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OPEN DEFECATION IN ERITREA: A BOX-JENKINS ARIMA APPROACH

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ABSTRACT

Most people who live in Eritrea defecate in the open. In fact, open defecation is far more common in rural Eritrea than in urban Eritrea. Given that most people in Eritrea live in rural areas, it leaves a lot to be desired, especially from a public health perspective. Using annual time series data on the number of people who practice open defecation in Eritrea from 2000 – 2017, the study predicts the annual number of people who will still be practicing open defecation over the period 2017 – 2021. The study applies the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that the ODR series under consideration is an I (1) variable. Based on the AIC, the study presents the ARIMA (0, 1, 1) model as the optimal model. The diagnostic tests further reveal that the presented model is very stable and its residuals are stationary in levels and also normally distributed. The results of the study indicate that the number of people practicing open defecation in Eritrea is likely to decline, although slightly, over the period 2018 – 2022, from approximately 66% to almost 62% of the total population. Indeed, open defecation is still very high in Eritrea. The study suggested a 3-fold policy recommendation to be put into consideration, especially by the Eritrean government.

1.0INTRODUCTION

The vast majority of people, especially in rural Eritrea, practice open defecation, that is, relieving themselves anywhere on the ground in the open. This may be due to a limited awareness of safe hygienic practices coupled with the availability of ample open space around their homesteads and villages. This historically has been the traditional norm in rural

Eritrea (UNICEF, 2015). Open defecation is terrible from a public health perspective (UNICEF, 2018), particularly, in terms of the spread of bacterial, viral and parasitic infections including diarrhoea, polio, cholera, soil-transmitted helminth, trachoma infection, schistosomiasis and hookworm and is also an important cause of child stunting (Megersa et al., 2019) and deaths (Thiga & Cholo, 2017). Thus, it has become even more 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. The main purpose of this study is to predict the annual number of open defecators in Eritrea over the period 2017 – 2021. This study, besides being the first of its kind in the case of Eritrea, will go a long way in uncovering the possibility of ending open defecation in the country.

1.2OBJECTIVES OF THE STUDY

i. To investigate the years during which open defection was practiced by people more than 50% of the total population in Eritrea.
ii. To forecast the number of people practicing open defecation in Eritrea for the period 2017 – 2021.
iii. To examine the trend of open defecation in Eritrea for the out-of-sample period.

2.0 LITERATURE REVIEW

Ayalew et al. (2018) examined diarrheal morbidity in under-five children and its associated factors in Dangla district in Northwest Ethiopia. A community-based comparative cross-sectional study design with a multistage random sampling technique was employed. 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 employed to collect data. The study revealed

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that while effective communication of innovation resulted in widespread awareness, low income levels significantly accounted for households' inability to sustain and utilize latrines. Nyoni (2019) forecasted total population in Eritrea using the Box-Jenkins ARIMA technique based on annual time series data on total population in Eritrea from 1960 to 2011. The study presented the ARIMA (1, 2, 3) model and concluded that total population in India will continue to sharply rise in the next 39 years, thereby posing a threat to both natural and non-renewable resources; without proper sanitation and hygiene (in the midst of open defecation), that would be a time bomb in terms of disease transmission. This study will adopt the ARIMA method in analyzing open defecation trends in Eritrea.

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 used to analyze the ODR series under consideration.

3.2 The Moving Average (MA) model

Given:

$$\mathrm{ODR}_t = \sum_{i=1}^{q} \alpha_i \mu_{t-i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . [1]$$

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

$$ODR_t = \sum_{i=1}^{p} \beta_i ODR_{t-1} + \mu_t \ldots \ldots \ldots \ldots \ldots [2]$$

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

$$ODR_t = \sum_{i=1}^{p} \beta_i ODR_{t-i} + \sum_{i=1}^{q} \alpha_i \mu_{t-i} + \mu_t \ldots \ldots \ldots \ldots \ldots [3]$$

3.5 The Autoregressive Integrated Moving Average (ARIMA) model

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

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

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 ODR] (as a percentage of total population) in Eritrea. Out-of-sample forecasts will cover the period 2017 – 2021. All the data was gathered from the World Bank online database.

3.7 Diagnostic Tests & Model Evaluation

3.7.1 Stationarity Tests: Graphical Analysis

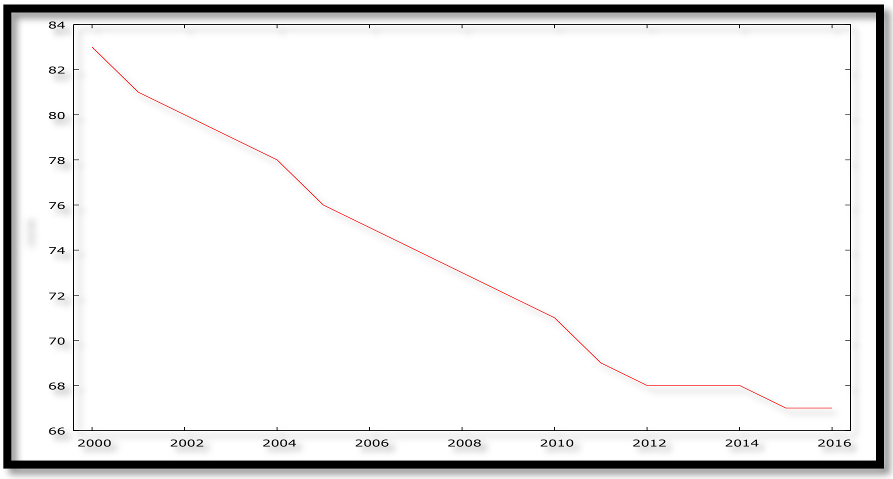

Figure 1

3.7.2 The Correlogram in Levels

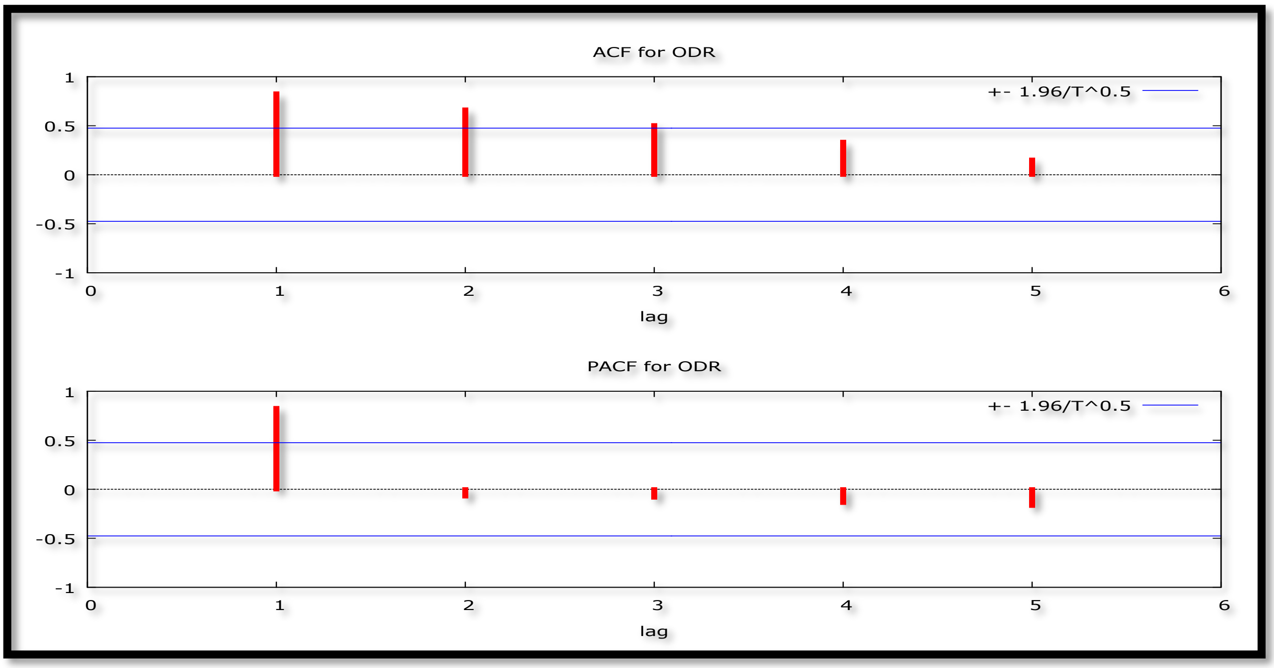

Figure 2: Correlogram in Levels

3.7.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODR	-2.708051	0.0942	-3.920350	@1%	Non-stationary
			-3.065585	@5%	Non-stationary
			-2.763459	@10%	Stationary

Table 2: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODR	-0.527652	0.9692	-4.667883	@1%	Non-stationary
			-3.733200	@5%	Non-stationary
			-3.310349	@10%	Non-stationary

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

3.7.4 The Correlogram (at First Differences)

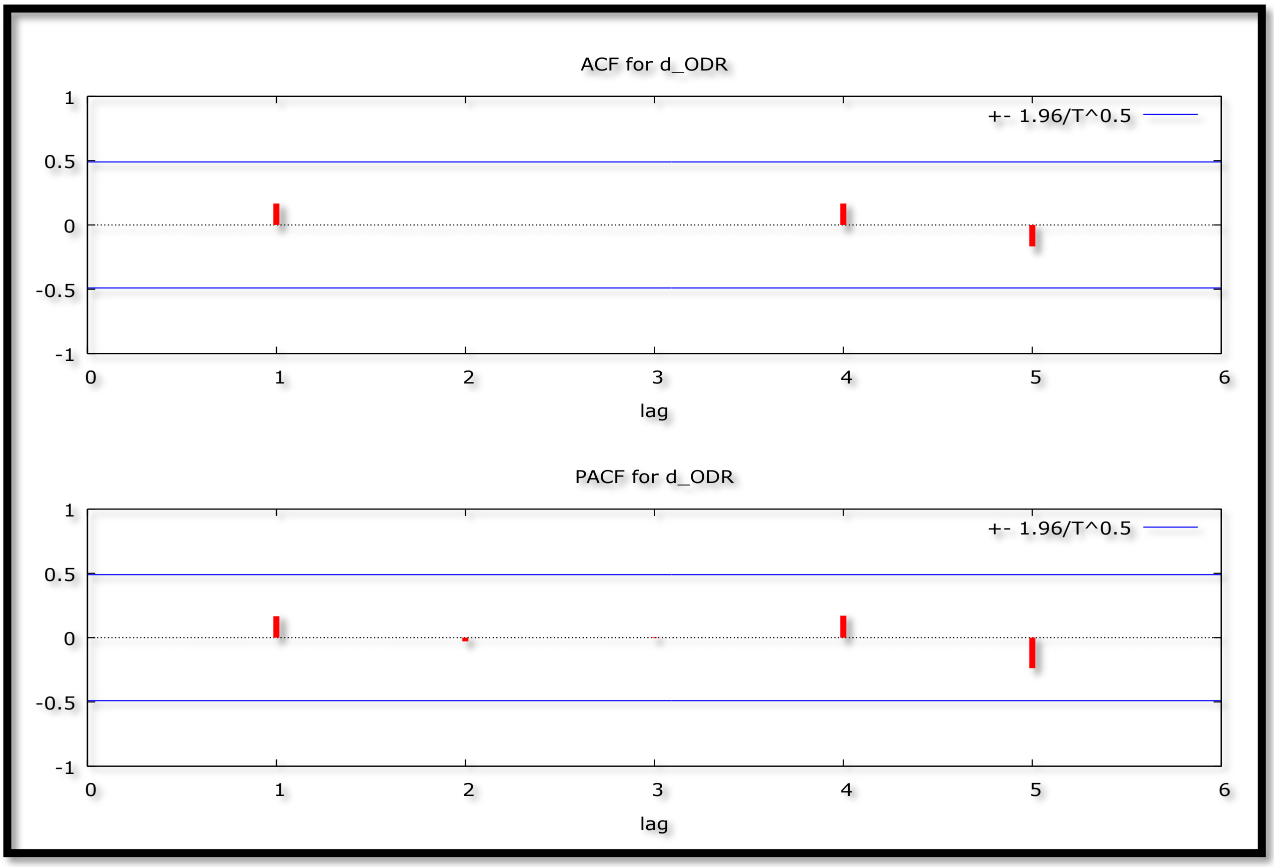

Figure 3: Correlogram (at First Differences)

3.7.5 The ADF Test (at First Differences)

Table 3: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODR	-2.894439	0.0694	-3.959148	@1%	Non-stationary
			-3.081002	@5%	Non-stationary
			-2.681330	@10%	Stationary

Table 4: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODR	-3.548119	0.0704	-4.728363	@1%	Non-stationary
			-3.759743	@5%	Non-stationary
			-3.324976	@10%	Stationary

Figure 3 as well as tables 3 and 4, indicate that ODR 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)	35.09058	0.54539	0.014272	0.41782	0.60229	0.58525
ARIMA (2, 1, 0)	37.05216	0.54465	0.010928	0.42328	0.60165	0.59203
ARIMA (3, 1, 0)	38.97261	0.54137	0.017679	0.44039	0.60053	0.61445
ARIMA (1, 1, 1)	37.05297	0.54452	0.012354	0.42432	0.6017	0.59354
ARIMA (0, 1, 1)	**35.05838**	0.54454	0.011389	0.42428	0.60167	0.59335
ARIMA (0, 1, 2)	37.05042	0.54452	0.01268	0.42429	0.60172	0.59354

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

3.8 Residual & Stability Tests

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

Table 6: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-3.671490	0.0171	-3.959148	@1%	Non-stationary
			-3.081002	@5%	Stationary
			-2.681330	@10%	Stationary

Table 7: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-4.301117	0.0204	-4.728363	@1%	Non-stationary
			-3.759743	@5%	Stationary
			-3.324976	@10%	Stationary

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

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

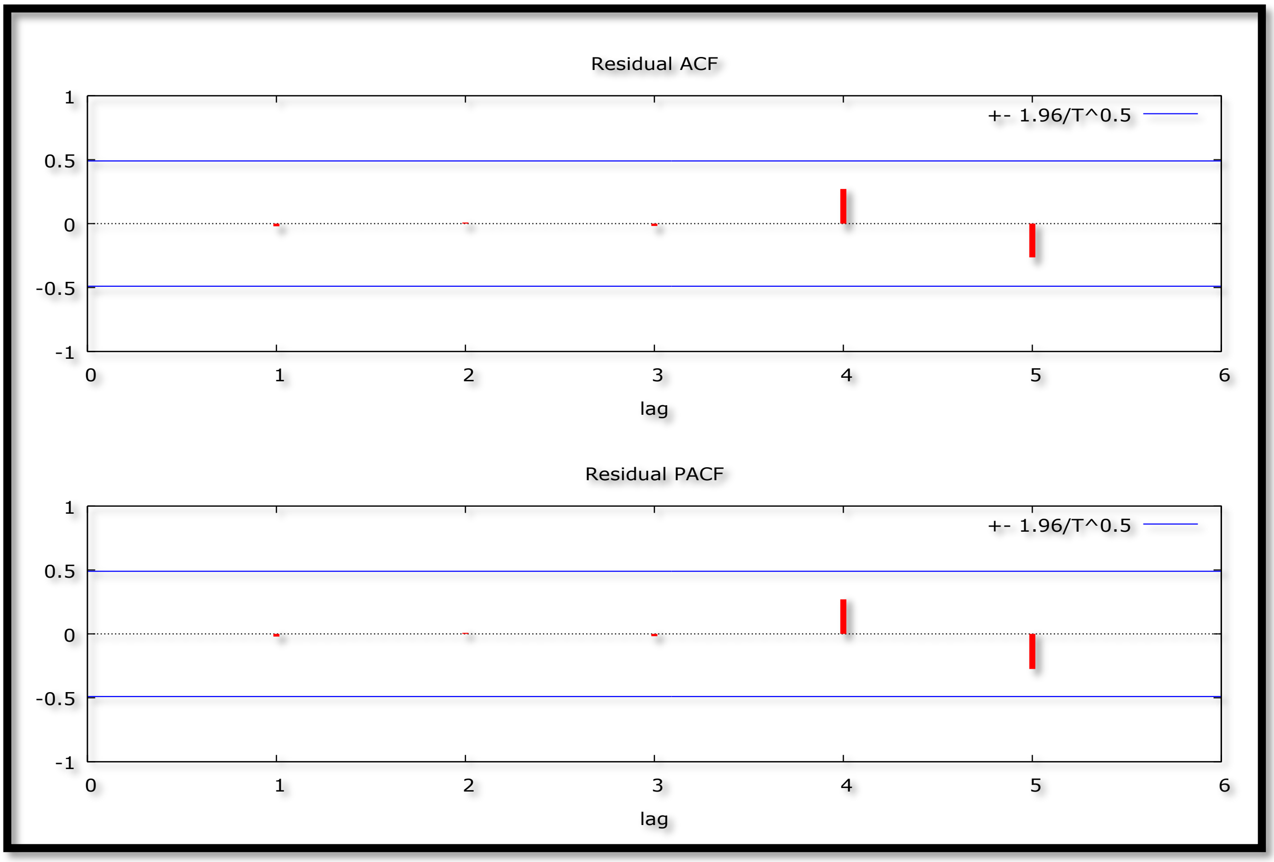

Figure 4: Correlogram of the Residuals

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

3.8.3 Stability Test of the ARIMA (2, 1, 0) Model

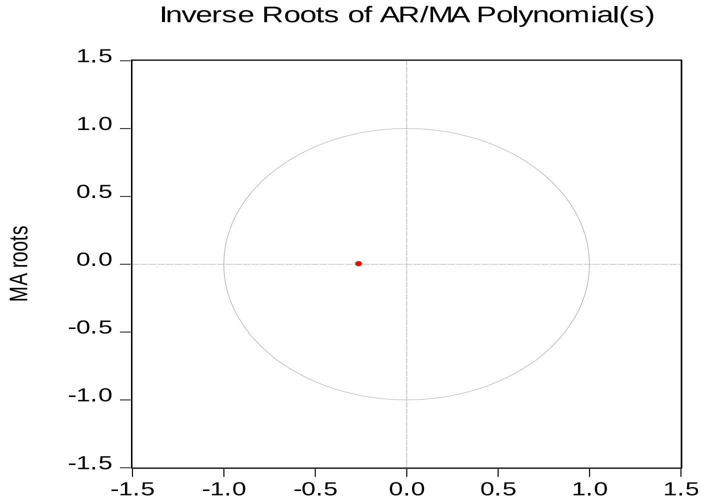

Figure 5: Inverse Roots

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 (0, 1, 1) model is really stable and suitable for forecasting annual number of people practicing open defecation in Eritrea.

3.8.4 Normality Test of the Residuals of the ARIMA (0, 1, 1) Model

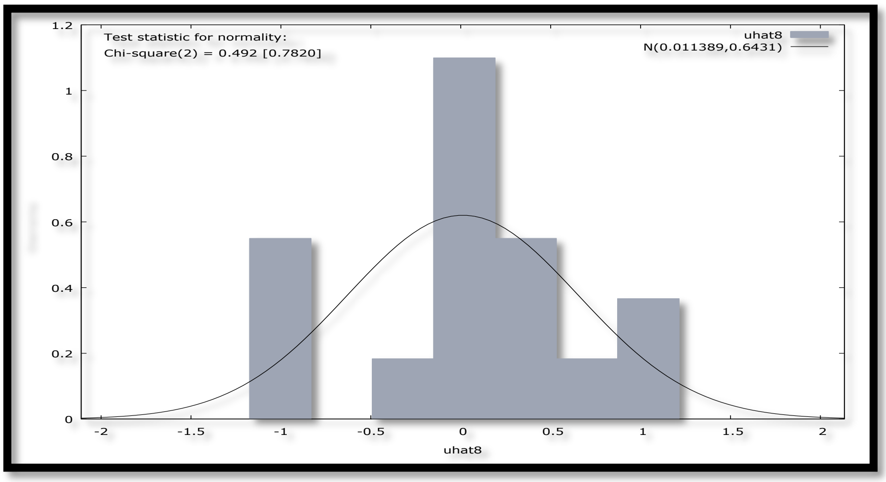

Figure 6: Normality Test

As shown in figure 6 above, the residuals of the optimal model are normally distributed since the p-value of the Chi-square statistic is statistically insignificant. This is a desirable feature which confirms that the applied model is indeed stable as already shown in figures 4 and 5.

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4.0 FINDINGS

4.1 Descriptive Statistics

Table 8: Descriptive Statistics

Description	Statistic
Mean	73.471
Median	73
Minimum	67
Maximum	83

As shown in table 8 above, the mean is positive, that is, 73.471. This means that, over the study period, the annual average number of people practicing open defecation in Eritrea is approximately 73% of the total population. This is a serious warning signal for policy makers in Eritrea with regards to the need to promote an open defecation free society. The minimum number of people practicing open defecation in Eritrea over the study period is approximately 67% of the total population, while the maximum is 83% of the total population. In fact, the number of people practicing open defecation in Eritrea has declined over the years from 83% in 2000 to 67% of the total population in 2017.

4.2 Results Presentation

Table 9: Main Results

ARIMA (0, 1, 1) Model:

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

$$\Delta \mathrm{ODR}_t = -0.999415 + 0.237021\Delta \mathrm{ODR}_{t-1} \ldots \ldots \ldots \ldots [5]$$

Variable	Coefficient	Standard Error	z	p-value
constant	-0.999415	0.182997	-5.461	0.0000***
α_1	0.237021	0.280910	0.8438	0.3988

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

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Forecast Graph

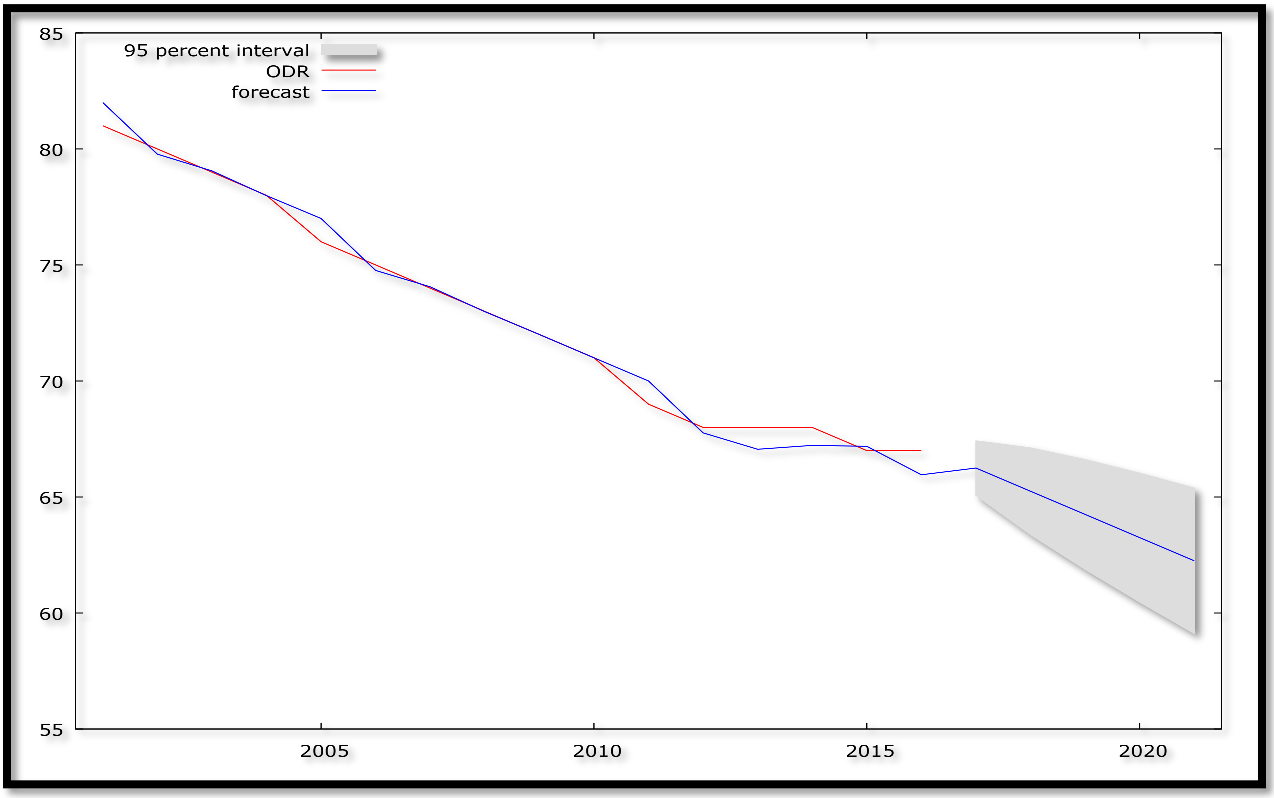

Figure 7: Forecast Graph – In & Out-of-Sample Forecasts

Figure 7 shows the in-and-out-of-sample forecasts of the ODR series. The out-of-sample forecasts cover the period 2018 – 2022.

Predicted ODR – Out-of-Sample Forecasts Only

Table 10: Predicted ODR

Year	Predicted ODR	Standard Error	Lower Limit	Upper Limit
2017	66.25	0.599	65.07	67.42
2018	65.25	0.953	63.38	67.12
2019	64.25	1.207	61.88	66.61
2020	63.25	1.416	60.47	66.03
2021	62.25	1.598	59.12	65.38

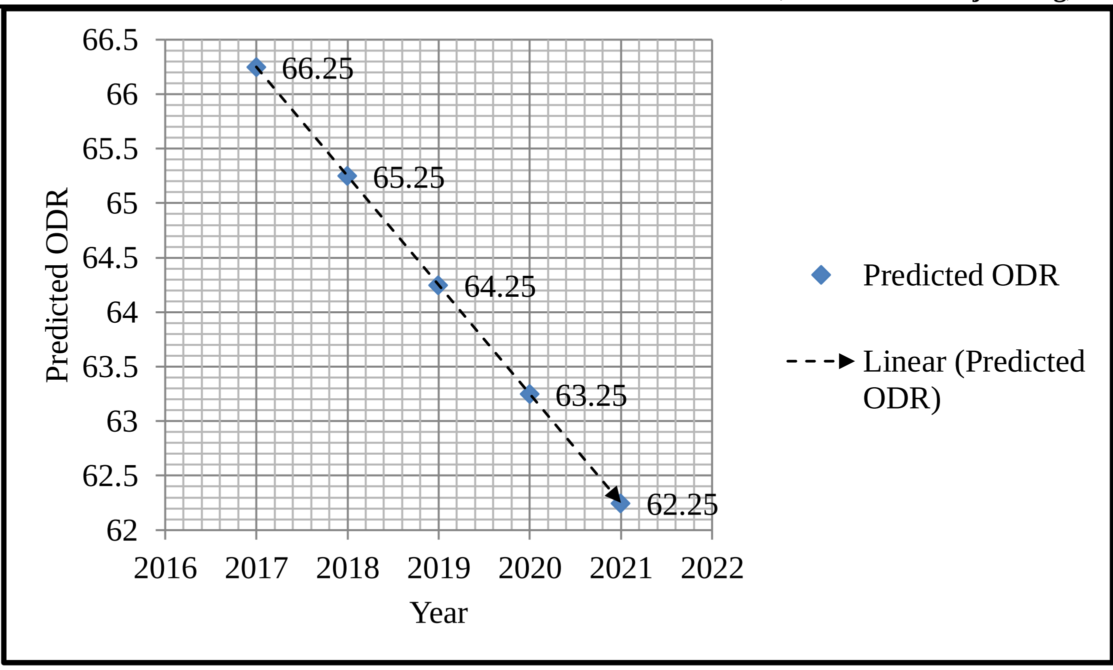

Figure 8: Graphical Analysis of Out-of-Sample Forecasts

Table 10 and figure 8 show the out-of-sample forecasts only. The number of people practicing open defecation in Eritrea is projected to slightly fall from approximately 66% in 2017 to 62% of the total population by the year 2022. Open defecation will remain very high Eritrea for quite some time, even beyond the out-of-sample period. However, it is possible to significantly reduce the number of open defecators in Eritrea, especially if the current government considers the policy directions suggested below.

4.3 Policy Implications

i. The government of Eritrea should, first of all, make toilets a status symbol so that Eritreans stop thinking about toilets as "dark, dirty and smelly places" but rather consider toilets to be "rooms of happiness". In this regard, the Community-Led Total Sanitation (CLTS) approach ought to be intensified along with increased funding for construction of toilets in rural areas.

ii. The government of Eritrea must create demand for sanitation through teaching the public on the importance of investing in toilets.

iii. There is need for the government of Eritrea to encourage a habit of systematic hand-washing, and not defecating in the open.

5.0 CONCLUSION

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

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