of the residuals of the ARIMA models was examined using the Jacque-bera test and the p-values obtained for all ARIMA models were greater than 0.05 indicating that the residuals are normally distributed (Table 4). For the Machine Learning models, fine tree reported the highest R^2 of .90 and the least RMSE of 0.22165 compared with other nine Machine Learning models (Table 5). This implies that the fine tree outperformed other Machine Learning models. Generally, Machine Learning models were found to be superior to both regression and ARIMA models. Fine tree Machine Learning was found to outperform the best of the regression and ARIMA models both in terms of fitness and forecasting performance (Table 6). The plot of the actual new cases and predicted new cases of Covid-19 as shown in Fig. 4 reveals that the fine tree algorithm fitted the data well. Hence, the fine tree was used to forecast new cases of Covid-19 between 01/12/21 and 15/12/21 as shown in Fig. 5. A spike in the new cases of Covid-19 is projected between 14/12/21 and 15/12/21 as this may be due to the fact that these periods are very close to the Christmas season.

From Fig. 5, it was observed that the values for new cases of Covid-19 in Nigeria was relatively low for 1st and 2nd December. There was an increase in the number of cases on the 3rd day. A consistent upsurge in the number of new cases was observed between 14/12/2021 and 14/12/2021. This may be due to the fact that the festive period was approaching.

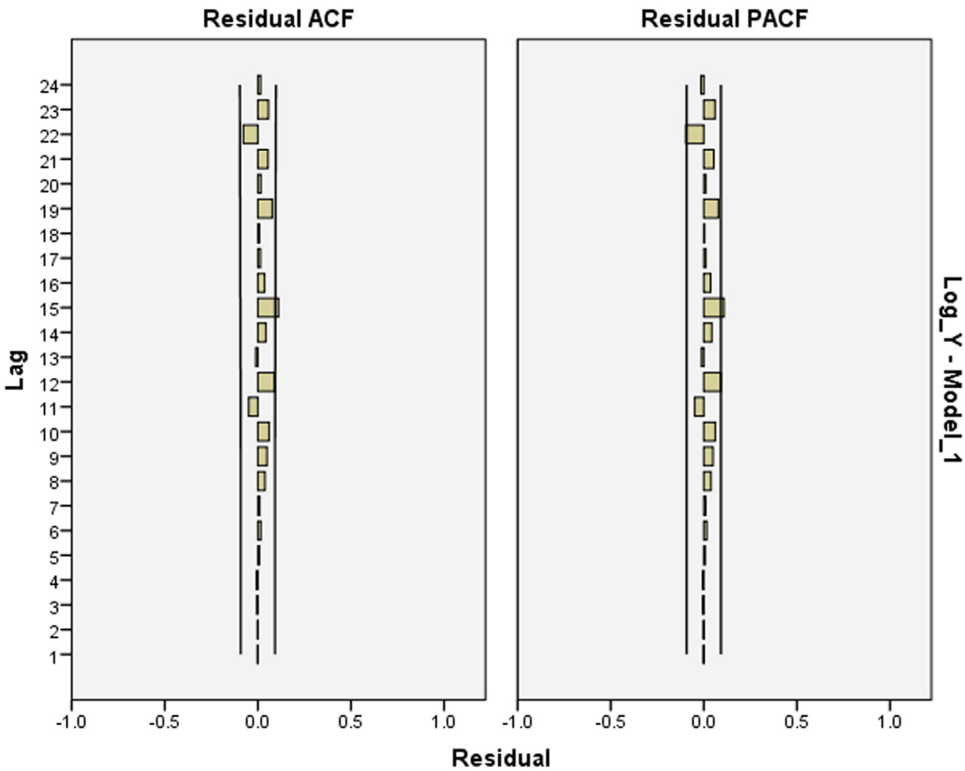

Fig. 3. The residuals ACF and PACF plots for ARIMA (4,1,4) model.

Table 4
Model selection criteria for the data based on ARIMA model.

	Performance Evaluation Criteria				Ljung-Box statistics		JB test for normality of the residuals
ARIMA Models	R^2	AIC	BIC	RMSE	Test statistic	P-value	P-value
ARIMA (4,1,2)	0.853	-8.5825	-8.5010	0.6734	17.201	0.142	0.7292
ARIMA (4,1,3)	0.855	-8.5965	-8.5241	0.6415	16.465	0.125	0.8410
ARIMA (4,1,4)	**0.856**	**-8.6024**	**-8.5299**	**0.6364**	16.021	0.099	0.5341
ARIMA (4,1,5)	0.857	-8.5713	-8.4808	1.4196	14.404	0.109	0.8261
ARIMA (5,1,4)	0.856	-8.5386	-8.4480	0.6372	15.781	0.072	0.5324
ARIMA (5,1,5)	0.858	-8.5176	-8.4179	1.4971	9.608	0.294	0.5868

AIC- Akaike Information Criteria, BIC- Bayesian Information Criteria, JB- Jacque Bera. Bolded values are the highest R^2, least AIC, BIC and RMSE

Table 5
Summary results of the performance of the different machine learning models.

Model Type	Model Summary			
	R^2	MSE	RMSE	MAE
Fine Tree	**0.90**	**0.04913**	**0.22165**	**0.12915**
Bagged Trees	0.88	0.05959	0.24412	0.13848
Exponential GPR	0.88	0.06172	0.24844	0.14560
Medium Tree	0.87	0.06517	0.25529	0.15719
Boosted Trees	0.85	0.07392	0.27188	0.18628
Trilayered Neural Network	0.85	0.07485	0.27358	0.16458
Wide N.N.	0.85	0.07649	0.27657	0.16493
Matern 5/2 GPR	0.84	0.07927	0.28155	0.16971
Squared exponential GPR	0.84	0.08077	0.28420	0.16957
Rational Quadratic GPR	0.84	0.08069	0.28405	0.16949

Bolded values are the highest R^2, least RMSE and MAE.

Table 6
Summary results of the comparison between the best regression model, ARIMA model and machine learning algorithm.

Models	Type	MSE	RMSE
Regression	Inverse	0.1706	0.4130
ARIMA	ARIMA(4,1,4)	0.4051	0.6364
Machine learning algorithm	Fine tree	**0.04913**	**0.22165**

Bolded values are the least MSE and RMSE.

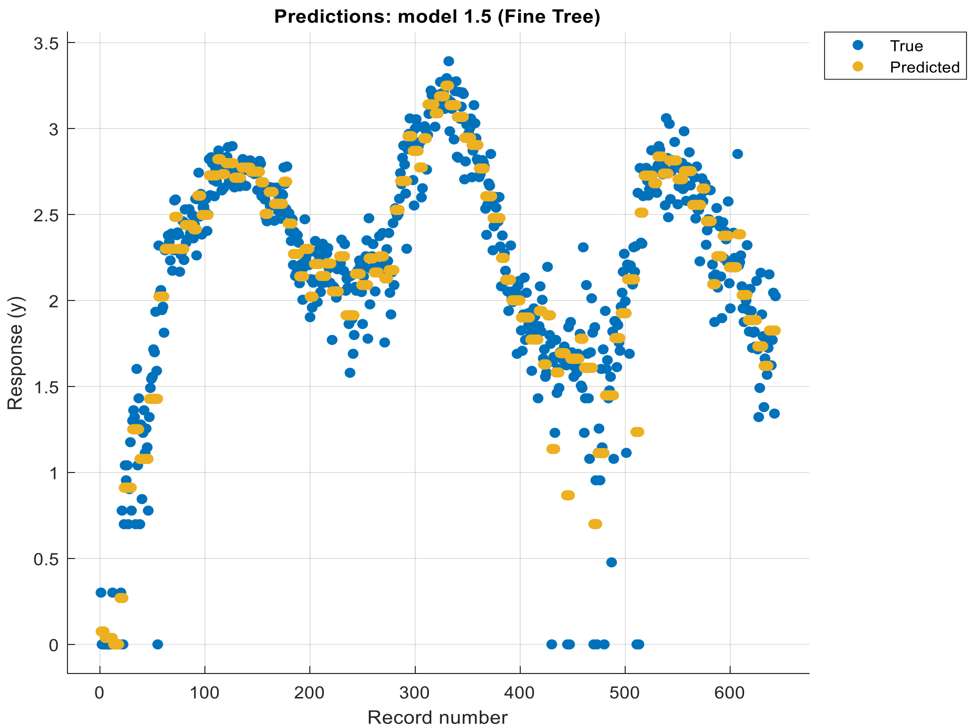

Fig 4. True and predicted new cases of Covid-19 pandemic in Nigeria based on fine tree.

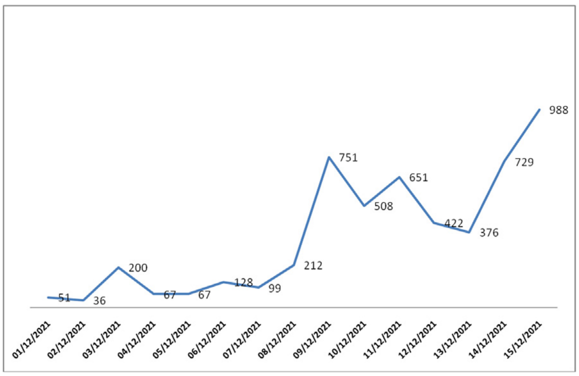

Fig 5. Forecasted values for new cases of COVID-19 between 01/12/21 and 15/12/21.

Discussion

Findings revealed that Nigeria had experienced three different waves of Covid-19 with the highest new cases reported on 23rd January, 2021. This may be due to the Christmas and New Year celebrations. Among the regression models, inverse regression model outperformed models considered in this study. This is not in line with the study of [10] where the cubic regression model was found to be the best fit for new cases of COVID-19 in Nigeria with R^2 value of 81%. This disparity may be due to the fact that the former study was conducted during the first wave of COVID-19 in Nigeria compared with this present study that accommodated three waves. From the results of the time series models, the ARIMA (4,1,4) performed better than other ARIMA models in terms of forecasting accuracy. The model had the least RMSE value of 0.6364. In the study of [7], the ARIMA (2,1,0) performed better than other proposed ARIMA models. The model was then considered the best among the competing models. This disparity may be due to the fact that the former study was conducted during the first wave of the pandemic in Nigeria whereas this study has considered the three waves. The superiority of the Machine Learning models over regression and ARIMA models is corroborated by that of the study [29] in Brazil Machine Learning model was found to be superior to both regression and ARIMA model. This finding is not in agreement with that of [21] which support the use of regression model. This disparity may be due to the fact the study does not consider Machine Learning, differences in the periods of the data as well as the [21] focused on the confirmed cases where this present study considered new cases of Covid-19.

Conclusion, limitation and recommendations

Findings from this study has shown that Fine tree Machine Learning model is best for forecasting new cases of Covid-19 in Nigeria. Fine tree algorithm was then used to forecast new cases of Covid-19 in Nigeria for 15 days (1/12/21 to 15/13/2021). The forecast shows tendency of increase in the new cases of Covid-19 from 729 cases on 14/12/21 to 988 cases on 14/12/21. This therefore indicates Covid-19 is not over in Nigeria and hence the need to maintain and improve on the existing Covid-19 preventive measures. Appropriate public health and social measures like the use of face masks and hand sanitizers should still be encouraged while citizens and foreigners should ensure that they are fully vaccinated.

This study only applied the convectional ARIMA models and common Machine Learning model and there is need for further study on Covid-19 prediction used the space time ARIMA and other Machine Learning models such as Interpretable Temporal Attention Network, state neural based framework, hybridized VMD artificial intelligence forecasting models among other models. This will help provide more understanding of the dynamics of Covid-19 spread in Nigeria for better decision making and strategic planning.

Declaration of Competing Interest

We hereby declare that this manuscript is original and there is no competing interest.

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