OPEN DEFECATION IN NIGER: A BOX-JENKINS ARIMA APPROACH

Dr. Smartson. P. NYONI[1], Thabani NYONI[2]

[1] Medical Doctor, ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe
[2] MSc Economics Scholar, Department of Economics, University of Zimbabwe, Harare, Zimbabwe

ABSTRACT

Using annual time series data on the number of people who practice open defecation in Niger from 2000 – 2017, the study predicts the annual number of people who will still be practicing open defecation over the period 2018 – 2022. This research applies the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that the ODG series under consideration is an I (1) variable. Based on the AIC, the study presents the ARIMA (1, 1, 0) model as the best model. The diagnostic tests further point to the notion that the presented forecasting model is indeed stable and its residuals are stationary in levels. The results of the study indicate that the number of people practicing open defecation in Niger will slightly decline over the period 2018 – 2022, from 67% to 63% of the total population. This means that over the out-of-sample period, the number of open defecators in Niger is expected to fall by approximately 4%. Clearly, open defecation will definitely remain one of the major public health issues in Niger in future unless more serious sanitation and hygiene policies are effectively implemented in the country. In order to help improve the effectiveness of already existing Water, Sanitation and Hygiene (WASH) policy frameworks, the study suggested a four-fold policy recommendation to be put into consideration, especially by the government of Niger.

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

1.0 INTRODUCTION

The majority of people, especially in rural Niger, practice open defecation, that is, answering the call to nature anywhere on the ground in the open, for example in fields, bushes and forests. In urban areas of Niger, people defecate openly streets canals or other open spaces. In fact, more than 65% of the total population in Niger comprises of persistant open defecators. This could be attributed to a limited awareness of sanitation and hygienic practices coupled with the availability of abundant open space around their locations in cities, homesteads and villages. The practice of open defecation continues to be a traditional norm in rural Niger and a persistant habit in urban Niger. Open defecation is unpleasant, especially from a public health perspective, particularly, with regards to the spread of bacterial, viral and parasitic infections including diarrhoea, polio, cholera, soil-transmitted helminth, trachoma infection, schistosomiasis and hookworm and is also a well-known cause of child stunting and deaths. Against this background, it is obviously important for public health researchers and policy makers to model and forecast the number of people practicing open defecation in order to formulate evidence-driven policies to end open defecation in Niger. The main objective of this study is to predict the annual number of open defecators in Niger over the period 2018 – 2022. This study, besides being the first of its kind in the case of Niger, will go a long way in uncovering the possibility of ending open defecation in the country. This study will also help policy makers in evaluating the effectiveness of already existing Water, Sanitation and Hygiene (WASH) programmes in Niger.

2.0 LITERATURE REVIEW

Ayalew *et al.* (2018) examined diarrheal morbidity in under-five children and its associated determinants in Dangla district in Northwest Ethiopia. A community-based comparative cross-sectional study design with a multistage random sampling technique was applied. Descriptive and inferential statistics were done. The study revealed that child immunization, latrine presence, water shortage in household, and solid waste disposal practices had statistically significant association with diarrhoea occurrence in Ethiopia. In Ghana, Alhassan & Anyarayor (2018) assessed the adoption of sanitation innovations introduced in Nadowli-Kaleo district in Upper West region of Ghana as part of the efforts to attain Open Defecation Free (ODF) status. Interviews were used in data collection. The study showed that while effective communication of innovation resulted in widespread awareness, low income levels significantly accounted for households' inability to sustain and utilize latrines. Adhikari & Ghimire (2020) investigated various determinants of open defecation in Nepal. Bivariate analysis was done to determine the relationship between dependent variables (toilet status – having and not having toilets in the household) and independent variables (demographic, socio-economic and geographical characteristics) using the Chi-square test. The multivariate logistic regression model was estimated to analyze significant predictors for a household not having a toilet after controlling other variables. The results of the study showed that Nepal still has a large number of residences without a toilet. This study will apply the ARIMA method in analyzing open defecation trends in Niger.

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 ODG series under consideration.

3.2 The Moving Average (MA) model

Given:

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

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). ODG is the annual number of people (as a percentage of the total population) who practice open defecation in Niger 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:

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

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $ODG_{t-1} \ldots ODG_{t-p}$ are previous period values of the ODG 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:

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

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 ODG 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 employed.

3.5 The Autoregressive Integrated Moving Average (ARIMA) model

A stochastic process ODG_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 $\Delta^d ODG_t$ satisfies an ARMA (p, q) process; then the sequence of ODG_t also satisfies the ARIMA (p, d, q) process such that:

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

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

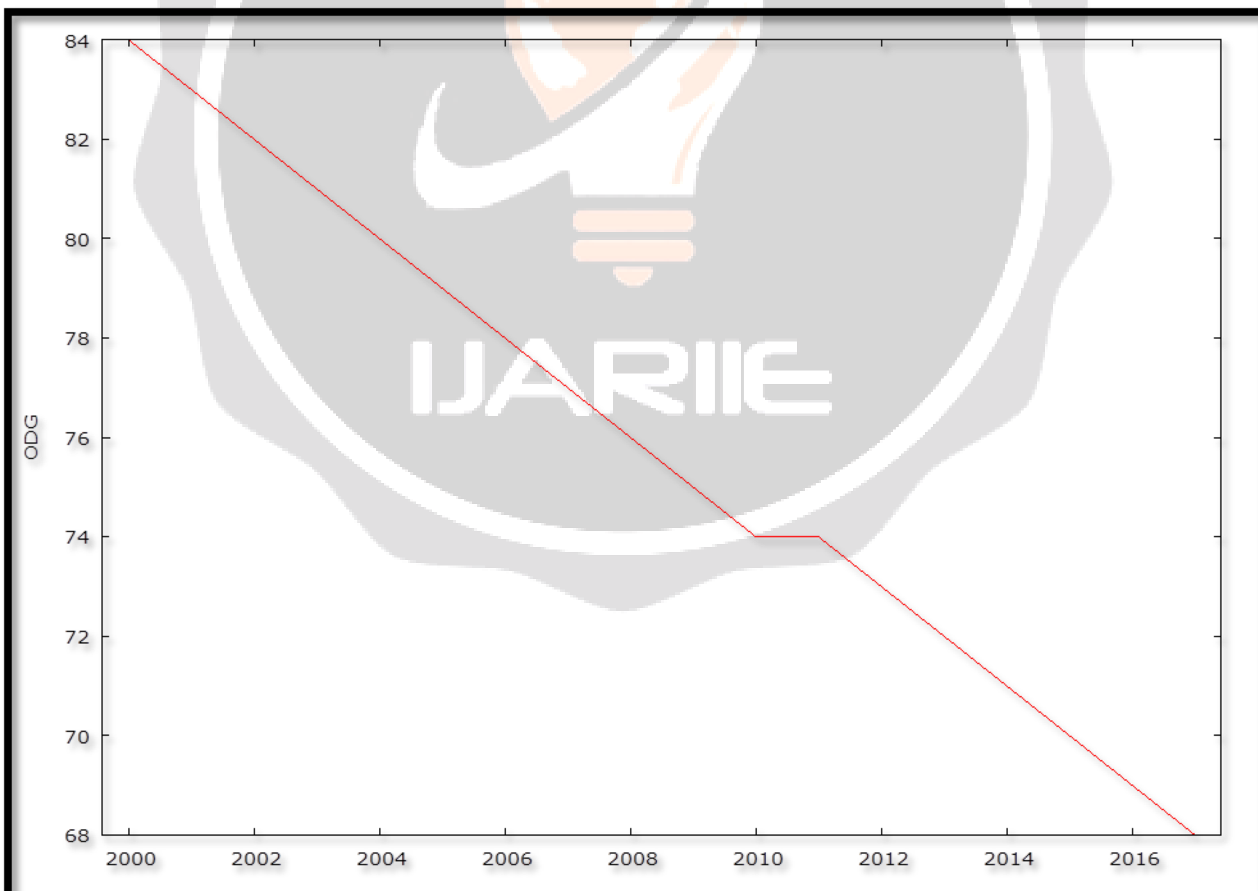
3.6 Data Collection

This study is based on annual observations (that is, from 2000 – 2017) on the number of people practicing Open Defecation [OD, denoted as ODG] (as a percentage of total population) in Niger. 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

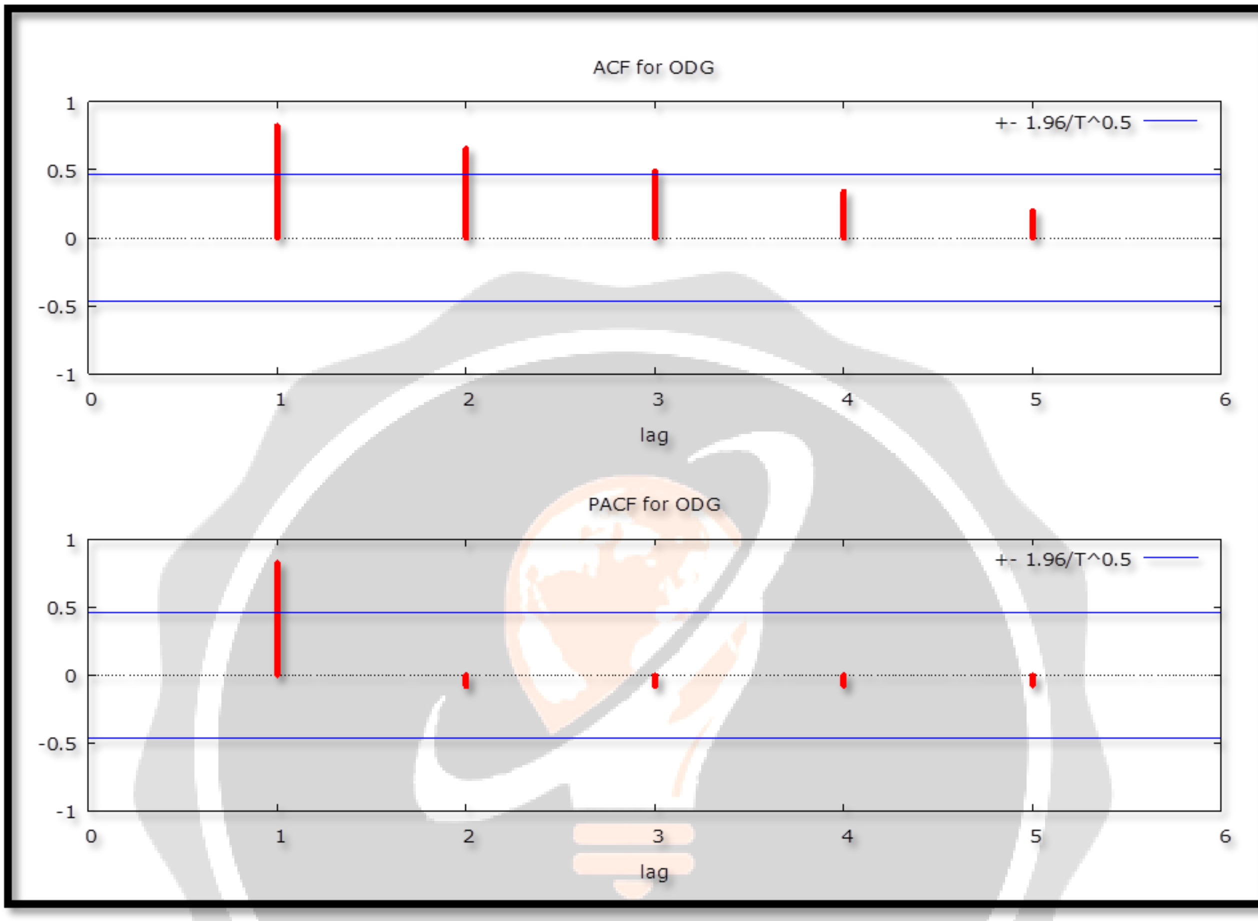
3.7.1 Stationarity Tests: Graphical Analysis

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
ODG	-0.509427	0.8667	-3.886751	@1%	Non-stationary
			-3.052169	@5%	Non-stationary
			-2.666593	@10%	Non-stationary

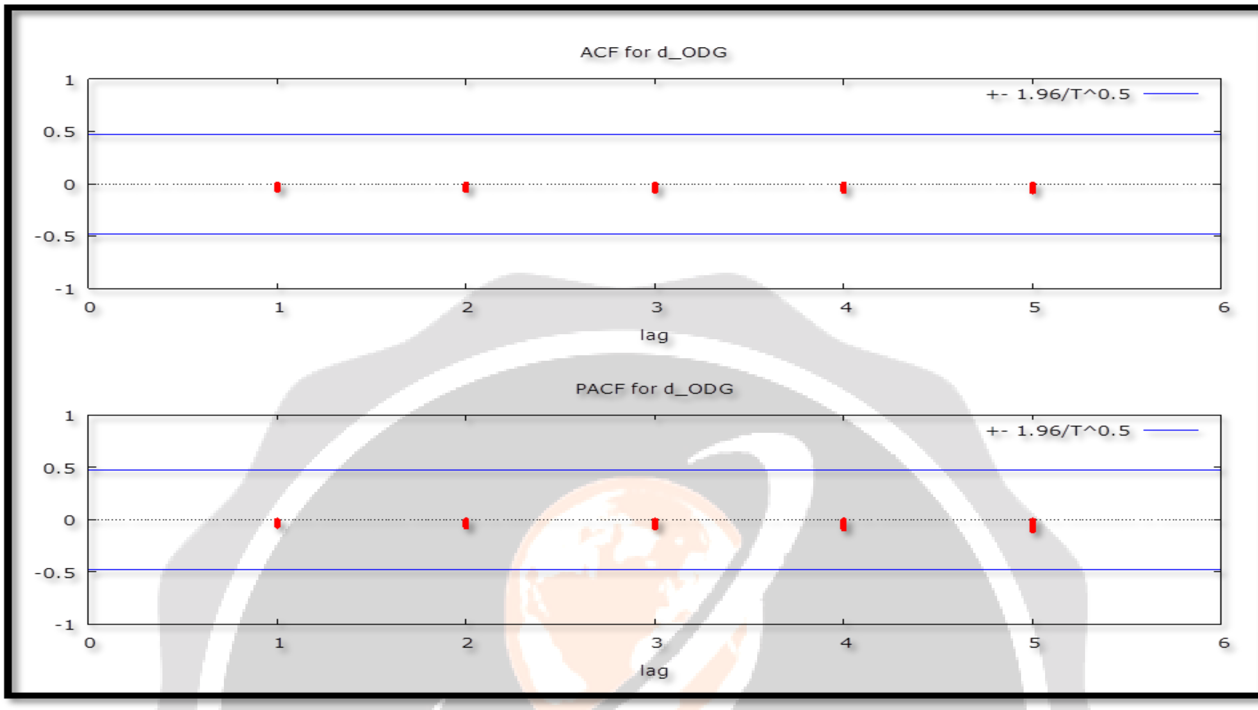
Table 2: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODG	-2.070628	0.5242	-4.616209	@1%	Non-stationary
			-3.710482	@5%	Non-stationary
			-3.297799	@10%	Non-stationary

Tables 1 and 2 show that ODG 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
ΔODG	-4.000000	0.0086	-3.920350	@1%	Stationary
			-3.065585	@5%	Stationary
			-2.673459	@10%	Stationary

Table 4: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODG	-3.881594	0.0389	-4.667883	@1%	Non-stationary
			-3.733200	@5%	Stationary
			-3.310349	@10%	Stationary

Figure 3 as well as tables 3 and 4, indicate that ODG 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)	**4.997645**	0.25462	-0.0021949	0.11046	0.23478	0.14794
ARIMA (2, 1, 0)	6.889919	0.25382	-0.0071042	0.11034	0.23411	0.14759
ARIMA (3, 1, 0)	8.777787	0.25273	-0.0015715	0.11044	0.23323	0.14742
ARIMA (4, 1, 0)	10.62722	0.25119	-0.0029951	0.11088	0.23199	0.14758
ARIMA (5, 1, 0)	12.40905	0.24882	-0.0053978	0.11193	0.23013	0.14833
ARIMA (6, 1, 0)	14.04788	0.24457	-0.0098807	0.11428	0.22692	0.1504

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 (1, 1, 0) model is finally chosen.

3.8 Residual & Stability Tests

3.8.1 ADF Test (*in levels*) of the Residuals of the ARIMA (2, 1, 0) Model

Table 6: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-3.759354	0.0136	-3.920350	@1%	Non-stationary
			-3.065585	@5%	Stationary
			-2.673459	@10%	Stationary

Table 7: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-3.649519	0.0576	-4.667883	@1%	Non-stationary
			-3.733200	@5%	Stationary
			-3.310349	@10%	Stationary

Tables 6 and 7 indicate that the residuals of the chosen optimal model, the ARIMA (1, 1, 0) model; are stationary. Hence, the model is quite stable.

3.8.2 Correlogram of the Residuals of the ARIMA (1, 1, 0) Model

Figure 4: Correlogram of the Residuals

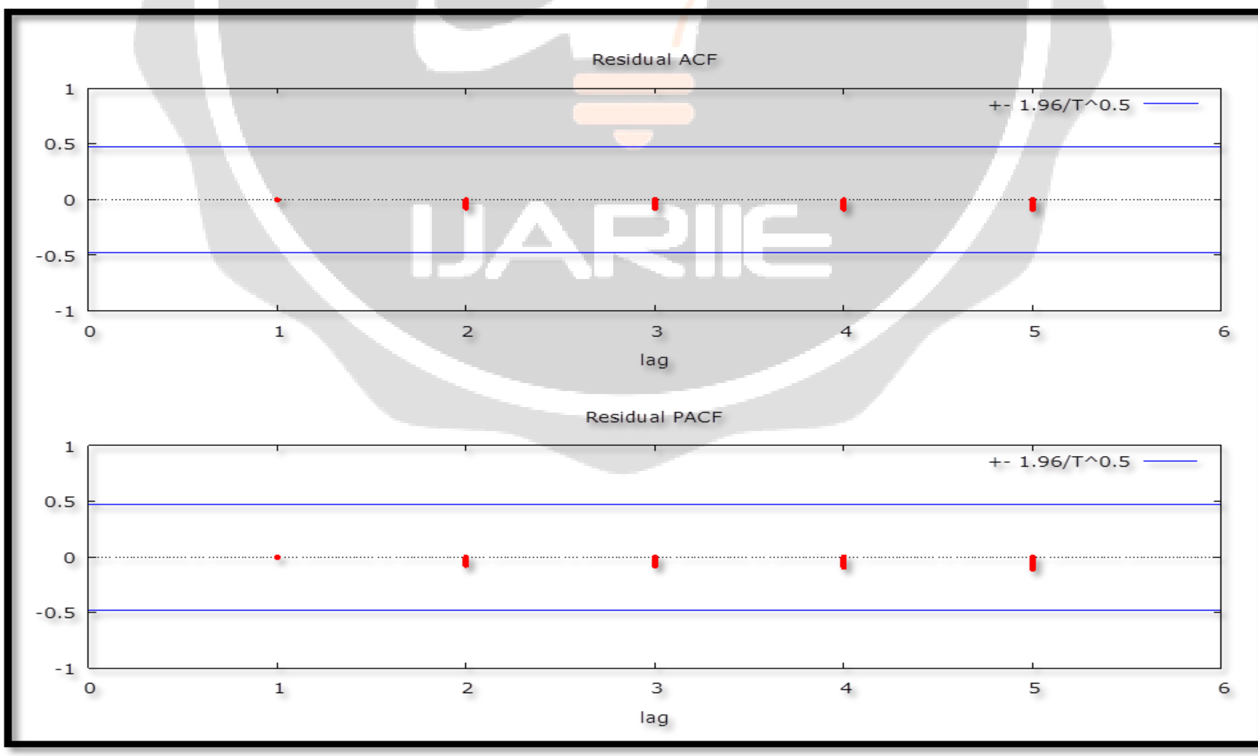
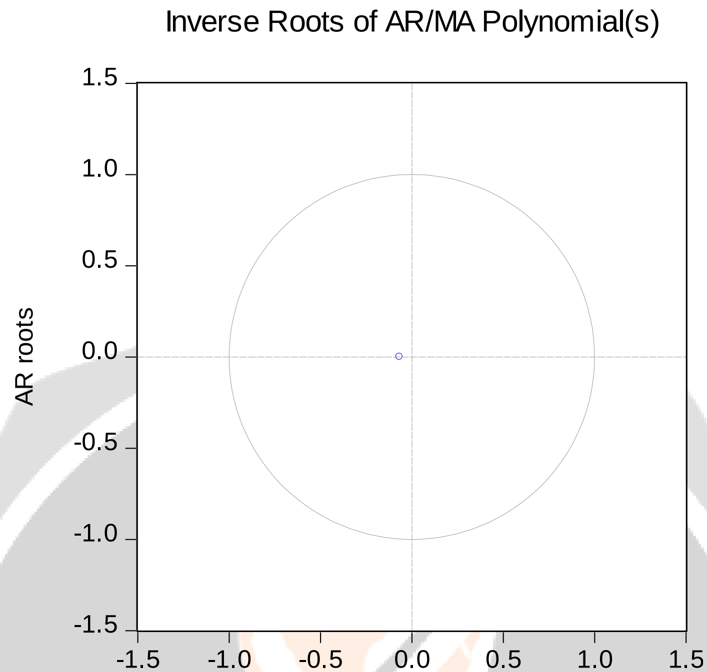


Figure 4 indicates that the applied model is adequate since ACF and PACF lags are quite short and within the bands and this means that the “no autocorrelation” assumption is not violated in this study.

3.8.3 Stability Test of the ARIMA (1, 1, 0) Model

Figure 5: Inverse Roots



Since all the AR roots lie inside the unit circle, it implies that the estimated ARIMA process is (covariance) stationary; thus confirming that the ARIMA (1, 1, 0) model is really stable and suitable for forecasting annual number of people practicing open defecation in Niger.

4.0 FINDINGS

4.1 Descriptive Statistics

Table 8: Descriptive Statistics

Description	Statistic
Mean	75.889
Median	75.5
Minimum	68
Maximum	84
Standard deviation	4.9216
Skewness	0.065643
Excess kurtosis	-1.133

As shown in table 8 above, the mean is positive, that is, 75.889. This means that, over the study period, the annual average number of people practicing open defecation in Niger is approximately 76% of the total population. This is a warning alarm for policy makers in Niger with regards to the need to promote an open defecation free society. The minimum number of people practicing open defecation in Niger over the study period is approximately 68% of the total population, while the maximum is 84% of the total population. In fact, the number of people practicing open defecation in Niger has declined (but not significantly) over the years from 84% in 2000 to 68% of the total population in 2017.

4.2 Results Presentation[1]

Table 9: Main Results

ARIMA (1, 1, 0) Model:

Guided by equation [5], the chosen optimal model, the ARIMA (1, 1, 0) can be expressed as follows:

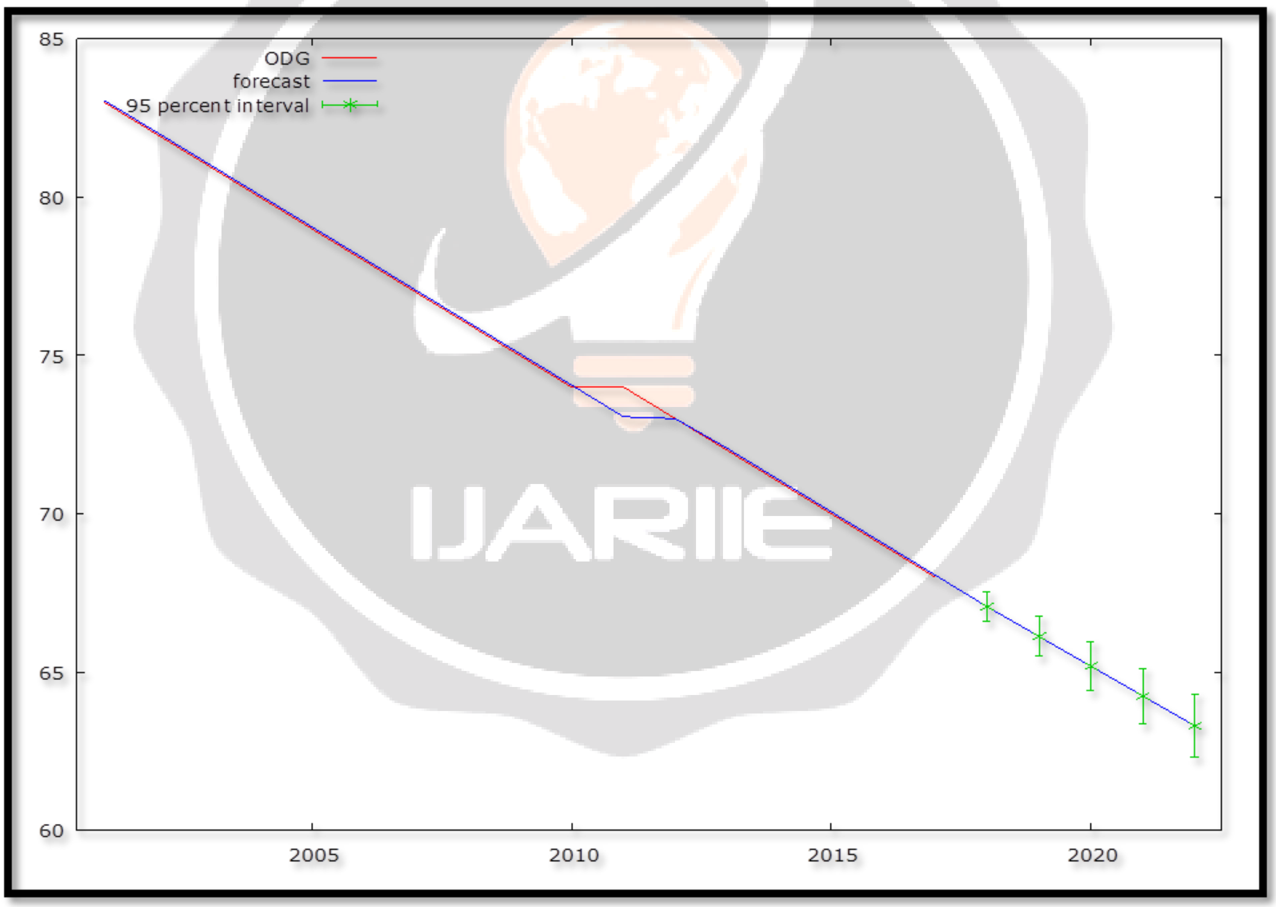
$$\Delta ODG_t = -0.940764 - 0.062991\Delta ODG_{t-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

Variable	Coefficient	Standard Error	z	p-value
constant	-0.940764	0.053754	-17.5	0.0000***
$\emptyset_1$	-0.062991	0.242474	-0.2598	0.795

Table 9 shows the main results of the ARIMA (1, 1, 0) model.

Forecast Graph

Figure 6: Forecast Graph – In & Out-of-Sample Forecasts



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

Figure 6 shows the in-and-out-of-sample forecasts of the ODG series. The out-of-sample forecasts cover the period 2018 – 2022.

Predicted ODG – Out-of-Sample Forecasts Only

Table 10: Predicted ODG

Year	Predicted ODG	Standard Error	Lower Limit	Upper Limit
2018	67.06	0.235	66.6	67.52
2019	66.12	0.322	65.49	66.75
2020	65.18	0.39	64.42	65.95
2021	64.24	0.448	63.36	65.12
2022	63.3	0.5	62.32	64.28

Figure 7: Graphical Analysis of Out-of-Sample Forecasts

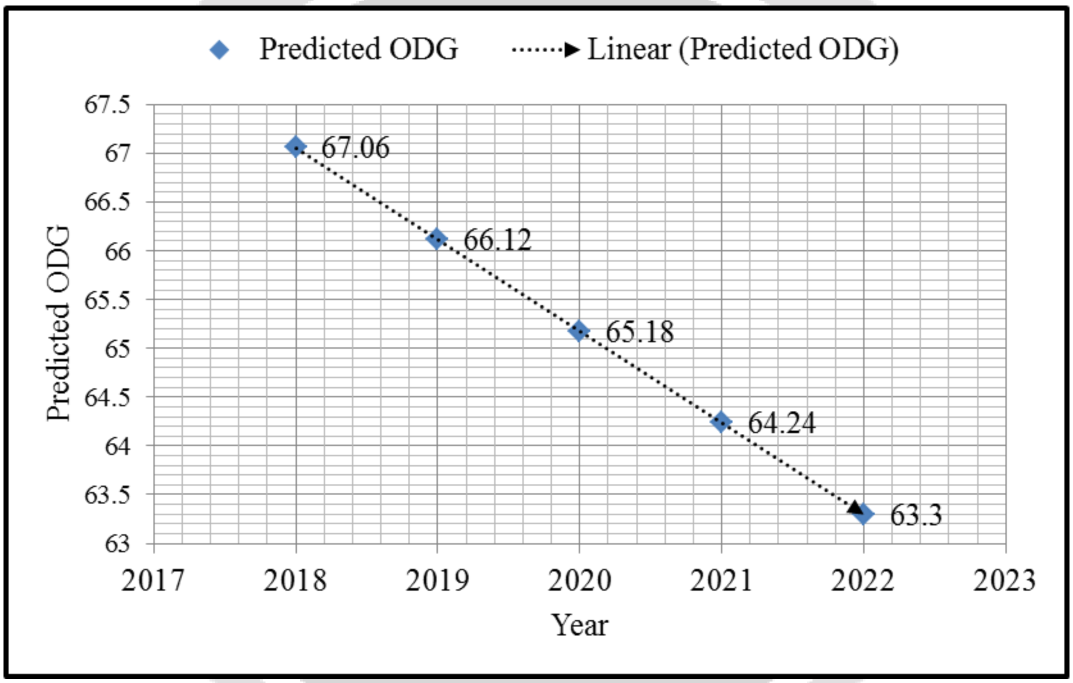


Table 10 and figure 7 show the out-of-sample forecasts only. The number of people practicing open defecation in India is projected to fall slightly from approximately 67% in 2018 to 63% of the total population by the year 2022. The results of this study suggest that existing WASH-related programmes in Niger are not yet effective in ending the practice of open defecation.

4.3 Policy Implications

i. The government of Niger should first make toilets a status symbol so that people stop thinking about toilets as “dark, dirty and smelly places” but rather consider toilets to be “rooms of happiness”. In this regard, the government of Niger ought to engage in massive sanitation marketing, especially through national media channels such as the national radio station and newspaper.
ii. The government of Niger should create more demand for sanitation through teaching the public on the importance of investing in toilets. In this regard, there should be nation-wide educational campaigns on sanitation and hygiene.
iii. The government of Niger should encourage a habit of systematic hand-washing, not defecating in the open, as well as keeping toilets fly-proof. The government should avail financial resources for sanitation-related products and facilities.

5.0 CONCLUSION

The study shows that the ARIMA (1, 1, 0) model is not only stable but also the most suitable model to forecast the annual number of people practicing open defecation in Niger over the period 2018 – 2022. The model predicts a very small decrease in the annual number of people practicing open defecation in Niger. This indicates persistence of open defecation in Niger. These findings are essential for the government of Niger, especially when it comes to long-term planning with regards to materializing the much needed open defecation free society.

REFERENCES

[1] Adhikari, R., & Ghimire, S. (2020). Open Defecation Free: Where Do We Need To Focus? *Health Prospect: Journal of Public Health*, 19 (1): 1 – 6.

[2] Alhassan, A., & Anyarayor, B. K. (2018). Determinants of Adoption of Open Defecation Free (ODF) Innovations: A Case Study of Nadowli-Kaleo District, Ghana, *Journal of Development and Communication Studies*, 5 (2): 54 – 69.

[3] Ayalew, A. M., *et al*. (2018). Assessment of Diarrhea and Its Associated Factors in Under-five Children Among Open Defecation and Open Defecation Free Rural Settings of Dangla District, Northwest Ethiopia, *Journal of Environmental and Public Health*, pp: 1 – 8.

[4] Box, G. E. P., & Jenkins, G. M. (1970). Time Series Analysis: Forecasting and Control, *Holden Day*, San Francisco.

[5] Nyoni, T (2018b). Modeling and Forecasting Inflation in Kenya: Recent Insights from ARIMA and GARCH analysis, *Dimorian Review*, 5 (6): 16 – 40.

[6] Nyoni, T. (2018a). Modeling and Forecasting Naira/USD Exchange Rate in Nigeria: A Box-Jenkins ARIMA Approach, MPRA Paper No. 88622, *University Library of Munich*, Munich, Germany.

[7] Nyoni, T. (2018c). Box – Jenkins ARIMA Approach to Predicting net FDI inflows in Zimbabwe, MPRA Paper No. 87737, *University Library of Munich*, Munich, Germany.