OPEN DEFECATION IN NIGERIA: A BOX-JENKINS ARIMA APPROACH

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ABSTRACT

Surprisingly, in this 21st century, the practice of open defecation has continued unabated in Nigeria (Ngwu, 2017). In this study, which is the first of its kind in Nigeria, the Box-Jenkins ARIMA model was applied in analyzing open defecation. The data was collected from the online World Bank data base and covers the period 2000 – 2017. The out-of-sample forecasts cover the period 2018 – 2022. The diagnostics tests employed in this study show that the open defection series under consideration is an I (1) variable. The study finally presents the ARIMA (4, 1, 0) as the optimal model in forecasting the number of people practicing open defecation in Nigeria. The model, through the residual ADF tests, and the inverse roots of the AR/MA polynomials; has been shown to be quite stable and suitable for forecasting and control of open defecation in Nigeria. The results of the study indicate that by 2022 the number of open defecators will be approximately 17.8% of the total population. The study offers a two-fold policy recommendation for consideration by the government of Nigeria.

Keyword: - *Box-Jenkins ARIMA, Forecasting, Open Defecation*

1.0 INTRODUCTION

Open defecation continues to be a critical health challenge worldwide (Ngwu, 2017), affecting approximately 1 billion people globally and contributing significantly to an estimated 842 000 people who die annually from sanitation related diseases (WHO, 2014). The existence of open defecation is associated with diseases, especially diarrheal diseases; under nutrition and poverty, and is usually considered as an affront to personal dignity. Countries such as Nigeria, where open defecation is most widely practiced have the highest numbers of deaths of children under the age of five, as well as high levels of under nutrition, high levels of poverty, and large disparities between the rich and the poor (Osumanu *et al*., 2019). In fact, fecal contamination of the environment is the root cause of an annual 5 400 cases of cholera affecting Nigeria (WSP, 2012). The practice of open defecation is more prevalent in rural communities in Nigeria, where it is tied to the culture, values, tradition, and morals of the people. In some rural communities in Nigeria, people find delight in defecating openly in rivers and lakes where they have the source of drinking water, hence denying self of safe and clean water as well as sanitary environment (Ngwu, 2017).

1.2 OBJECTIVES OF THE STUDY

i. To investigate the trends open defecation in Nigeria over the period 2000 – 2017.
ii. To forecast the number of people practicing open defecation in Nigeria for the period 2018 – 2022.
iii. To examine the trend of open defecation in Nigeria for the out-of-sample period.

2.0 LITERATURE REVIEW

In Thailand, Guterres *et al*. (2014) investigated factors that influence household to use and maintain latrines. The study was designed as a cross-sectional survey, based on a quantitative data design. The study basically found out that 47.2% of the households continued to use and maintain latrines and 52.8% had stopped by one year after the open defecation free declaration in Haupu village. Level of education is one of the most essential factors seen to be influencing household to use and maintain latrines. In Nigeria, Abubakar (2017) examined access to sanitation facilities and explored the socioeconomic and local factors that influence the type of facility used by households. For data analysis, the study used the descriptive and inferential statistics. The results of the study indicated that 44.2% of the households used various kinds of pit latrines, followed by toilets that flash to septic tanks (10.3%). Osumanu *et al*. (2019) examined sociocultural and economic factors determining open defecation in the Wa Municipality in Ghana. The study employed a mixed method approach involving questionnaire administration to 367 households systematically selected from 21 communities, observation, and eight key informant interviews. The mixed logit model was used to determine the factors that significantly influence open defecation. The findings basically revealed that 49.8% of the households had no form of toilet facility at home and were either using communal/public toilets or practicing open defecation. The study also revealed that six factors (education, household size, occupation income, traditional norms, and beliefs and owners of a toilet facility) were positively significant in determining open defecation.

In another Nigerian study Nyoni (2019a) modeled and forecasted total population growth dynamics over the period 1960 – 2017 using the ARIMA approach and found out that annual total population in Nigeria is likely to continue rising sharply. The projected rise in total population in Nigeria is a real threat to natural resources in the country. Given the high levels of open defecation in the country, and the projected population explosion, Nigeria is likely to be in a worse scenario from a public health perspective as well as from a natural resource economics perspective. In another recent Nigerian study (Nyoni, 2019b) used annual time series data on GDP per capita from 1960 – 2017, to model and forecast the same using ARIMA models and basically established that living standards in Nigeria will tumble over the next decade, hence Nigeria's economy was essentially backsliding. This leaves a lot to be desired especially given the fact that poor performing economies are associated with high levels of poverty which has a strong association with the practice of open defecation. No study has been done to forecast the number of open defecators in Nigeria. This study is the first of its kind and is anticipated to enhance the eradication of open defecation in Nigeria.

3.0 METHODODOLOGY

3.1 The Box – Jenkins (1970) Methodology

The first step towards model selection is to difference the series in order to achieve stationarity. Once this process is over, the researcher will then examine the correlogram in order to decide on the appropriate orders of the AR and MA components. It is important to highlight the fact that this procedure (of choosing the AR and MA components) is biased towards the use of personal judgement because there are no clear – cut rules on how to decide on the appropriate AR and MA components. Therefore, experience plays a pivotal role in this regard. The next step is the estimation of the tentative model, after which diagnostic testing shall follow. Diagnostic checking is usually done by generating the set of residuals and testing whether they satisfy the characteristics of a white noise process. If not, there would be need for model re – specification and repetition of the same process; this time from the second stage. The process may go on and on until an appropriate model is identified (Nyoni, 2018c). This approach will be employed to analyze the ODA series under consideration.

3.2 The Moving Average (MA) model

Given:

$$ODA_t = \alpha_0 \mu_t + \alpha_1 \mu_{t-1} + \cdots + \alpha_q \mu_{t-q} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where μ_t is a purely random process with mean zero and varience σ^2. Equation [1] is reffered to as a Moving Average (MA) process of order q, usually denoted as MA (q). ODA is the annual number of people (as a percentage of the total population) who practice open defecation at time t, $\alpha_0 \ldots \alpha_q$ are estimation parameters, μ_t is the current error term while $\mu_{t-1} \ldots \mu_{t-q}$ are previous error terms.

3.3 The Autoregressive (AR) model

Given:

$$ODA_t = \beta_1 ODA_{t-1} + \cdots + \beta_p ODA_{t-p} + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $ODA_{t-1} \ldots ODA_{t-p}$ are previous period values of the ODA series and μ_t is as previously defined. Equation [2] is an Autoregressive (AR) process of order p, and is usually denoted as AR (p).

3.4 The Autoregressive Moving Average (ARMA) model

An ARMA (p, q) process is just a combination of AR (p) and MA (q) processes. Thus, by combining equations [1] and [2]; an ARMA (p, q) process may be specified as shown below:

$$ODA_t = \beta_1 ODA_{t-1} + \cdots + \beta_p ODA_{t-p} + \mu_t + \alpha_1 \mu_{t-1} + \cdots + \alpha_q \mu_{t-q} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

While ARMA models just like AR and MA models are meant for stationary series, reality indicates that most time series data is either I (1) or I (2). In fact, in this study, the ODA series has been found to be an I (1) variables (that is, it only became stationary after first differencing). Therefore, in this paper, the model presented below is the one that will be applied.

3.5 The Autoregressive Integrated Moving Average (ARIMA) model

A stochastic process ODA_t is referred to as an Autoregressive Integrated Moving Average (ARIMA) [p, d, q] process if it is integrated of order "d" [I (d)] and the "d" times differenced process has an ARMA (p, q) representation. If the sequence $\Delta^d ODA_t$ satisfies an ARMA (p, q) process; then the sequence of ODA_t also satisfies the ARIMA (p, d, q) process such that:

$$\Delta^d ODA_t = \sum_{i=1}^{p} \beta_i \Delta^d ODA_{t-i} + \sum_{i=1}^{q} \alpha_i \mu_{t-i} + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [4]$$

where Δ is the difference operator, vector $\beta \in \mathbb{R}^p$ and $\alpha \in \mathbb{R}^q$.

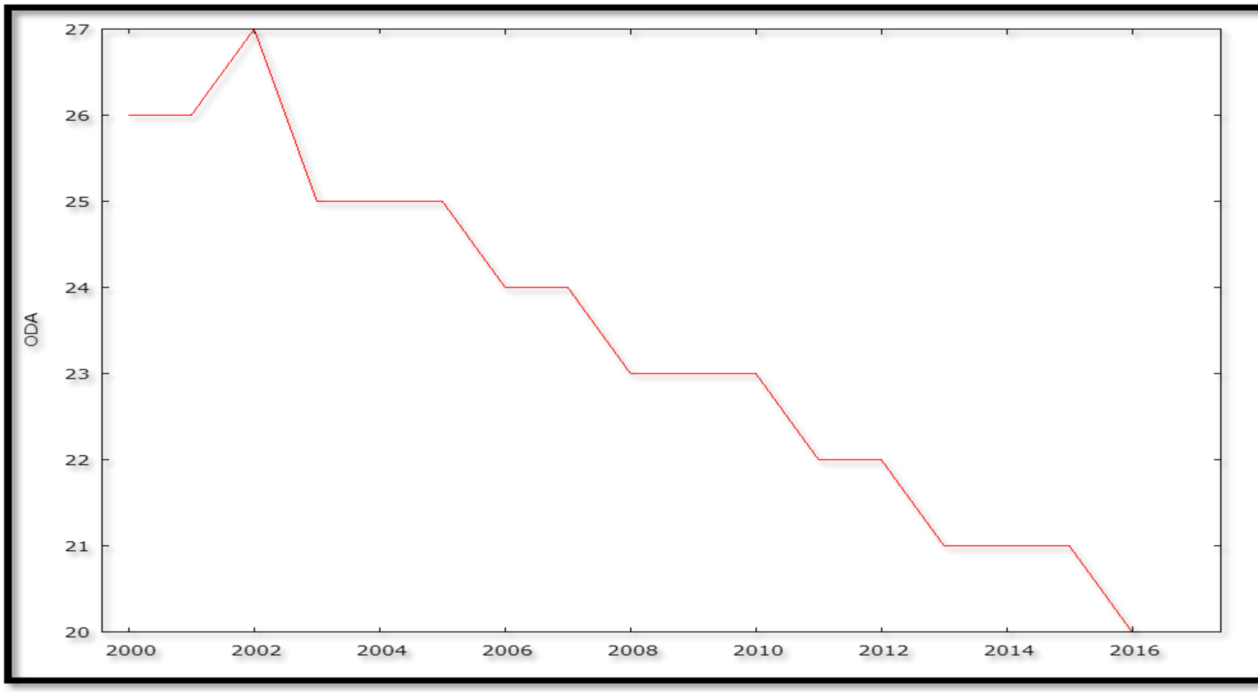
3.6 Data Collection

This study is based on annual observations (that is, from 2000 – 2017) on the number of people practicing Open Defecation [OD, denoted ODA] (as a percentage of total population) in Nigeria. Out-of-sample forecasts will cover the period 2018 – 2022. All the data was gathered from the World Bank online database.

3.7 Diagnostic Tests & Model Evaluation

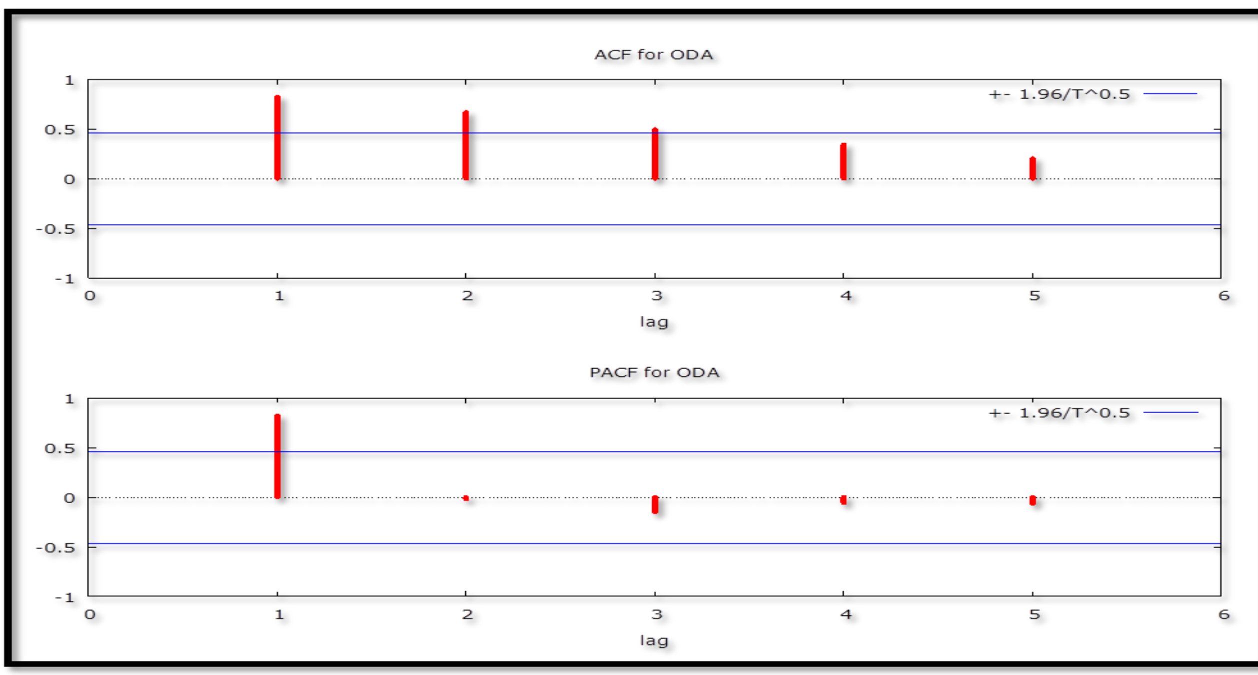
3.7.1 Stationarity Tests: Graphical Analysis

Figure 1



3.7.2 The Correlogram in Levels

Figure 2: Correlogram in Levels



3.7.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODA	-1.142585	0.6693	-3.959148	@1%	Non-stationary
			-3.081002	@5%	Non-stationary
			-2.681330	@10%	Non-stationary

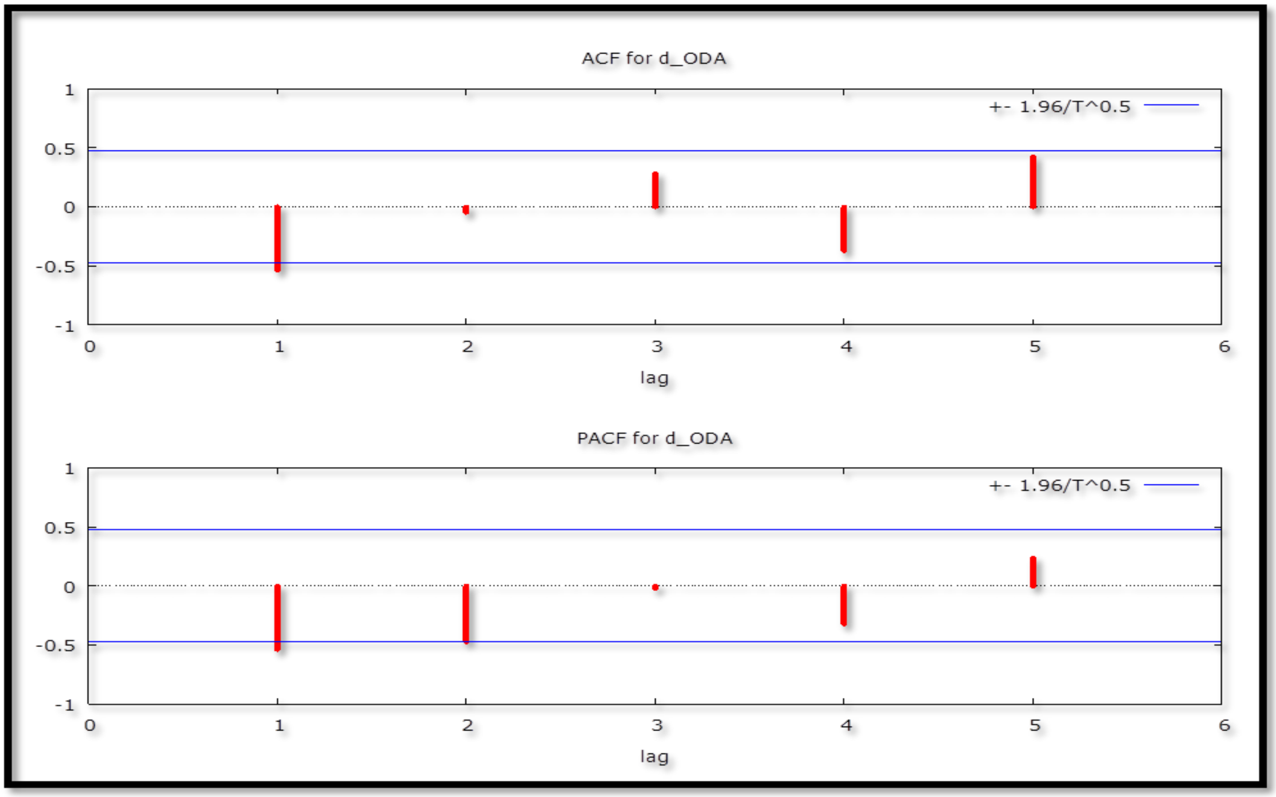
Table 2: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODA	-7.233141	0.0001	-4.667883	@1%	Non-stationary
			-3.733200	@5%	Non-stationary
			-3.310349	@10%	Stationary

Tables 1 and 2 show that ODA is not stationary in levels as already suggested by figures 1 and 2.

3.7.4 The Correlogram (at First Differences)

Figure 3: Correlogram (at First Differences)



3.7.5 The ADF Test (at First Differences)

Table 3: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODA	-4.704296	0.0034	-4.057910	@1%	Stationary
			-3.119910	@5%	Stationary
			-2.701103	@10%	Stationary

Table 4: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODA	-4.690949	0.0135	-4.886426	@1%	Non-stationary
			-3.828975	@5%	Stationary
			-3.362984	@10%	Stationary

Figure 3 as well as tables 3 and 4, indicate that ODA is an I (1) variable.

3.7.6 Evaluation of ARIMA models (with a constant)

Table 5: Evaluation of ARIMA Models (with a constant)

Model	AIC	U	ME	MAE	RMSE	MAPE
ARIMA (1, 1, 0)	35.45488	0.72974	0.011401	0.43434	0.5719	1.822
ARIMA (2, 1, 0)	25.82702	0.64443	0.1019	0.34068	0.50805	1.42269
ARIMA (3, 1, 0)	27.50268	0.64236	0.10612	0.32608	0.50573	1.3693
ARIMA (4, 1, 0)	**21.57182**	0.57288	0.11732	0.2736	0.46079	1.1369
ARIMA (5, 1, 0)	23.32069	0.56905	0.11397	0.27189	0.45776	1.1305
ARIMA (6, 1, 0)	21.88944	0.54721	0.12103	0.25046	0.44428	1.033

A model with a lower AIC value is better than the one with a higher AIC value (Nyoni, 2018b) Similarly, the U statistic can be used to find a better model in the sense that it must lie between 0 and 1, of which the closer it is to 0, the better the forecast method (Nyoni, 2018a). In this research paper, only the AIC is used to select the optimal model. Therefore, the ARIMA (4, 1, 0) model is finally chosen.

3.8 Residual Test

3.8.1 Correlogram of the Residuals of the ARIMA (4, 1, 0) Model

Figure 4: Correlogram of the Residuals

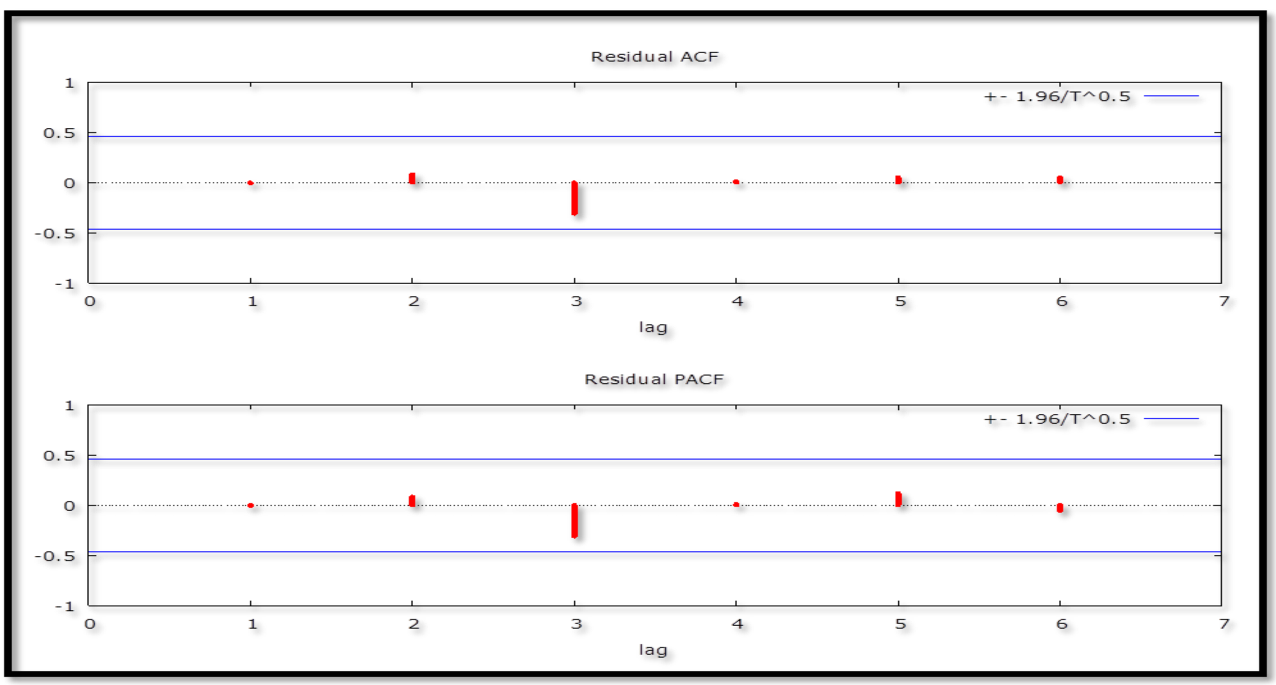


Figure 4 indicates that the estimated model is adequate since ACF and PACF lags are quite short and within the bands. This apparently indicates that the "no autocorrelation" assumption is not violated in this research.

4.0 FINDINGS

4.1 Descriptive Statistics

Table 6: Descriptive Statistics

Description	Statistic
Mean	23.222
Median	23
Minimum	20
Maximum	27
Standard deviation	2.1572
Skewness	0.066696
Excess kurtosis	-1.1401

As shown in table 6 above, the mean is positive, that is, 23.222. This means that, over the study period, the annual average number of people practicing open defecation in Nigeria is approximately 23% of the total population. This is a warning alarm for policy makers in Nigeria with regards to the need to promote an open defecation free society. The minimum number of people practicing open defecation in Nigeria over the study period is approximately 20% of the total population, while the maximum is 27% of the total population. However, the number of people practicing open defecation in Nigeria has declined over the years from 27% in 2000 to 20% in 2017 of the total population. This is a desirable health outcome and there is need to intensify policies and strategies that discourage the practice of open defecation in Nigeria. The skewness is 0.066696 and the most important characteristic is that it is positive, meaning that the ODA series is positively skewed and non-symmetric. Excess kurtosis is -1.1401; showing that the ODA series is not normally distributed.

4.2 Results Presentation[1]

Table 7: Main Results

ARIMA (4, 1, 0) Model:

Guided by equation [4], the chosen optimal model, the ARIMA (4, 1, 0) model can be expressed as follows:

$$\Delta ODA_t = -0.404678 - 1.24982\Delta ODA_{t-1} - 1.55419\Delta ODA_{t-2} - 0.982694\Delta ODA_{t-3} - 0.732239\Delta ODA_{t-4} \ldots\ldots\ldots [5]$$

Variable	Coefficient	Standard Error	z	p-value
constant	-0.404678	0.01348	-30.02	0.0000***
$\emptyset_1$	-1.24982	0.199057	-6.279	0.0000***
$\emptyset_2$	-1.55419	0.338737	-4.588	0.0000***
$\emptyset_3$	-0.982694	0.301301	-3.262	0.0011***
$\emptyset_4$	-0.732239	0.188882	-3.877	0.0001***

Table 7 shows the main results of the ARIMA (4, 1, 0) model.

[1] *The *, ** and *** imply statistical significance at 10%, 5% and 1% levels of significance; respectively;*
$\emptyset_i = \beta_i$

Forecast Graph

Figure 5: Forecast Graph – In & Out-of-Sample Forecasts

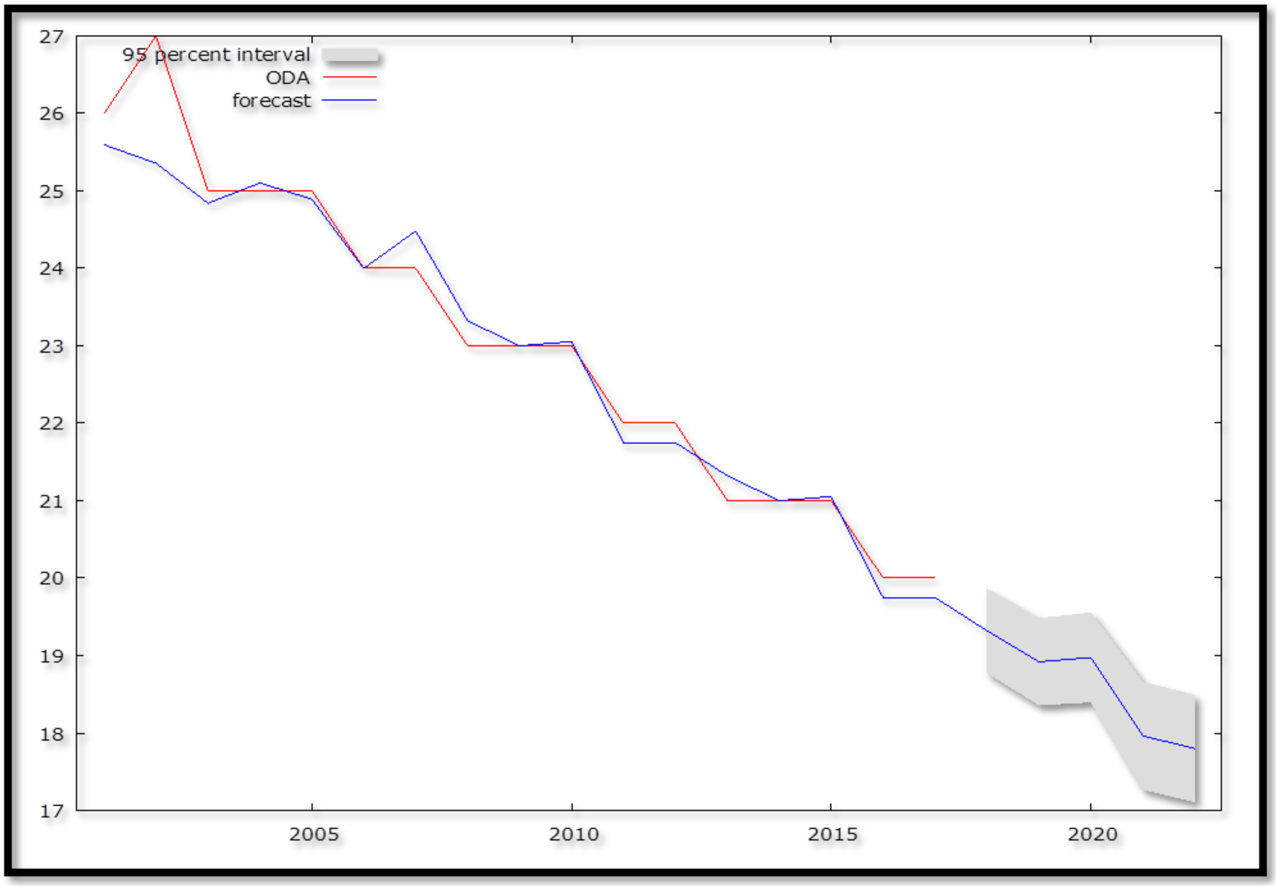


Figure 5 shows the in-and-out-of-sample forecasts of the ODA series. The out-of-sample forecasts cover the period 2018 – 2022.

Predicted ODA – Out-of-Sample Forecasts Only

Table 8: Predicted ODA

Year	Predicted ODA	Standard Error	Lower Limit	Upper Limit
2018	19.32	0.275	18.78	19.86
2019	18.92	0.284	18.36	19.47
2020	18.98	0.291	18.4	19.55
2021	17.96	0.35	17.28	18.65
2022	17.8	0.35	17.11	18.49

Figure 6: Graphical Analysis of Out-of-Sample Forecasts

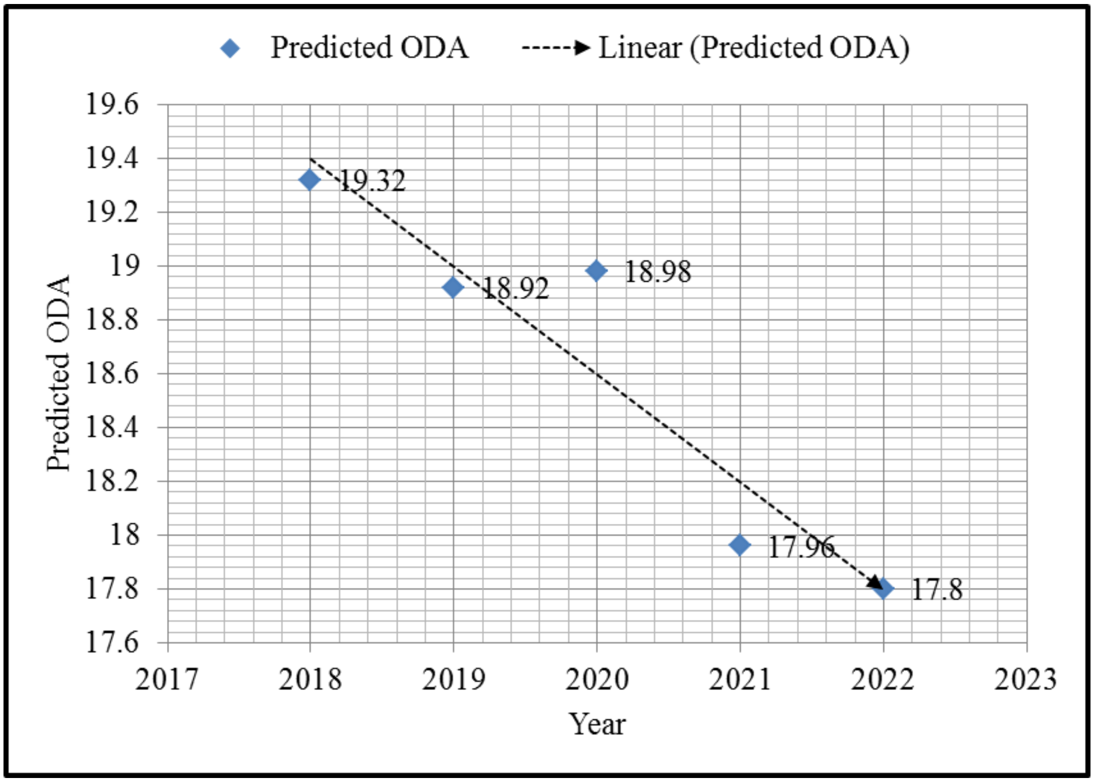


Table 8 and figure 6 show the out-of-sample forecasts only. The number of people practicing open defecation in Nigeria is projected to fall from approximately 19.32% in 2018 to about 17.8% of the total population by the year 2022.Indeed, it is possible to end open defecation in Nigeria even though it is clear that by 2025 Nigeria will still be having a significant number of open defecators. This simply means that the country's National Road Map on making Nigeria Open Defecation Free by 2025 is predicted to fail. However, an intensification of the existing policy frameworks, along with the recommendations suggested below will go a long way in maintaining the projected downwards trends in the number of open defecators in Nigeria.

4.3 Policy Implications

i. The government of Nigeria should continue to make toilets a status symbol so that people, especially those who live in rural areas, stop thinking about toilets as "dark, dirty and smelly places" but rather consider toilets to be "rooms of happiness". In this regard, there need to address the behavioral and attitudinal challenges linked with open defecation in Nigeria.
ii. The government of Nigeria should create more demand for sanitation through teaching the public on the importance of investing in toilets, especially in light of disease transmission and other risks associated with open defecation.

5.0 CONCLUSION

Open defecation is an old sanitation issue globally, and in developing countries in particular, which persist till date despite its damning effects. Why the practice continues to persist is a question that remains largely unanswered (Osumanu *et al*., 2019). The study reveals that the ARIMA (4, 1, 0) model is not only stable but also the most suitable model to forecast the annual number of people practicing open defecation in Nigeria over the period 2018 – 2022. The model predicts a significant decrease in the annual number of people practicing open defecation in Nigeria and such a trend should be maintained. These findings are quite essential for the government of Nigeria, especially when it comes to long-term planning with regards to materializing the much needed open defecation free society.

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