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OPEN DEFECATION IN SOLOMON ISLANDS: 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 Solomon Islands from 2000 – 2017, the study predicts the annual number of people who will still be practicing open defecation over the period 2018 – 2022. The study applies the Box-Jenkins ARIMA method. The diagnostic ADF tests show that the ODPS series under consideration is an I (1) variable. Based on the AIC, the study presents the ARIMA (3, 1, 0) model as the optimal model. The diagnostic tests further reveal that the presented model is quite 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 Solomon Islands is likely to decline slightly over the period 2018 – 2022, from approximately 53.5% to 52.7% of the total population. This points to the fact that open defecation is persistant in Solomon Islands and is still unacceptably high. The study suggested a two-fold policy recommendation to be put into consideration, especially by the government of the Solomon Islands.

INTRODUCTION

Open defecation is defined as the disposal of human feces in open areas, such as fields, forests, road side, beaches, and open bodies of water (UN, 2019). Open defecation is widespread in Solomon Islands, especially in rural areas (UNDP, 2014). Open defecation results in the spread of untreated fecal matter throughout the environment and is associated with a variety of negative health outcomes. Fecal contamination is associated with diarrheal diseases, trachoma and schistosomiasis (Prus-Ostun et al., 2008; Clasen et al., 2010). Exposure to fecal bacteria has been linked to stunting, a measure of linear growth retardation that is often used as a predictor of long-term educational and economic outcomes (Sudfeld et al., 2015). Furthermore, open defecation, and inadequate sanitation more generally, is associated with psychosocial stress (Bisung & Elliot, 2016). Therefore, it has become increasingly inevitable for public health researchers to model and project the number of people practicing open defecation in order to formulate effective policies to end open defecation. The main goal of this study is to predict the number of people practicing open defecation in Solomon Islands over the period 2018 – 2022. This study will go a long way in assessing the possibility of ending open defecation in Solomon Islands.

LITERATURE REVIEW

In an Ethiopian study, Ashenafi et al. (2018) examined the latrine utilization coverage of the kebeles who have already declared open defecation free. Community-based cross-sectional study design with multistage sampling technique was used. Bivariate and multivariate logistic regression models were fitted to identify factors associated with latrine utilization. Their results generally show that the extent of latrine utilization was high in the community. Bhatt et al. (2019) explored various motivations of people who practice open defecation in Hattimudha village in Nepal. The maximum variation sampling method was employed to recruit participants for 20 in-depth interviews and 2 focus group discussions. A content analysis approach was applied to analyze data. The study generally found out that open defecation is either a voluntary choice or a compulsion and that this choice is closely linked with personal preferences, cultural and traditional norms with special concerns for privacy for women and girls in different communities. Adhikari & Ghimire (2020) investigated various determinants of open defecation in Nepal. Bivariate analysis was done to examine the association 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 used to determine significant predictors for a household not having a toilet after controlling other variables. The results of the study indicate that Nepal still has a large number of residences without a toilet. No study has been done so far, in Solomon Islands, to model and forecast the number of people practicing open defecation. This study is the first of its kind, and is expected to significantly enhance existing policy frameworks in the fight against open defecation in Solomon Islands.

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 ODPS series under consideration.

3.2 The Moving Average (MA) model

Given:

$$\mathrm{ODPS}_t = \sum_{i=1}^{q} \alpha_i L^i \mu_t + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where L is the lag operator.

or as:

$$\mathrm{ODPS}_t = \alpha(L)\mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where:

$\alpha(L)=\theta(L)$ …………………………………..…………………………….……….. [3]

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

$$\mathrm{ODPS}_t = \sum_{i=1}^{p} \beta_i L^i \mathrm{ODPS}_t + \mu_t \ldots \ldots [4]$$

Or that:

$$\beta(L)\mathrm{ODPS}_t = \mu_t \ldots \ldots [5]$$

where:

$\beta(L)=\phi(L)$ ……………..…………………...………..……………………….………… [6]

or that :

$$\mathrm{ODPS}_t = \left(\beta_1 L + \cdots + \beta_p L^p\right)\mathrm{ODPS}_t + \mu_t \ldots \ldots [7]$$

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $\mathrm{ODPS}_{t-1} \ldots \mathrm{ODPS}_{t-p}$ are previous period values of the ODPS series and μ_t is as previously defined. Equation [4] 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 mixture of AR (p) and MA (q) processes. Thus, by combining equations [1] and [4]; an ARMA (p, q) process is specified as shown below:

$$\phi(L)\mathrm{ODPS}_t = \theta(L)\mu_t \ldots \ldots [8]$$

where $\phi(L)$ and $\theta(L)$ are polynomials of orders p and q respectively, algebraically defined as:

$$\phi(L) = 1 - \beta_1 L \ldots \beta_p L^p \ldots \ldots [9]$$

$$\theta(L) = 1 + \alpha_1 L + \cdots + \alpha_q L^q \ldots \ldots [10]$$

It is indeed critical to remember that the ARMA (p, q) model, just like the AR (p) and the MA (q) models; can only be applied for stationary time series data. However, in real life, a myriad of time series are non – stationary. Actually, in this study, the ODPS series has been found to be an I (1) variables (that is, it only became stationary after first differencing). Due to that, ARMA models are not suitable for modeling and forecasting non – stationary time series data. In such as a case, the model described below is the one that should ideally be used.

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3.5 The Autoregressive Integrated Moving Average (ARIMA) model

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

$$\Delta^d ODPS_t = \sum_{i=1}^{p} \beta_i \Delta^d L^i ODPS_t + \sum_{i=1}^{q} \alpha_i L^i \mu_t + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots \ldots \ldots \ldots [11]$$

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 ODPS] (as a percentage of total population) in Solomon Islands. 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

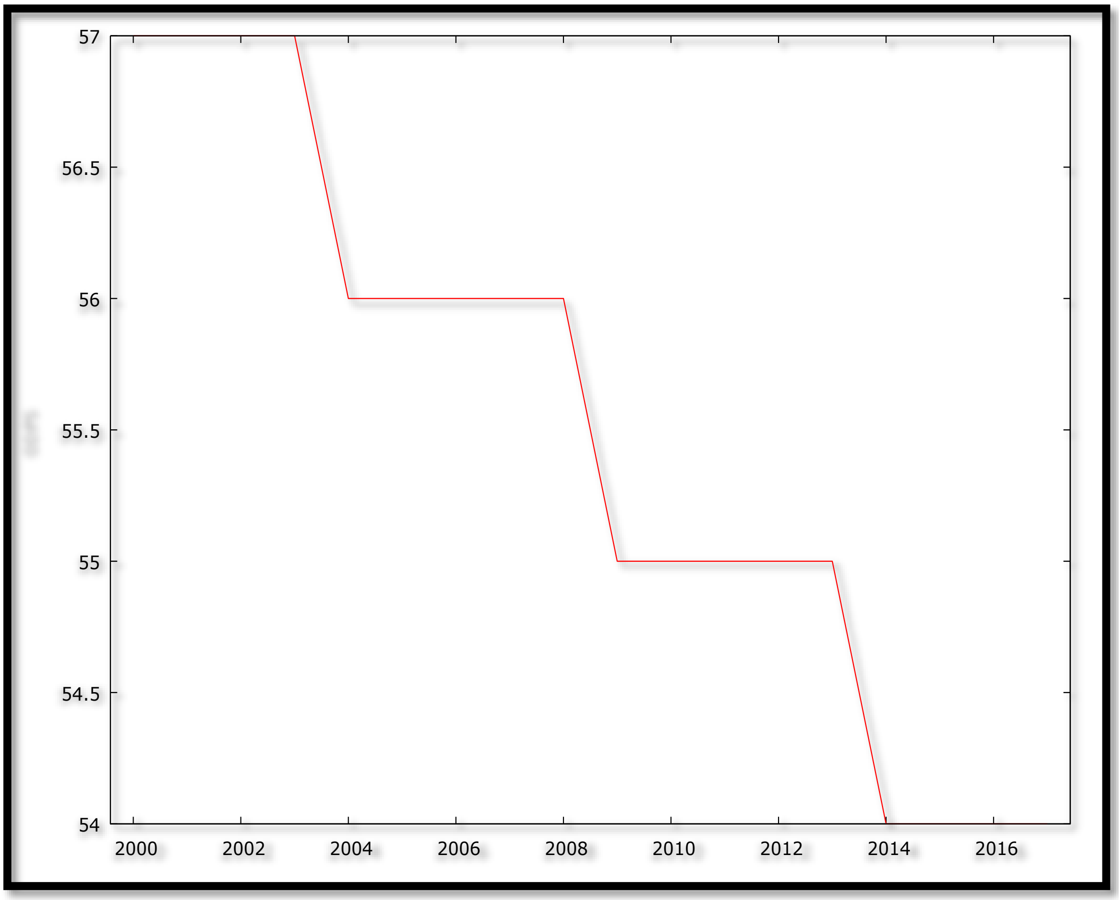

Figure 1

3.7.2 The Correlogram in Levels

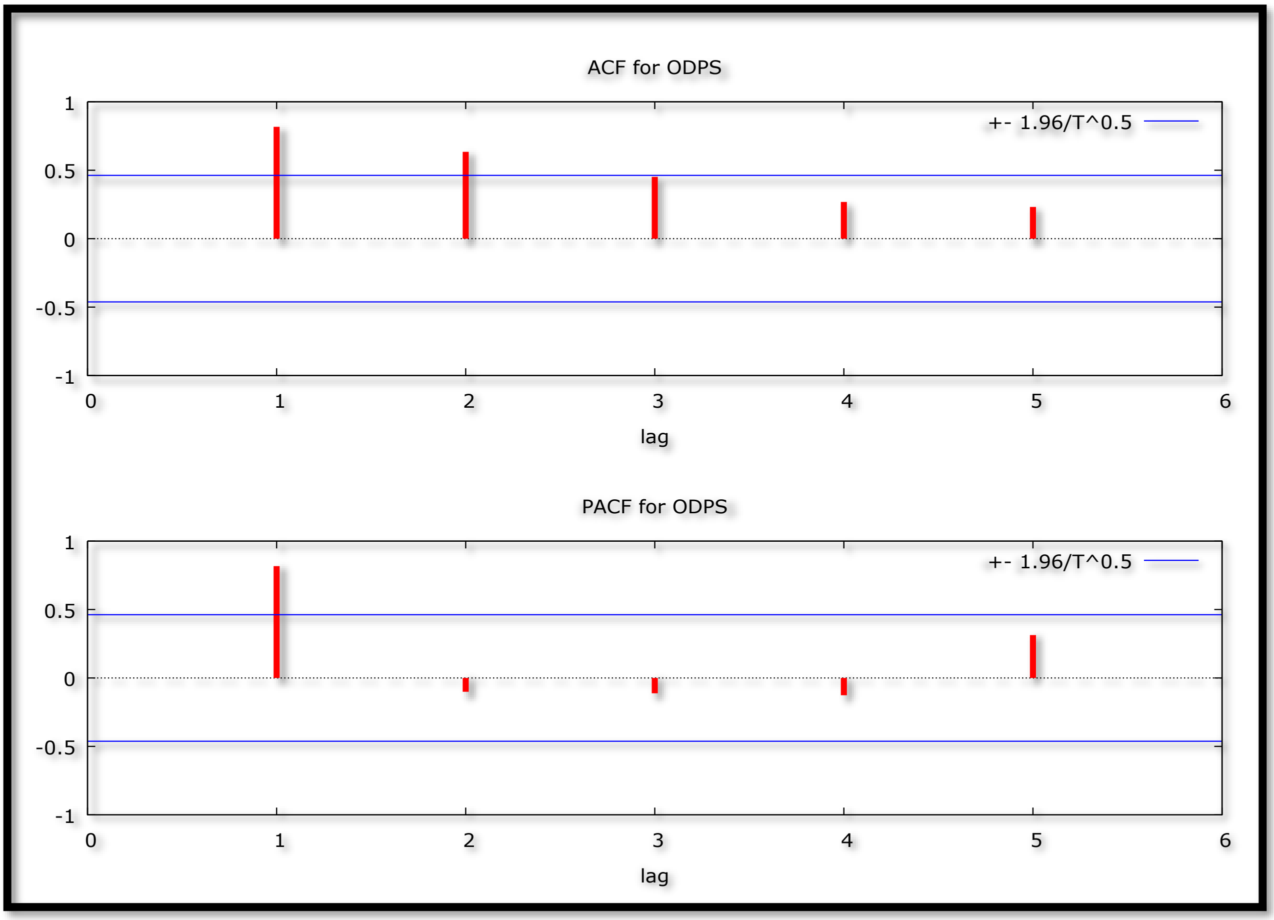

Figure 2: Correlogram in Levels

3.7.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ODPS	-0.727607	0.8138	-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
ODPS	-1.77E+10	-1.0000	-4.800080	@1%	Stationary
			-3.791172	@5%	Stationary
			-3.342253	@10%	Stationary

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

3.7.4 The Correlogram (at First Differences)

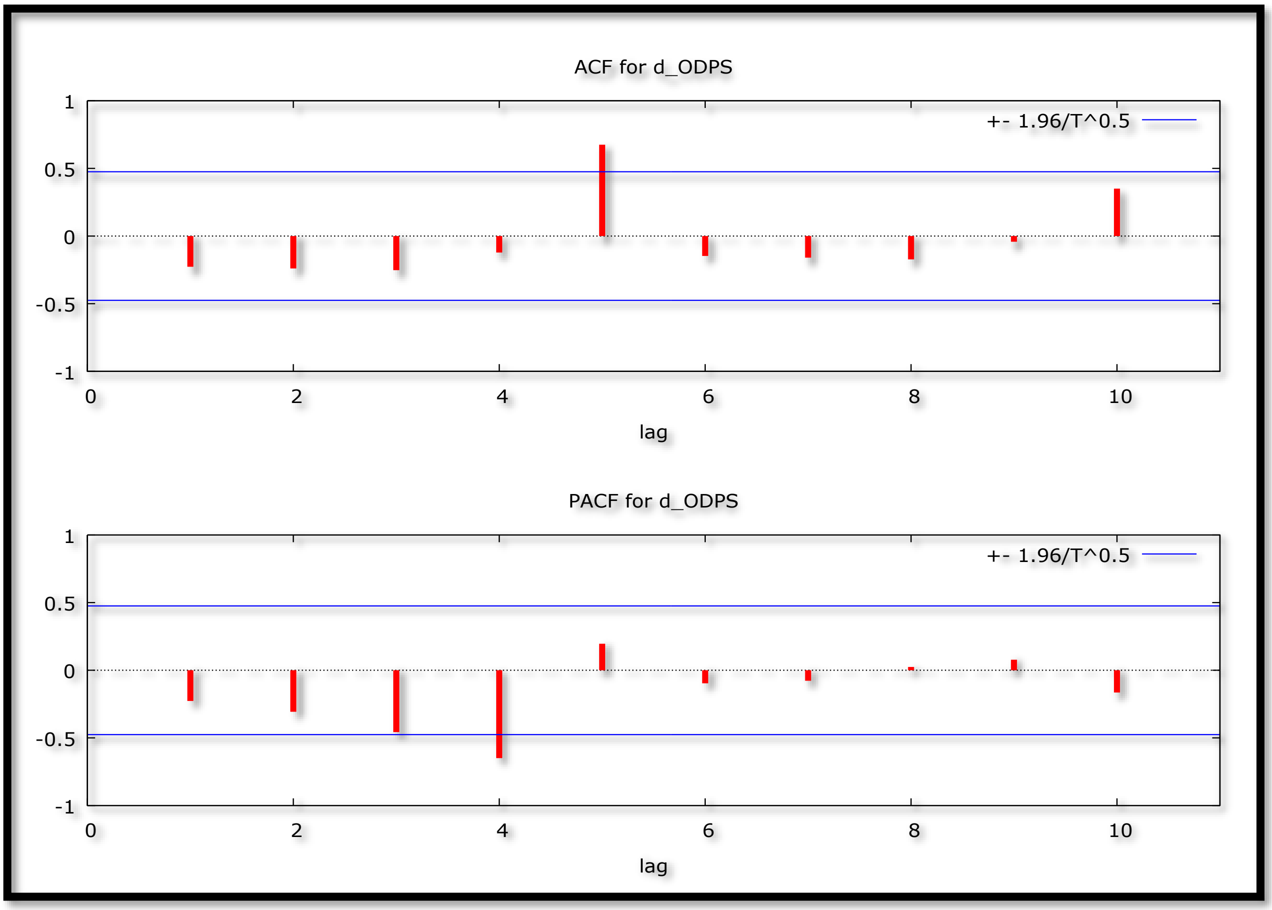

Figure 3: Correlogram (at First Differences)

3.7.5 The ADF Test (at First Differences)

Table 3: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔODPS	-2.83E+14	1.0000	-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
ΔODPS	-2.57E+14	1.0000	-4.886426	@1%	Stationary
			-3.828975	@5%	Stationary
			-3.362984	@10%	Stationary

Figure 3 as well as tables 3 and 4, indicate that ODPS 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)	20.58251	0.87904	0.0023356	0.2777	0.37114	0.50226
ARIMA (2, 1, 0)	20.84241	0.83067	0.0094218	0.25551	0.35126	0.46132
ARIMA (3, 1, 0)	16.80678	0.6853	0.032191	0.19427	0.29183	0.34912

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 (3, 1, 0) model is finally chosen.

3.8 Residual & Stability Tests

3.8.1 ADF Test (in levels) of the Residuals of the ARIMA (3, 1, 0) Model

Table 6: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-10.17888	0.0000	-4.057910	@1%	Stationary
			-3.119910	@5%	Stationary
			-2.701103	@10%	Stationary

Table 7: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R	-10.28404	0.0000	-4.886426	@1%	Stationary
			-3.828975	@5%	Stationary
			-3.362984	@10%	Stationary

Tables 6 and 7 indicate that the residuals of the chosen optimal model, the ARIMA (3, 1, 0) model; are stationary. Hence, the model is quite stable.

3.8.2 Correlogram of the Residuals of the ARIMA (3, 1, 0) Model

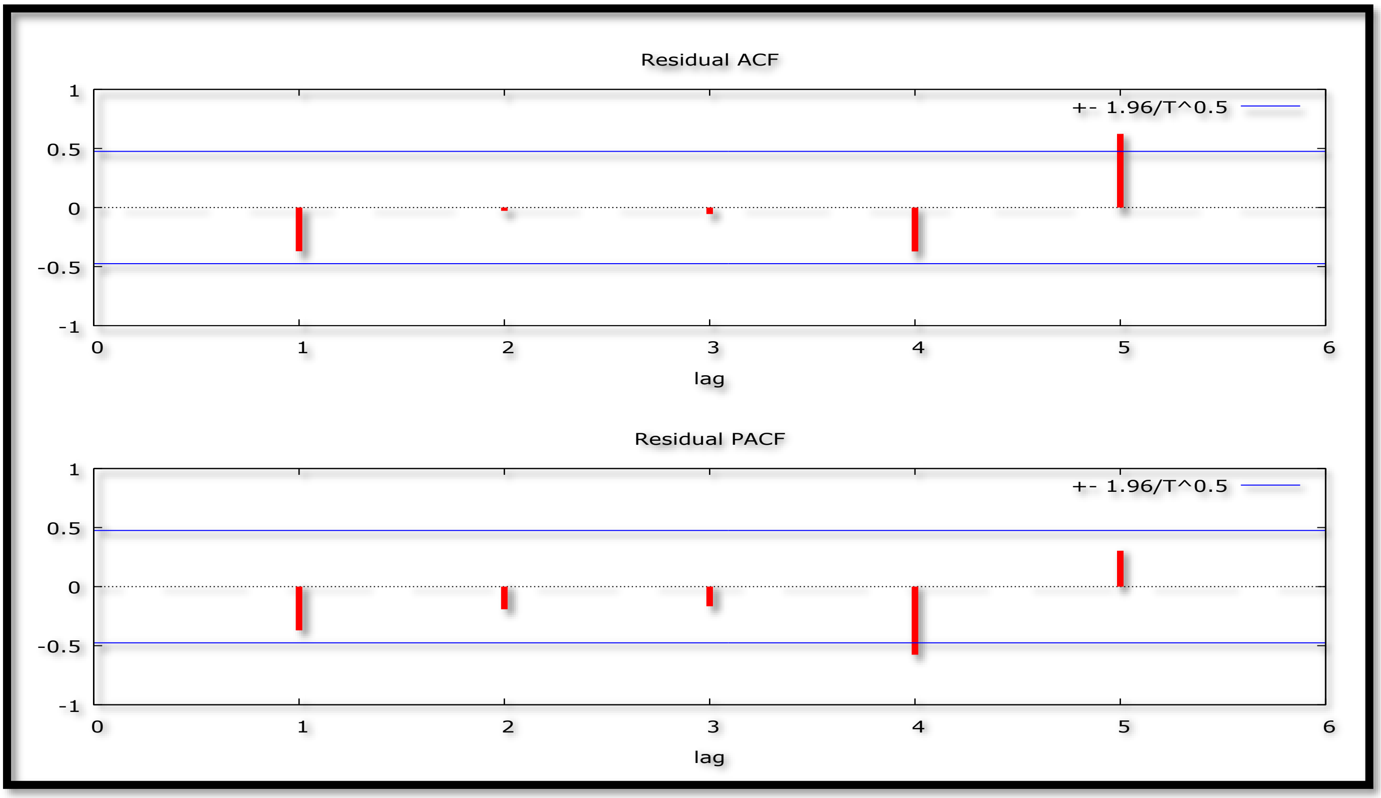

Figure 4: Correlogram of the Residuals

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

3.8.3 Normality Test of the Residuals of the ARIMA (3, 1, 0) Model

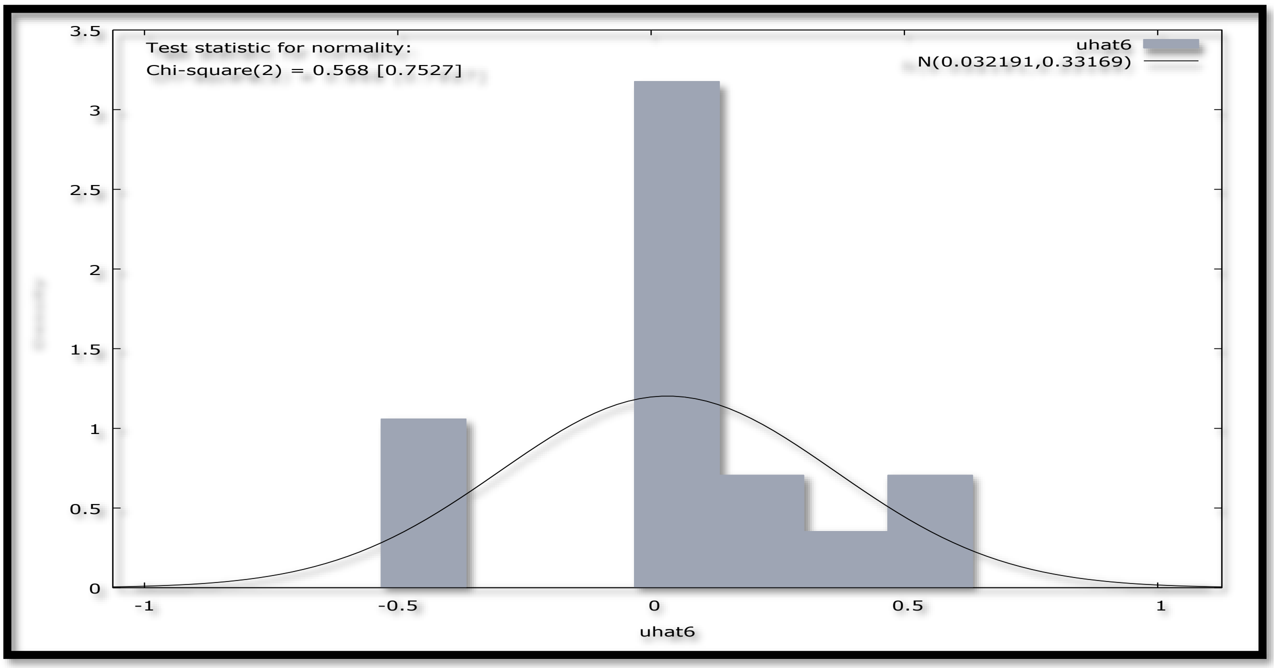

Figure 5: Normality Test

Figure 5 shows that the normality assumption is also valid as shown by the p-value of the Chi-square statistic which is statistically insignificant. This further points to the adequacy of the ARIMA (3, 1, 0) model.

3.8.4 Stability Test of the ARIMA (3, 1, 0) Model

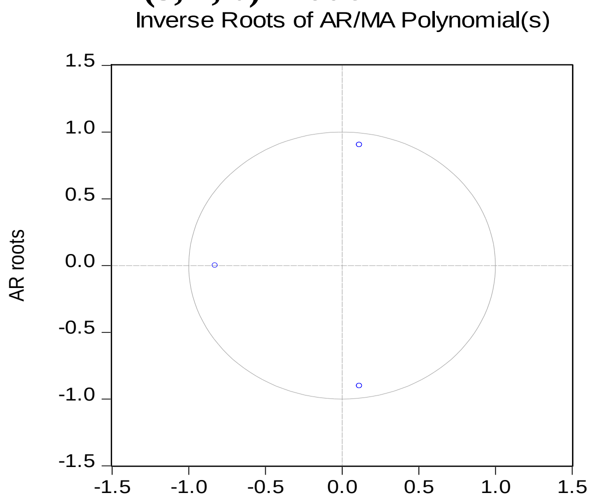

Figure 6: Inverse Roots

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 (3, 1, 0) model is really stable and suitable for forecasting annual number of people practicing open defecation in Solomon Islands.

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FINDINGS

4.1 Descriptive Statistics

Table 8: Descriptive Statistics

Description	Statistic
Mean	55.5
Median	55.5
Minimum	54
Maximum	57
Standard deviation	1.0981
Skewness	0.0000
Excess kurtosis	-1.2385

As shown in table 8 above, the mean is positive, that is, 55.5. This reveals that, over the study period, the annual average number of people practicing open defecation in Solomon Islands is approximately 56% of the total population. This is a warning signal for policy makers in the Solomon Islands with regards to the need to promote an open defecation free society. The minimum number of people practicing open defecation over the study period is approximately 54% of the total population, while the maximum is 57% of the total population. The number of people practicing open defecation in Solomon Islands has slightly declined over the years from 57% in 2000 to 54% of the total population. This implies that open defecation is persistant in Solomon Islands. There is need for intensification of initiatives in order to significantly eradicate open defecation in the country.

4.2 Results Presentation

Table 9: Main Results

ARIMA (3, 1, 0) Model:

Guided by equation [11], the chosen optimal model, the ARIMA (3, 1, 0) model can be expressed as follows:

$$\Delta ODPS_t = -0.206946 - 0.550158\Delta ODPS_{t-1} - 0.553863\Delta ODPS_{t-2} - 0.558141\Delta ODPS_{t-3} \dots\dots\dots [12]$$

Variable	Coefficient	Standard Error	z	p-value
constant	-0.206946	0.0276911	-7.473	0.0000***
β_1	-0.550158	0.203844	-2.699	0.0070***
β_2	-0.553863	0.205040	-2.701	0.0069***
β_3	-0.558141	0.206769	-2.699	0.0069***

Table 9 shows the main results of the ARIMA (3, 1, 0) model.

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Forecast Graph

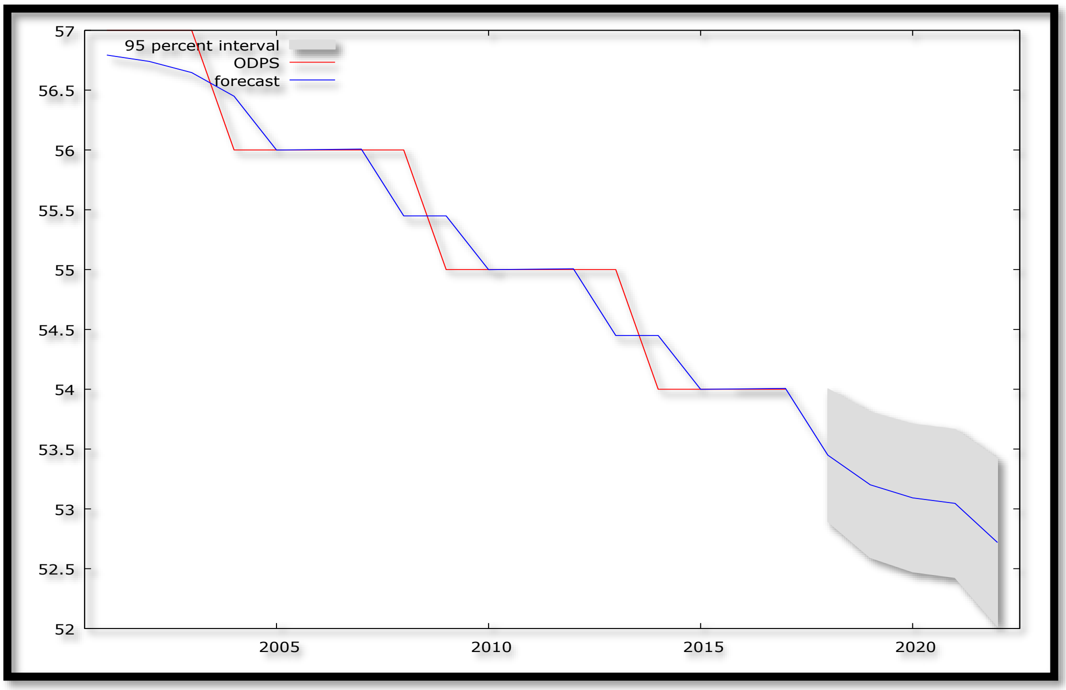

Figure 7: Forecast Graph – In & Out-of-Sample Forecasts

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

Predicted ODPS – Out-of-Sample Forecasts Only

Table 10: Predicted ODPS

Year	Predicted ODPS	Standard Error	Lower Limit	Upper Limit
2018	53.45	0.283	52.89	54
2019	53.2	0.310	52.59	53.81
2020	53.09	0.316	52.47	53.71
2021	53.05	0.316	52.43	53.67
2022	52.72	0.358	52.02	53.42

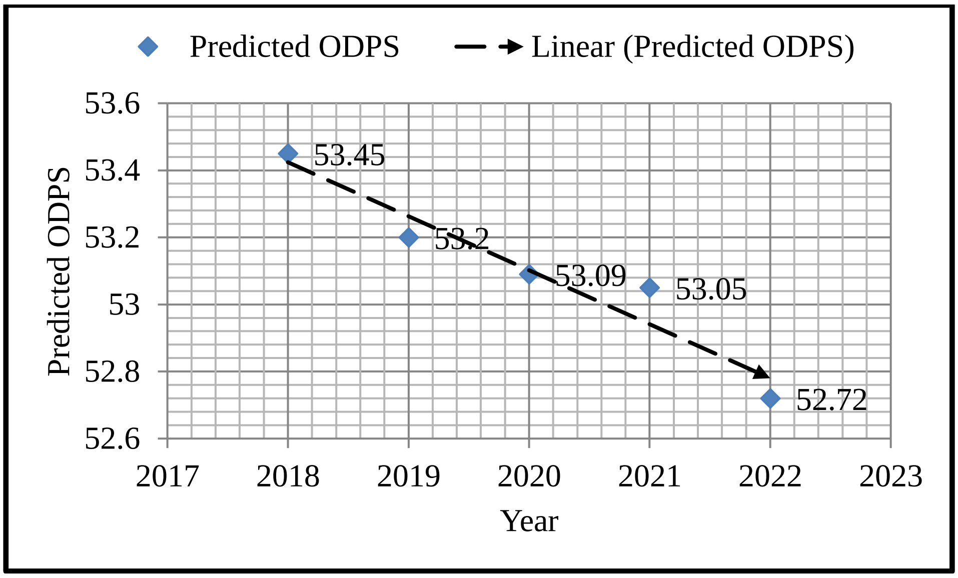

Figure 8: Graphical Analysis of Out-of-Sample Forecasts

Table 10 and figure 8 show the out-of-sample forecasts only. The number of people practicing open defecation in Solomon Islands is projected to slightly fall from approximately 53.5% in 2018 to 52.7% of the total population by the year 2022. Indeed, open defecation is very persistant in Solomon Islands.

4.3 Policy Implications

i. The government of the Solomon Islands should make toilets a status symbol, especially in rural areas, 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, there is need to intensify the country's rural water and sanitation initiatives to end open defecation.
ii. The government of the Solomon Islands should encourage a habit of systematic hand-washing, not defecating in the open, as well as keeping toilets fly-proof.

CONCLUSION

The study shows that the ARIMA (3, 1, 0) model is not only stable but also the most suitable model to forecast the annual number of people practicing open defecation in Solomon Islands over the period 2018 – 2022. The model predicts a very small decrease in the annual number of people practicing open defecation in Solomon Islands. These results are vital for the government of the Solomon Islands, especially when it comes to long-term planning with regards to materializing the much needed open defecation free society.

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