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EKSU JOURNAL OF SCIENCE AND TECHNOLOGY (EJST)

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Modeling the Impact of Western Sanctions on Russian and its Effect on Nigeria Economy

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ABSTRACT

The research investigated the effects of western sanctions on Russia as it affects Nigeria's economy using Autoregressive Distributed Lag (ARDL) model. Data was collected from World Bank's Development Indicator Database for the periods of January 2015 to August 2022. The variables of interest as it affects Gross domestic product (GDP) were Foreign Direct Investment (FDI), Oil Exportation, Exchange rate and Inflation Rate. The data was tested for normality and stationary. Thereafter, it was subjected to the test of non-spherical disturbance so as to remove the problems associated with assumption of using the model. The methods employed co-integration and determination of optimal lag length using AIC, SBC and HQC to validate the results. The result of the analysis revealed that during pre-sanction period, the null hypothesis of no co-integration was rejected and conclude that there exists a long run relationship between the variables included in the model. Also during the sanction period, the p -value > 0.05 which implies that there is long-run relationship between GDP and the independent variables. The study reveals that there exists long run relationship and short run relationship in both pre-sanction and during sanction periods respectively. The study found that the economic sanctions placed on Russia led to a short-run downturn in some economic status of Nigeria. Nigeria will likely have a slight recession, which would cause the country's GDP to fall slightly and this will lead to an increase in inflation rate and exchange rate. The adjusted R-Square revealed that 79.82% variation in the gross domestic product per capita is accounted for by the variations in inflation rate, exchange rate, foreign direct investment and oil export rate. The F-statistic value of 13.34 with a p-value of 0.0000 revealed the significance and adequacy of the ARDL model indicating a good fit of the model.

Keywords: Autoregressive Distributed Lag (ARDL), Gross Domestic Product (GDP), Co-integration, Sanction.

Introduction

Following Russia's invasion of Ukraine in February 2022, numerous countries, labor unions, international

organizations, and businesses responded by introducing sanctions. The introduction of Sanctions are a kind of political, economic, and sometimes



even military punishment used by one or more nations against another (Whang, 2011). As a response, sanctions were targeted towards exports, important state-owned enterprises, banks, persons and corporations. Grain production in Russia decreased by almost six million tonnes between 1970 and 1980 as a result of the United States' food embargo against the Soviet Union because of the conflict in Afghanistan (Tarrant, 1981). According to the IMF (2019), between 2014 and 2018, the country's economy struggled as a result of sanctions placed on Russia due to its unlawful occupation of Crimea and Sevastopol. The IMF (2019) forecast that Russia's annual growth rate will decrease by 0.2 percentage points using global macroeconomic models. Russia's GDP growth has lagged behind than that of the rest of the globe for some time, suggesting that it has less of an impact on the world economy as a whole (Korhonen, 2019). Also, monetary policy punishments on Russia have had several detrimental effects on economies (Ahn & Ludema, 2020). These will undoubtedly affect the company that supplies grain shipments. It is logical to predict that the current crisis will have an impact on grain prices and other by products in which Russia is a significant global grain exporter. The Food and Agricultural Organization of the United Nations issued a warning in 2022 that the conflict between Russia and Ukraine would have a significant impact on the

food supply. Market price, supply chain, production, humanitarian, growth, and exchange rate risks are a few of effects on food supply. Given that many developing countries must rely on foreign sources for their food supply, this problem might have disastrous global implications (FAO 2022, Araujo-Enciso and Fellmann 2019). Early in February 24, 2022, Russia launched a full-scale military assault on Ukraine that resulted in the devastation of infrastructure and the deaths of civilians (Welsh, 2022). Due to the globalization of agricultural markets and the fact that it is a battle between two important participants in the global food and fertilizer sectors, the war is raising substantial concerns for the security of the world's food supply (FOA, 2022a). While exportable resources are frequently concentrated in a small number of countries, Russia and Ukraine are both regarded as "global breadbaskets" and are significant producers and exporters of essential agricultural products, minerals, fertilizers, and energy, despite having only 2% of the global GDP (Moher, 2009).

Due to their concentration, these markets may be more vulnerable to shocks and volatility (FAS, 2022). The COVID-19 epidemic, high worldwide demand, a drought, and poor South American crops resulted in supply chain disruptions that added to already high food prices, therefore the conflict



occurred at a disastrous time for the global food markets. All of these factors add up to higher food prices (Barklie, 2022). The confrontation between Russia and Ukraine will make these issues worse. Months into the conflict, its impacts are already apparent: exports from Ukraine have ceased, harvests in the future are unclear, and the price of agricultural commodities has increased globally, putting millions of lives in peril (FOA, 2022a).

Additionally, price increases and trade interruptions may raise the number of individuals who are underweight by lowering the availability of humanitarian aid to prevent and cure acute malnutrition (The World Bank, 2021). According to projections by the World Food Programme (WFP), there will be an additional 47 million people who are acutely hungry from a pre-war baseline of 276 million. According to this, up to 323 million people may endure severe food insecurity by the end of 2022. (Anderson et al., 2021). The World Bank has calculated that every percentage point increase in food prices pushes 10 million people into extreme poverty. If food costs remain this high for a year, there might be a more than 100 million rise in global poverty.

The aim of this study is to evaluate the effects that the Russian sanctions have on Nigeria's economy using ARDL model with the purpose to examine the relationships between the various

factors that affect Nigeria GDP and to predict the future effect of sanctions on Nigeria economy.

Given the importance of grain to Nigeria's economy, it's critical to assess how several possible futures will affect the country's financial situation in the short and long terms relationship.

Literature Review

Empirical Review

Akinlo (2008) investigated 11 sub-Saharan African countries including Nigeria from 1980 to 2003. The study shows that there is cointegration between the use of energy and economic growth in seven of the countries, bidirectional causality in three countries, and unidirectional causality from GDP to energy consumption in two countries using Autoregressive Distributed Lag (ARDL) and Vector Error Correction Model (VECM). In Nigeria, there was neither a long-term relationship nor a causative relationship between energy use and economic growth. However, the same author, Akinlo (2009), showed a long-term relationship and unidirectional causality from power use to GDP per capita utilizing an enhanced sample period from 1980 to 2006 and the VECM technique for Nigeria. A similar study was also conducted by Yuan *et al.* (2007) in China with the same techniques and sample size and reveals the same results as Akinlo (2009).



Enang (2010), examined the relationships between industrialization, power availability, and economic development in Nigeria from 1970 to 2008 and found that there was a long-term association between the variables. The same author, Enang (2010) found a similar impact of energy supply on growth.

In a related study, it was determined that all the variables are significant in impacting GDP per capita from 1970 to 2008 using ARDL bound testing on real GDP per capita, population, electricity consumption, and industrial output. Similarly, to this, (Okonkwo, 2009) shows that economic growth, labor supply, capital stock, and energy use in Nigeria cointegrate. From 1972 to 2003, Tang (2008) also looked at this relationship in Malaysia. The results show that there is no long-term relationship, but that there is bidirectional causality between the variables.

Chandran *et al.* (2010) also demonstrate that there is a long-run causal relationship between energy consumption and economic development from 1971 to 2003. To examine power consumption, industrial output, and economic growth in Cote d'Ivoire from 1971 to 2008, Kouakou (2011) uses ARDL bounds testing techniques. The analysis demonstrates that the variables' cointegration exists. Granger causality was tested and found to be bidirectional in the short run

between economic growth and electricity consumption, but long-term causality solely goes from consumption to growth.

In Pakistan, Shahbaz and Lean (2012) conducted a related analysis of energy usage and economic growth from 1972 to 2009. Similar analytical methods to those employed by Kouakou (2011) were utilized to determine how the variables would relate over time, with electricity consumption having a favorable effect on growth. The causality finding demonstrates the presence of feedback causality among the variables. As a result, the situation in Pakistan and Cote d'Ivoire is similar, supporting the relationship between power and economic growth.

Similar to this, Wolde-Rufael (2006) investigates seventeen African countries between 1971 and 2001 and finds causation in twelve countries and long-term relationships in nine of them. This finding demonstrates that there is a relationship between electricity and economic growth in the African context, however, it may not be as significant as it is in industrialized nations.

In five of the seven nations studied by Yoo & Kwak (2010), Argentina, Brazil, Chile, Columbia, and Ecuador, the Granger (1969) causality test shows a causative relationship between electricity consumption and economic development across annual data from



1975 to 2006. While no causal relationship was found in Peru, bidirectional causality was found in Venezuela. Given Peru's higher growth and resource-management prudence than Ecuador, the results for Peru probably require further investigation. The region does, however, typically show a linkage between power use and economic expansion.

Yakubu *et al.* (2015) studied the relationship between electricity supply and the manufacturing sector's output in Nigeria using time series data from 1971 to 2010. It uses Autoregressive Distributed Lag (ARDL) bounds testing technique to cointegration. The results reveal the long-run relationship between the variables and shows significant and negative error correction term. Manufacturing output was found to be positively dependent on electricity in both the short run and long run, but only significant in the long run. This implies that the electricity supply must be increased if the productive capacity of the manufacturing sector is to be improved.

Lawal & Aweda (2015) investigated the level of relationship in Nigeria between the exchange rate, the price of crude oil, and the inflation rate. The results of the empirical research demonstrated that, regardless of the underlying characteristics of their series, the macroeconomic variables have a highly substantial level relationship with the exchange rate. In both the long and short

runs, the conditional level connection model and its corresponding conditional unrestricted equilibrium correction model (ECM) relate crude oil prices negatively to the inflation rate and favorably to the exchange rate. The delayed response of the Nigerian exchange rate to shocks in the price of crude oil and the inflation rate can be seen in the long-run speed of adjustment to equilibrium.

Adenomon & Ojo (2020) examined the long- and short-term effects of the unemployment rate, interest rate, and inflation rate on real gross domestic product per capita (RGDPPC) (a proxy for economic growth). The findings demonstrated a long-term association between Nigeria's real gross domestic product per capita (a proxy for economic growth), unemployment rate, and interest rate. The findings also showed that only the unemployment rate had a substantial long-term positive impact on real gross domestic product per capita, whereas the inflation rate had a large short-run negative impact.

Concept of sanctions

International actors (such as states or international organizations) or groups of such actors may impose economic sanctions on another state or organization to punish it for breaking a rule or deter it from breaching a rule that the party applying the sanctions deems important (Miyagawa, 1992). One or more senders create economic diplomacy disruptions to exert



influence on the policymaking of the targeted country. Economic sanction is a term coined in the 1960s by economist Milton Friedman. The basic premise is to prevent the target from gaining an economically advantageous position. Some examples of this include making it difficult for the target to make purchases, preventing the target from entering potentially lucrative markets, or making investors wary of the target (Miyagawa, 1992). Many nations and organizations have taken this stance against Russia because of its military aggression in Ukraine. (Melander & Baczynska, 2022). Since World War One's ended, economic sanctions have gained favour as a nonviolent approach of settling international conflicts, especially those with a political or economic component. The efficacy of their decision is still up for debate, despite widespread agreement that it represents the best option for most people (Miyagawa, 1992) Even while foreign policy instruments are sometimes criticized for being useless, this one can't be criticized since it

achieved its goal of securing policy concessions from the target.

Russia Grain Supply and Nigeria's trade partnership

Grain is Russia's most important agricultural product, since it is grown on more than half of the country's arable territory, making it Russia's most important agricultural export. Grain exports accounted for 34% of the total value of food exports from the country's agriculture business during the years 2011 and 2019. (Figure 1). Wheat accounts for 75% of Russia's total grain exports, with barley and maize following closely. Turkey, Egypt, Nigeria, Sudan, Morocco, and Yemen are just a few of the many nations that are major consumers of this commodity. This development resulted from the fact that food exports from Russia saw significant increase at the turn of the century (Araujo *et al.*, 2019). Wheat and other grain prices, as well as the by-products produced from these grains would decrease if Russia's role in exporting grains were disrupted by sanctions or other factors.

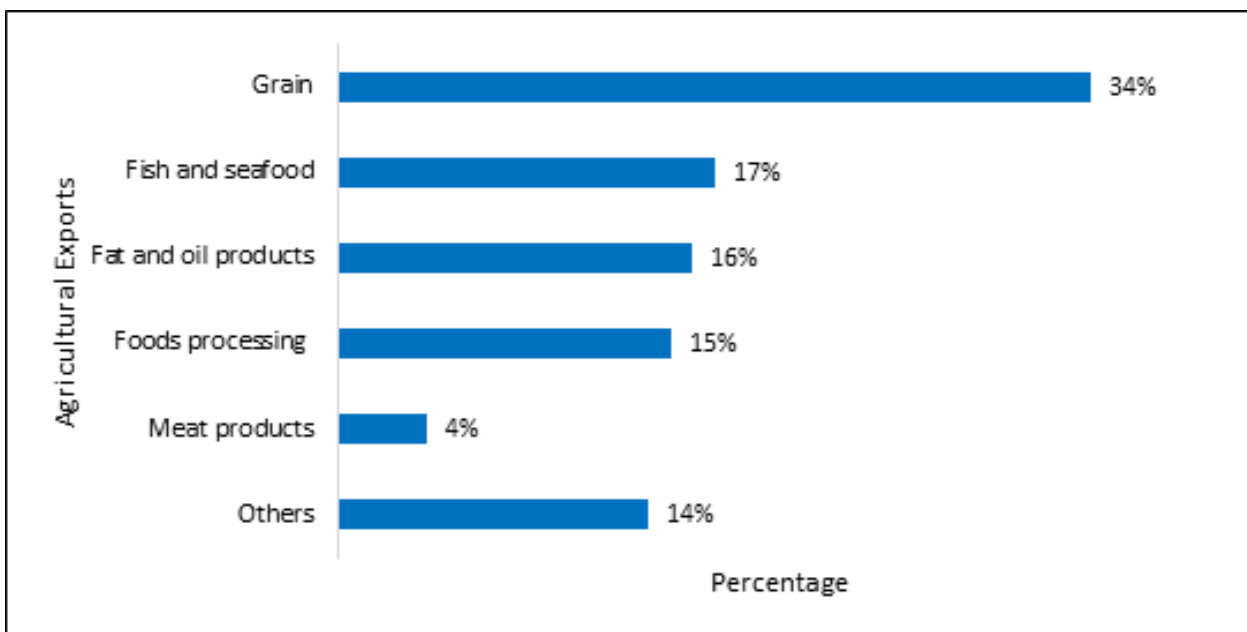


Figure 1: Russia's Agricultural Export Market in 2020

Figure 1, shows the percentage of Russia's Agriculture Export Market and most of the export are on Grain which is 34%

Source: (Agapkin & Makhotina, 2021)

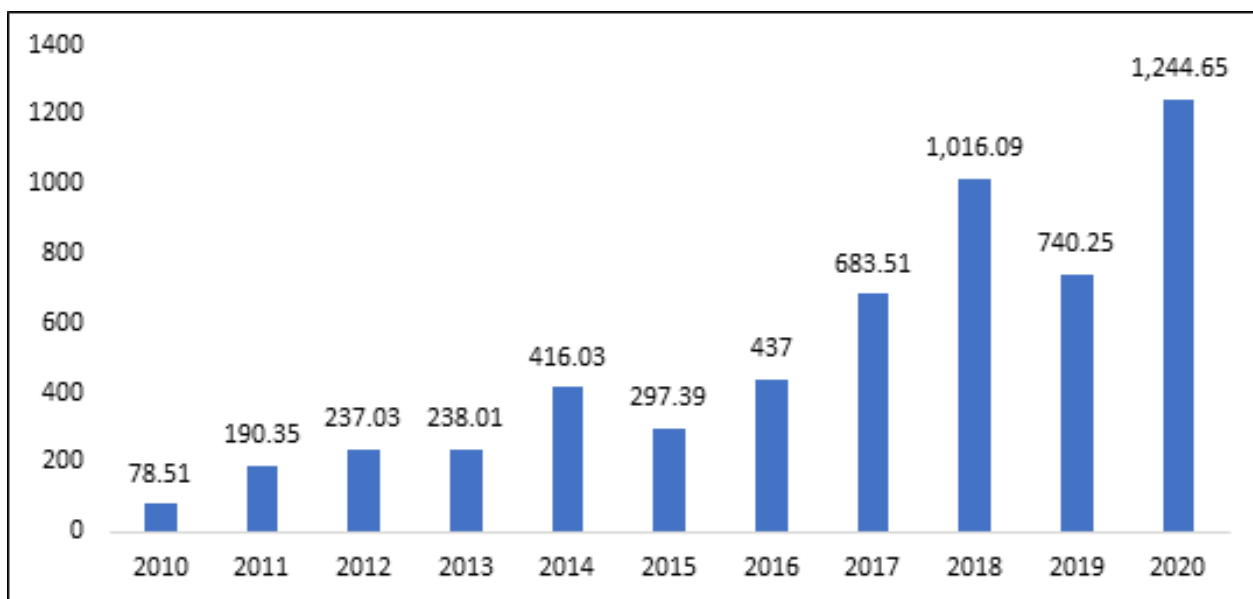


Figure 2: Value of imports from Russia to Nigeria from 2010 to 2020

Source:(Statista, 2022)

From figure 2 above, it can be deduced that Nigeria's top import trading partners include Russia in 2020 Over 1.2 billion U.S. dollars' worth of products were imported from Russia into Nigeria, the highest amount

documented since 2010. However, recent events in Russia's invasion of Ukraine have been considered as a danger to this commercial partnership.



Methodology

Source of data

The World Bank's Development Indicator Database (2022) was used as a source for monthly data on gross domestic product, net foreign direct investment, foreign portfolio investment, exchange rate, inflation rate, and export oil rate for the years 2015–2022.

Data Source: <https://www.cbn.gov.ng/>, <https://www.imf.org/en/Data>, <https://www.statista.com/statistics/1294200/import-value-of-durum-wheat-from-russia-into-nigeria/>

Model Specification

The Autoregressive Distributed Lag Model (ARDL) model plays a key role when faced with making a vital economic decision from previous data. Change in economic variables may bring change in other economic variables beyond the time. The ARDL model can also be used if all the variables are integrated of order one i.e., stationary after the first difference I_1 . The general model of the ARDL (p, q) is as follows:

$$y_t = \varphi + \sum_{i=1}^p \alpha_i y_{t-1} + \sum_{i=1}^q \beta_i x_{t-1} + \varepsilon_t \quad \dots (1)$$

Where;

y_t = dependent variable

y_{t-1} = lag of the dependent variable

x_t = independent variable

x_{t-1} = lag of the independent variable

P = optimal lag order associated with the dependent variable, q is the optimal lag order associated with the independent variable in years, φ is a constant.

α_i = coefficient for dependent variable,

β_i is the coefficient for independent variable

ε_t = error term

The effect of sanctions on Nigeria's major economic variables was evaluated using an empirically verified linear regression model based on the aforesaid research methodology and in accordance with past research on the impact of sanctions on the Nigerian economy and supply of grains. The model can be represented mathematically as:

$$\text{GDP} = f(\text{FDI}, \text{EXCHR}, \text{INFR}, \text{EPO}) \quad (2)$$

The econometric specification is as follows:

$$(\text{GDP})_{it} = \beta_0 + \beta_1(\text{FDI})_{it} + \beta_2(\text{EXCH})_{it} + \beta_3(\text{INFR})_{it} + \beta_4(\text{EPO})_{it} + \varepsilon_{it} \quad (3)$$

Regression model specification

$$(\text{GDP}) = \beta_0 + \beta_i(X)_{it} + \varepsilon_{it} \quad (4)$$

The null hypothesis of no co-integration between the variables may be rejected if the computed F- statistics are larger than the upper limit. However, if the estimated F-statistics are less than the lower limit, the null hypothesis of no long run association cannot be rejected. After confirming the presence of co-integration among the variables, we proceeded to a full ARDL Model estimation.

Stationary Test (Augmented Dickey Fuller, ADF)

A time series data is said to be stationary when its properties like mean, variance and co-variance do not change over time. The ADF model tests the unit root as follows:

$$\Delta y_t = \mu + \delta y_{t-1} + \sum_{i=1}^k \beta_i \Delta y_{t-1} + \varepsilon_t \quad (5)$$



Where:

$$\delta = \alpha - 1$$

α = coefficient of y_{t-1} and

Δy_{t-1} = first difference of y_t

The hypothesis for the Augmented Dickey Fuller (ADF) test is given as;

H_0 : there is no unit root (the series is non stationary)

H_1 : there is unit root (the series is stationary)

Co-integration Test (ADRL Bounds Test)

There is co-integration between two or more variables if there exists a form of the equilibrium relationship spanning the long-run. The Bounds test is guided by the assumption of stationary variables at level I_0 , at the first difference I_1 and never at the second difference I_2 (Giles, 2013). To perform the bounds test for co-integration, the conditional $ARDL(p, q_1, q_2, q_3)$ model with 4 variables. The hypothesis for the bounds test is given as:

$$H_0: b_{ij} = 0,$$

$$H_1: b_{ij} \neq 0$$

$$H_2: b_{ij} \neq 0$$

i.e., The null hypothesis shows that the coefficients of the long-run equations are all equal to zero which implies there is no co-integration.

Determination of Optimal Lag Length

The choice of appropriate lag length is vital in autoregressive modeling because we want to have Gaussian error terms (i.e., standard normal error terms that do not suffer from non-normality, autocorrelation and heteroscedasticity). The selection of optimal number of lags can be determined using proper model

order selection criteria such as the Akaike Information Criterion (AIC), Schwartz Bayesian Criterion (SBC) or the Hannan-Quinn criterion (HQC). The value of the general

$$ARDL(p, q_1, q_2, \dots, q_K)$$

model is given by:

$$AIC_p = (1 + \log 2\pi) - \frac{n}{2} \log \delta^2 - P \quad (6)$$

$$SBC_p = (\log \delta^2) + \left(\frac{\log n}{n}\right) - P \quad (7)$$

$$SBC_p = (\log \delta^2) + \left(\frac{\log n}{n}\right) - P \quad (8)$$

Where δ is the Maximum Likelihood (ML) estimator of the regression disturbance, n is the number of estimated parameters and

$$p = 0, 1, 2, \dots, P$$

Where P is the optimum order of the model

Model diagnostics (Post Estimation Test)

Normality of Residuals: In order to ensure that our model satisfies the assumption of the classical normal linear regression model, it is important to check one of the assumptions known as the normality of the disturbance term. The Jarque-Bera (JB) test of normality is an asymptotic test based on OLS residuals

Autocorrelation Test: We shall employ the use of the Breush-Godfrey test to check for the presence of autocorrelation in our disturbance term in this study.

The hypothesis for the Breush-Godfrey test is given as:



H_0 : there is no serial correlation between the residual

H_1 : there is a serial correlation between the residual

Heteroscedasticity Test: For the purpose of this study, we shall be employing the Breusch-Pagan-Godfrey test to check for heteroscedasticity in our disturbance term.

Data Analysis and Discussions

Descriptive statistics of the Economic data

Table 1: Descriptive statistics of the variables (pre-sanctions period)

Statistics	GDP (Million USD)	FDI (Million USD)	Inflation Rate (Million USD)	EXCH (Million USD)	EPO (Million USD)
Mean	5320.051	1.533	13.559	303.1792	1130.194
Standard Deviation	3822.414	1.699	3.088	66.20266	276.844
Sample Variance	1461.160	2.890	9.537	4382.793	76642.486
Kurtosis	2.290	5.773	-.1284	-0.461	0.196
Skewness	1.852	2.212	0.057	-0.295	-0.261
Minimum	2303.510	-1.150	8.200	167.00	285.590
Maximum	17179.50	8.560	18.720	411.580	1801.69

Table 2: Descriptive statistics of the variables (during sanctions period)

Statistics	GDP (Million USD)	FDI (Million USD)	Inflation Rate (Million USD)	EXCH (Million USD)	EPO (Million USD)
Mean	4538.345	5.1406	17.564	416.678	2286.3112
Standard Deviation	842.382	2.17704	1.8796	2.352	350.865
Sample Variance	709607	4.740	3.533	5.534	123106.5
Kurtosis	-2.552	-0.564	-1.311	0.683	-0.874
Skewness	0.014	0.452	0.488	1.063	0.185
Minimum	3597.92	2.41	15.60	413.75	1782.88
Maximum	5484.06	8.84	20.52	421.07	2788.29



It can be seen from table 1 and table 2 that the descriptive statistics shows that inflation rate and exchange rate increases during sanction period than before sanction and this is an indication that sanction on Russia has an impact on Nigeria economy.

Unit Root Test

Table 3: Stationary test at first level (ADF test)

Pre sanction period				During sanction period		
Variables	ADF test	p-value	Conclusion	ADF test	p-value	Conclusion
GDP	-1.7107	0.6945	NS	-32.737	0.01**	Stationary
Exchange rate	-2.1929	0.4968	NS	-1.9095	0.01**	Stationary
Inflation rate	-1.999	0.5763	NS	-9.6172	0.01**	Stationary
FDI	-0.35412	0.99	NS	-1.345	0.01**	Stationary
Oil export	-2.1409	0.5181	NS	-8.8384	0.01**	Stationary

*Significance at 5% level

From table 3, it can be observed that during pre-sanction period the test show p-values for all the variables were higher than the significant level $\alpha=0.05$ and this shows that it is not stationary. However, during the period of sanction, the p-value is less than level of significance at first difference and this shows that it is stationary.

Determination of optimal lag length

The results of the optimal lag length determination from lag one (1), lag two (2) lag three (3), lag four (4) and lag (5) and their corresponding Akaike information criterion (AIC), Schwarz Criterion (SC), Hannan-Quinn Criterion values and selected ARDL models are presented in Table 4. The decision for the selection of the optimal lag length was chosen based on the lag length with the minimum AIC value. From the result, the autoregressive distributed lag order of five (5) is selected based on the minimum AIC value of 2.571 which is the optimal lag length that minimizes the AIC at which the model does not have autocorrelation.

**Table 4:** Selection of Optimal lag length

Lag length	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5
AIC	2.681	2.674	2.697	2.606	2.571
SBC	2.766	2.829	2.923	2.727	2.721
HQC	2.726	2.736	2.787	2.907	2.944

Bounds Cointegration Test

Hypothesis

H_0 : There is no co-integration (Long run relationship does not exist)

H_1 : There is possibility of co-integration (Long run relationship exist)

The null hypothesis shows that the coefficients of the long-run equations are all equal to zero which implies there is no co-integration and long run relationship does not exist. The bounds test is a method for testing whether a variable in a time series model is cointegrated with one or more other

variables. Table 5 shows the bounds cointegration test to determine the cointegration and long run relationship between GDP and other economic factors. For the pre-sanction period, since $p\text{-value} < 0.05$, we reject the null hypothesis of no cointegration and conclude that there exists a long run relationship between the variables included in the model. For the during sanction period, the $p\text{-value} > 0.05$ which implies that there is no long-run relationship between GDP and the independent variables.

Table 5: ARDL Bounds F-test (Wald) for Co-integration

	Test statistics	Value	k	p-value
Pre-sanction period	F-statistic	21.339	4	0.000
During sanction	F-statistic	0.35892	4	0.9927

*Significance at 5% level

Result of the ARDL estimation for the pre-sanction period

The adjusted R-Square in table 6 revealed that 79.82% variation in the gross domestic product per capita is accounted for by the variations in

inflation rate, exchange rate, foreign direct investment and oil export rate. The F-statistic value of 13.34 with a p-value of 0.0000 revealed the significance and adequacy of the ARDL model indicating a good fit of the model.

**Table 6:** Estimates of the Long run relationship for the pre-sanction period

Dependent variable: GDP				
Long-run relationship	Variable	Coefficient	t-Statistics	p-value
	d(Exchange rate)	-38.84336	-1.387	0.1711
	d(L (Exchange rate, 1))	7.42760	0.266	0.7913
	d(L (Exchange rate, 2))	-5.38923	-0.182	0.8561
	d(L (Exchange rate, 3))	-13.00607	-0.421	0.6756
	d(L (Exchange rate, 4))	25.30022	0.970	0.3364
	d(Inflation rate)	-911.57415	-0.930	0.3535
	d(L (Inflation rate, 1))	1025.30458	0.946	0.3483
	d(L (Inflation rate, 2))	-593.50481	-0.553	0.5824
	d(L (Inflation rate, 3))	14.24338	0.012	0.9903
	d(L (Inflation rate, 4))	2110.50027	1.810	0.0759
	d(FDI)	115.05311	0.365	0.7164
	d(L (FDI, 1))	-542.23716	-1.505	0.1384
	d(L (FDI, 2))	-257.60172	-0.741	0.4622
	d(L (FDI, 3))	40.61973	0.126	0.9002
	d(L (FDI, 4))	423.01202	1.450	0.1529
	d(Oil export)	-0.43768	-0.237	0.8139
	d(L (Oil export, 1))	-2.06831	-1.250	0.2168
	d(L (Oil export, 2))	1.34982	0.755	0.4538
	d(L (Oil export, 3))	0.33142	0.192	0.8488
	d(L (Oil export, 4))	-0.99585	-0.503	0.6179

*Significance at 5% level; **significance at 10% level; ***significance at 1% level



The R-Square in table 7 revealed that 74.6% and adjusted R-Square is 53.44% variation in the gross domestic product per capita is accounted for by the variations in inflation rate, exchange rate, foreign direct investment and oil export rate. The F-statistic value of 3.525 with a p-value of 0.07841 revealed the insignificant and adequacy of the ARDL model.

Comparing table 6 and table 7, one can observed that the adjusted R-square of 53.44% is lower in the sanction period. The fit of the model is inadequate and this suggest that sanctions on Russia has greatly affected the economy of Nigeria.

Table7: Estimates of the long run and short run relationship for the during sanction period

Dependent variable: GDP				
Short-run relationship	Variable	Coefficient	t-Statistics	p-value
	d (Exchange rate)	-961.0552	-2.095	0.0810
	d (Inflation rate)	3692.9147	1.601	0.1605
	d (FDI)	3526.2946	3.240	0.0177*
	d (Oil export)	5.0080	1.674	0.1452
	Ect	-1.1534	-3.465	0.0134*
	R squared	0.746		
	Adj R squared	0.5344		
	F statistic	3.525		0.07841
Long-run relationship	Variable	Coefficient	t-Statistics	p-value
	d (Exchange rate)	-961.055	-1.067	0.3346
	d (Inflation rate)	3692.915	0.801	0.4597
	d (FDI)	3526.295	2.844	0.0361*
	d (Oil export)	5.008	1.492	0.1958
	Ect	-1.153	-2.996	0.0303*
	Intercept	517900.15	2.981	0.0308*
	R squared	0.746		
	Adj R squared	0.492		
F statistic	2.937		0.131	

*Significance at 5% level; **significance at 10% level; ***significance at 1% level



Discussion of findings

From the result obtained in this study, the Gross Domestic product (GDP) of Nigeria increase from Q1 of 2021 to Q3 of 2021. However, before the sanction in February 2022, the growth rate of Nigeria's GDP as at January 2022 was 4978 US dollars which decrease to 3857 US dollars at the end of February 2022. In May also, there was a further reduction in Nigerian GDP value that is from 13857 US dollars in February to 3677.15 US dollars. GDP quantifies the valuation of finished goods and services, or those purchased by the end user and produced in a nation during a specific period of time. Decrease in GDP as reported in this study means that Nigerian Economy is shrinking and this could lead to loss of job, economic recession and loss of opportunities. Due to the severity and scope of the sanctions, Nigeria could further suffer different financial consequences. Negative economic growth as reported in March and April 2022 implies decline in value. Negative growth rates as a result of sanction are accompanied with a general decline of the money supply and diminishing wage growth. The graph of the effect of sanctions before and after are in the appendix.

Conclusions

This study found that the economic sanctions placed on Russia led to a downturn in some economic status of Nigeria. The initiative's research demonstrates the depth of the damage inflicted by the sanctions on the Nigeria

economy. Between late 2022 and early 2023, Nigeria will likely have a slight recession, which would cause the country's GDP to fall slightly, it will lead to an increase in inflation rate and exchange rate. Foreign direct investment and oil exportation will not be affected by the impact of the Russian sanction as a result of there are many foreign investors who are ready and will be willing to invest in Nigeria economic growth.

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APPENDIX

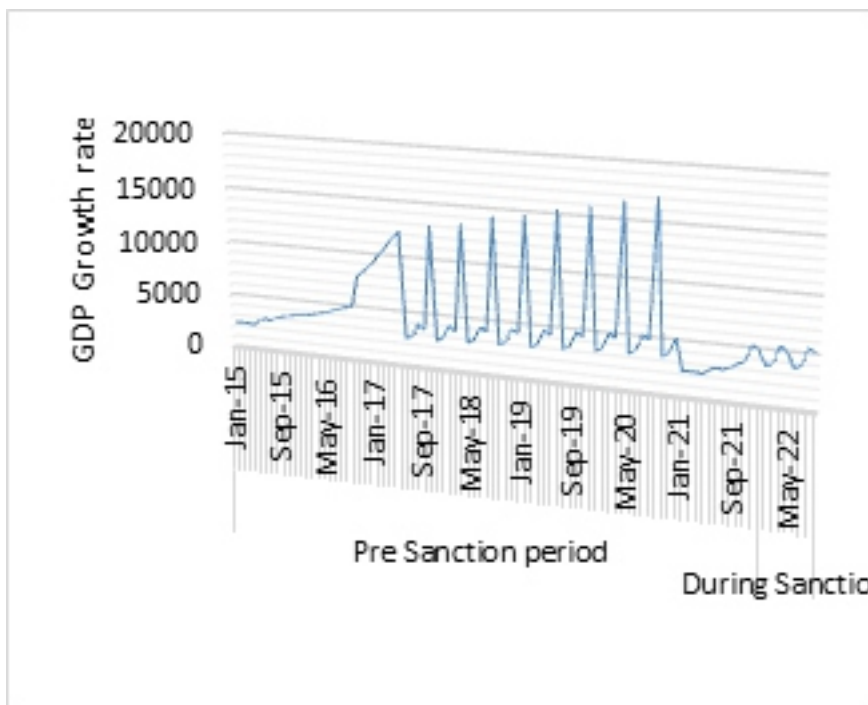


Figure 6: Nigeria GDP growth rate before and during sanction

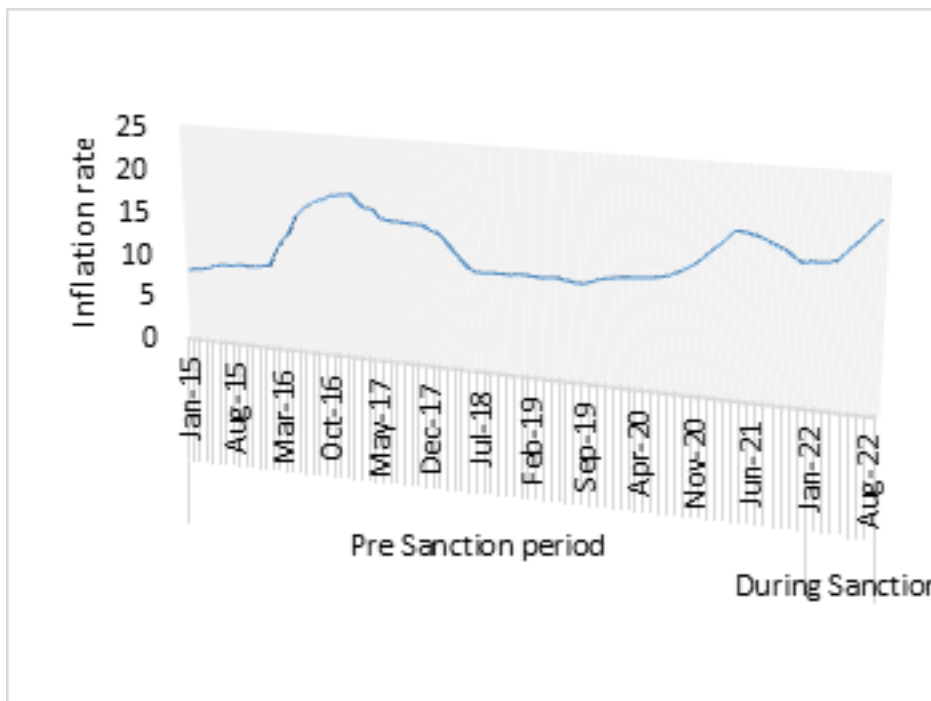


Figure 8: Nigeria inflation rate growth before and during sanction

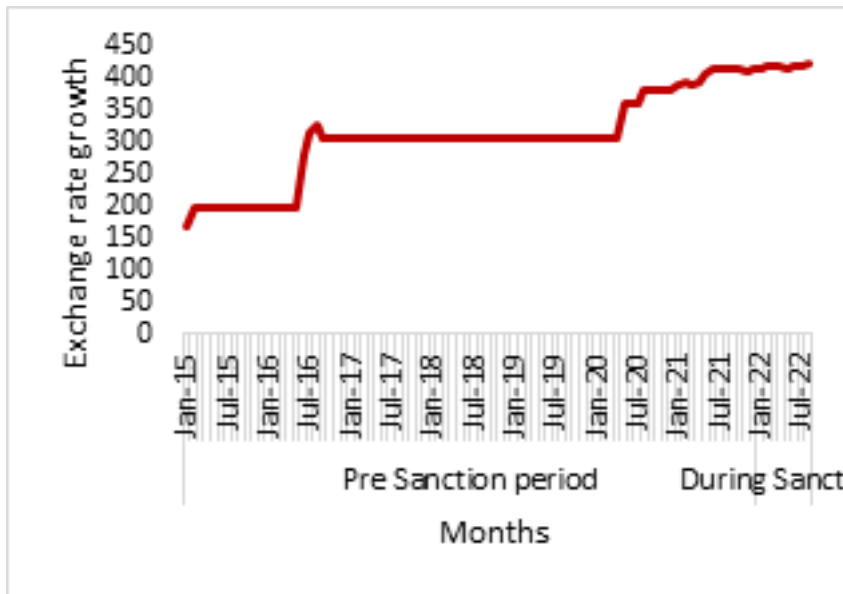


Figure 7: Nigeria exchange rate growth before and during sanction

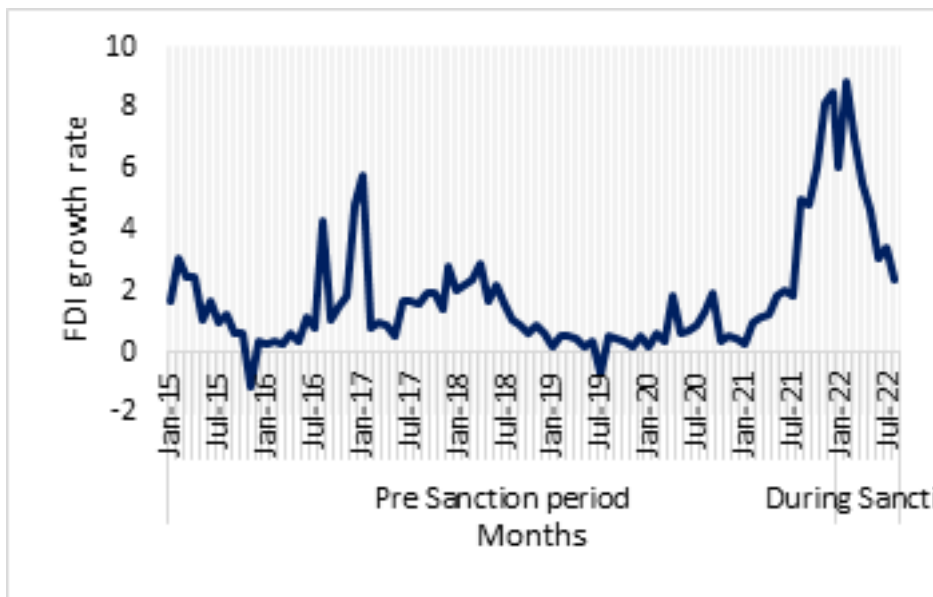


Figure 9: Nigeria FDI growth rate before and during sanction

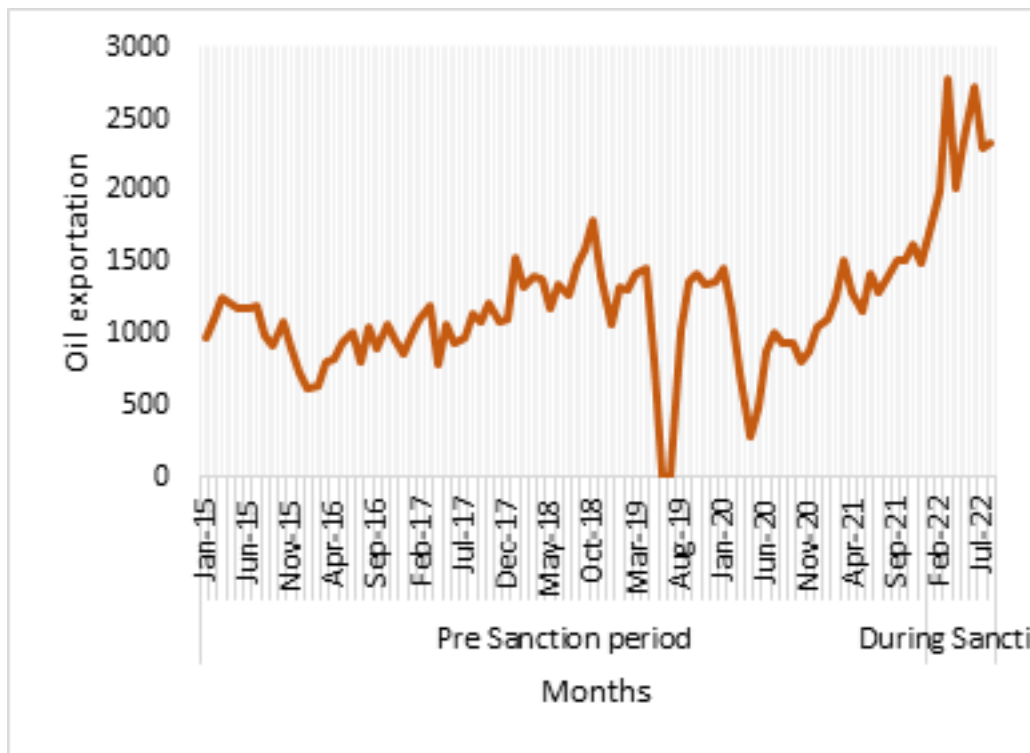


Figure 10: Nigeria oil exportation growth rate before and during sanction



PROJECTING THE EFFECTS OF POPULATION GROWTH AND THE POOR WASTE MANAGEMENT SYSTEMS ON GROUNDWATER CONTAMINATION IN DELTA STATE.

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ABSTRACT

Population growth and rapid urbanization in Delta State are driving a sharp increase in waste generation, with poorly managed landfills posing significant threats to groundwater and public health. This study projected population and domestic waste growth and assessed their implications for groundwater quality in the state. Using 1991 and 2006 census data, population and waste generation trends were projected, while a systematic review of peer-reviewed studies published between 2013 and 2025 was conducted to evaluate the impact of population growth on groundwater quality. Results reveal elevated levels of heavy metals, microbial contamination, and physicochemical pollutants in groundwater near dumpsites, frequently exceeding WHO standards. These pollutants are associated with kidney and liver damage, neurological disorders, endocrine disruption, and increased risk of waterborne



diseases, with population projections indicating an increase from 4,112,445 in 2006 to approximately 9,769,951 by 2035, alongside a corresponding rise in estimated waste generation from about 1,657,504 tonnes in 2025 to 2,248,995 tonnes by 2035. With continuous increase in population-waste generations are expected to continue rising and groundwater vulnerability to contamination will heighten in view of the region's porous soils and shallow aquifers. The study underscores the urgent need for reforms, including engineered sanitary landfills, leachate management, routine groundwater monitoring, and stricter policy enforcement, to safeguard public health and promote environmental sustainability.

Keywords: Solid waste management; Aquifer pollution; Niger Delta; projected population growth

Introduction

Population growth and urbanization are among the major drivers of increasing municipal solid waste (MSW) generation worldwide. The global population reached 8 billion in 2022, intensifying pressure on natural resources, infrastructure, and waste management systems (United Nations, 2022). In developing countries, this demographic expansion has contributed to a rise in unsustainable waste disposal practices, including open dumping and poorly managed landfills, which in turn pose significant environmental and public health risks (Hoornweg and Bhada-Tata, 2012). Among the most critical of these risks is the contamination of groundwater by leachates, a problem exacerbated in regions with shallow aquifers and highly permeable soils (Mor, et al., 2006; Li, et al., 2021).

In Nigeria, population growth has been rapid, increasing from about 122 million in 2000 to over 216 million in

2022 (World Bank, 2023). Delta State, located in the Niger Delta, exemplifies this demographic trend with a population of 4,098,391 recorded in the 2006 national census (National Population Commission [NPC], 2006), the state has since experienced steady growth, fuelled by rural–urban migration, industrial development, and natural population increase. Projections suggest that Delta State's population will continue to expand at an annual growth rate of approximately 2.5–3.0% (United Nations, 2022). This expansion has translated into a corresponding increase in waste generation, which in Nigeria ranges from 0.5 to 1.2 kg per person per day depending on socioeconomic status and location (Oyelola and Babatunde, 2008).

Waste management systems in Delta State, however, have not kept pace with this demographic and consumption-driven surge. Disposal methods are



dominated by open dumping, roadside heaps, and unsanitary dumpsites, most of which lack engineered liners or leachate management systems (Abila and Kantola, 2013). These conditions, combined with weak regulatory enforcement, often result in indiscriminate disposal of waste close to residential neighborhoods and water bodies (Akudo, et al., 2010). Such practices create a high potential for groundwater contamination, particularly in areas where the geology enhances infiltration.

The hydrogeological setting of Delta State makes groundwater especially vulnerable to pollution from waste disposal. The Benin Formation, which underlies much of the state, is characterized by sandy lithology and high permeability, conditions that favor groundwater recharge and also facilitate contaminant migration (Aladejana, et al., 2020). Shallow aquifers, often accessed by hand-dug wells, are especially prone to leachate infiltration. Empirical studies in parts of the Niger Delta have documented elevated levels of heavy metals such as lead, cadmium, and chromium, as well as nitrates and microbial contaminants, in groundwater samples near dumpsites (Olobaniyi, et al., 2007; Amadi et al., 2012). These pollutants often exceed World Health Organization permissible limits, underscoring the public health risks associated with current waste management practices.

Despite the growing body of research on groundwater contamination from waste disposal in Nigeria, few studies have explicitly connected population growth projections to future waste generation and the resulting risks of groundwater pollution. Addressing this gap is particularly important in Delta State, where rapid demographic expansion, unsanitary waste management practices, and a geologically vulnerable aquifer system converge to heighten the risk of groundwater contamination. This study, therefore, seeks to examine the effect of projected population growth, and poor waste disposal practices, on groundwater quality in Delta State. By integrating demographic projections with waste generation estimates and hydrogeological vulnerabilities, the study provides a framework for assessing the implications of population-driven waste pressure on groundwater resources.

Methodology

Study Area

Delta State is located in the South-South geopolitical zone of southern Nigeria, within the Niger Delta region. Geographically, it lies between latitudes 5°00' and 6°30' N and longitudes 5°00' and 6°45' E, covering an area of approximately 17,698 km² (Britannica, 2024). The state is characterized by tropical rainforest vegetation, high rainfall, and a humid equatorial climate. The hydrogeology of Delta State forms part of the Niger Delta Basin, which is



underlain by three major lithostratigraphic units: the Benin Formation, the Agbada Formation, and the Akata Formation (Ibezue et al., 2018; Odesa et al., 2025; Doust and Omatsola, 1990). The Benin Formation

is a highly permeable sandy aquifer system, often exceeding 2,000 m in thickness, and represents the principal source of potable groundwater for the population (Olobaniyi et al., 2007).



Figure 1 : Map of Delta state showing all the local government areas (extracted from Ozoemenam,et al., 201)2

This systematic study integrates the use of 1991 and 2006 data to project the growth in generated waste and population density. Review of peer reviewed manuscripts published between (2013 to 2025) was synthesized to evaluate the effect of population growth on groundwater quality within Delta State

Data Sources

1. Population Data: Baseline population data for Delta State were obtained from the 1991 and 2006 censuses (NPC, 2006).
2. Waste Generation Data: Per capita waste generation rates for Nigerian urban and semi-urban areas (0.62 kg/person/day)



reported for Nigeria (Oyelola and Babatunde, 2008; World Bank, 2025).

3. **Groundwater Vulnerability and Health Implications:** Hydrogeological information was obtained from previous studies of the Benin Formation (Aladejana, et al., 2020; Olobaniyi et al., 2007; WHO, 2017).

Population Projection

Annual growth rate was computed using

$$r = \left(\frac{Pt}{Po}\right)^{\frac{1}{t}} - 1$$

Where:

Pt = population at later census (2006),
 Po = population at earlier census (1991); t = number of years between censuses (15 years here); r = annual growth rate; for local government without 1991 population data, the average growth rate was utilized in the projection of the population using Po=2,590,491 (1991); Pt= 4,112,445 (2006) (NPC, 2006).

Population growth was projected using the Compound Annual Growth Rate (CAGR) model, which has been widely used for Nigerian demographic projections (United Nations, 2022). The formula is:

$$Pt = Po \times (1 + r)^t \dots \dots \dots (equ 2)$$

Where:

- Pt = projected population at year t
- Po = base year population (2006 census = 4,098,391)
- r = annual growth rate
- t = number of years after the base year

Population was projected for 2025 (19 years after 2006) and 2035 (29 years after 2006) to align with near- and mid-term waste and groundwater management planning.

Waste Generation Estimation

Waste generation was estimated by combining population projections with per capita generation rates. The formula applied was:

$$Tw = \frac{Po \times Pc \times 365}{1000} \dots \dots \dots (equ 2)$$

Where:

Tw is the Total Waste (kg/day); Po is the Population, and Pc is the per capita waste generation rate (average of 0.62 kg) for low-income countries (World Bank, 2025). Daily waste generation was scaled to annual total for assessment of cumulative impacts on waste management infrastructure and leachate load potential.

Limitations of the projections and analysis

- **Projection uncertainty.** Projections are driven by historical CAGRs; future demographic change can be affected by migration, economic



shocks, climate impacts, or policy interventions. The CAGRs used (1991–2006) may not fully reflect post-2006 dynamics.

- **Single per-capita waste benchmark.** The illustrative waste tonnages used a single per-capita figure (0.62 kg/person/day) reported for Nigeria (Oyelola and Babatunde, 2008; World Bank, 2025). Local per-capita generation differs by income, consumption patterns, and urbanization; using an averaged figure may under- or overestimate actual loads.

- **Simplified contamination inference.** The study did not model contaminant transport (advection-dispersion, attenuation and sorption). The contamination risk depends on waste composition, landfill engineering, rainfall, aquifer properties, and depth to water table (Mor et al., 2006; Aladejana et al., 2020).



Results and Discussion Table 1: Projected population for Delta State (2025 to 2035)

LGA	1991	2006	CAGR % (1991-2006)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Aniocha N.	60998	104062	3.63%	204888.1	212325.5	220032.9	228020.1	236297.2	244874.8	253763.8	262975.4	272521.4	282413.9	292665.6
Aniocha S.	107034	142045	1.90%	203111.9	206971.1	210903.5	214910.7	218994	223154.9	227394.8	231715.3	236117.9	240604.1	245175.6
Bomadi	—	86016	3.20%	156492.5	161500.2	166668.3	172001.6	177505.7	183185.9	189047.8	195097.4	201340.5	207783.4	214432.4
Burutu	167648	207977	1.45%	273403.6	277368	281389.8	285470	289609.3	293808.6	298068.9	302390.8	306775.5	311223.8	315736.5
Ethiopo E.	113929	200942	3.86%	412656.6	428585.1	445128.5	462310.5	480155.6	498689.7	517939.1	537931.5	558695.7	580261.3	602659.4
Ethiopo W.	105861	202712	4.43%	461912.5	482375.3	503744.5	526060.4	549364.8	573701.7	599116.7	625657.5	653374.2	682318.7	712545.4
Ika N.E.	126560	182819	2.48%	291182	298403.3	305803.7	313387.7	321159.7	329124.4	337286.7	345651.4	354223.6	363008.3	372010.9
Ika S.	109204	167060	2.87%	285995.1	294203.1	302646.7	311332.7	320268	329459.7	338915.1	348642	358648	368941.2	379529.8
Isoko N.	111919	143559	1.67%	196650.1	199934.1	203273	206667.7	210119	213628	217195.6	220822.8	224510.5	228259.8	232071.8
Isoko S.	150836	235147	3.00%	412331.7	424701.6	437442.7	450566	464082.9	478005.4	492345.6	507116	522329.4	537999.3	554139.3
Ndokwa E.	75578	103224	2.10%	153203.9	156421.2	159706	163059.8	166484.1	169980.3	173549.8	177194.4	180915.5	184714.7	188593.7
Ndokwa W.	—	150024	3.20%	272944.9	281679.1	290692.9	299995	309594.9	319501.9	329726	340277.2	351166.1	362403.4	374000.3
Okpe	—	128398	3.20%	233599.8	241075	248789.4	256750.7	264966.7	273445.6	282195.9	291226.2	300545.4	310162.9	320088.1
Oshimili N.	—	118540	3.20%	215664.8	222566	229688.1	237038.2	244623.4	252451.3	260529.8	268866.7	277470.5	286349.5	295512.7
Oshimili S.	—	150032	3.20%	272959.5	281694.2	290708.4	300011	309611.4	319519	329743.6	340295.4	351184.8	362422.7	374020.3
Patani	—	67391	3.20%	122607.2	126530.7	130579.7	134758.2	139070.5	143520.7	148113.4	152853	157744.3	162792.1	168001.5
Sapele	142652	174273	1.34%	224422.9	227430.2	230477.8	233566.2	236695.9	239867.7	243081.9	246339.2	249640.1	252985.3	256375.3
Udu	—	142480	3.20%	259219.8	267514.8	276075.3	284909.7	294026.8	303435.7	313145.6	323166.3	333507.6	344179.8	355193.6
Ughelli N.	166029	320687	4.49%	738756.3	771926.5	806586	842801.7	880643.5	920184.4	961500.7	1004672	1049782	1096917	1146169
Ughelli S.	139748	212638	2.84%	362009.7	372290.7	382863.8	393737.1	404919.3	416419	428245.3	440407.4	452915	465777.8	479005.9
Ukwuani	—	119034	3.20%	216563.5	223493.5	230645.3	238026	245642.8	253503.4	261615.5	269987.2	278626.8	287542.8	296744.2
Uvwie	—	188728	3.20%	343360.7	354348.2	365687.4	377389.4	389465.8	401928.8	414790.5	428063.8	441761.8	455898.2	470486.9
Warri N.	90893	136149	2.73%	227123.9	233324.4	239694.2	246237.8	252960.1	259865.9	266960.3	274248.3	281735.3	289426.7	297328
Warri S.	235750	311970	1.89%	445258.8	453674.2	462248.6	470985.1	479886.8	488956.6	498197.9	507613.8	517207.7	526983	536942.9
Warri S.W.	—	116538	3.20%	212022.4	218807.1	225809	233034.9	240492	248187.7	256129.7	264325.9	272784.3	281513.4	290521.8



Table 2: Projected waste generated from 2025 to 2035

LGA	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Aniocha N.	48609.7	50374.2	52202.8	54097.8	56061.5	58096.6	60205.5	62390.9	64655.7	67002.7	69434.9
Aniocha S.	48188.3	49103.9	50036.9	50987.6	51956.3	52943.5	53949.4	54974.5	56019.0	57083.3	58167.9
Bomadi	37127.8	38315.9	39542.0	40807.4	42113.2	43460.8	44851.6	46286.8	47768.0	49296.6	50874.1
Burutu	64865.0	65805.6	66759.7	67727.8	68709.8	69706.1	70716.8	71742.2	72782.5	73837.8	74908.5
Ethiophe E.	97902.8	101681.8	105606.7	109683.2	113916.9	118314.1	122881.0	127624.3	132550.6	137667.0	142980.9
Ethiophe W.	109588.7	114443.5	119513.4	124807.8	130336.8	136110.7	142140.4	148437.3	155013.0	161880.1	169051.4
Ika N.E.	69082.9	70796.2	72551.9	74351.2	76195.1	78084.8	80021.3	82005.8	84039.5	86123.7	88259.6
Ika S.	67852.3	69799.7	71802.9	73863.7	75983.6	78164.3	80407.6	82715.3	85089.2	87531.3	90043.5
Isoko N.	46655.2	47434.4	48226.5	49031.9	49850.7	50683.2	51529.7	52390.2	53265.1	54154.6	55059.0
Isoko S.	97825.7	100760.5	103783.3	106896.8	110103.7	113406.8	116809.0	120313.3	123922.7	127640.3	131469.6
Ndokwa E.	36347.6	37110.9	37890.3	38685.9	39498.4	40327.8	41174.7	42039.4	42922.2	43823.6	44743.9
Ndokwa W.	64756.2	66828.4	68966.9	71173.8	73451.4	75801.8	78227.5	80730.8	83314.2	85980.2	88731.6
Okpe	55421.6	57195.0	59025.3	60914.1	62863.3	64875.0	66951.0	69093.4	71304.4	73586.1	75940.9
Oshimili N.	51166.5	52803.8	54493.5	56237.3	58036.9	59894.1	61810.7	63788.6	65829.9	67936.4	70110.4
Oshimili S.	64759.6	66831.9	68970.6	71177.6	73455.3	75805.9	78231.7	80735.1	83318.6	85984.8	88736.3
Patani	29088.6	30019.4	30980.0	31971.4	32994.5	34050.3	35139.9	36264.4	37424.8	38622.4	39858.4
Sapele	53244.3	53957.8	54680.8	55413.6	56156.1	56908.6	57671.2	58444.0	59227.1	60020.8	60825.0
Udu	61499.9	63467.9	65498.9	67594.8	69757.9	71990.1	74293.8	76671.2	79124.7	81656.7	84269.7
Ughelli N.	175269.9	183139.6	191362.5	199954.7	208932.7	218313.7	228116.0	238358.4	249060.7	260243.6	271928.5
Ughelli S.	85886.8	88326.0	90834.4	93414.1	96067.1	98795.4	101601.2	104486.7	107454.1	110505.8	113644.1
Ukwuani	51379.7	53023.8	54720.6	56471.7	58278.8	60143.7	62068.3	64054.5	66104.2	68219.5	70402.6
Uvwie	81462.3	84069.1	86759.3	89535.6	92400.8	95357.6	98409.0	101558.1	104808.0	108161.8	111623.0
Warri N.	53885.2	55356.2	56867.4	58419.9	60014.8	61653.2	63336.3	65065.4	66841.7	68666.5	70541.1
Warri S.	105637.7	107634.2	109668.5	111741.2	113853.1	116005.0	118197.5	120431.4	122707.5	125026.7	127389.7



The table presents the **projected population of Delta State LGAs (2025–2035)**, based on Census figures (1991, 2006) and a calculated compound annual growth rate (CAGR).

Population projections and growth patterns

Projected populations for Delta State LGAs indicate heterogeneous but substantial growth between 2006 and 2035 from 4,112,445 in 2006 to approximately 9,769,951 by 2035 with an average growth rate of 2.91%.

Ughelli North, Ethiope West, and Ethiope East demonstrate the steepest population increases across the projection period. Ughelli North

expands from 320,687 persons in 2006 to an estimated 1,146,169 by 2035, representing a 257.4% rise. Similarly, Ethiope West grows from 202,712 in 2006 to 712,545 by 2035 ($\approx 251.5\%$), while Ethiope East advances from 200,942 to 602,659 ($\approx 199.9\%$). In contrast, LGAs such as Warri South and Aniocha North exhibit relatively slower, though still notable, growth: Warri South increases from 311,970 in 2006 to 536,943 by 2035 ($\approx 72.1\%$), whereas Aniocha North moves from 104,062 to 292,666 ($\approx 181.2\%$). On the other hand, Sapele and several other LGAs record more modest increases within the same timeframe, underscoring spatial variations in demographic expansion (Figure 2)

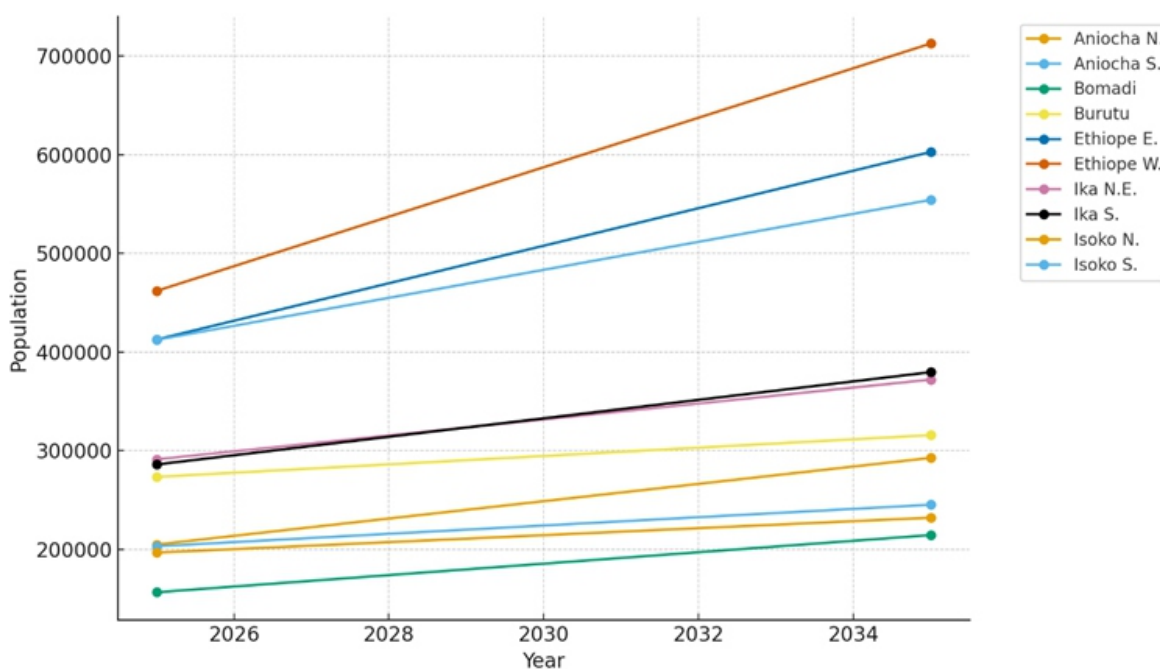


Figure 2: Population Projection trends (2025 – 2035)



The demographic projections highlight pronounced spatial disparities in growth within Delta State, with LGAs such as Ughelli North, Ethiope West, and Ethiope East experiencing exponential increases, while others like Warri South and Sapele show relatively slower expansion. Such uneven patterns reflect broader urban–rural dynamics in Nigeria, where rapidly urbanizing or industrializing LGAs often attract higher migration flows and sustain higher fertility rates (National Population Commission [NPC] and ICF, 2019).. Similar studies in Lagos and Abuja have also demonstrated accelerated population expansion in peri-urban and industrial zones, driven by both natural increase and in-migration (Adelekan, 2016; Olajide et al., 2018). Comparable trends have been reported in other parts of Sub-Saharan Africa, where cities like Accra in Ghana and Nairobi in Kenya are experiencing disproportionate growth compared to surrounding districts, exacerbating pressures on infrastructure and environmental systems (Cobbinah and Amoako, 2012; UN-Habitat, 2018)

The waste generation projections across the 25 LGAs of Delta State from 2025 to 2035 reveal a consistent upward trend, with a projected rate of about 1,657,504 tonnes in 2025 to 2,248,995 tonnes by 2035.

The growth is most prominent in rapidly urbanizing LGAs such as Ughelli North, Ethiope West, Ethiope East, and Warri

South, reflecting both population increase and socioeconomic activities. For instance, Ughelli North is projected to generate 175,269.9 tonnes in 2025, rising sharply to 271,928.5 tonnes in 2035, an increase of more than 55% within a decade. Similarly, Ethiope West shows continuous growth, from 109,588.7 tonnes in 2025 to 169,051.4 tonnes in 2035, while Ethiope East follows closely, increasing from 97,902.8 tonnes to 142,980.9 tonnes during the same period. These high-growth areas align with their status as hubs of commerce, oil-related activities, and population influx.

Conversely, LGAs such as Patani, Sapele, Ndokwa East, and Isoko North show relatively slower growth in waste generation. In Patani, the projection shows growth from 29,088.6 tonnes in 2025 to 39,858.4 tonnes in 2035, reflecting modest demographic expansion and less urbanized settlement patterns. These variations underscore the uneven urbanization dynamics in Delta State. This is consistent with Ugwuanyi and Isife (2012), who observed that surging urban population growth in southwestern Nigeria has dramatically increased waste generation rates. Similarly, Adewumi et al. (2005) measured daily waste outputs across southwestern cities and found that it range from 0.46 to 0.71 kg per person per day. This highlights how demographic and urban features influence waste volumes.



In general, the state's waste burden is projected to increase substantially across all LGAs, with total waste generation expected to double between 2025 and 2035. This finding is consistent with earlier estimates by Macrotrends. (2025) and World Population Review. (2025), who emphasized that Nigerian cities are experiencing annual urban growth rates, including Lagos with an over 3.75% annual growth rate. This rapid urban expansion results in unprecedented municipal solid waste

generation in urban areas. Comparable patterns have been observed in other developing nations such as Ghana, Kenya, and India, where municipal solid waste is projected to double within two decades under current urbanization trends (UNEP, 2021)

A pie chart illustrating the percentage contribution of each LGA to the total waste load, highlighting hotspots such as Ughelli North, Ethiope West, and Warri South is shown in figure 3.

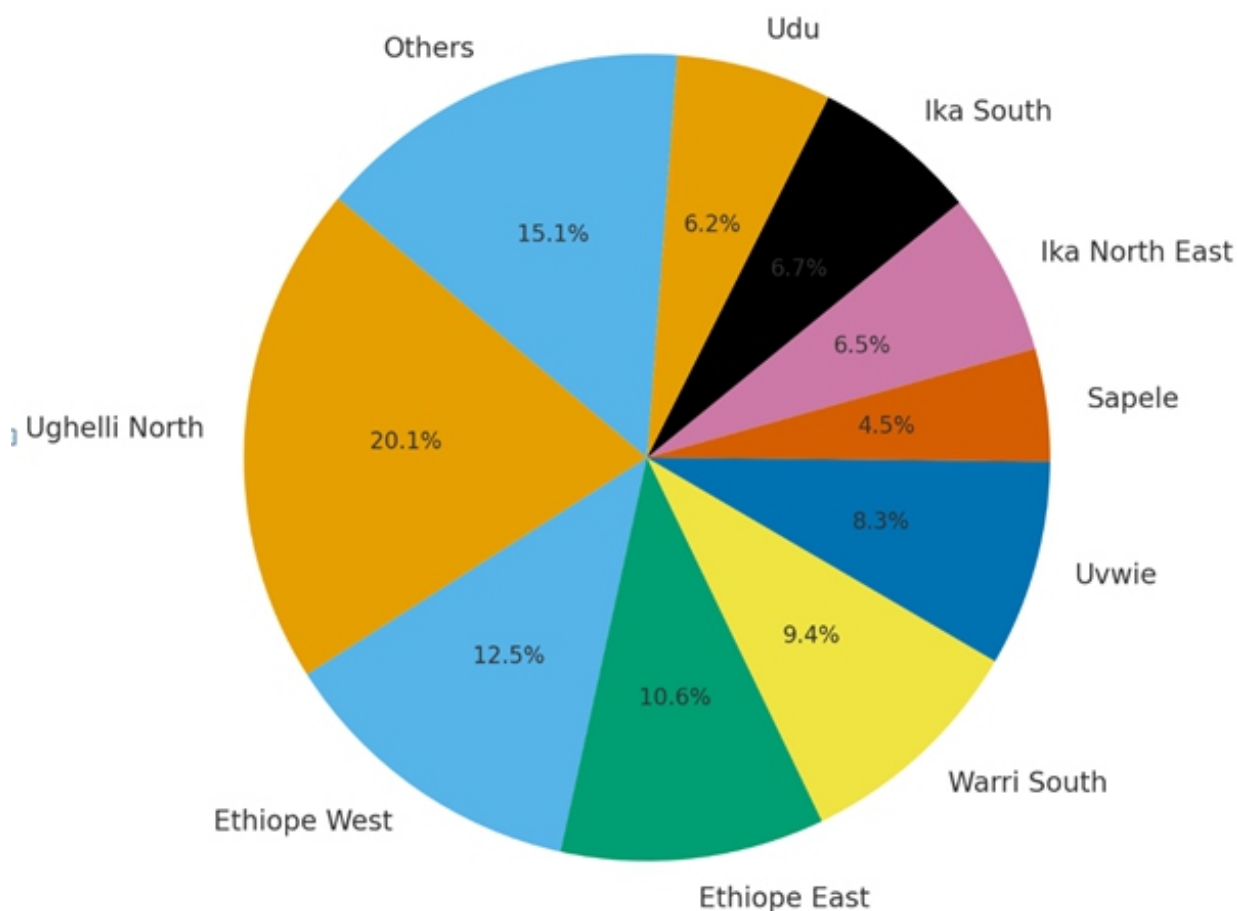


Figure 3: Pie chart showing the percentage contribution of each LGA to the total waste load.



The implications of this trajectory are profound. If left unmanaged, rising waste volumes will aggravate landfill overflows, leachate contamination, greenhouse gas emissions, and public health risks, particularly in LGAs with shallow aquifers and fragile ecosystems such as Sapele, Burutu, and Bomadi. This aligns with documented challenges in Lagos and Port Harcourt.

Residents living near landfill sites in Lagos have shown significantly elevated rates of respiratory and skin disorders (Abiola et al., 2021). In Port Harcourt, open dumpsites have been shown to contaminate nearby groundwater resources, posing environmental and health risks (Abiye and Raimi, 2025; Ugwoha and Emete, 2015).

Table 3: Reported cases of groundwater contamination from waste disposal in Delta State

Author(s)	Location	Sample Source	Analytical Method	Contaminants	Health Risks
Ogbaran and Uguru, 2021	Ozoro , Isoko North LGA,	4 groundwater samples:	ASTM standard , AAS, CF.PLI	Heavy metals: Fe, Cd, Cu, Zn, Pb, Ni	neurological disorders, kidney disease, infertility, endocrine, cardiovascular and , cancer
Ohwohere–Asuma and Aweto, 2013	Effurun, Warri	leachate , groundwater and , surface water	standard APHA methods	, EC , TDS, NO ₃ ⁻ , NH ₃ ⁻ , PO ₄ ³⁻ , Cl ⁻ , SO ₄ ²⁻ ; Fe , Cu , Zn , Pb , Cr , Mn	Potential contamination of shallow groundwater with ammonia, nitrates, phosphate; long-term risk of pollution; surface water shows higher ion concentrations indicating runoff pollution
Asibor, G. et al., 2016	okovo delta state	Groundwater	Lab analysis and geoelectric survey (VES)	NI	carcinogenic
Rawlings, and Seghosime., 2022	Ekurede Itsekiri, Warri South LGA,	Groundwater (10 boreholes) and leachate (5 points) from dumpsite	Physicochemical analysis; Heavy Metal Pollution Index (HPI)	pH, TDS, NH ₄ -N, Fe, Cr, Cd, Pb, coliform bacteria;	
Ogbeibu, et al., 2012	Ekurede-Urhobo, Warri, Delta State, Nigeria	Groundwater around an open dump-site	Physicochemical analysis; Duncan Multiple Range (DMR) test	EC, Nitrate, BOD, THC, TDS, TSS, coliform bacteria, THB, Fe	
Oboh and Egun.,2017	Agbor, Ika South LGA,	Boreholes close to municipal solid waste dumpsite	Physico-chemical, heavy metal and Microbial analysis	Pb, microbial contaminants above WHO limits	Waterborne diseases (cholera, typhoid, dysentery, skin rashes, mental disorder)
Oseji, rt al.,2018	Sapele, Delta State, Nigeria	Groundwater and geoelectric survey (VES)	VES), and lab analysis for metals	Pb , Ni, Cd	Unsafe for drinking and domestic use; potential exposure to heavy metals
Olaseni,et al.,2020	Agbarho,	Borehole water	geophysical, physiochemical and microbiological analyses	Acidic pH (5.1), total coliform 70 cfu/mL	Unsafe for drinking; microbial contamination from abattoir effluent; risk of waterborne diseases
Izeze et al..2018	Effurun,	boreholes	phsicochemical, microbial and heavy metal	Fe, Pb, Cd, Cl- Total Coliform Count	Typhoid, worm infestation, potential heavy metal toxicity (Pb, Cd, Fe)
Akpomrere and Uguru,2020	Ozoro, Isoko North LGA,	boreholes,	AAS	Copper (Cu)	headaches, dizziness, nausea, stomach cramps, liver & kidney failure, connective tissue problems
Ozoemenam et al.,2018	Ekpan community, Effurun,	borehole water	physicochemical and microbial analysis;	Pb, Cd, Cr, Mn, Hg; total coliforms; pH, BOD, NO ₃ ⁻ SO ₄ ²⁻ , salinity, total hardness	Pb, Cd, Mn, Cr, BOD, total coliforms exceeded WHO drinking water limits; potential toxicity for human consumption



IMPLICATIONS FOR GROUNDWATER IN DELTA STATE

1) Widespread leachate influence on shallow aquifers.

Across Ozoro, Effurun/Ekpan, Agbarho, Agbor, Sapele, and Warri, the studies consistently report landfill/dumpsite leachate signals as indicated by elevated EC/TDS and anions (NO_3^- , $\text{NH}_4^+/\text{NH}_3$, Cl^- , SO_4^{2-}), heavy metals (Fe, Pb, Cd, Cr, Ni, Mn, Cu, Hg), and faecal indicators (leachate fingerprint). This is especially of great concern because the Niger Delta's principal aquifer (Benin Formation) is unconfined/semiconfined, sandy, and highly permeable, with shallow water table conditions that facilitate rapid downward migration of contaminants from surface dumps. (Ogbaran and Uguru, 2021; Ohwoghere-Asuma & Aweto, 2013; Oboh and Egun, 2017; Oseji et al., 2018; Rawlings and Seghosime, 2022).

The findings observed that coliforms and metals (notably Pb, Cd, Mn, Cr) exceed drinking-water limits, implying immediate public-health implications, microbial waterborne disease, neurotoxicity (Pb), renal and endocrine effects (Cd), and carcinogenic risk (Cr(VI), PAH co-contaminants where present) etc. WHO drinking-water guidelines set *E. coli* at "0 per 100 mL," nitrate at 50 mg/L, and other specified guidelines for heavy metals were exceeded. This therefore indicates that groundwater around many dumpsites in

Delta State are unsafe without treatment (Izeze et al., 2018; Ozoemenam et al., 2018; World Health Organization [WHO], 2022). This aligns with the findings of Abd El-Salam, and Abu-Zuid, (2015), who also observed that proximity to dumpsites correlates with groundwater contamination.

CONCLUSION

The findings from this study show that rapid population growth and poor waste management practices in Delta State have significantly increased the volume of municipal solid waste, much of which is disposed of through open dumps and uncontrolled landfills. These disposal methods, combined with the porous nature of the Benin Formation aquifers, have led to widespread groundwater contamination, with heavy metals (Pb, Cd, Cr, Ni, Fe, Mn, Hg), nitrates, ammonia, chlorides, and microbial pathogens frequently exceeding WHO drinking water standards. Such pollution poses serious public health risks, including neurological disorders, kidney and liver damage, cancers, cardiovascular problems, and outbreaks of waterborne diseases like cholera and typhoid. The situation in Delta State mirrors national and global trends observed in other rapidly urbanizing regions such as Lagos, Port Harcourt, Accra, and Nairobi, where inadequate waste infrastructure similarly threatens groundwater security. If unaddressed, the projected rise in population and



waste generation by 2035 will further intensify these risks, undermining safe water access, public health, and sustainable development across the state.

RECOMMENDATIONS

Following the observations and findings, this study recommends that to effectively address groundwater pollution from uncontrolled landfills in Delta State, government and regulatory agencies must prioritize both immediate and long-term policy actions. In the short term, policies should mandate regular groundwater monitoring, enforce stricter controls on waste dumping, and provide low-cost water treatment systems for affected communities, alongside public sensitization on the health risks of consuming untreated groundwater. In the long term, investment in engineered sanitary landfills with leachate treatment, expansion of recycling and composting programs, and integration of sustainable waste management into urban planning should be adopted. Strengthening institutional capacity and aligning state waste management strategies with global best practices will secure safe groundwater, protect public health, and promote environmental sustainability.

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POST-NATAL DEPRESSION OF YOUNG MOTHERS FROM LOW-INCOME MILIEU

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Abstract

This study assessed Post-natal Depression of Young Mothers in Low-income Milieu (Ibarapa Central Local Government Area, Oyo State). A descriptive survey was conducted among 200 young mothers at four health centres in Igbo-Ora. Data were collected on socio-demographic characteristics, symptomatology, perceived aetiology and treatment modalities. The study revealed a high PND prevalence of 61.0%, with symptoms primarily manifesting as loss of interest (76.0%) and anxiety (71.5%). Most symptoms (71.5%) emerged within 1 to 3 weeks post-partum. While respondents acknowledged PND's negative impact on infant cognitive and emotional development, a paradox emerged as 55.5% believed mother-child bonding was not affected. However, 89.5% confirmed the availability of healthcare personnel and 100% supported universal mental health screening, a significant treatment gap persists because 61.0% of the sampled population remained without a formal diagnosis. In conclusion, although healthcare infrastructure and screening acceptance were high, specialised PND support was deficient. So, interventions should focus on bridging the diagnostic gap and integrating psycho-social support into routine post-natal care. Recommendation, clinical screening should be mandatory during early post-natal visits (within 1–3 weeks). Additionally, healthcare providers should establish localised peer-support groups and integrate psychological education into routine immunisation clinics to improve the help-seeking behaviour of mothers.

Key words: Post-natal, Depression, Mothers, Low-income, Milieu.



Depression is a mood disorder that usually affect how someone thinks, feels and behaves resulting in series of emotional and physical issues. Post-natal Depression of mothers which is also known as postpartum depression is an incidence of depression which manifests in the first four weeks after delivery but some women are susceptible to depression several months after delivery for different reasons. It is a most common psychiatric complication of childbearing (Bradshaw, Riddle, Salimgaraev, Zhaunova, and Payne, 2022). It sometimes goes unrecognised or unnoticed and untreated but has potentially harmful effects on the husband, siblings and parents etc. of the depressed mother. Some scientists observed that women generally, may be reluctant to access professional assistance due to the social stigma attached to it, as a sort of mental illness. Even where some seek medical attention, they are often afraid of taking medication because of the effect on their child during lactation (Bradshaw, Riddle, Salimgaraev, Zhaunova, and Payne, 2022).

It has been estimated that approximately 13% of new mothers have this disorder and can be associated with complications with time if not treated Gaillard, Le Strat, Mandelbrot, Keita, and Dubertret, 2014. Moreover, Gavin, Gaynes, Lohr, Meltzer-Brody and Gartleher, 2025 found that it affects 10% - 15% of women of child bearing

age and 50% are undiagnosed among mothers Samar, Nahla, ... Walid *et al* 2025. Some new mothers experience different types of depression. Some studies have reported the prevalence of depression among mothers in Nigeria 10.7% to 44.39% by Tsiga-Ahmed *et al*, 2024, Abba *et al*, 2023 and 35.6% as reported by Adeyemo, Oluwole, Kanma-Okafor, Izuka and Odeyemi, 2020. Nevertheless, being single mother and having a female baby where one is expecting a male child are important risk factors for postpartum depression in Nigeria due to over thinking. If not treated, it can lead to a potentially adverse effect on the woman, the child and the stakeholders especially her immediate family.

According to DSM-IV diagnostic criteria, certain women have a recurrence of depression especially after childbirth, however, others undergo the first onset of depression in the postpartum period (American Psychiatric Association, 2000, Meltzer-Brody, Stuebe, Dole, Savitz, Rubinow, & Thorp, 2011). Women having the history of postpartum depression, medical complications during childbirth, lack of emotional support, premature delivery and mixed feelings about the pregnancy are susceptible to its occurrence (Wisner, Hanusa, Pindl, Perel, 2004). Occasionally, it seems like depression with a long period of hopelessness is accompanied with sadness and symptoms ranging from sleep problems, fatigue, to crying jags,



change in appetite and suicidal thoughts that shows up from nowhere. Scientists are still trying to pinpoint the exact cause of depression, but for now, research has found that biological changes triggered by series of factors could be the cause. These factors can be internal e.g. genetic, chronic pain, hormonal swings, gut bacteria or external issues for example, childhood abuse, loss of a loved one, financial stress, or side effects of medication, all affecting the individual. The psychological and psychological changes that occur after delivering a baby may trigger the condition (Wisner, Parry & Piontek, 2002).

Moreover, the symptoms of depression are majorly the same, be it an experienced postpartum or not; but the focus is on mothering or infant care cases in postpartum depression. Women with postpartum depression sometimes present comorbid symptoms for example, compulsion, obsessions or psychotic features, panic attack, anxiety or substance use disorders as the case may be (Spinelli, 2004, Bradshaw *et al*, 2022). Postpartum can cause disruptions in maternal-infant interactions, lower cognitive functioning and behavioural problems in children (Oberlander, Reebye, Misri, Papsdorf, Kim and Grunau, 2007). If post-natal depression increases and persists, children can develop emotional problems, for example, anxiety, depressive disorders, disruptive disorders but if given an early

intervention, it can have positive effect on both mother and child. Maternal postpartum depression can also cause negative infant feeding outcome and reduce the rate of initiating and maintaining breastfeeding. Mother-child relationship quality is of importance from an evolutionary standpoint as it plays a role in the accumulation of offspring embodied capital, thus affecting children quality and their capacity to subsequently invest in their own future generation. Therefore, screening of postpartum depression should be strictly encouraged among women of child bearing age (American College of Obstetricians and Gynecologists (ACOG, 2010).

Women susceptible to postpartum depression should be identified as quickly as possible because early intervention is key, so that a good follow-up can be done and adequate care initiated. They should also be assessed for manic features Cox, Holden, Sagowky (1987). However, the stigma of mental illness posed a barrier to the delivery of optimal clinical care to women with postpartum depression. Hence, there is need for counselling to assure women of child bearing age of the safety of their information by engaging a multidisciplinary approach where medical doctors work hand in hand with the professional counsellors and psychologists to successfully attend to the patients (Dennis and Chung-Lee, 2006, Stancin, & Perrin, 2014).



Therefore, this issue does not only affect the husband, siblings and parents of the depressed mother but also, the societal resources and healthy development of the future generations. In spite of the significant effect of PDD, there is a critical gap in its formal diagnosis and treatment. Therefore, this study examined the implication of Post-natal Depression of mothers on early childhood development in order to understand post-natal depression, symptomatology, effects on child outcome, treatment modalities available for women undergoing post-natal depression in the study area.

Purpose of the Study

The primary purpose of this study is to examine the Post-natal Depression of Young Mothers from Low-income Milieu (Ibarapa Central, Oyo State, Nigeria).

In pursuit of the aim above, the study is designed to:

1. examine the socio-demographic characteristics of the respondents in the study area.
2. identify Post-natal Depression of young mothers in the study area.
3. explore the perceived aetiology of Post-natal Depression of mothers.
4. identify the effect of post-natal depression of mothers on child outcomes.
5. be acquainted with treatment modalities for post-natal depression of mothers

Research Questions

The research questions were formulated to facilitate the research;

1. What are the sociodemographic characteristics of the respondents?
2. What is the level of Post-natal Depression among mothers in the study area?
3. What are the perceived aetiology of Post-natal Depression of mothers in the study area?
4. What are the effects of post-natal depression of mothers on child outcomes?
5. What are the treatment modalities for post-natal depression of mothers in the study area?

Materials and Methods

The study adopted descriptive survey research design which is well-suited for this research in order to systematically describe the characteristics of the population so as to provide a foundational understanding for future hypothesis generation and for effective resource planning (Achimugu and Mohammed, 2021). The design was adopted because it involves the use of questionnaire to elicit information from the respondents on Post-natal Depression of Young Mothers in Low-income Milieu. These designs helped the researcher to obtain valid answers via questionnaire which also helped the subjects to express their views clearly. The population was made up of the mothers in Ibarapa Central Local Government Area who were of different age groups, educational background,



socio-economic status and residential areas.

A total of 200 women who met up with the eligibility criteria were selected for this study. A multi-stage sampling technique through proportional allocation was used to choose the respondents for this study. The selection procedure was as follows:

Stage 1: the selection of a town in Ibarapa Central where the research was carried out.

Stage 2: Random selection of 4 hospitals that were in close proximity.

Stage 3: Random selection of 200 respondents from the four healthcare centres.

i.	Olugbon Medical Centre	47	23.5%
ii.	Igbo-Ora General Hospital	72	36.0%
iii.	Gafsor Hospital	29	14.5%
iv.	World Health Centre	52	26.0%
	Total	200	100%

A structured questionnaire was adapted and used as the major research instrument. The questionnaire was divided into five sub-sections according to the variables.

Section A: Socio-demographic characteristics of the respondents

Section B: Symptomatology of Post-natal Depression of mothers in the study area.

Section C: Perceived Aetiology of Post-natal Depression of mothers in the study area.

Section D: Effects of post-natal depression of mothers on child outcomes

Section E: Possible treatment

modalities for mothers with post-natal depression in the study area.

Its reliability was determined through the pilot testing of a portion (30 pieces) of the questionnaire in another location that is different from the study area. Its reliability was 0.75 using Cronbach's alpha.

The validity content of the research was ensured by submitting the drafted questionnaire to the experts in child development and family studies option for proper correction and assessment. Its reliability was determined through the pilot testing of a portion (30 pieces) of the questionnaire in another location that is different from the study area. Its reliability was 0.75 using Cronbach's alpha. The validated questionnaire was used for data collection. The questionnaire was self-administered and the respondents were asked not to include their names, so that no one could be traced or linked with any response because their responses are genuine and should be kept as confidential as possible. This was done to facilitate genuine responses which was collected from the correspondents due to the safe spaces provided to them. Copies of the questionnaire was distributed to them after brief introduction and was retrieved after completion. Descriptive statistics such as: percentages, mean, frequency counts and standard deviation was used to analyse the research objectives.



Results and Discussions

Table 1: Socio demographic characteristics of respondents

Variables	Frequency	Percentage	Mode	Std. deviation
Name of hospital				
Olugbon medical Centre	47	23.5		
Igbo-Ora general hospital	72	36.0		
Gafisor medical Centre	29	14.5		
World Health Centre	52	26.0		
Total	200	100.0	2.31	.990
Age				
15-25	71	35.5		
26-36	57	28.5		
37-47	50	25.0		
48 and above	22	11.0		
Total	200	100.0	2.11	1.018
Marital status				
Single	41	20.5		
Married	122	61.0		
Divorce	32	16.0		
Separate	5	2.5		
Total	200	100.0	2.00	1.058
Educational level				
O'level	43	21.5		
ND	64	32.0		
HND	65	32.5		
Bsc	19	9.5		
Msc	9	4.5		
Total	200	100.0	2.44	1.068
Occupation				
Civil servant	47	23.5		
Self employed	72	36.0		
Private firm	52	26.0		

Socio-demographic Characteristics of Respondents



Table 1 showed the socio-demographic characteristics of the respondents in the four health centres included in the study in Ibarapa Central Local Government, Igboora of Oyo State. Considering the age range of the respondents' majority were 15-25(35.5%). Majority, 61.0% were married. Majority, 36.0% are self-employed. Educationally, majority had ND 32.0%, HND 32.5%.

From the findings of the study in Ibarapa Central Local Government, Igboora, Oyo State, as seen above, the study participants in the four health centers displayed a distinct socio-demographic profile. The data revealed that the respondents' population is predominantly young, with the largest age cohort being 15-25 years old (35.5%). This suggests that the health services in these centers are frequently accessed by young adults, which could be due to a variety of factors such as reproductive health needs, vaccine programs, or general health maintenance among a younger demographic. Also, a significant majority of the respondents (61.0%) were married. This demographic pattern is consistent with the predominant

marital customs in many Nigerian communities where marriage is a key social foundation. The high percentage of married individuals may influence the types of health issues presented at the centers, such as maternal and child health concerns or family planning. In terms of economic status, the data indicated that a considerable portion of the participants were self-employed (36.0%). This suggests that many respondents are engaged in informal work sector, which can have implications on their healthcare access and affordability. Self-employment subsequently mean that they may lack stable income, paid sick leave or health insurance, which can act as a barrier to consistent healthcare utilisation. Lastly, the educational attainment of the respondents is notable. The findings showed a high level of educational achievement, with majority having obtained a National Diploma (ND) (32.0%) or a Higher National Diploma (HND) (32.5%). This suggests that the study population is relatively well-educated, which could positively impact health literacy and decision-making. A higher level of education is often correlated with better health-seeking behaviour and a greater understanding of health information.

**Table 2: Symptomatology of Post-natal Depression of mothers**

Variables	YES		NO		Mean	Standard deviation
	F	%	F	%		
Did you experience symptoms of depression after childbirth	122	61.0	78	39.0	1.39	.489
I experienced sadness	128	64.0	72	36.0	1.36	.481
I experienced withdrawal	123	61.5	77	38.5	1.39	.488
I experienced loss of interest	152	76.0	48	24.0	1.24	.428
I experienced anxiety	143	71.5	57	28.5	1.29	.453
Duration of depression after childbirth						
1-3 weeks	143	71.5			1.38	.654
4-6 weeks	38	19.0				
7 weeks and above	19	9.5				
Sought professional help or support	93	46.5	107	53.5	2.09	.678
Received a formal diagnosis	78	39.0	122	61.0	2.12	.614

Table 2 presented the identification of post-natal depression among mothers amongst mothers in Ibarapa central local government of Oyo State. Out of 200 respondents that participated in the survey 61.0% experienced post-natal depression among mothers while 39.0% did not experience post-natal depression among mothers. 61.5% experienced withdrawal while 38.5% did not. 64.0% experienced sadness while 36.0% did

not experience post-natal depression among mothers. 76.0% of the respondents experienced loss of interest while 24.0 did not experience such. 71.5% experienced anxiety while 28.5% did not experience such. Some of the respondents experienced noticeable symptoms of post-natal depression among mothers after 1-3weeks of delivery (71.5%), 19.0% experienced symptoms of post-natal depression



among mothers after 4-6 weeks while 9.5% experienced post-natal depression among mothers after 7 weeks and above. Ninety-three (93) respondents sought professional help and support when they noticed the symptoms while 107 respondents did not. 122 respondents did not receive formal diagnosis of post-natal depression among mothers while 78 respondents did receive formal diagnosis of this form of depression.

The study established a high prevalence of post-natal depression (PND) within the sampled population. A significant majority of the respondents, 61.0%, reported experiencing PND, while 39.0% did not. This finding underscores the need for increased awareness and screening for this condition in the region. The data also revealed the specific symptoms mothers experienced. A high proportion of mothers reported feeling sadness (64.0%) and a higher percentage experienced loss of interest (76.0%). These two symptoms are cardinal features of major depressive episodes, suggesting that the PND observed was not merely a transient "baby blues" but a more significant clinical concern. In addition, a large number of respondents reported experiencing withdrawal (61.5%) and anxiety (71.5%). The high prevalence of anxiety, in particular, may indicate a co-morbid anxiety disorder, which is common with depression. However, the onset of these symptoms varied among the respondents. Majority, 71.5%, experienced

noticeable symptoms within 1-3 weeks after delivery. This early onset is consistent with the typical clinical presentation of PND, as the symptoms often emerge shortly after childbirth..

A relatively smaller percentage of respondents experienced symptoms later, with 19.0% reporting onset after 4-6 weeks and 9.5% after 7 weeks and above. This later onset may indicate different risk factors or could be a sign of a more insidious progression of the illness. The study also highlighted crucial insights into help-seeking behaviour of the respondents and the diagnostic process in the study area. The data revealed a disparity between those who sought help and those who did not. A minority of the respondents, 93, (46.5%) actively sought professional help and support, while a majority, 107, (53.5%) did not. Their reluctance to seek help may be attributed to a number of factors, including social stigma, lack of awareness of PND as a treatable medical condition, or limited access to mental health services in the local government area. Moreso, lack of formal diagnosis is particularly alarming. A substantial majority of mothers, 122 (61%) did not receive a formal diagnosis of PND, while only 78 (39%) did. This finding showed a significant gap in the healthcare system's ability to identify and formally diagnose PND. It suggests that many mothers are not being screened during their post-natal check-ups, or that



healthcare providers may lack the necessary training or resources to make an accurate diagnosis. The low rate of formal diagnosis, coupled with the high prevalence of symptoms, indicated that

a large number of mothers with PND were likely undiagnosed hence, untreated, which can have long-term negative consequences for both the mother and the child.

Table 3: Perceived Aetiology of Post-natal Depression of Mothers

Variables	Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree		Mean	Std. Deviation
	F	%	F	%	F	%	F	%	F	%		
	Loss of a child	52	26.0	61	30.5	60	30.0	13	6.5	14		
Ailment	65	2.5	51	25.5	35	17.5	27	13.5	22	11.0	2.45	1.355
Weakness	65	32.5	37	18.5	34	17.0	28	14.0	36	18.0	2.76	2.076
Self-doubt	33	16.5	35	17.5	28	14.0	64	32.0	40	20.0	3.22	1.385
Absence of affection	23	11.5	31	15.5	16	8.0	73	36.5	57	28.5	3.55	1.352
Absence of care	15	7.5	24	12.0	33	16.5	68	34.0	60	30.0	3.67	1.232
Weakness	41	20.5	55	27.5	27	13.5	45	22.5	32	16.0	2.86	1.396
Sadness	48	24.0	51	24.0	34	17.0	24	12.0	43	21.5	2.82	1.474



Perceived Aetiology of Post-natal Depression of Mothers

Table 3 represents the causes of post-natal depression among mothers amongst mothers in Ibarapa central local government, Igboora in Oyo state. Out of 200 respondents that participated in the survey, 13.5% disagreed that the loss of a child could result into post-natal depression among mothers while 56.5% agreed that it could be a cause. About 24.5% disagreed that the presence of an ailment can cause post-natal depression among mothers while 58% agreed. 32% disagreed to weakness during delivery being a cause of post-natal depression among mothers, 17% were undecided while 51% agreed to weakness being a cause. 68 respondents agreed to self-doubt being a cause of post-natal depression among mothers while 104 respondents disagreed. More than two third of the respondents disagreed that absence of affection, absence of care, weakness after delivery and sadness can be a cause of maternal delivery after delivery.

The study identified several perceived aetiology for PND among the mothers surveyed, with varying levels of agreement among the respondents. A significant majority of participants (56.5%) agreed that the loss of a child could lead to PND, while 58% agreed that the presence of an ailment could also be a cause. This showed that respondents recognise a strong link between significant life stressors, such

as bereavement and illness, and the onset of PND. This aligns with clinical understanding, where emotional trauma and physical health challenges are well-established risk factors for depression. Nevertheless, the data revealed a lower level of consensus on other potential causes. While 51% of the respondents agreed that weakness during delivery could be a factor, a substantial portion (32%) disagreed, and 17% were undecided. This split opinion may reflect a lack of awareness about the psychological impact of physical exhaustion and trauma during childbirth, which can be a direct contributor to PND. The findings also highlighted a notable disparity between the respondents' views on emotional factors. A majority of respondents (104) disagreed that self-doubt was a cause of PND, while only 68 agreed. This is a particularly interesting finding, as self-doubt and feelings of inadequacy are core psychological symptoms of PND.

The respondents' failure to connect this internal emotional state with the condition suggests a potential lack of understanding of the psychological and emotional underpinnings of PND in the study area. Furthermore, the data indicates a widespread disagreement among more than two-thirds of the respondents that factors such as absence of affection, absence of care, weakness after delivery and sadness can be causes of PND. This finding is highly significant and points to a major misconception among the study



population. These factors such as lack of social support and persistent negative emotional states were clinically recognised as major contributors to PND. The respondents' rejection of these factors as causes suggested that many in the community may view PND

as being caused by only major, external stressors (like child loss or illness) rather than a combination of internal and external emotional and social factors. This misperception can be a barrier to both help-seeking and effective community-based interventions.

Table 4: Effects of Post-Natal Depression of Mothers on Child Outcomes

Variables	Yes		No		Mean	Standard Deviation
	F	%	F	%		
Poor cognitive development	105	52.5	95	47.5	1.48	.501
Poor emotional development	117	58.5	83	41.5	1.47	.500
Poor social development	106	53.0	94	47.0	1.42	.494
Poor mother to child bonding	89	44.5	111	55.5	1.56	.498

Effects of Post-Natal Depression of Mothers on Child Outcomes

Table 4 indicated the effects of post-natal depression among mothers on the respondents' child(ren) in Ibarapa central local government, Igboora of Oyo state. Out of 200 participants in the survey 52.5% agreed to post-natal depression among mothers causes poor cognitive development of the newborn. Also, 58.5% of the respondents agreed to post-natal depression among mothers having poor effect on the newborn's emotional development. And 53.0% of the participants said it had poor social development on the newborn child. But

55.5% said it does not affect mother-child bonding Meaning that post-natal depression among mothers affect cognitive, emotional and social development of the child but it did not affect mother-child bonding in the study area. Based on the data provided, here's an academic interpretation of the effects of post-natal depression (PND) on child outcomes among mothers in Ibarapa Central Local Government, Oyo State.

The study findings indicate that the mothers surveyed were largely aware of the negative impact of PND on their



children's development. A slight majority of respondents agreed that PND can lead to poor cognitive development (52.5%), poor emotional development (58.5%) and poor social development (53.0%) in the newborn child. These perceptions were consistent with established psychological and developmental research, which demonstrates that a mother's mental health is a crucial determinant of early childhood development. For instance, when a mother is depressed, it affects her ability to engage in responsive and stimulating interactions with her infant may be impaired, which can in turn affect the child's developmental trajectory.

Yet, a significant discrepancy arose in the respondents' perception of mother-child bonding. As majority of the mothers, 55.5%, believed that PND

does not affect mother-child bonding. This finding is particularly concerning as it contradicts extensive research demonstrating that PND can severely disrupt the attachment process. The emotional withdrawal, lack of interest and sadness associated with PND often make it difficult for mothers to form a secure attachment with their infants. Also, a mother that is struggling with depression may be less likely to respond to her baby's cues, leading to a strained and insecure bond. The respondents' perception that this critical aspect of development is unaffected suggests a major gap in their understanding of PND's full impact on child outcomes. This misunderstanding could lead mothers to overlook key signs of distress in both themselves and their children, potentially delaying their help seeking behaviour.

**Table 5: Possible Treatment Modalities for Post-natal Depression of Mothers**

Variables	YES		NO		Mean	Std. Deviation
	F	%	F	%		
Support & Counselling	102	51.0	98	49.0	1.49	.501
Local support & resources	77	38.5	123	61.5	1.62	.488
Cultural beliefs	106	53.0	94	47.0	1.47	.500
Access to healthcare services	134	67.0	66	33.0	1.33	.471
Professional healthcare personnels	179	89.5	21	10.5	1.11	.307
Mental health screening	200	100			2.0	
Support from partner	104	52.0	96	48.0	1.0	
Community initiatives	142	71.0	58	29.0	1.32	.466
Self-care activities						
Exercising	137	68.5	63	31.5		
Working	63	31.5	137	68.5	1.29	.455
Support from social networks	156	78.0	44	22.0	1.22	.415
Adequate guidance	77	38.5	123	61.5	1.62	.488
Better enlightenment	88	44.0	112	56.0	1.56	.498

Possible treatment modalities of post-natal depression of mothers in the study area

In table 5, the study revealed that out of 200 respondents 51.0% of the respondents agreed with support and counselling, 61.5% of them said there

were no local support and resources, 67.0% accepted access to healthcare services, 53.0% chose the presence of cultural beliefs, 89.5% said yes to availability of professional healthcare personnel, all the respondents agreed to



mental health screening being performed on mothers or mothers to be. 52.0% agreed with support from partners, 71.0% agreed with the presence of adequate community initiatives. 68.5% chose exercising while 31.5% chose working, 78.0% agreed with support from social networks being of help as possible treatment modalities.

The study showed a mixed but generally positive view among respondents regarding various treatment and support modalities for PND. As majority of respondents (51.0%) agreed that support and counselling were effective and a high percentage (78.0%) also admitted the value of support from social networks. This suggested that the community understood the importance of emotional and social support in managing PND. There was also a strong consensus on the need for professional intervention. A significant majority (89.5%) agreed on the importance of the availability of professional healthcare personnel. Remarkably, all 200 respondents agreed that mental health screening should be performed on mothers or mothers-to-be. This unanimous agreement highlighted a strong perceived need for a pro-active, systemic approach to identifying PND, indicating that the community recognised the current deficit in early diagnosis. Despite the perceived effectiveness of various interventions, the data also emphasised the significant barriers to access. As majority of

respondents (61.5%) stated there were no local support and resources, while 67.0% acknowledged the importance of access to healthcare services. This contrast suggests a clear awareness of a gap between the need for and the availability of local resources for PND.

The influence of cultural beliefs is also a prominent factor, with 53.0% of respondents choosing its presence as a potential treatment modality. This indicates that cultural practices and beliefs are seen as a relevant form of support, possibly in the absence of formal healthcare options. Respondents also identified personal coping strategies and community-based support as potential treatments. Also, majority (68.5%) chose exercising as a helpful modality, while a lower percentage (31.5%) chose working. Furthermore, a high proportion of respondents (71.0%) agreed on the value of adequate community initiatives. This highlighted that mothers in the study area see a need for and would benefit from structured community-level programs that combine emotional support, physical activity, and social networking. The findings collectively point to a strong need for integrated care models that combine professional medical services, community-based support systems and pro-active screening to effectively address PND in the study area.

Discussion of findings

This study investigated post-natal



depression (PND) among mothers in four health centers within the Ibarapa Central Local Government Area of Oyo State, specifically Olugbon Medical Centre, Igboora General Hospital, the World Health Centre, and Gafsol Hospital. The demographic data of the respondents revealed that the majority were aged 15-25 (35.5%), married (61.0%), and self-employed (36.0%). Educational backgrounds were primarily comprised of National Diploma (ND) and Higher National Diploma (HND) holders, at 32.0% and 32.5% respectively. The study identified several common symptoms of PND among participants, including sadness (64.0%), anxiety (71.5%), withdrawal (61.5%), and a significant loss of interest (76.0%). These findings align with the DSM-IV diagnostic criteria, which note that PND can be a recurrence of prior depression or a first-time occurrence during the postpartum period (American Psychiatric Association, 2000; Meltzer-Brody et al., 2011). The onset of symptoms was most frequently observed within 1-3 weeks postpartum (71.5%), with 19.0% experiencing symptoms at 4-6 weeks and 9.5% at 7 weeks or more.

The research identified several potential causes of PND, including the loss of a child (56.5%), concurrent illness (58.0%), and complications or weakness during delivery (51.0%). These findings are consistent with established research indicating that PND affects a significant percentage of

women of child-bearing age (Gavin et al., 2025) and can co-occur with other mental health conditions such as anxiety, panic attacks, or substance use disorders (Spinelli, 2004; Bradshaw et al., 2022). The study further explored the influence of PND on a child's development. Majority of respondents reported that maternal PND led to poor cognitive (52.5%), emotional (58.5%), and social (53.0%) development in their newborns. This is in line with previous studies (Gaillard et al., 2014) and supports the notion that maternal depression can have adverse effects on child development. However, a significant number of participants (55.5%) stated that PND did not affect the mother-child bond, a finding that contradicts previous research by Oberlander et al. (2007), who found that maternal depression can disrupt mother-infant interactions. Conversely, the study's finding on bonding aligns with the perspective of Blakemore, Burnett, and Dahl (2010), who emphasize that attachment is a crucial component of a child's emotional development.

The respondents identified several available treatment modalities for PND, including support and counseling (51.0%), access to healthcare services (67.0%) and the presence of cultural beliefs (53.0%). A substantial number of the respondents (89.5%) also highlighted the importance of professional healthcare personnel. This finding contrasts with Radecki et al.



(2011), who reported that healthcare professionals often lack confidence and training in diagnosing maternal depression.

The study's findings indicate a strong consensus for the need for comprehensive support systems. All the respondents agreed that mental health screenings should be performed for all mothers or expectant mothers. Majority of respondents also supported partner involvement (52.0%) and self-care activities such as exercising (68.5%) and gainful employment (31.5%). More than two-thirds of respondents emphasised the importance of social networks, better public awareness and adequate community initiatives to support mothers both before and after delivery.

Conclusion

This study has provided valuable insight into the prevalence and the influence of post-natal depression among mothers in Ibarapa Central Local Government Area of Oyo State. By examining four local health centers, Olugbon Medical Centre, Igboora General Hospital, World Health Centre, and Gafsol Hospital, the research identified key demographic characteristics of the respondents, with majority being young, between 15 and 25 years old, married and self-employed. The findings confirmed that PPD is a significant health concern in this community, with a high percentage of respondents reporting core symptoms

like sadness, anxiety, withdrawal and loss of interest. The research also successfully identified the timing of post-natal depression onset, with the majority of symptoms manifesting within the first 1-3 weeks post-delivery, aligning with established diagnostic criteria (American Psychiatric Association, 2000). The study further highlighted specific etiological factors, including the loss of a child, pre-existing ailments and weakness during delivery. These findings are consistent with existing literature, which suggests that post-natal depression affects a substantial portion of women of childbearing age and can co-occur with other mental health issues (Gavin et al., 2025; Spinelli, 2004). Crucially, the study established a clear link between Post-natal Depression and negative child outcomes. A significant majority of respondents agreed that Post-natal Depression negatively impacts a newborn's cognitive, emotional and social development. However, the finding that Post-natal Depression does not significantly affect mother-child bonding in this specific context is noteworthy, as it contradicts some previous research (Oberlander et al., 2007) while aligning with others that emphasize the importance of attachment for a child's development (Blakemore, Burnett, & Dahl, 2010). This indicates a complex dynamic that may be unique to the cultural or social environment of the study area, where other factors might be mitigating the effects of depression on the maternal-



infant bond. The study concludes that post-natal depression is a pervasive issue with detrimental effects on child development, underscoring the need for targeted interventions.

Recommendations

Based on the findings of this study, the following recommendations were suggested to address the burden of postpartum depression in Ibarapa Central Local Government Area. They were tailored to the specific context of the study area while aiming for actionable and culturally sensitive interventions. Firstly, establish universal mental health screening: Given the high prevalence of post-natal depression symptoms, it is recommended that all health centres in the study area, including those surveyed and beyond, institute mandatory mental health screenings for all pregnant women and new mothers. This should be a routine part of anti-natal and post-natal care. The screenings should be administered by trained healthcare professionals using validated tools to facilitate early detection and intervention. Secondly, boost professional training and capacity building: The study's finding that professional healthcare personnel are a key treatment modality (89.5%) while also being identified in other research as lacking confidence in diagnosing post-natal depression (Radecki et al., 2011) suggests a need for enhanced training.

It was recommended that the Oyo State

Ministry of Health, in collaboration with professional medical associations, develop and implement specialised training programmes for healthcare workers in grassroots areas. These programs should focus on post-natal depression symptom identification, patient communication and evidence-based therapeutic approaches, such as psychotherapy and counselling. Thirdly, launch community-based support systems: The findings highlight the importance of social support and community initiatives. It is recommended that community leaders and local non-governmental organizations (NGOs) work together to create accessible, community-based support groups for new mothers. These groups can facilitate peer-to-peer counseling and create a safe space for mothers to share their experiences, reducing feelings of isolation. This aligns with the participants' agreement on the value of support from social networks and adequate community initiatives. Fourthly, enhance culturally relevant self-care activities:

The study identified exercising and being gainfully employed as preferred self-care activities. This indicates a need to promote self-care options that are both effective and culturally acceptable. Public health campaigns and educational materials should be developed to inform new mothers about the benefits of physical activity and productive leisure. These campaigns should be delivered through local media



and health centers, emphasising how these activities can improve mental well-being and overall health. Fifthly, sensitise women of child-bearing age and involve their partners and families: Since majority of respondents were married, it is crucial to include partners and families in the post-natal depression awareness and support process. It was recommended that health centres offer informational sessions and resources to partners on how to recognise post-natal depression symptoms and provide effective emotional and practical support. This approach will strengthen the family unit and contribute to a more supportive environment for especially the mother and the child.

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MODELLING AND FORECASTING QUARTERLY ENERGY CONSUMPTION IN ILORIN, NIGERIA: TREND, SEASONALITY, AND ARIMA ANALYSIS

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ABSTRACT

The absence of reliable city-level forecasts, which limits proactive energy planning and demand-management strategies necessitates this study. Quarterly energy consumption pattern in Ilorin Metropolis, Nigeria, from 2003 to 2022 was analyzed, using time series decomposition and Autoregressive Integrated Moving Average (ARIMA) modelling approach. The analysis identified a persistent downward trend in energy consumption, coupled with pronounced seasonal variation characterized by higher usage in the first quarter and lower usage in the fourth quarter of each year. A multiplicative time series model and ARIMA (0, 1, 4) were fitted to the data, with the ARIMA model selected based on the lowest Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hanna-Quinn Information Criterion (HIQ) values. Model diagnostics confirmed stationarity, white noise residuals, and strong predictive ability, with a Mean Absolute Percentage Error (MAPE) of 3.61%. Forecasts for 2023-2030 indicate a continuing downward trend, implying the need for proactive energy management policies. The findings provide empirical evidence to guide policymakers, energy planners, and utility companies in formulating strategies for sustainable energy distribution and consumption in the metropolis.

Keywords: Energy consumption, Time series analysis, Seasonality, ARIMA model, Forecasting, Nigeria.

1. Introduction

Energy consumption is generally acknowledged as a key driver of economic growth, urban development, and improvements in living standards. In developing economies, rising energy demand is closely associated with population growth, urbanization, and

expanding industrial and commercial activities (IEA, 2023; Adebayo & Riti, 2024). Understanding the pattern of energy consumption is therefore essential for effective energy planning, infrastructure development, and sustainability policy formulation.



Over the years, energy demand has increased steadily in Nigeria; yet supply remains inadequate and unstable, resulting in regular shortages and reliance on alternative energy sources such as generators (World Bank, 2024). These challenges are particularly prominent in rapidly urbanizing cities, where seasonal climatic conditions, economic cycles, and socio-cultural practices further influence consumption patterns. Despite the availability of historical consumption data, empirical studies that rigorously model urban-level energy demand using modern time series techniques remain limited, especially outside major metropolitan areas.

Time series analysis provides a systematic framework for examining and forecasting energy consumption. Decomposition techniques allow observed series to be separated into trend, seasonal, and irregular components, offering valuable insights into long-term growth and recurring fluctuations. When combined with forecasting models such as the autoregressive integrated moving average (ARIMA) framework, decomposition enhances predictive performance and interpretability (Hyndman & Athanasopoulos, 2021; Ahmed et al., 2023). Recent studies have demonstrated the continued relevance of ARIMA-based approaches for electricity demand forecasting in developing economies, particularly when data availability is limited (Khan

et al., 2024; Li & Zhang, 2025).

Ilorin Metropolis, the capital of Kwara State, represents a fast-growing urban center experiencing sustained population increase and expanding economic activity. At the same time, the city faces persistent energy supply challenges, including frequent outages and seasonal shortfalls. Climatic conditions and festive periods are also believed to influence consumption levels, yet systematic empirical evidence on these dynamics remains scarce. The absence of reliable city-level forecasts limits proactive energy planning and demand-management strategies.

This study addresses this gap by applying decomposition analysis and ARIMA modelling to quarterly energy consumption data for Ilorin Metropolis. By identifying underlying trends, seasonal patterns, and future demand trajectories, the study provides evidence-based insights to support urban energy planning and policy formulation. The findings contribute to the growing literature on energy demand forecasting in sub-Saharan Africa and offer practical guidance for managing demand growth under supply constraints.

2. Materials and Methods

2.1 Data Source

The dataset comprises quarterly energy consumption figures for Ilorin Metropolis from 2003 to 2022, obtained



from IBEDC, Ilorin, Kwara State.

2.2 Analytical Tools

This paper employed time series decomposition and autoregressive integrated moving average (ARIMA) modelling techniques to analyze and forecast energy consumption. A multiplicative decomposition model was adopted because of the presence of both trend and seasonal variation in the data. The study variable (energy consumption), denoted by Y_t is expressed as

$$Y_t = T_t \times S_t \times I_t \quad (1)$$

Where

$T_t =$ Trend component at time t

$S_t =$ Seasonal component at time t

$I_t =$ Irregular (random) component at time t

2.3 ARIMA Modelling

The first step in ARIMA modelling is to test for stationarity. This was achieved through the **Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test**, which tests the null hypothesis of stationarity against the alternative of non-stationarity. When non-stationarity was detected, the series was transformed through **first differencing**, defined as:

$$\nabla Y_t = Y_t - Y_{t-1} \quad (2)$$

The second step is the plotting and visually inspecting the autocorrelation function.

Thirdly, the fitting of the ARIMA model (p, d, q), denoted by:

$$\Phi(B)(1 - B)^d Y_t = \Theta(B)\varepsilon_t \quad (3)$$

Where

$B =$ Backshift operator

$p =$ order of the autoregressive component

$q =$ order of the moving average component

$d =$ degree of differencing

$\Phi(B)$ and $\Theta(B)$ are polynomials in B

$\varepsilon_t =$ white noise error term

The last step is the, comparison of 24 ARIMA models. The optimum model is the one with minimum Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hanna-Quinn Information Criterion (HIQ) value.

2.4 Model diagnostics

The selected ARIMA model was evaluated for its predictive performance through the use of Mean Absolute Percentage Error (MAPE). It measures the accuracy of the forecasts as:

$$MAPE = \frac{100}{n} \sum_{t=1}^n \left| \frac{Y_t - \hat{Y}_t}{Y_t} \right| \quad (4)$$

Where

$Y_t =$ observed value

$\hat{Y}_t =$ forecasted value

$n =$ number of observations

3. RESULTS

3.1 Data description

The results obtained by analyzing the quarterly energy consumption pattern in Ilorin Metropolis, Nigeria, from 2003 to 2022, using time series decomposition and the Autoregressive Integrated Moving Average (ARIMA) modelling approach are presented as follows:

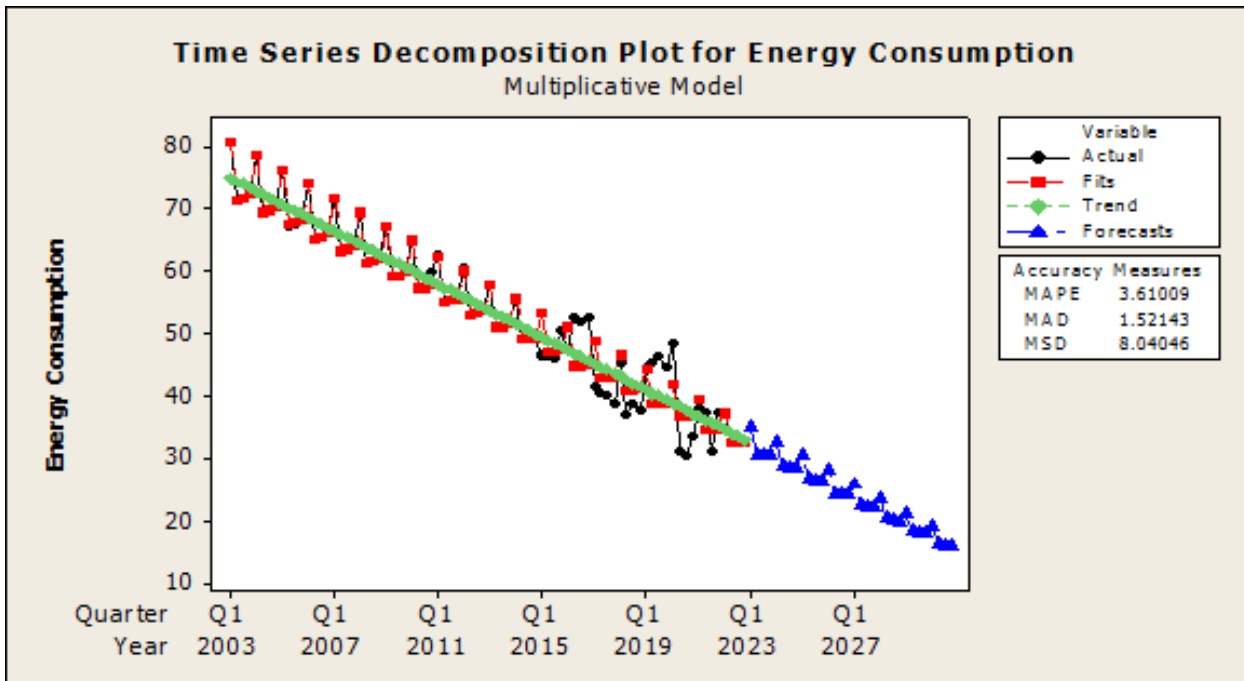


Figure 1: Plots of actual, fits, trend and forecasts data.

In Figure 1, the actual series shows a generally increasing pattern over time, indicating rising energy demand that is consistent with urban growth and expanding economic activity. The fitted values closely track the observed data, suggesting that the selected model adequately

captures the underlying structure of the series. The trend component highlights a sustained long-term upward movement, while the forecast segment projects continued growth in energy consumption beyond the sample period.

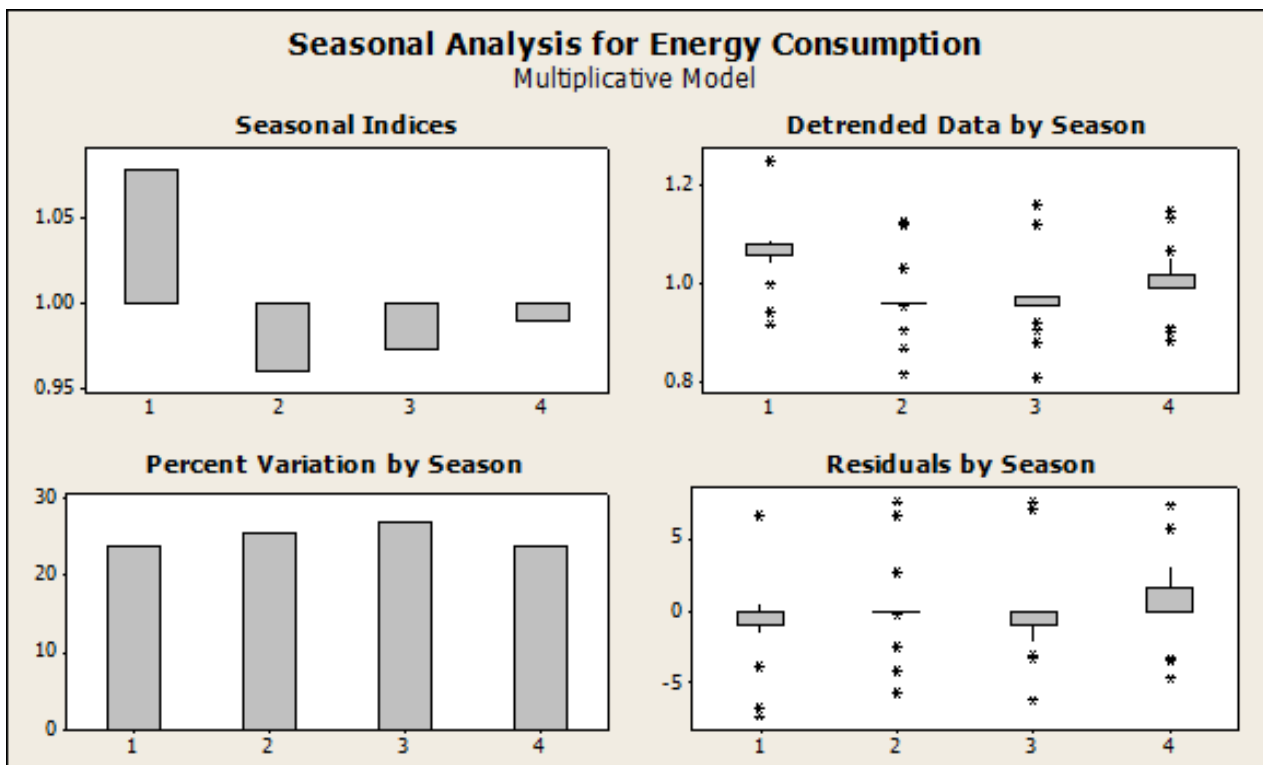


Figure 2: The seasonal analysis plot



The plot in Figure 2 illustrates recurring fluctuations across quarters, confirming the presence of seasonality in the series. Peaks and troughs correspond to specific quarters, suggesting that energy usage is influenced by climatic

conditions and socio-economic activities that vary systematically throughout the year. This justifies the application of decomposition techniques prior to forecasting.

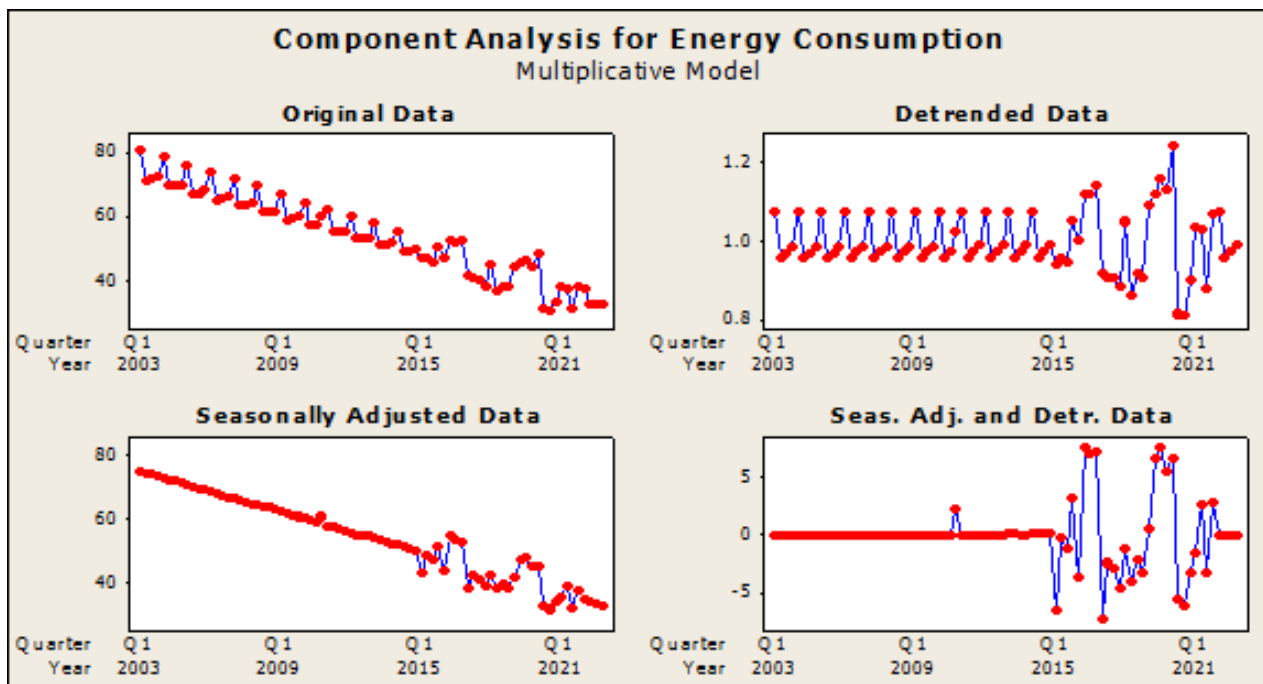


Figure 3: The component analysis plot

In Figure 3, the trend component shows a steady increase over time, reinforcing evidence of long-term growth in energy demand. The seasonal component exhibits stable and repetitive patterns,

while the irregular component captures short-term random fluctuations that are not explained by trend or seasonality.

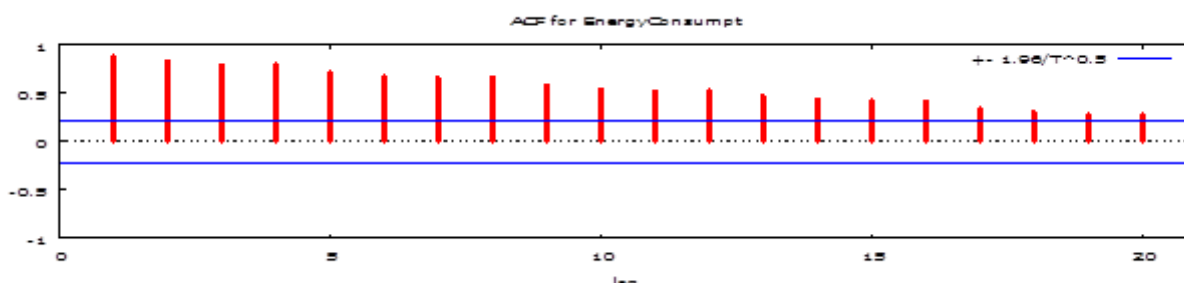


Figure 4: ACF plot of energy consumption data

The slow decay in the ACF and significant spikes at several lags in Figure 4 indicate strong persistence and non-stationarity in the series. These

features suggest the presence of a unit root, necessitating differencing before ARIMA modelling.



3.2 Test for stationarity

Table 1: KPSS stationary test results (Level form)

Series	KPSS test statistic	1% critical value	5% critical value	10% critical value	Decision (5%)
Energy consumption	0.5151	0.731	0.467	0.350	Non-stationary

Table 1 revealed that the KPSS test statistic (0.5151) is higher than the 5% critical value (0.467) hence, the null hypothesis of stationarity is rejected at

5% level; and we conclude that the series is non-stationary in levels and therefore require differencing.

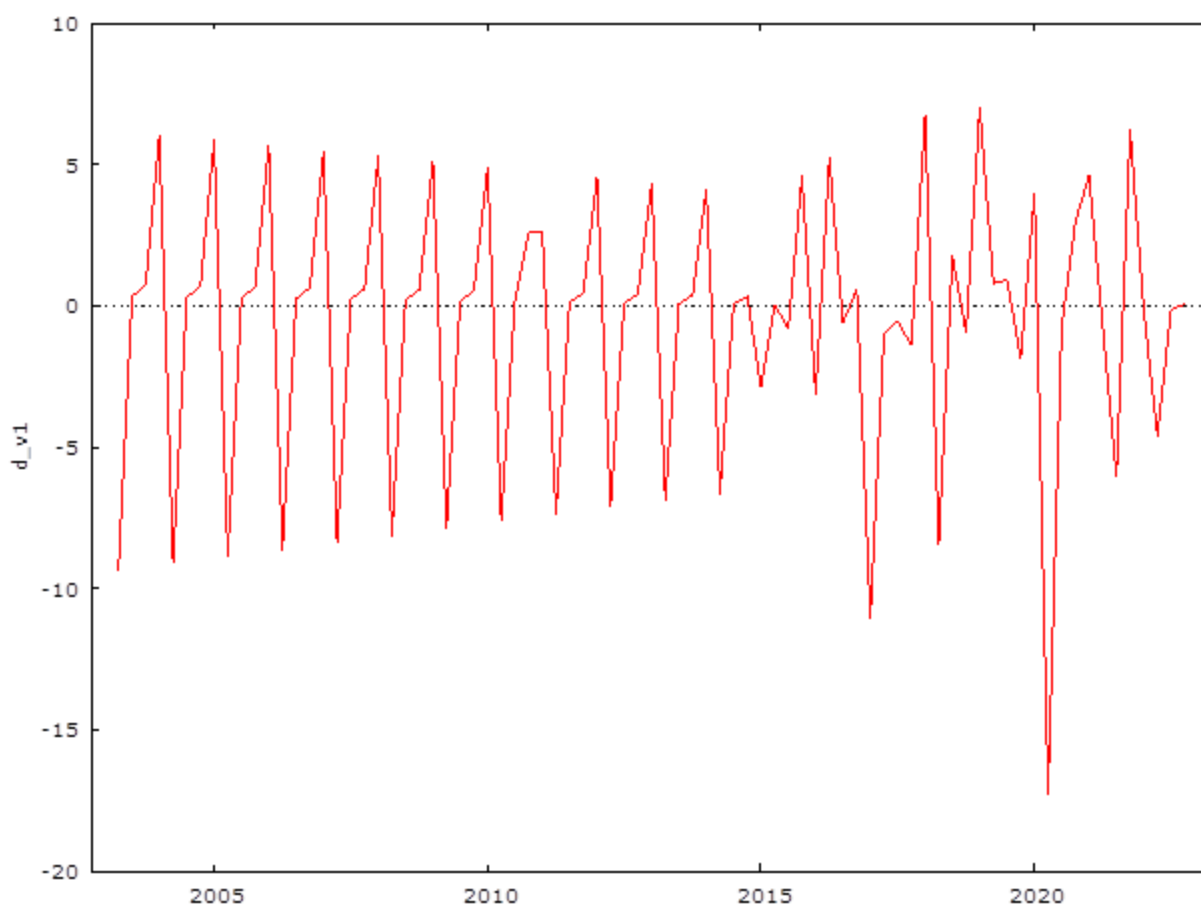


Figure 5: Time plot of the first differenced data



In Figure 5, the series fluctuates around a constant mean with no obvious trend after differencing, indicating that

stationarity has been achieved. This satisfies a key requirement for ARIMA modelling.

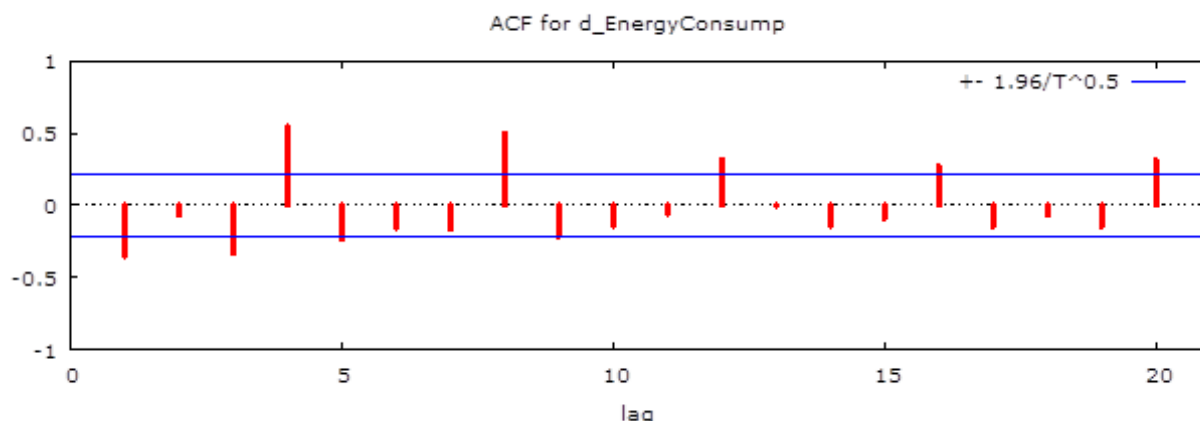


Figure 6: The ACF plot of the first differenced data

The rapid decay of autocorrelations and the limited number of significant spikes in Figure 6 suggest that the differenced data is stationary and suitable for

ARIMA modelling. The plot guided the identification of the autoregressive and moving average orders used in the final model specification.

Table 2: KPSS stationary test results (After first differencing)

Series	KPSS test statistic	1% critical value	5% critical value	10% critical value	Decision (5%)
Energy consumption	0.1787	0.731	0.467	0.350	Stationary

Table 2 revealed that the KPSS test statistic (0.1787) is lower than the 5% critical value (0.467) hence, we fail to reject the null hypothesis of stationarity at 5% level; and we conclude that the differenced series is stationary.

3.3 Model Identification

Since we achieved stationarity at first differencing, therefore the order of the integration is 1, and we proposed (p and q) to be 1, 2, 3 and 4 in which 24 ARIMA models are generated and we select the best among them by considering Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Hanna -Quinn Information Criterion (HIQ).

**Table 3: Results of ARIMA model identification for energy consumption data in Ilorin metropolis**

MODEL	AIC	SIC	HQC
ARIMA(0, 1, 1)	439.3634	446.4718	442.2113
ARIMA(0, 1, 2)	439.8734	448.3512	443.6703
ARIMA(0, 1, 3)	441.8210	453.6682	446.5673
ARIMA(0, 1, 4)	405.4181	419.6348	411.1138
ARIMA(1, 1, 0)	468.4575	475.5659	471.3053
ARIMA(1, 1, 1)	440.1151	449.5929	443.9122
ARIMA(1, 1, 2)	441.8637	453.7109	446.6100
ARIMA(1, 1, 3)	432.8658	447.0825	438.5614
ARIMA(1, 1, 4)	406.6807	423.2668	413.3256
ARIMA(2, 1, 0)	466.2925	475.7703	470.0896
ARIMA(2, 1, 1)	440.8314	452.6786	445.5777
ARIMA(2, 1, 2)	437.6334	451.8501	443.3291
ARIMA(2, 1, 3)	418.1503	434.7365	424.7952
ARIMA(2, 1, 4)	406.1196	425.0752	413.7138
ARIMA(3, 1, 0)	440.9259	452.7732	445.6723
ARIMA(3, 1, 1)	438.5367	452.7534	444.2324
ARIMA(3, 1, 2)	426.8259	443.4121	433.4708
ARIMA(3, 1, 3)	410.3773	429.3329	417.9715
ARIMA(3, 1, 4)	410.3400	431.6384	413.8568
ARIMA(4, 1, 0)	437.7465	451.9631	443.4421
ARIMA(4, 1, 1)	439.5356	456.1217	446.1805
ARIMA(4, 1, 2)	424.4761	443.4317	432.0703
ARIMA(4, 1, 3)	409.9365	431.2616	418.4800



It was observed from table 3 that ARIMA (0, 1, 4) model has the least values for all the criteria considered; therefore, this model will be used for further analysis.

Table 4: Results of ARIMA (0, 1, 4) model estimation for the energy consumption data in Ilorin

Parameter	Coefficient	Std. Error	Z	P-value
Const	-0.533440	0.00310807	-171.6	0.0000***
Theta_1	-0.947071	0.104358	-9.075	1.14e-019***
Theta_2	-0.0969412	0.0842844	-1.150	0.2501
Theta_3	-0.947068	0.234179	-4.044	5.25e-05***
Theta_4	0.999998	0.163873	6.102	1.05e-09***

Key (1% ***) (5 %**) (10 %*)

Table 4 shows that the constant term, theta_1, theta_3 and theta_4 are found to be significant at all levels of significance, 1%, 5% and 10% while theta_2 is found to be insignificant at all significance level.

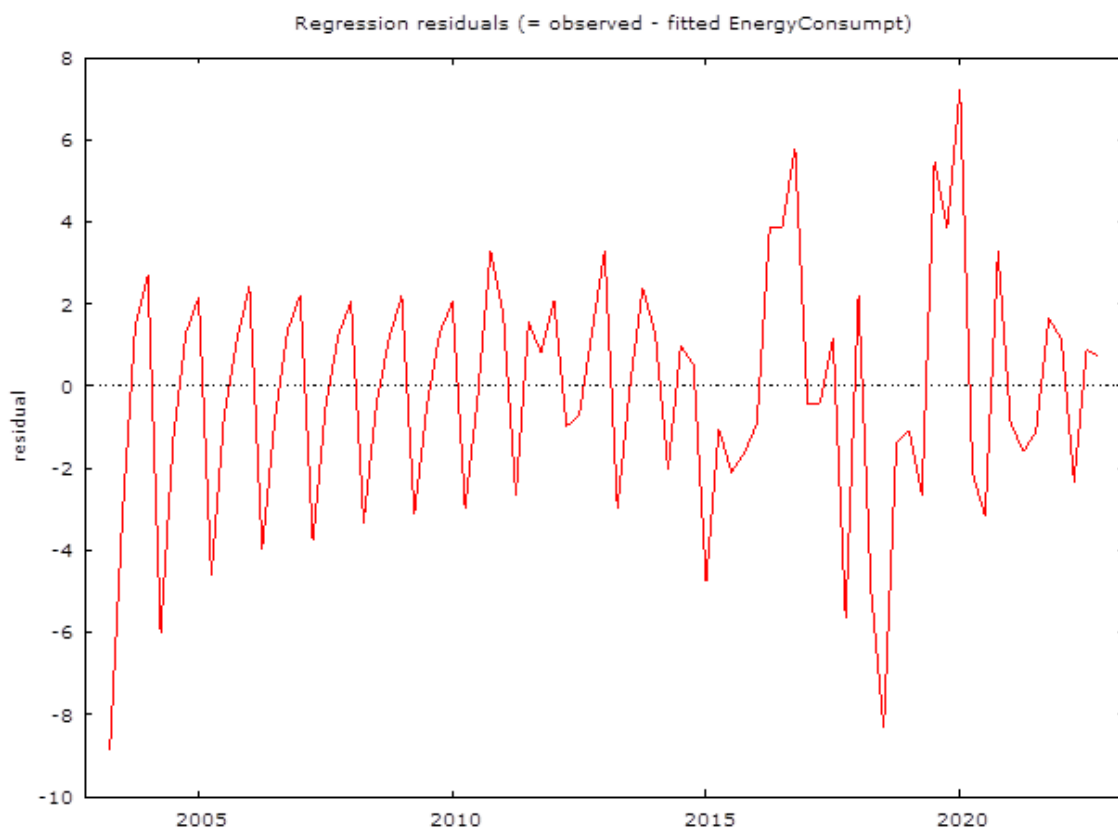


Figure 7: The residual plot of ARIMA (0, 1, 4) model



The residuals plotted in Figure 7 appear to be randomly distributed around zero with no visible pattern or trend, indicating that the model has adequately captured the systematic structure in the data. This supports the assumption of white-noise residuals.

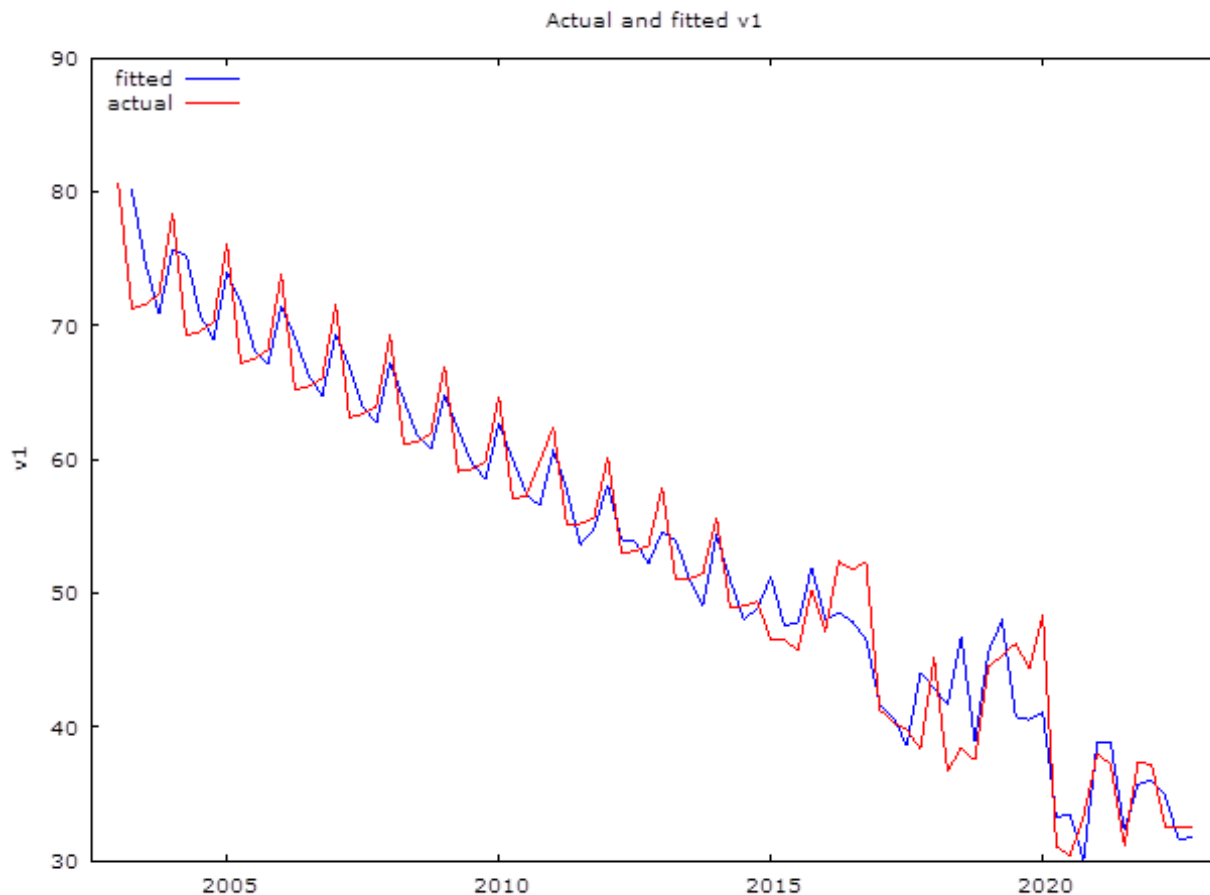


Figure 8: The plot of actual and fitted values of ARIMA (0, 1, 4) model

The close alignment between the actual energy consumption series and fitted values from the ARIMA (0,1,4) model in Figure 8 demonstrates the model's strong in-sample performance and its ability to reproduce observed dynamics accurately.

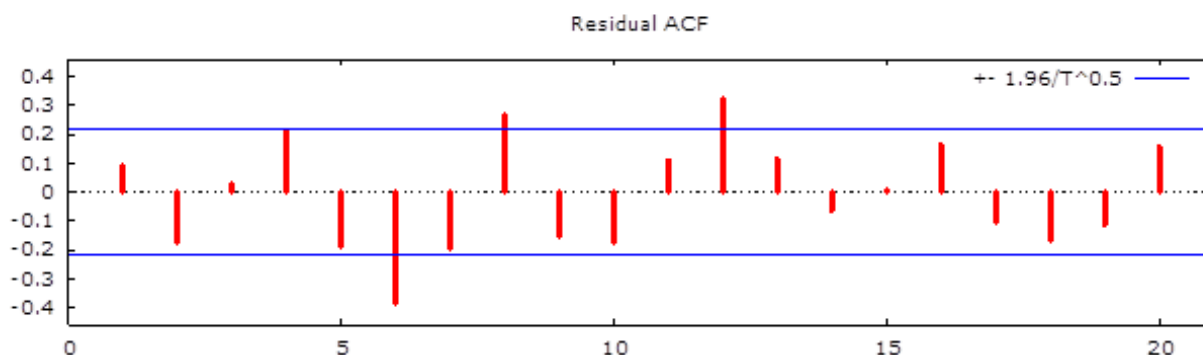


Figure 9: The plot of residual correlogram of ARIMA (0, 1, 4) mode



The correlogram of the residuals from the ARIMA (0,1,4) model in Figure 9 revealed that most autocorrelation coefficients lie within the 95% confidence bounds, indicating the absence of significant residual autocorrelation. This confirms that the model is well specified and that no important temporal dependence is yet to be modelled.

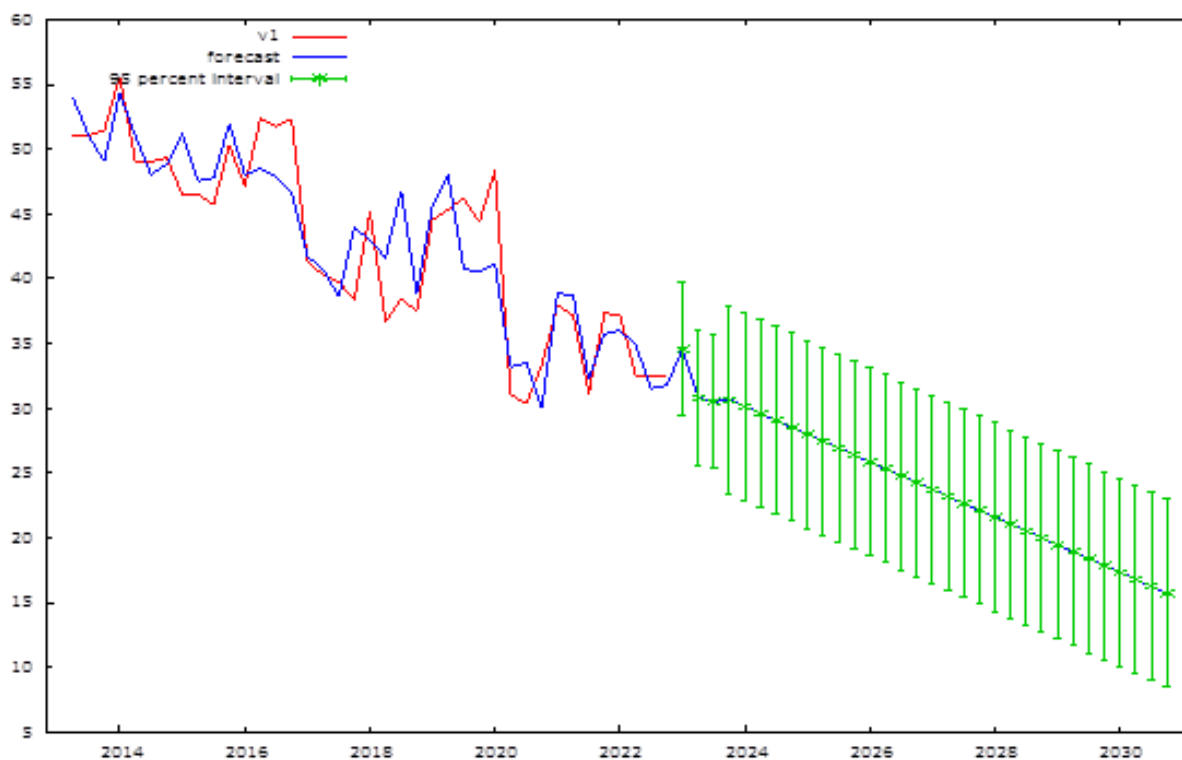


Figure 10: Result of the actual, forecast and 95% confidence interval graphical representation of ARIMA (0, 1, 4) model

The forecast plotted in Figure 10 indicates a continued upward trajectory in energy demand, while the widening confidence bands reflect increasing uncertainty as the forecast horizon extends.

4. Discussion of Findings

The decomposition analysis of the 20-year quarterly energy consumption data for Ilorin Metropolis revealed a persistent downward trend throughout the study period. The results indicate

that energy usage was highest in the first quarter (Q1) and lowest in the fourth quarter (Q4) each year. This seasonal variation can be attributed to a combination of climatic conditions, socio-cultural activities, and economic cycles. In Q1, elevated consumption is likely linked to the post-harvest period, increased agricultural processing, and festive activities that typically occur during December and early January (Oladipo et al., 2022). Conversely, Q4 often coincides with reduced agricultural activity and milder climatic conditions, leading to lower demand for electricity-intensive cooling or processing equipment.



The ARIMA (0, 1, 4) model was identified as the most statistically adequate model based on Akaike Information Criterion (AIC) and other selection metrics. This finding is consistent with studies in other sub-Saharan African contexts where ARIMA models have demonstrated strong performance in capturing both short-term fluctuations and long-term trends in urban energy demand (Nwosu and Ilechukwu, 2019; Semekonawo & Kam, 2022). The model's residuals passed diagnostic checks for white noise, indicating robustness and suitability for predictive purposes.

Forecasts for the period 2023-2030 suggest a continued decline in energy consumption. Several possible explanations exist for this projected trend. It could reflect positive developments such as improved energy efficiency through technological upgrades, increased adoption of renewable energy sources like solar photovoltaic, or demographic shifts such as outmigration from the city's core. On the other hand, a sustained decline may also signal underlying challenges, including economic stagnation, limited industrial expansion, or persistent inadequacies in electricity supply infrastructure (Adebayo et al., 2022).

The evaluation of the forecasting model using the Mean Absolute Percentage Error (MAPE) yielded a value of 3.61%, which indicates a high degree of predictive accuracy. In time series

forecasting, a MAPE below 10% is generally considered excellent, values between 10-20% are good, 20-50% are acceptable, and anything above 50% is regarded as poor (Hyndman and Athanasopoulos, 2021). Thus, a MAPE of 3.61% confirms that the chosen model provides highly reliable forecasts of energy consumption in Ilorin Metropolis.

The implication of this low error margin is that the ARIMA model effectively captured the underlying patterns of trend and seasonality in the data, with only minimal deviation between predicted and observed values. This result is consistent with previous research in energy demand forecasting across sub-Saharan Africa, where ARIMA and related models have demonstrated strong accuracy when fitted to well-structured time series data (Nwosu and Ilechukwu, 2019; Ouedraogo, 2020). A forecasting error of this magnitude enhances confidence in the model's suitability for medium-term planning and policy formulation. Furthermore, the 3.61% MAPE suggests that the forecasts are robust enough to guide infrastructure investment, supply allocation, and demand management strategies. In urban contexts such as Ilorin, where seasonal climatic variations and socio-economic activities strongly influence energy use, an accurate forecasting model can help stakeholders anticipate demand peaks and adjust supply mechanisms accordingly (Oladipo et



al., 2022). Policymakers, distribution companies, and urban planners can therefore rely on these forecasts to reduce the risks of under- or over-estimating energy needs, both of which have significant economic consequences.

These findings highlight the need for targeted policy interventions. Energy planners should address potential supply constraints while encouraging efficient energy use and diversifying energy sources. Additionally, further research is warranted to disentangle the relative contributions of demand-side efficiency improvements and supply-side constraints to the observed downward trend.

4.1 Conclusions

This study applied time series decomposition and ARIMA modelling to analyze and forecast quarterly energy consumption in Ilorin Metropolis over two decades. The results revealed a persistent downward trend, with notable seasonal variations characterized by peak usage in Q1 and the lowest in Q4. The ARIMA (0, 1, 4) model demonstrated strong predictive accuracy, with forecasts indicating a continued decline in consumption through 2030. These patterns underscore the dual possibilities of improved efficiency and supply-side limitations. The findings provide valuable insights for policymakers, urban planners, and energy managers in developing strategies for sustainable

and reliable energy provision.

The study successfully modelled and forecasted energy consumption in Ilorin Metropolis using time series decomposition and ARIMA techniques. The persistent downward trend and strong seasonality have significant implications for energy planning. The ARIMA(0, 1, 4) model provided reliable forecasts with minimal error

Acknowledgement

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EMPOWERING THE NEXT GENERATION OF DATA SCIENTISTS: A COMPREHENSIVE CURRICULUM FRAMEWORK FOR DATA SCIENCE AND ANALYTICS EDUCATION

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Abstract

In today's data-driven world, the demand for skilled data scientists and analysts is skyrocketing. To meet this demand, educational institutions must develop curricula that equip students with the knowledge, skills, and competencies required to excel in data science and analytics. This paper proposes a comprehensive curriculum framework that integrates theoretical foundations, practical skills, and real-world applications. The framework covers essential topics, including data preprocessing, machine learning, statistical inference, data visualization, and ethics. It also emphasizes hands-on learning, project-based assessments, and collaboration with industry partners. By adopting this framework, educators can prepare students to tackle complex data challenges, drive business insights, and contribute to informed decision-making. This curriculum development initiative aims to bridge the gap between academia and industry, ensuring that graduates are job-ready and equipped to thrive in the rapidly evolving field of data science and analytics.

Keywords: Data Science Education, Analytics Curriculum, Data-Driven Decision Making, Industry-Academia Collaboration, Hands-on Learning.

Introduction

In today's rapidly evolving digital landscape, the demand for data scientists and analytics professionals has reached unprecedented levels. As organizations across various sectors increasingly rely on data-driven decision-making to enhance their

competitive edge, the need for a well-prepared workforce becomes paramount. This urgency calls for educational institutions to not only recognize the significance of data science but also to respond with comprehensive curricula that equip students with the necessary knowledge



and skills. With data being generated at an exponential rate, the ability to critically analyze and interpret this information is essential for driving innovation and improving outcomes in diverse fields, from healthcare to finance and beyond.

The rise of data science as a critical discipline necessitates a curriculum framework that goes beyond traditional teaching models. Existing educational programs often fall short by emphasizing technical skills at the expense of practical applications and soft skills, which are vital in today's collaborative work environments. A comprehensive approach to data science education should integrate theoretical foundations with real-world applications, ensuring that graduates are not only proficient in technical competencies but also adept at communicating insights and working effectively in teams. This framework must address the evolving needs of the industry by incorporating current trends and technologies, preparing students to tackle complex data challenges head-on.

Moreover, the implementation of this curriculum framework requires a commitment to hands-on learning and industry collaboration. Engaging students through project-based assessments and partnerships with industry leaders fosters an environment where theoretical knowledge is applied in practical contexts. By bridging the

gap between academia and industry, this framework aims to produce job-ready graduates who can contribute meaningfully to their organizations. Emphasizing ethical considerations and responsible data use is also crucial, as future data scientists must navigate the societal implications of their work. In proposing this comprehensive curriculum framework, we seek to empower the next generation of data scientists, enabling them to drive business insights and contribute to informed decision-making in an increasingly data-centric world.

Research Question

This following research question is raised to guide the study:

1. What constitutes a comprehensive curriculum framework for data science and analytics education?
2. What are incidences and consequences constituting a comprehensive curriculum framework for data science and analytics education?

Aims and Objectives

The aim and objective is to develop a comprehensive curriculum framework for data science and analytics education that equips students with the necessary skills and knowledge to excel in the evolving data-driven landscape.

In specific term, the objective of this study is to:



Integrate theoretical foundations, practical skills, and real-world applications into the curriculum, ensuring that graduates are prepared to meet industry demands and tackle complex data challenges effectively.

Significant of the Study

1. Core Curriculum Components

A. Data Acquisition and Management:

- i. Data Collection: Understanding various data sources, including structured and unstructured data, and ethical considerations related to data collection.
- ii. Data Cleaning and Preprocessing: Techniques for handling missing data, outliers, and data inconsistencies.
- iii. Data Storage and Retrieval: Working with databases, data warehouses, and cloud-based storage solutions.

B. Statistical Thinking and Inference:

- i. Foundations of Probability and Statistics: Essential concepts for understanding data distributions, hypothesis testing, and statistical inference.
- ii. Experimental Design: Designing and conducting experiments to gather meaningful data.
- iii. Statistical Modeling: Building and evaluating statistical models for prediction and inference.

C. Machine Learning:

- I. Supervised Learning: Algorithms for classification, regression, and other predictive tasks.

- ii. Unsupervised Learning: Techniques for clustering, dimensionality reduction, and anomaly detection.
- iii. Deep Learning: Introduction to neural networks and their applications in data analysis.

D. Data Visualization and Communication:

- i. Principles of Visual Design: Creating effective and informative visualizations.
- ii. Tools and Technologies: Using tools like Tableau, Python libraries (Matplotlib, Seaborn), and others.
- iii. Communicating Insights: Presenting data-driven findings to both technical and non-technical audiences.

E. Programming and Software Engineering:

- i. Python Programming: Mastering Python for data manipulation, analysis, and machine learning.
- ii. Version Control (Git): Using Git for collaborative development and code management.
- iii. Software Development Best Practices: Writing clean, efficient, and well-documented code.

F. Ethical Considerations and Responsible Data Use:

- I. Data Privacy and Security: Understanding regulations like GDPR and CCPA, and implementing best practices for data protection.
- ii. Bias and Fairness in Machine



Learning: Identifying and mitigating biases in algorithms and datasets.

- iii. Societal Impact of Data Science: Considering the ethical implications of data-driven technologies and their potential impact on society.

2. Curriculum Structure and Implementation

A. Foundations of Data Science:

An introductory course covering core concepts and providing a foundation for advanced topics.

- i. Specialized Courses: Offering elective courses in areas like natural language processing, computer vision, and big data analytics.
- ii. Hands-on Projects: Integrating practical projects throughout the curriculum to allow students to apply their knowledge and develop their skills.
- iii. Industry Partnerships: Collaborating with industry partners to provide internships, guest lectures, and real-world case studies.
- iv. Continuous Evaluation: Assessing student learning through various methods, including exams, projects, and presentations.

3. Pedagogical Approaches

- i. Active Learning: Incorporating interactive lectures, group discussions, and hands-on activities to engage students.

- ii. Problem-Based Learning: Presenting students with real-world problems to solve using data science techniques.

Literature Review

Longbing Cao's (2017). Existing curriculum frameworks have limitations, such as focusing on technical skills while neglecting soft skills and practical applications. Industry requirements and trends in data science and analytics emphasize the need for a comprehensive approach. Key skills and knowledge areas for data scientists and analytics professionals include statistics, programming, data visualization, machine learning, and communication.

Curriculum Framework

The proposed curriculum framework for data science and analytics education is designed to equip students with a robust skill set necessary for thriving in a data-driven world. This framework is structured around five key components: foundational skills, data science core, practical applications, specialized topics, and soft skills.

Foundational Skills form the bedrock of the curriculum, emphasizing essential concepts in statistics and probability, programming languages such as Python, R, and SQL, and data visualization techniques. Mastery of these foundational skills enables students to perform basic data analysis and interpret results effectively. A



strong grasp of statistics and probability is crucial for understanding data distributions and making informed decisions based on data insights. Programming skills provide the technical proficiency needed to manipulate and analyze data, while data visualization equips students to present findings in a clear and impactful manner.

The **Data Science Core** encompasses advanced topics such as machine learning, predictive modeling, and data mining. These subjects are central to the practice of data science, allowing students to develop algorithms and models that uncover patterns and insights from large datasets. By engaging with machine learning techniques, students can learn to build systems that improve automatically through experience. Predictive modeling will enable them to forecast trends and behaviors, while data mining will provide the tools to extract valuable information from vast amounts of unstructured data, enhancing their analytical capabilities.

Incorporating **Practical Applications** into the curriculum is vital for bridging theory and practice. This component includes real-world projects, case studies, and collaboration opportunities that allow students to apply their knowledge in authentic settings. By working on projects that reflect industry challenges, students gain hands-on experience that enhances their problem-

solving skills and prepares them for future employment. Case studies provide insights into how data science is applied across different sectors, fostering a deeper understanding of the field's impact on various industries.

To keep pace with technological advancements, the curriculum also addresses **Specialized Topics** such as generative AI, natural language processing, and computer vision. These areas represent cutting-edge developments in data science and are essential for students who wish to specialize in advanced analytical techniques. Generative AI explores the creation of new content through algorithms, while natural language processing focuses on the interaction between computers and human language. Computer vision enables machines to interpret and process visual data, opening opportunities in fields such as autonomous systems and image analysis.

Lastly, the inclusion of **Soft Skills** is crucial for fostering well-rounded data professionals. Skills such as effective communication, ethical considerations, and domain knowledge are emphasized to prepare students for collaborative environments. Communication skills are essential for articulating complex data insights to both technical and non-technical audiences, while an understanding of ethics ensures that students are mindful of the societal implications of their work. Domain knowledge allows graduates to



contextualize data science applications within specific industries, enhancing their relevance and effectiveness in the workforce.

Implementation and Assessment

To ensure the successful implementation of this curriculum framework, several strategies have been proposed. *Hands-on learning and project-based evaluation* will be at the forefront of the educational experience, allowing students to engage directly with real-world data and analytical challenges. This experiential approach not only solidifies theoretical knowledge but also cultivates critical thinking and adaptability.

Mentorship and guidance from industry experts and faculty members play a pivotal role in the learning process. By connecting students with seasoned professionals, the curriculum fosters a culture of continuous learning and development. Mentorship provides students with insights into industry practices and trends, enhancing their readiness for the job market.

Finally, **continuous assessment and feedback** mechanisms will be integrated into the curriculum to monitor student progress and facilitate improvement. Regular assessments will help identify areas for growth, ensuring that students receive the support they need to succeed. This iterative feedback process will create an adaptive learning environment, allowing the curriculum to evolve in response to emerging trends in data science and analytics. Through these strategies, the proposed curriculum framework aims to prepare the next generation of data scientists to meet the demands of an increasingly complex and data-centric world.

Findings and Discussion

Ho 1: What constitutes a comprehensive curriculum framework for data science and analytics education?

Table 1: Showing Regression analysis constitutes a comprehensive curriculum framework for data science and analytics education.

	R= .491 ^a					
	R ² = .241					
	R ² adj= .218					
	Std Error = 2.17820					
	Model	Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	354.819	7	50.688	10.683	.000 ^b
	Residual	1119.718	236	4.745		
	Total	1474.537	243			

Source: SPSS Processing of Field Data, 2024



Table 1 show that constitutes a comprehensive curriculum framework for data science and analytics education have significant positive relationship to student ability in data scientific, the result of the test showed a coefficient of regression $R = .491^a$ and $R^2 = .241$. The implication of this coefficient of regression is that there was strong direct association between the curriculum framework for data science and education analytics.

Also, the F- statistics, which is $F = 10.683$ was significant at 0.05 level. This mean that a comprehensive curriculum framework for data science have significant composite

contributions to education of every learner. Therefore, the null hypothesis, which states that there is no significant composite contribution a comprehensive curriculum framework for data science and analytics education is rejected.

H₀₂: The incidences and consequences constitutes a comprehensive curriculum framework for data science and analytics education.

Table 2: Showing ANOVA test the incidences and consequences constitutes a comprehensive curriculum framework for data science and analytics education.



Items	Source of Variations	Sum of Squares	Df	Mean Square	F	Sig.
Statistics and Mathematics	Between Groups	139.743	10	13.974	20.771	.000
	Within Groups	156.761	233	.673		
	Total	296.504	243			
Programming (Python,R, etc)	Between Groups	88.182	10	8.818	23.480	.000
	Within Groups	87.507	233	.376		
	Total	175.689	243			
Machine Learning/AL	Between Groups	110.746	10	11.075	14.503	.000
	Within Groups	177.922	233	.764		
	Total	288.668	243			
Big Data Technologies.	Between Groups	31.551	10	3.155	25.391	.000
	Within Groups	28.953	233	.124		
	Total	60.504	243			
Data Ethics and Privacy	Between Groups	135.658	10	13.566	16.181	.000
	Within Groups	195.338	233	.838		
	Total	330.996	243			
Business Knowledge/Communication Skills	Between Groups		10	5.704	14.483	.000
	Within Groups	91.762	233	.394		
	Total	148.799	243			

Source: SPSS Processing of Field Data, 2024

Table 2 above show the incidences and consequences constitutes a comprehensive curriculum framework for data science and analytics education. The table shows that Statistics and Mathematics is significantly supported education in many ways with ($F = 20.771$; $P < .05$), with Programming (Python, R, etc) ($F = 23.480$, $p < .05$),

Machine Learning/AL ($F = 14.503$, $p < .05$), led to Big Data Technologies ($F = 25.391$, $p < .05$), Data Ethics and Privacy ($F = 16.181$, $p < .05$), and Business Knowledge/Communication Skills ($F = 14.483$, $p < .05$). Therefore, the null hypothesis, which states that the incidences and consequences constitutes a comprehensive



curriculum framework for data science and analytics education is hereby rejected.

Conclusion

This paper proposes a comprehensive curriculum framework for data science and analytics education, emphasizing the integration of theoretical foundations, practical skills, and real-world applications. By empowering the next generation of data scientists, we can drive business growth and innovation.

Future Work and Recommendations:

Future research and development should focus on:

1. Refining the curriculum framework based on industry feedback and trends
2. Exploring new teaching methods and technologies
3. Encouraging diversity and inclusion in data science and analytics education

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Assessment of Liver fluke infection among the cattle slaughtered at Ilokun Abattoir, Ado-Ekiti, Nigeria.

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Abstract

Liver flukes are intestinal trematode parasites that cause fascioliasis in ruminants especially cattle and sheep. This study examined the presence of liver fluke infection among cattle slaughtered at Ilokun Abattoir, Ado-Ekiti, Ekiti State, Nigeria. After slaughter, the animals were dissected, and their livers and bile ducts were inspected for liver flukes. Of the 254 cattle examined, 20 (7.87%) were found to be infected. There was no significant difference ($P = 0.8$) in infection prevalence between male and female cattle, nor was there a significant difference ($P = 0.58$) between adult and young cattle. Although consuming beef from infected cattle is generally safe when thoroughly cooked, severe infections can negatively affect the animals' health and reduce meat quality by decreasing fat content and marbling. Regular treatment of cattle against liver fluke infection is therefore recommended to improve both animal health and production quality.

Keywords: Liver fluke, fasciola, abattoir, Ado-Ekiti, trematode

Introduction

Liver flukes are among the most important helminth parasites of livestock and are responsible for substantial economic losses to farmers worldwide (Skuce and Zadoks, 2013). Liver fluke infection was first recorded in 1379 and has since been recognized as a clinically and economically

significant disease (Rojo-Vázquez et al., 2012). The infection causes considerable morbidity and mortality in livestock, particularly sheep and cattle. Liver flukes impair feed utilization, retard growth, reduce fertility, diminish meat and milk quality, and often result in the condemnation of infected livers.



Collectively, these impacts contribute to major reductions in livestock productivity (Yesuf et al., 2020). Pathologies and clinical signs associated with liver fluke infection include weight loss, weakening, pallor of mucous membranes, anemia, ventral edema, appetite changes, soft stool consistency or diarrhea, stomach hypotonia and decreased milk production (Predescu and Cozma, 2009). Liver lesions arise from the toxic and mechanical effects of the parasites, their excretory products, and the decomposed remains of flukes within the bile ducts and liver tissues. These factors collectively damage the complex vascular and biliary systems of the liver (Shrimali et al., 2016).

An adult liver fluke produces between 10,000 and 20,000 eggs per day which are passed out with the host feces. Under favourable environmental conditions, the eggs hatch and release miracidia that infect freshwater snails of the genus *Lymnaea*, acting as an intermediate hosts (Dalton, 1999). Within the snails, the miracidia develop into infective metacercaria. Humans and domestic ruminants such as cattle and sheep become infected through oral ingestion of metacercaria on contact with the infected pastures (Pile et al., 2001).

The clinical and economic consequences of liver flukes infection pose significant concerns for the cattle industry due to reduced productivity

and increased susceptibility to secondary diseases (Claridge et al., 2012; Beesley et al., 2018). Therefore monitoring the prevalence of liver fluke infection in cattle and other livestock is essential for effective disease surveillance and control. This study was undertaken to assess the prevalence of liver fluke infection among cattle slaughtered at Ilokun Abattoir in Ado-Ekiti, Nigeria.

Materials and methods

Study area

The study area is Ilokun Abattoir, Ado-Ekiti, Ekiti State, Nigeria. Ilokun Abattoir is the main abattoir in Ado-Ekiti metropolis where most meat sellers purchase meat for sale. The abattoir is located along Iworoko road in Ado-Ekiti. Cattle are brought to this abattoir from the neighbouring Kwara and Kogi States. The study was carried out from April to June, 2024.

Examination of bile ducts and liver for the presence of liver flukes

After animals have been slaughtered and dissected by butchers, the bile ducts and the livers were collected and examined for the presence of liver flukes with the assistance of the veterinary officers. Liver flukes observed in the bile ducts and the livers were collected and transported in a bottle containing 70% of formalin to the Zoology and Environmental Biology Laboratory in Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria.



Statistical analysis

Data were analysed using SPSS Version 25. Statistics involved were descriptive and Chi-square. The probability value (P -value) of $P < 0.05$ was regarded as significant.

Results

During the study, a total of 254 cattle were examined. These animals were sourced from Omu-Aran (44.9%) and Jebba (31.9%) in Kwara State, and from Kabba (23.2%) in Kogi State (Table 1). The overall prevalence of liver fluke infection among the examined cattle was 7.87% (Table 1). Cattle originating from Omu-Aran recorded the highest prevalence (11.4%), followed by those from Jebba (7.41%), while the lowest prevalence was observed among cattle brought from Kabba (1.69%). However,

there was no significant difference ($P = 0.79$) in the prevalence of infection among cattle sourced from the different locations (Table 1). The prevalence of liver fluke infection in relation to sex is presented in Table 2. Of the 254 cattle examined, 108 (42.5%) were males and 146 (57.5%) were females. Although female cattle had a higher prevalence of infection compared with males, the difference was not statistically significant ($P = 0.80$) (Table 3). Only one out of twenty-one young cattle (calf) examined was infected with liver flukes whereas 19 (8.15%) out of 233 adult cattle examined had liver fluke infection (Table 4). Similarly, no significant difference existed in the prevalence of infection among the adult cattle and the young cattle (Table 4).

Table 1: Prevalence of Liver Fluke infection of the cattle slaughtered at Ilokun Abattoir, Ado-Ekiti in relation to source

Source	Number examined	Number infected with liver flukes	P-value
Omu-Aran	114 (44.9%)**	13 (11.4%)*	0.79
Jebba	81 (31.9%)**	6 (7.41%)*	
Kabba	59 (23.2%)**	1 (1.69%)*	
Total	254	20 (7.87%)	

* = % across the group, ** = % down the group



Table 2: Prevalence of liver fluke infection in cattle slaughtered at Ilokun Abattoir, Ado-Ekiti in relation to sex

Sex	Number examined	Number infected with liver flukes	P-value
Male	108 (42.5%)**	8 (7.4%)*	0.80
Female	146 (57.5%)**	12 (8.2%)*	
Total	254	20 (7.8%)	

* = % across the group, ** = % down the group

Table 3: Prevalence of Liver Fluke Infection in Cattle Slaughtered at Ilokun Abattoir, Ado-Ekiti, Nigeria, in Relation to Age

Age	Number examined	Number infected with liver flukes	P-value
Adult cattle	233 (91.7%)**	19 (8.15%)*	0.58
Young cattle	21 (8.3%)**	1 (4.76%)*	
Total	254	20 (7.87%)	

* = % across the group, ** = % down the group

Discussion

This study confirms the presence of liver fluke infection among cattle slaughtered at Ilokun Abattoir in Ado-Ekiti. Liver fluke infection remains a major health challenge in Nigeria cattle industry (Isah, 2019). The disease has a

significant effects on animal health and their productivity, resulting in substantial economic losses. Cattle infected with liver flukes have been reported to have lower weights of carcasses, a condition attributed to the pathological alterations caused by the



parasites within the hepatic parenchyma. These alterations impair the liver's capacity for synthesis and metabolism, ultimately affecting overall growth and performance (Molalege *et al.*, 2010; Magaji *et al.*, 2014; Mehmood *et al.*, 2017). The damage due to the migration of the immature flukes and presence of the adults in the bile ducts affects cattle metabolism, leading to depressed haematocrit, hypoalbuminaemia and eventually emaciation (Stalker and Hayes, 2007). We could speculate that the catabolic processes associated with the parasitism could interfere with adequate muscle and fat development, hindering carcass conformation and the deposition of fat (Charlier *et al.*, 2009). The difference observed in the prevalence of infection among the cattle sourced from various locations in this study may be attributed to environmental conditions, variations in management practices by local farmers and also by the availability of snail intermediate hosts (Isah, 2019).

In this study, the higher prevalence of liver fluke infection recorded in female cattle compared with the males may be associated with the age distribution of the animals examined. Female cattle slaughtered in many abattoirs are typically older than their male counterparts, as they are often retained longer for breeding and milk production. Advancing age in these animals may lead to a decline in immunity, thereby increasing their susceptibility to infections (Hossain *et*

al., 2010; Kuchai *et al.*, 2011; Ardo *et al.*, 2013). Also, adult cattle are more infected with liver fluke infection than the young cattle and this conforms to most previous studies reported worldwide (Vassilev, 2009; Nyirenda *et al.*, 2019; Kelly *et al.* 2019; Ahmad *et al.*, 2020). Higher prevalence of liver fluke infection has been reported to increase with age as prolonged exposure to metacercariae-contaminated pastures is most likely to cause heavy infections in adult cattle compared to young cattle (Nyirenda *et al.*, 2019). However, Yatswako *et al.* (2017) reported higher prevalence of liver fluke infection in young cattle than adult ones. They speculated that the developed immune system and acquired immunity in adult cattle were responsible for the lower prevalence of infection. Despite efforts to develop a vaccine against the parasite, control of bovine liver fluke still relies largely on preventive measures such as drainage, avoiding or fencing off snail habitats and anthelmintic treatment (Howell *et al.*, 2015; Beesley *et al.*, 2018).

Conclusion

Observation of liver fluke infection among cattle in this study establishes continue existence of liver fluke infection in Nigeria. Even though consuming beef of cattle infected with liver flukes may appear safe when thoroughly cooked, but severe infection could make animals becoming unhealthy and thin, which could affect beef quality by lowering the fat and



marbling of the meat. These have negative impact on the cattle industry thereby reducing the quantity and quality of animal protein available for the citizens. This also tends to lower productivity thereby constitute economic losses. Therefore control of liver fluke infection by adopting the right preventive measures and consistent treatment and of cattle against liver fluke infection are necessary to increase cattle production and quality in Nigeria.

Declarations

Consent and Ethical statement

E t h i c a l A p p r o v a l
(MAFS/V/2024/06/005) for conducting this research was obtained from Ministry of Agriculture and Food Security, Ado-Ekiti. Informed consent to carry out the study was also obtained from the cattle sellers and butchers at the abattoir.

Conflict of Interests

The author declares no conflict of interests.

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A Self-efficient, Sustainable and Renewable Energy Remote-Control Lawn Mower

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Abstract

Traditional lawn maintenance is a time-consuming and labour-intensive task that often relies on fossil fuels, contributing to pollution and environmental degradation. In response to these challenges, this paper presents the design and implementation of a renewable energy-powered, remote-control lawn mower. The remotecontrolled solar-powered lawn mower is designed to streamline lawn care operations efficiently. Utilising a solar panel, it harnesses renewable energy from the sun to power its operations. The system aims to reduce the environmental impact of lawn maintenance; it is both eco-friendly and cost-effective by reducing the reliance on fossil fuels. The designed lawn mower integrates solar panels, a rechargeable battery, a remotecontrol system, and cutting-edge safety features. The robotic functionality of the design extends beyond mowing lawns. It incorporates obstacle detection capabilities, ensuring it navigates around objects with ease. Additionally, it offers flexibility in terms of movement, with a servo motor that facilitates smooth directional changes. Testing the system design on different types of grass at different cutting heights, the results demonstrate the system's efficiency, reliability, and environmental benefits.

Keywords - Lawn mowers, Solar-powered, Arduino IDE, ATMEGA328P microcontroller, LCD module, DC motor

I. INTRODUCTION

Lawn maintenance is an important aspect of landscaping, providing a clean

and attractive outdoor space. However, traditional gas-powered mowers used in lawn maintenance produce harmful pollutants such as carbon monoxide,



nitrogen oxides, and volatile organic compounds (VOCs), contributing to air and noise pollution. In addition, the use of fossil fuels for lawn maintenance is not sustainable in the long run. As urban areas expand and environmental concerns rise, innovative solutions for lawn care are essential. Traditional gaspowered mowers contribute significantly to air pollution and noise. A renewable energy remotecontrol lawn mower presents an eco-friendly alternative that utilises solar power and smart technology (Thompson, 2018; Raut et al., 2025).

In recent years, the development of solar-powered grass cutters has emerged as a more sustainable and cost-effective solution. These machines use solar panels to generate the electricity needed to power the machine. The use of solar energy makes this technology environmentally friendly, as it reduces reliance on non-renewable fossil fuels and helps to reduce air and noise pollution (Thompson, 2018; Miller, 2021). Solar-powered grass cutters have several advantages over traditional gas-powered mowers, including lower operating costs, quieter operation, and lower maintenance costs. The use of solar power also helps to reduce carbon emissions, which are a significant contributor to climate change. These mowers are also more durable, as they have fewer moving parts and are less prone to damage than gas-powered mowers (Smith et al., 2023).

The development of a solar-powered grass cutter with lawn coverage capabilities is an important step towards sustainable lawn maintenance practices. By reducing reliance on fossil fuels and promoting the use of renewable energy, this technology can help to mitigate the environmental impact of lawn maintenance. In addition, the lower operating and maintenance costs of solar-powered grass cutters make them an attractive alternative to gas-powered mowers. To achieve these goals, the mower will integrate advanced technologies, including highefficiency solar panels and robust battery systems, to ensure optimal performance. Smart control systems will further enhance the user experience, allowing for programmable mowing schedules and real-time monitoring via smartphone applications (Jazman et al. 2025). Traditional lawn mowers often rely on fossil fuels, contributing to greenhouse gas emissions and air pollution. And emit approximately 87 million tons of greenhouse gases annually in the U.S. alone, according to the Environmental Protection Agency (EPA, 2020). By utilising renewable energy sources such as solar or wind, this project seeks to minimise these harmful emissions while also promoting energy independence (IEA, 2021; Debjyoti, 2025). The incorporation of a remote-control feature enhances usability, allowing homeowners to manage their lawns carefully and effortlessly to operate the mower from a distance and enabling those with mobility limitations to



maintain their lawns more easily (Smith and Jones, 2022).

This paper aims to design and build a solar-powered grass cutter with lawn coverage capabilities. The mower will be equipped with sensors to detect the edges of the lawn and navigate around it, ensuring that all areas of the lawn are covered. The mower will also be equipped with a blade that can be adjusted to cut grass at different heights, and its speed will be adjustable to suit the terrain (Akshay et al., 2019; Athipatla et al., 2023; Premraja et al., 2025). The research design is intended to enhance the aesthetic appeal of the environment without requiring human intervention, and the main contributions of this research work are as follows:

1. To explore and incorporate advances in grasscutting technology, as well as to improve the performance of traditional lawnmowers.
2. To assure safety, reduce maintenance needs, and reduce electricity consumption and human labour in machine operation.
3. To demonstrate the feasibility and potential of using renewable energy sources in lawn maintenance practices.
4. The project also offers safety advantages. The Smart Solar Grass Cutter with Lawn Coverage is designed to operate automatically with obstacleavoidance technology

and safety features to prevent accidents. This reduces the risk of injuries associated with traditional lawn mowers, which require human operation and can pose a hazard to users.

5. The project also offers safety advantages. The Smart Solar Grass Cutter with Lawn Coverage is designed to operate automatically with obstacleavoidance technology and safety features to prevent accidents. This reduces the risk of injuries associated with traditional lawn mowers, which require human operation and can pose a hazard to users.

The rest of the paper is organised as follows: Section 2 is the literature review, Section 3 discusses the solar-based lawn mower components, while Section 4 is on design methodology and system architecture. Section 5 is on the experimental results and discussion. Finally, Section 6 includes the conclusion and recommendations of the paper.

II. LITERATURE REVIEW

Solar panels are a key component of solar-based lawn mowers, as they are responsible for converting sunlight into electrical energy that powers the mower's motor. The emergence of IoT technology has led to the development of smart lawn care solutions. Kumar et al. (2021) highlighted how connected devices can allow users to remotely



manage their lawn care through smartphone applications, including features for scheduling and real-time monitoring. Several studies have been conducted on the effectiveness of solar-powered grass cutters. Research conducted by Oyewole et al. (2019) examined the performance of a solar-powered grass cutter in a residential lawn setting. The study found that the mower was effective at cutting grass and had lower operating costs than a traditional gaspowered mower. Another study by Jabbar et al., (2021) evaluated the impact of solar grass cutters on air pollution levels in urban areas. The study found that the use of solar-powered grass cutters could significantly reduce air pollution and improve air quality in urban areas (Aditya et al., 2024).

The solar panel is typically made of photovoltaic (PV) cells, which are semiconductor devices that convert sunlight into electricity (Goldschmidt and Fischer, 2015). The size and efficiency of the solar panel can affect the performance of the lawn mower, as a larger and more efficient panel can generate more power and allow for longer operation times. The battery, on the other hand, stores the energy generated by the solar panel and provides power to the cutting mechanism. Lithium-ion batteries are commonly used in solar-based lawn mowers due to their high energy density, long cycle life, and low self-discharge rate.

The solar-powered lawn mowers have several advantages over conventional gasoline and electric mowers. Mowers powered by solar energy provide a distinctive blend of effectiveness, practicality, and environmental friendliness when compared to current technologies. Mowers powered by solar energy provide several benefits, including being environmentally friendly. Solar-powered mowers create no emissions and are substantially quieter than gasoline and electric mowers, which both contribute to air and noise pollution (Singh et al., 2016). Additionally, they don't need any fossil fuels, which can lessen reliance on non-renewable resources.

Solar-powered mowers provide comparable ecofriendliness and convenience to robotic mowers, but also have the advantage of not requiring sophisticated mapping and navigational equipment to function. In comparison to most robotic models, they also frequently have greater mowing capacity (Tahir et al., 2022). While gasoline mowers may have more power and be able to handle larger lawns, they require regular maintenance and refuelling, which can be time-consuming and costly (Guo and Sun, 2017). Electric mowers, while quieter and more eco-friendly than gasoline mowers, can still contribute to electricity consumption and may have limited battery life.

A solar-powered lawnmower with a DC



motor, rechargeable battery, solar panel, stainless steel blade, and control switch was created by Tanimola et al. (2014). The D.C. motor, which is directly connected to the shaft of the D.C. motor and provides the necessary torque to drive the stainless-steel blade, is used to mow the lawn. Through the solar charging controller, the battery is recharged. Because of the components employed, which have an efficiency of roughly 93%, the machine was determined to be quite efficient. Due to its flaws, the device has a short operating time when the battery is fully charged.

III. SOLAR-BASED LAWN MOWER COMPONENTS

A solar-based lawn mower is a type of lawn mower that utilises solar energy to power its cutting mechanism. It consists of three main components: the solar panel, the battery, and the cutting mechanism. The solar panel captures sunlight and converts it into electrical energy, which is stored in the battery. The battery, in turn, powers the cutting mechanism, which can be either a rotary or reel mower (Goldschmidt and Fischer, 2015).



Fig 1. Solar Panel



The solar panel is typically made of photovoltaic (PV) cells, as shown in Fig. 1, which are semiconductor devices that convert sunlight into electricity. The size and efficiency of the solar panel can affect the performance of the lawn mower, as a larger and more efficient panel can generate more power and allow for longer operation times. The battery, on the other hand, stores the energy generated by the solar panel and provides power to the cutting mechanism. Lithium-ion batteries are commonly used in solar-based lawn mowers due to their high energy density, long cycle life, and low self-discharge rate (Hiremath et al., 2015).

The cutting mechanism of a solar-based lawn mower can be either a rotary or a reel mower. Rotary mowers use a horizontal spinning blade to cut the grass, as shown in Fig. 2, while Fig. 3 is reel mowers, which use a series of blades that rotate vertically to create a scissor-like cutting action. Both types of cutting mechanisms have their advantages and disadvantages, and the choice of mechanism will depend on factors such as the type of grass and terrain to be mowed, as well as the user's preferences (Dutta et al., 2016; Kathari and Hort, 2025).



Fig. 2. Rotary Mower Blade



Fig. 3. Reel Mower Blade

III. METHODOLOGY AND SYSTEM ARCHITECTURAL DESIGN

The remote-controlled solar-powered lawn mower consists of different components and devices (Tanimola et al., 2014; Kumar et al., 2021; Smith et al., 2023). This section will explain the methodology deployed, functions and specifications of each of the electronics components used. The system design processes involved hardware and software sections.

A. Hardware Section

The hardware section consists of three different units, namely the remote signal unit, the power supply unit, and the lawn mower unit. The remote signal unit

consists mainly of the push buttons, the encoder (HT12E), and the RF 433Mhz transmitter. The HT12E is a 12-bit device, of which 8-bit its for addressing and the 4-bit its for data. Each of the data bits has been used to send signals, namely start, stop, left, and right, to the lawn mower unit. The 8-bit address has been configured to 00000000; in this case, all the 8-bit (8-pin) have been set to the default low state. The corresponding signal is encoded by the encoder and sent over the RF 433 transmitter at the remote signal unit. The lawn mower unit is powered by the battery which is in turn being charged by the solar pane through the XL4015 CC/CV module, this is what consists of the power supply unit, the 12V from the



battery is mainly used to provide power to the geared motor driving the wheel and the dc motor for the grass cutter, but since the electronics unit cannot be powered with the 12V supply it is stepped down to 5V using the LD1085V50. The LD1085V50 is a low-dropout voltage regulator. The microcontroller and other electronic units of the lawn mower unit are powered by 5V.

The lawn mower unit is made up of the ATMEGA328P, the decoder (HT12D), the RF 433 Receiver, the relay module, the L293D motor driver, the ultrasonic sensor, the servo motor, the buzzer and the 16 x 2 LCD Module. The ATMEGA328P is the central processing unit that interfaces with other components that make up the unit. The 16 x 2 LCDs updated information about the state of the system. When the system is first powered on, the components are initialised and the device waits for a signal from the remote signal unit. The system does not operate until the start signal is received, once the start signal is sent from the remote signal unit, the signal is received by the RF 433 Receiver and decoded by the HT12D, the HT12D is also a 12bit device, the address bit must be configured the same as that of the encoder and as such as been configured with the address bit all set to default low. The decoded signal is processed by the microcontroller, and it acts accordingly based on this signal. Once the start signal is sent and successfully decoded,

the motors are started, and the mowing operation begins.

The ultrasonic sensor is used to detect the distance to avoid the lawn mower from hitting an obstacle, once the obstacle is detected as a distance preset to 50cm, the lawn mower's direction is changed, basically, it moves to the right, although from the remote signal unit, it is possible to either make the lawn mower go right or left by sending the corresponding signal. The servo motor is used for the smooth navigation of the lawn mower to either right or left during operation, and the buzzer is used to provide a user experience for great operation. The sound buzzes when the motor starts, stops, or is making a turn, either to the left or to the right.

B. Software Implementation

The software for the system designed was developed using the Arduino IDE, and it follows the C programming language for its implementation. The program input devices were sent via the input interface of the microcontroller, and the output devices were interfaced via the microcontroller. The ATMEGA328P was programmed using the Arduino IDE. The program is written with Arduino C as shown in Fig. 4, and it makes available several libraries for working with the sensors and modules. Most times, these libraries are written in C++ by third-party developers. The Arduino IDE includes a software library named "Wire.h" that makes interfacing with



serial modules simple to create. To create an executable cyclic executive program, users just need to define two functions:

- 1) `setup()`: a function that is called once at the beginning of a program to initialise settings.
- 2) `loop()`: a function that is called continually until the board shuts down

```
void setup()
{
  Serial.begin(9600);
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);
  pinMode(cuttingMotorPin, OUTPUT);
  pinMode(ultrasonicTriggerPin, OUTPUT);
  pinMode(ultrasonicEchoPin, INPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(buzzerPin, OUTPUT);
  pinMode(sw1, INPUT);
  pinMode(sw2, INPUT);
  pinMode(sw3, INPUT);
  pinMode(sw4, INPUT);

  setMotorDirection(false, false);
  digitalWrite(cuttingMotorPin, HIGH);
  digitalWrite(ledPin, LOW);
  digitalWrite(buzzerPin, LOW);
  digitalWrite(ultrasonicTriggerPin, LOW);

  // Initialize LCD
  lcd.init();
  lcd.backlight();

  // Attach the servo to the servo pin
  servo.attach(servoPin);
  servo.write(90);
  init_lcd();
  // Initialize the buzzer
  playBeeps(2); // Beep twice during initialization
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("  LAWM MOWER  ");
  lcd.setCursor(0,1);
  lcd.print("    READY    ");
  motorStopped = true;
}
```

Fig. 4. Setup function for Software Implementation



In the setup Function, as shown in Fig. 4, the pin mode is initialised for all the input and output devices, the LCD module is also initialised, the servo motor, which works with a PWM signal, is also initialised and attached to a PWM-enabled pin. In the Loop function, the Firmware runs by observing different flags which control the flow of the program in the design. The “motorStarted” flag returns true if the motor has been started, and except this flag is true, the lawn mower operation remains halted. Once the motorStarted flag is raised, it checks to see if the motor direction needs to be updated and checks the Flag “cuttingMotorRunning”. If this flag is false, it starts the cutting motor; else, it means the cutting motor has already been started, and then it skips this. The function “checkforobstacles()” is used to process the ultrasonic readings and calculate the distance of the lawn mower to an obstacle. If the threshold is

reached, i.e if the distance is below the set distance, it returns true, and the servo motor is controlled to navigate the lawn mower towards the right direction.

C. System Requirements

The minimum system requirements for the design used in this experiment are:

1. Windows 7 or higher
2. 4gb Ram or higher
3. 2.0ghz speed
4. 5gb hard disk space
5. Python 3.0 or higher installed on the system
6. Arduino IDE

I. SYSTEM DESIGN

The design was implemented, and the control unit was housed in an adaptable box. The lawn mower was fabricated using light but strong iron mesh plates along with bolts and nuts, which were used in the design of the wheels and chassis, as shown in Fig. 5.

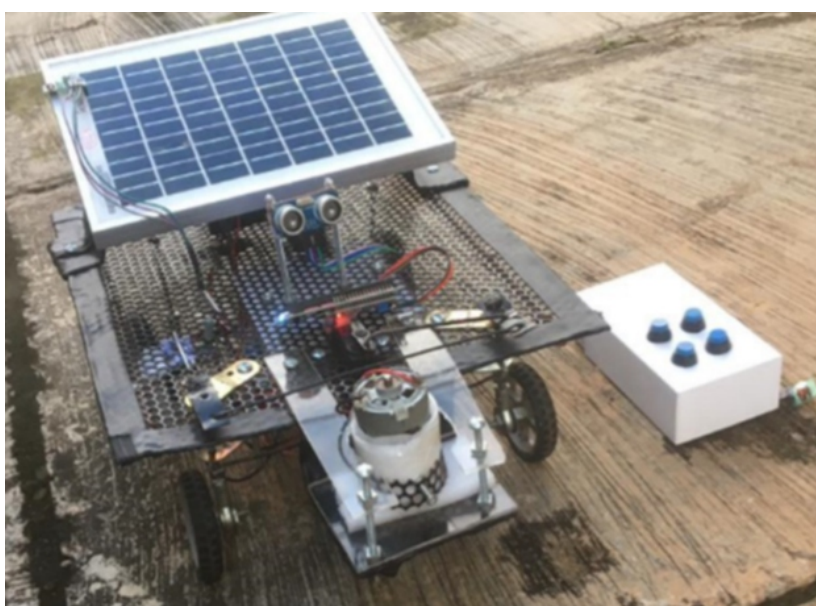


Fig. 5. System Structural Design



I. RESULTS AND DISCUSSION

The designed solar-based lawn mower is a sustainable innovation, offering an eco-conscious solution for lawn care and environmentally responsible lawn maintenance. The research serves as a model for how technology can be harnessed to simplify everyday tasks while minimising our ecological footprint, contributing to a greener and more sustainable future. The system was tested on the following sub-ending:

A. Motor Control Results

The testing of motor control is as follows: **Motor Responsiveness:** The DC motors used for propulsion and blade movement exhibited prompt responsiveness to control signals, ensuring precise and efficient movement control. The servo motor used for navigation also responds effectively at different testing angles of 30°, 35°, 40°, 45° and 50°. The lawnmower finally uses an angle of 40°. **Speed and Direction Control:** The system's ability to control the speed and direction of the motors was tested rigorously. Forward, backwards, left, and right movements were tested to ensure precise control. **Directional Accuracy:** The system effectively controlled motor direction, facilitating precise navigation with the servo motor.

B. Wireless Communication Results

Testing the wireless communication devices used, the following were deduced: **Reliable Transmission:** Control signals were reliably

transmitted and received between the remote signal unit and the lawn mower unit.

Satisfactory Range: The system's wireless range was evaluated and tested to ensure that it transmitted and received effectively within the intended expectations of 10m as stated in the module datasheet. The operating range was between 1m to 2m, but this is also effective in allowing remote control from a considerable distance. This challenge could be due to several reasons, some of which include: poor-quality modules, vibration noise from the motor and signal angle.

C. Obstacle Detection and Navigation Results

The testing of obstacle detection and navigation revealed:

Accurate Detection: The ultrasonic sensor accurately detected obstacles, and the system promptly responded to avoid collisions. The sensor's response time and precision were very accurate. **Effective Navigation:** The servo motor facilitated smooth navigation, allowing the mower to change direction as needed.

D. User Feedback Results

User feedback mechanisms delivered the following results:

1. **Audible Alerts:** The buzzer provided clear and audible alerts for different system states, enhancing user awareness.
2. **Informative Display:** The 16x2



LCD module displayed relevant information clearly, ensuring that users could monitor the mower's status effectively.

V. CONCLUSION AND RECOMMENDATION

A renewable energy remote-control lawn mower represents a significant step toward sustainable lawn care. By reducing emissions and enhancing convenience, this innovation aligns with modern environmental goals. The solar-based lawn mower design represents a remarkable fusion of renewable energy and robotics, providing a sustainable and efficient solution for lawn maintenance. The design effectively harnesses the power of a 5W, 12V solar panel, underscoring its commitment to environmental consciousness. By integrating a 12V, 1.3Ah lead-acid battery and employing meticulous voltage regulation through the XL4015 module, the system ensures optimal power management and reliable operation. The ATMEGA328P microcontroller offers precise control over various DC motors and a servo motor, facilitating smooth navigation and cutting operations. An ultrasonic sensor enhances obstacle detection capabilities, allowing the lawn mower to operate autonomously while avoiding collisions. The design user interaction is made intuitive and accessible through the integration of a 16x2 LCD module with I2C. The system is designed to showcase how sustainable technologies can enhance

convenience and reduce the ecological footprint in everyday tasks, exemplifying the power of innovation and renewable resources.

The system design functionality and its contributions to both convenience and environmental sustainability can be further expanded in the following areas:

1. **Smart Features Integration:** Explore the integration of smart features, including IoT connectivity and smartphone applications, enabling users to monitor and control the lawn mower remotely and receive real-time updates on its status.
2. **Safety Enhancement:** Implement additional safety features such as an emergency stop mechanism and advanced obstacle detection systems to further mitigate potential risks during operation.
3. **Environmental Impact Assessment:** Conduct a comprehensive life cycle assessment (LCA) to minimise the project's environmental footprint, considering materials, manufacturing, energy consumption, and end-of-life disposal.

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