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OPEN DEFECATION IN LESOTHO: A BOX-JENKINS ARIMA APPROACH

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ABSTRACT

Using annual time series data on the number of people who practice open defecation in Lesotho from 2000 – 2017, the study predicts the annual number of people who will still be practicing open defecation over the period 2018 – 2021. The study applies the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that the ODL series under consideration is an I (2) variable. Based on the AIC, the study presents the ARIMA (2, 2, 0) model as the optimal model. The diagnostic tests further reveal that the presented model is indeed stable and its residuals are not serially correlated and are also normally distributed. The results of the study indicate that the number of people practicing open defecation in Lesotho is likely to decline, over the period 2018 – 2022, from approximately 26.3% to almost 22.4% of the total population. Indeed, open defecation remains a significant public health issue in Lesotho. The study suggested a 3-fold policy recommendation to be put into consideration, especially by the government of Lesotho.

INTRODUCTION

Lesotho is a very small landlocked country, completely surrounded by South Africa. The population of Lesotho is approximately 2 million. The country is mostly rural. This could explain why open defecation is still a major problem, since most open defecators are people who have limited knowledge on sanitation and hygiene. In Lesotho, a combination of access to hygienic toilet, waste management problems, lack of clean water, as well as people dumping waste in water and defecating in the open, has resulted in high levels of environmental contamination and exposure to the risks of worm infestations and microbial infections. Most diarrheal illnesses in Lesotho are directly linked to faecal pollution of water sources from poor environmental hygiene and sanitation (Ramaili, 2006; Gwimbi et al., 2019). Thus, it has become even more imperative for public health researchers and policy makers, especially those in Lesotho; to analyze 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 Lesotho over the period 2018 – 2021. This study, besides being the first of its kind in the case of Lesotho, will go a long way in uncovering the possibility of ending open defecation in the country.

1.2 OBJECTIVES OF THE STUDY

i. To investigate the years during which open defection was practiced by people more than 27% of the total population in Lesotho.
ii. To forecast the number of people practicing open defecation in Lesotho for the period 2018 – 2021.
iii. To examine the trend of open defecation in Lesotho for the out-of-sample period.

LITERATURE REVIEW

Guterres et al. (2014) investigated the determinants of households' use and maintenance of latrines in Thailand. Their research 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 was found to be one of the most critical factors seen to be influencing household to use and maintain latrines. Sintondji et al. (2017) analyzed the influence of socio-demographic factors on household hygiene and sanitation behaviour in Benin using interviews and the results of their study basically revealed that 68% of households did not cover their containers during the transport of water, 58% of respondents defecated in water and 31% in the open air. Osumanu et al. (2019) looked at 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 applied to investigate the factors that significantly influence open defecation in Ghana. The results of their study basically show 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. No study has been done to forecast the number of open defecators in Lesotho. This study is the first of its kind in the case of Lesotho and is anticipated to fast-track the eradication of open defecation in Lesotho.

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 ODL series under consideration.

3.2 The Moving Average (MA) model

Given:

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

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, commonly denoted as MA (q). ODL is the annual number of people (as a percentage of the total population) who practice open defecation in Lesotho 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:

$$\mathrm{ODL_t} = \sum_{i=1}^{p} \beta_i \mathrm{ODL}_{t-i} + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [2]$$

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $\mathrm{ODL}_{t-1} \ldots \mathrm{ODL}_{t-p}$ are previous period values of the ODL 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 mere 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:

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

3.5 The Autoregressive Integrated Moving Average (ARIMA) model

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

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

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 ODL] (as a percentage of total population) in Lesotho. Out-of-sample forecasts will cover the period 2018 – 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

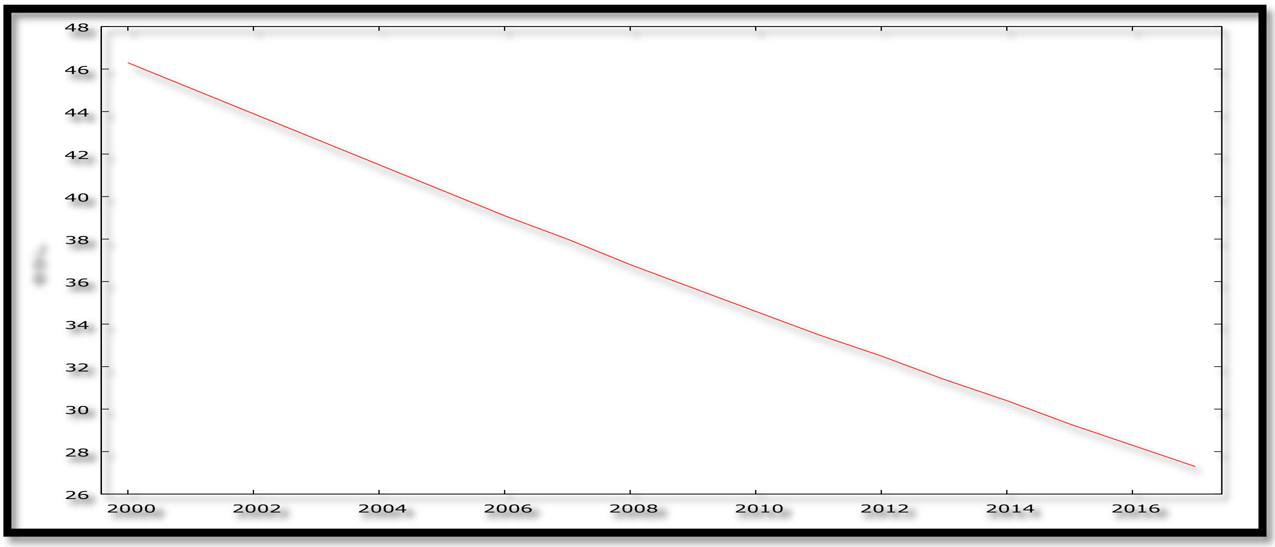

Figure 1

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3.7.2 The Correlogram in Levels

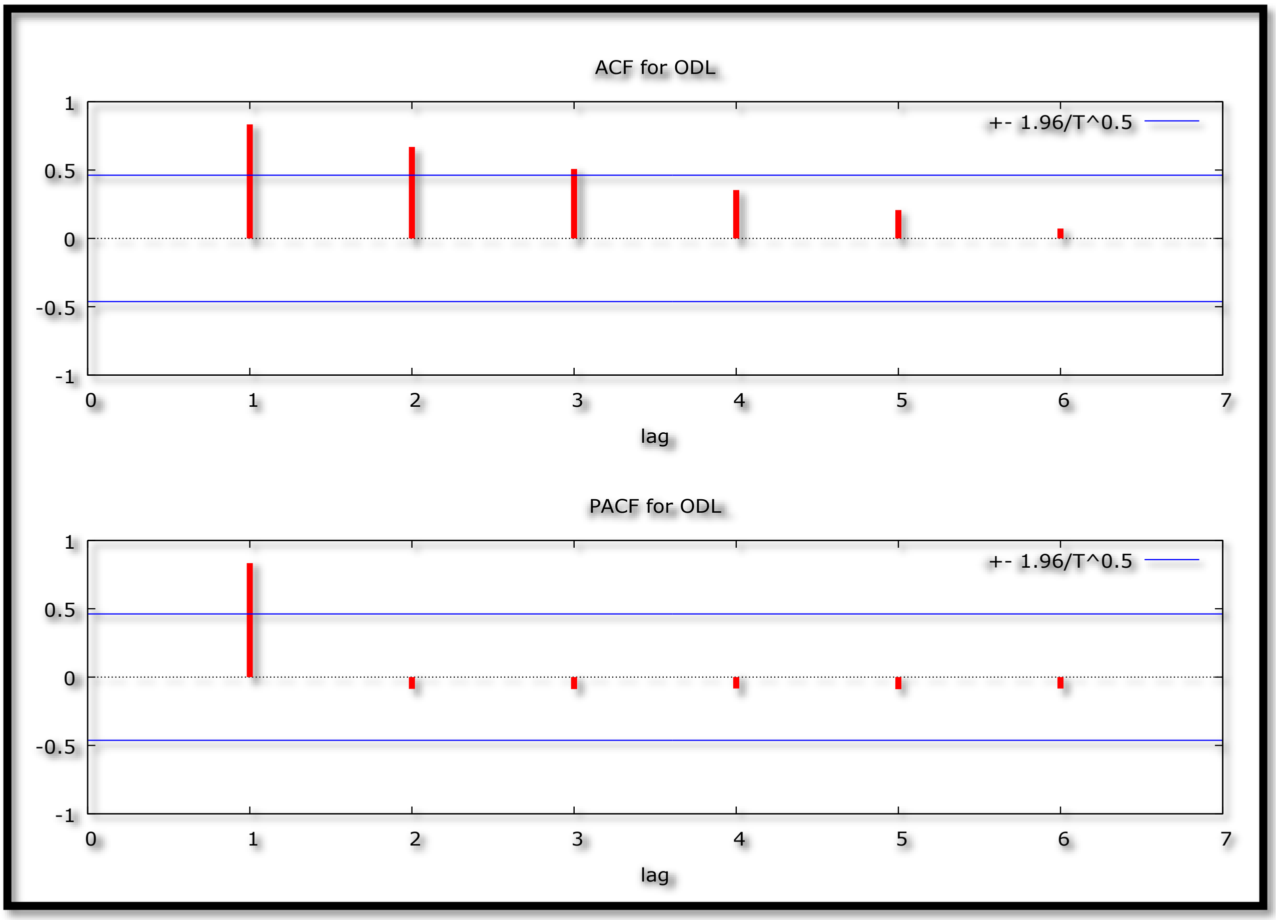

Figure 2: Correlogram in Levels

3.7.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODL	-6.157793	0.0002	-3.920350	@1%	Stationary
			-3.065585	@5%	Stationary
			-2.673459	@10%	Stationary

Table 2: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODL	0.198514	0.9952	-4.667883	@1%	Non-stationary
			-3.733200	@5%	Non-stationary
			-3.310349	@10%	Non-stationary

Table 1 shows that ODL is stationary in levels; but table 2 shows exactly the opposite.

3.7.4 The Correlogram (at First Differences)

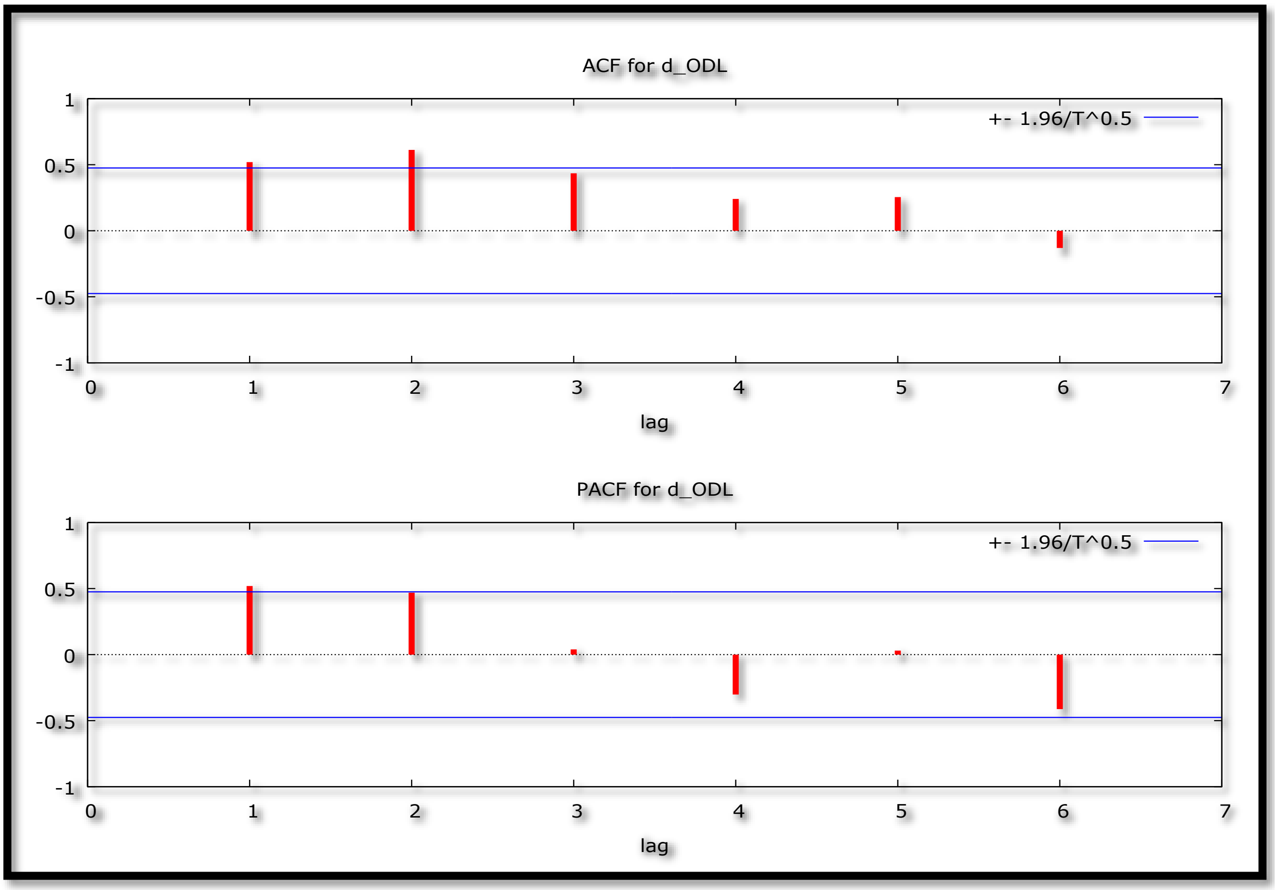

Figure 3: Correlogram (at First Differences)

3.7.5 The ADF Test (at First Differences)

Table 3: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODL	0.090580	0.9524	-4.004425	@1%	Non-stationary
			-3.098896	@5%	Non-stationary
			-2.690439	@10%	Non-stationary

Table 4: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODL	-7.051506	0.0002	-4.667883	@1%	Stationary
			-3.733200	@5%	Stationary
			-3.310349	@10%	Stationary

Figure 3 as well as tables 3 and 4, generally indicate that ODL is not an I (1) variable. The study could not rely on results shown in table 4. We, therefore, proceed to test for stationary in second differences.

3.7.6 The Correlogram (at Second Differences)

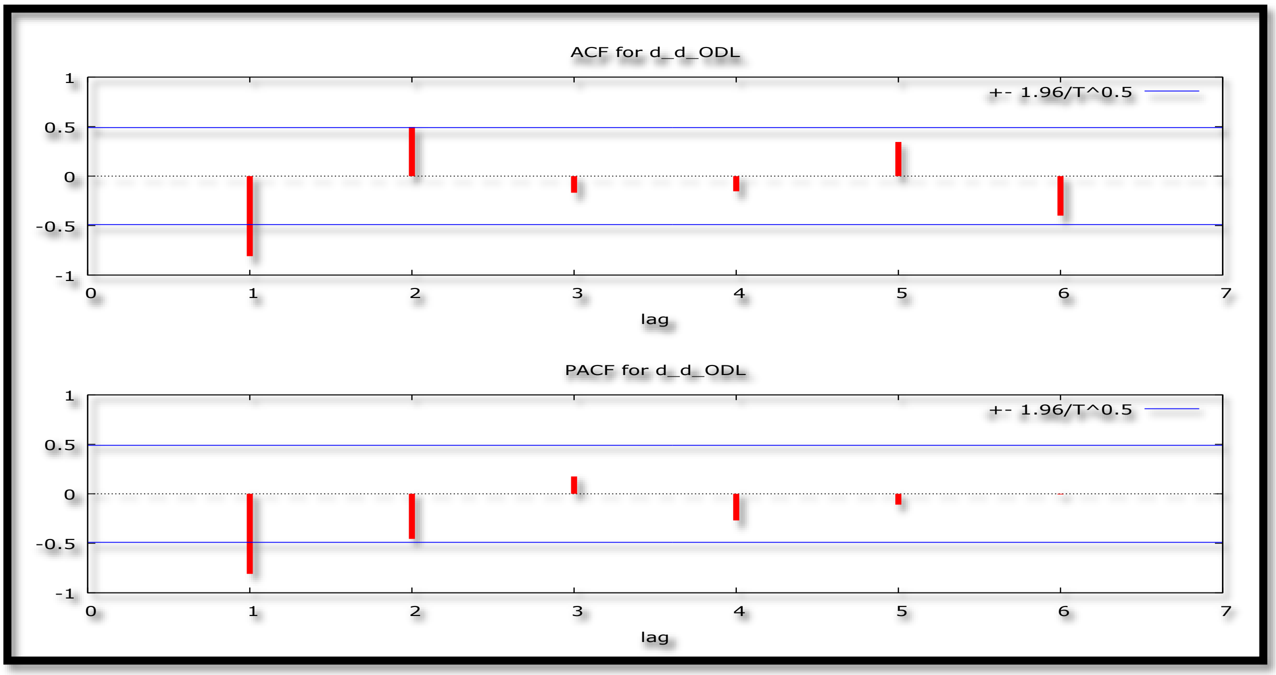

Figure 4: Correlogram (at Second Differences)

3.7.7 The ADF Test (at Second Differences)

Table 5: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
Δ^2ODL	-5.135635	0.0014	-4.004425	@1%	Stationary
			-3.098896	@5%	Stationary
			-2.690439	@10%	Stationary

Table 6: with intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
Δ^2ODL	-4.968582	0.0076	-4.800080	@1%	Stationary
			-3.791172	@5%	Stationary
			-3.342253	@10%	Stationary

Figure 4 as well as tables 5 and 6, indicate that ODL is an I (2) variable.

3.7.8 Evaluation of ARIMA models (with a constant)

Table 7: Evaluation of ARIMA Models (with a constant)

Model	AIC	U	ME	RMSE	MAPE
ARIMA (1, 2, 0)	-49.99667	0.039121	-0.000637	0.040963	0.09716
ARIMA (2, 2, 0)	**-51.96584**	0.03373	-0.0014115	0.035593	0.082924
ARIMA (3, 2, 0)	-50.60315	0.03296	-0.0007739	0.034811	0.085663
ARIMA (0, 2, 1)	-49.09725	0.039997	-0.0054334	0.04205	0.10306
ARIMA (0, 2, 2)	-50.65105	0.034357	-0.0084414	0.037298	0.080997
ARIMA (0, 2, 3)	-51.74066	0.030965	-0.0049172	0.033922	0.086128

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 (2, 2, 0) model is finally chosen.

3.8 Residual & Stability Tests

3.8.1 Correlogram of the Residuals of the ARIMA (2, 2, 0) Model

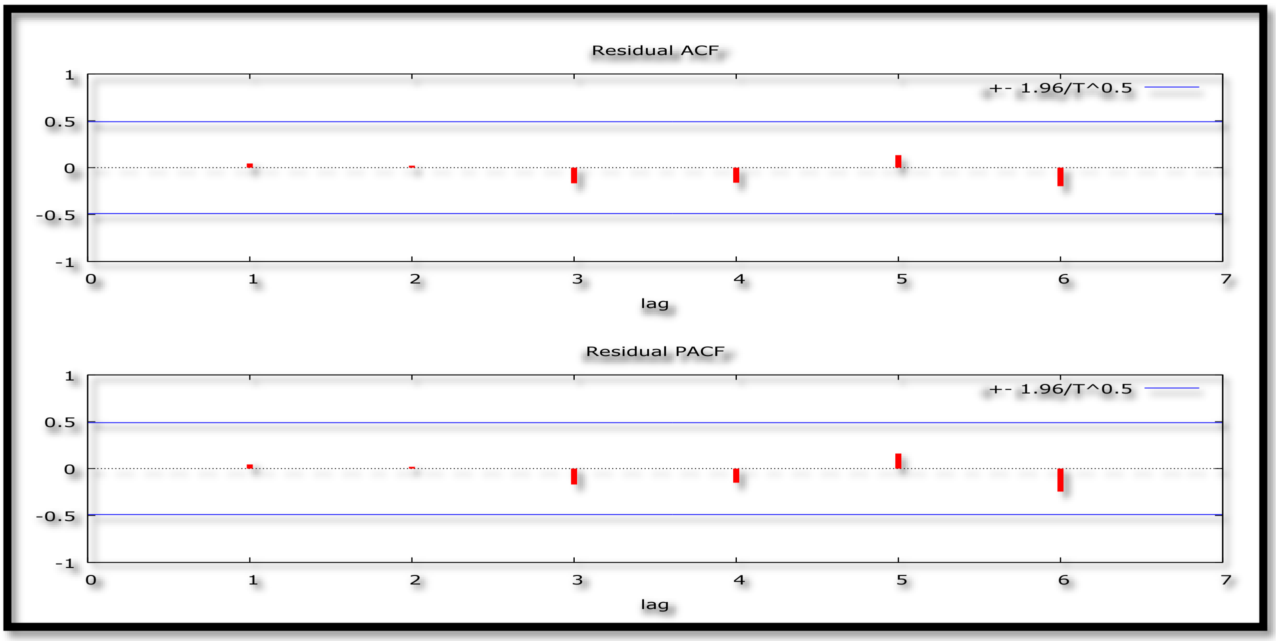

Figure 5: Correlogram of the Residuals

Figure 5 indicates that the estimated optimal model is adequate since ACF and PACF lags are quite short and within the bands. This implies that the "no autocorrelation" assumption is not violated in this study.

3.8.2 Stability Test of the ARIMA (2, 2, 0) Model

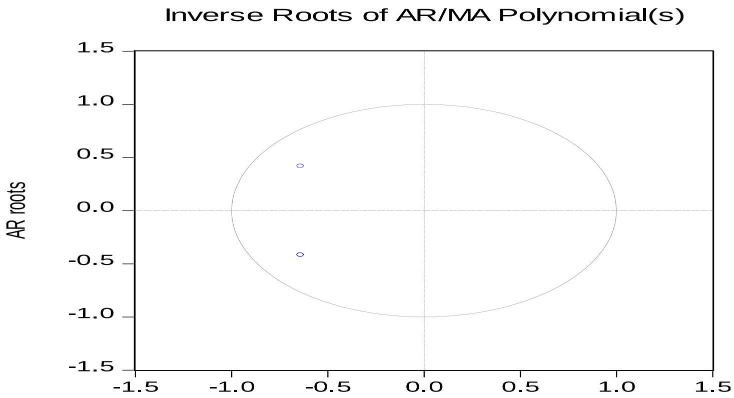

Figure 6: Inverse Roots

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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 (2, 2, 0) model is really stable and suitable for forecasting annual number of people practicing open defecation in Lesotho.

3.8.3 Normality Test of the Residuals of the ARIMA (2, 2, 0) Model

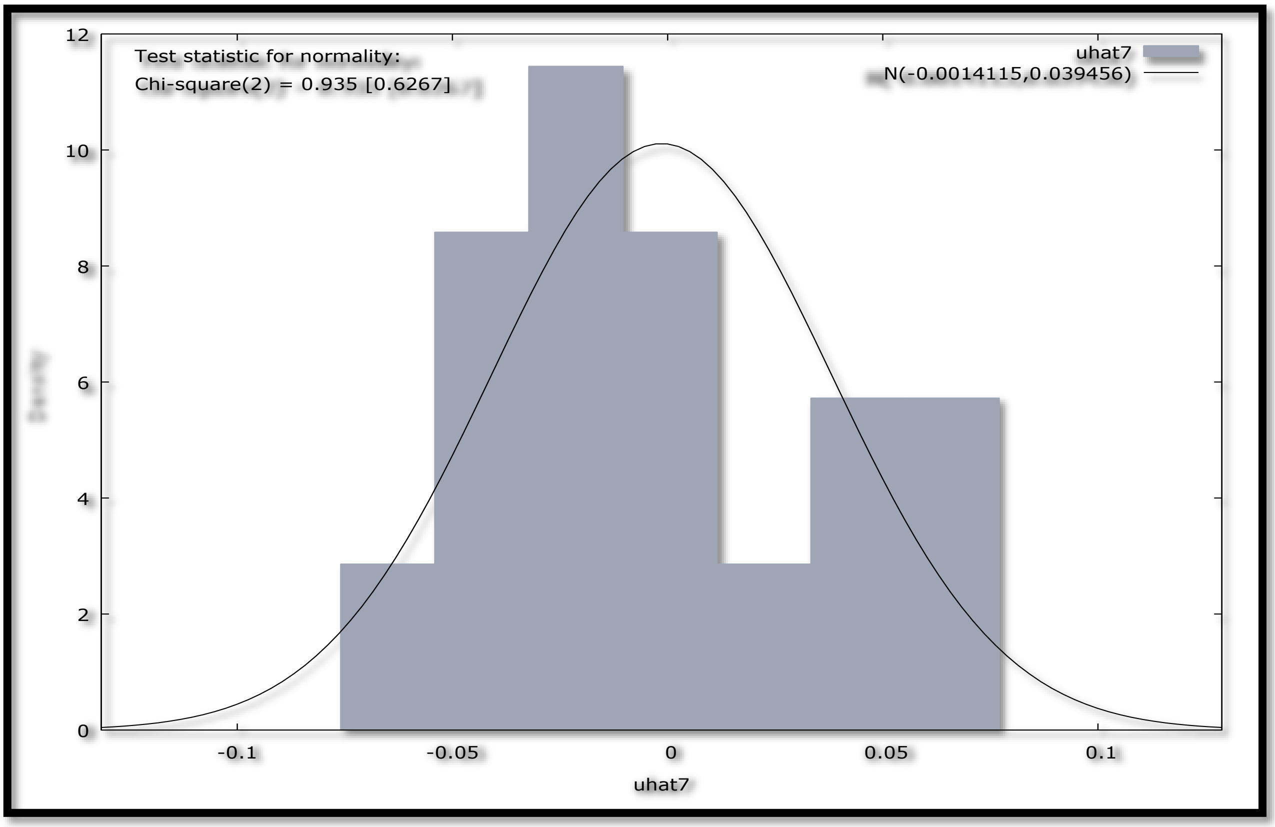

Figure 7: Normality Test

Since the probability value of the chi-square statistic is insignificant, we reject the null hypothesis and conclude that the residuals of the ARIMA (2, 2, 0) model are normally distributed.

FINDINGS

4.1 Descriptive Statistics

Table 8: Descriptive Statistics

Description	Statistic
Mean	36.483
Median	36.25
Minimum	27.3
Maximum	46.3

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As shown in table 8 above, the mean is positive, that is, 36.483. This means that, over the study period, the annual average number of people practicing open defecation in Lesotho is approximately 36% of the total population. This is a serious warning signal for policy makers in Lesotho with regards to the need to promote an open defecation free society. The minimum number of people practicing open defecation in Lesotho over the study period is approximately 27.3% of the total population, while the maximum is 46.3% of the total population.

4.2 Results Presentation

Table 9: Main Results

ARIMA (2, 2, 0) Model:

Guided by equation [4], the chosen optimal model, the ARIMA (2, 2, 0) model can be expressed as follows:

$$\Delta^2 \mathrm{ODL}_t = 0.0126234 - 1.18728\Delta^2 \mathrm{ODL}_{t-1} - 0.498355\Delta^2 \mathrm{ODL}_{t-2} \dots \dots \dots \dots \dots \dots \dots \dots . . \dots . . [5]$$

Variable	Coefficient	Standard Error	z	p-value
constant	0.0126234	0.00348064	3.627	0.0003***
β_1	-1.18728	0.219397	-5.412	0.0000***
β_2	-0.498355	0.222978	-2.235	0.0254**

Table 9 shows the main results of the ARIMA (2, 2, 0) model.

Forecast Graph

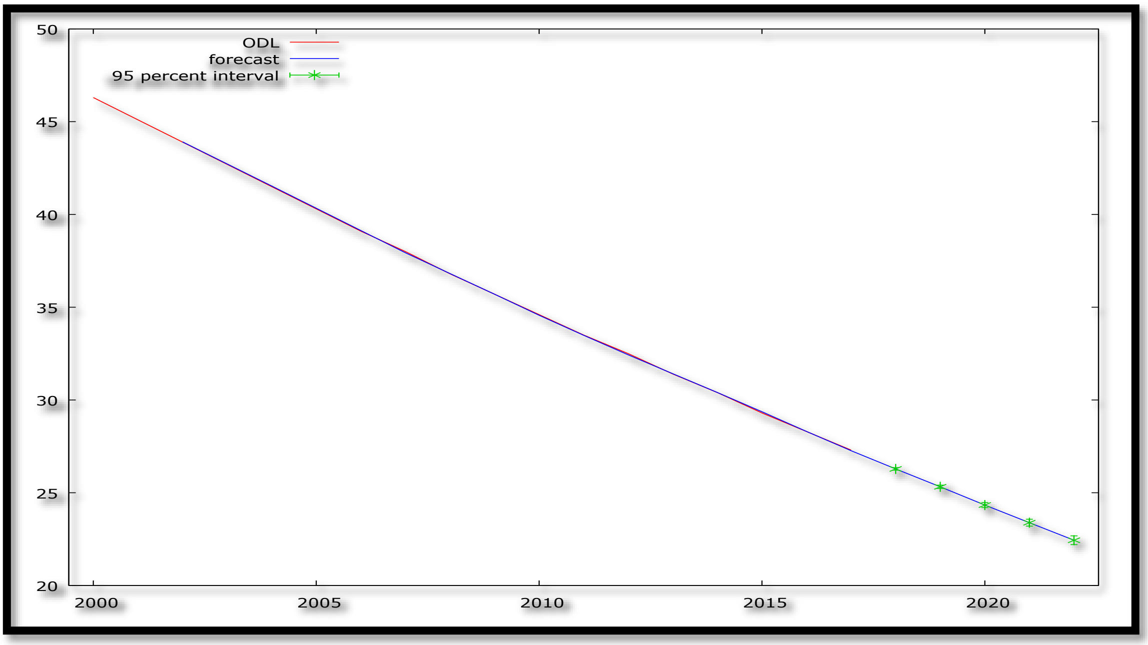

Figure 8: Forecast Graph – In & Out-of-Sample Forecasts

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Figure 8 shows the in-and-out-of-sample forecasts of the ODL series. The out-of-sample forecasts cover the period 2018 – 2022.

Predicted ODL– Out-of-Sample Forecasts Only

Table 10: Predicted

Year	Predicted ODL	Standard Error	Lower Limit	Upper Limit
2018	26.3	0.04	26.2	26.4
2019	25.3	0.05	25.2	25.4
2020	24.3	0.07	24.2	24.5
2021	23.4	0.09	23.2	23.6
2022	22.4	0.12	22.2	22.7

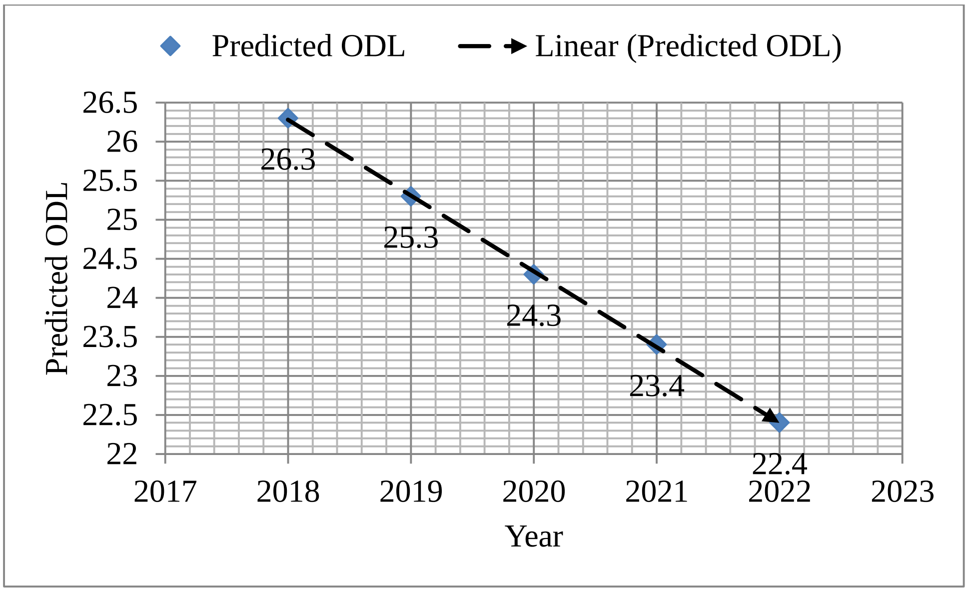

Figure 9: Graphical Analysis of Out-of-Sample Forecasts

Table 10 and figure 9 show the out-of-sample forecasts only. The number of people practicing open defecation in Lesotho is projected to fall from approximately 26.3% in 2018 to 22.4% of the total population by the year 2022. Open defecation will remain unacceptably high Lesotho for quite some time, even beyond the out-of-sample period. However, it is possible to significantly reduce the number of open defecators in the country, especially if the current government considers the policy directions suggested below.

4.3 Policy Implications

i. The government of Lesotho ought to make toilets a status symbol.
ii. The government of Lesotho should also create demand for sanitation through teaching the public on the importance of investing in toilets.

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

CONCLUSION

The study shows that the ARIMA (2, 2, 0) model is not only stable but also the most suitable model to forecast the annual number of people practicing open defecation in Lesotho over the period 2018 – 2022. The model predicts a commendable decrease in the annual number of people practicing open defecation in Lesotho. However, open defecation will still remain persistant in Lesotho. These findings are essential for the government of Lesotho, especially for long-term planning with regards to materializing the much needed open defecation free society.

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