



**AEFUNAI JOURNAL OF ECONOMICS,
FINANCE AND DEVELOPMENT**

AEFUNAIJEFDS

**Department of Economics and Development Studies
Alex Ekwueme Federal University, Ndufu-Alike Ikwo, Ebonyi State, Nigeria.**

Website: <https://www.ecofunai.ng>

ISSN (Print): 2536-6793 | ISSN (Electronic): 2536-6742

Volume 3 (1) February, 2026 (pp 104 - 123)

Submitted October 2025; Published February 2026.

ENVIRONMENTAL QUALITY AND LITERACY RATE NEXUS IN NIGERIA: A DYNAMIC ORDINARY LEAST SQUARES (DOLS) APPROACH.

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ABSTRACT

This paper examined the impact of environmental quality indicators on literacy rates in Nigeria. The data's stationary qualities were established using the Augmented Dickey-Fuller (ADF) unit root test, while the ARDL/Bounds cointegration technique was employed to establish long run relationship among the variables. The model was estimated using the Dynamic Ordinary Least Squares (DOLS) technique. Findings indicated a significant long-run impact of environmental quality indicators on literacy in Nigeria. Specifically, air quality and municipal solid waste had a positive and statistically significant impact on literacy rate; water quality index and population growth had a negative and statistically insignificant impact on literacy rates, while climate change index and governance quality had a positive insignificant impact on literacy rate in Nigeria within the study period. The paper, among others, recommended that the Federal Ministry of Environment (FME) promote literacy gains through sustainable urbanization by establishing green school certification standards where schools are incentivized to operate in an environmentally conscious manner, as well as integrating waste management education and school-based recycling clubs into primary and secondary curricula.

Keywords: Environmental Quality, Literacy, Human Capital Development, DOLS.

Adejor, G. A., Ogwuche, D. D., & Ologunla, S. E. (2026). *Environmental quality and literacy rate nexus in Nigeria: A dynamic ordinary least squares (DOLS) approach*. *AEFUNAI Journal of Economics, Finance and Development Studies*, 3(1), 104 - 123.

1. Introduction

Globally, knowledge acquisition and educational outcomes are influenced by the condition of the environment. Environmental quality has become a critical development concern as nations confront rising pollution levels and climate-related risks. At the same time, literacy rate and the overall learning process, widely recognised as a fundamental component of human capital by the United Nations, play a critical role in shaping an individual's capacity to respond to and mitigate environmental challenges (United Nations, 2023). The condition of the environment has been blamed for decline and disruption in global literacy through climate change and extreme weather events that lead to school closures, damage to infrastructure, prolonged school disruptions, and significant learning losses.

The World Bank report highlighted that extreme weather events, such as those linked to climate change, directly disrupt schooling, leading to learning losses and increased dropouts (World Bank, 2024). Over the past 20 years, schools have been closed in about 75 percent or more of extreme weather events affecting large populations, often with prolonged closures (World Bank, 2024). Reduced mental functioning, impaired cognitive ability, and low literacy rate have been linked to declining environmental conditions (Schmidt, 2019). Exposure to poor environmental conditions is associated with reduced physical and mental health and cognitive performance in school-aged children (Palacios *et al.*, 2020).

In Nigeria, poor water quality negatively influences literacy rates (Eniola & Adelaja, 2020); just as children of parents exposed to environmental hazards (such as lead and poor air quality) often experience lower literacy rates and educational attainment due to both direct health effects and socio-economic consequences of poor environmental conditions (Aremu & Olasunkanmi, 2020). In addition, Delprato and Shephard (2024) forecasted that climate change and unexpected climate shocks, particularly high emission rates, account for a reduction in primary education completion rates at the community level, ranging from 5.5% (medium emission scenario) to 4.4% (high emission scenario) from 2015 to 2054 in Nigeria. Similarly, Ekperiware *et al.* (2017) asserted the mutual relationship between literacy and environmental quality, and that improving environmental quality has the potential to enhance better educational opportunities and economic conditions. Despite this, the dynamic interrelationship between environmental quality and literacy remains insufficiently explored, particularly in developing economies such as Nigeria, using expanded environmental quality indicators as is done in this present study. The need for robust empirical evidence so as to initiate policy design for leveraging environmental quality as a tool for improving literacy rate is apt. This paper seeks to investigate the nexus between environmental quality and literacy rates in Nigeria, providing empirical clarity on their interdependence and hence contributing to policy-relevant discourse on achieving sustainable development. Specifically, the paper seeks to:

Research Question:

- a) Investigate the impact of air quality on literacy rate in Nigeria.
- b) Examine the impact of municipal solid waste on the literacy rate in Nigeria.
- c) Evaluate the impact of water quality on literacy rates in Nigeria.
- d) analyse the impact of climate change on the literacy rate in Nigeria.

The main objective of the study is to examine the impact of environmental factors on literacy rates in Nigeria.

Objectives of the Study

- a) Investigate the impact of air quality on the literacy rate in Nigeria.
- b) Examine the effect of municipal solid waste on the literacy rate in Nigeria.
- c) Evaluate the impact of water quality on literacy rates in Nigeria; and
- d) Analyse the impact of climate change on the literacy rate in Nigeria.

2. Literature Review**2.1 Conceptual Literature Review**

Environmental quality entails how pristine the physical environment is, in the face of deterioration and degradation by human activities and other natural phenomena. It is the continuous weakening and waning of the resilience of the environment, such that its ability to adequately support life is hampered. Decline in environmental quality due to the use of dirty energy sources, as well as intensive natural resources exploration, manufacturing, and construction activities, has been linked to impaired learning outcomes (Erundu & Nwakanma, 2025). The increasing deterioration in environmental quality across the world due to the consumption of fossil fuels is an increasing threat to global warming, which poses a serious challenge to healthy living. Indicators of environmental quality include air quality, municipal solid waste, water quality, climate change vulnerability, and the environmental sustainability index, among others.

Literacy rate is a reflection of the ability of a population to acquire information and practically apply knowledge and skills. According to the United Nations Educational, Scientific, and Cultural Organisation (UNESCO, 2019), literacy rate is the percentage of the population aged 15 and above who can both read and write with understanding. Literacy enables a population to access and understand information on a large spectrum of issues, such as environmental issues including climate change, deforestation, and pollution, as well as enhances their participation in environmental decision-making processes and in environmental sustainability advocacy. The literacy rate reveals how well primary education and literacy programmes are

working generally, instills fundamental literacy skills in the populace, puts these abilities to use in daily life, and makes it possible for people to master written language and stay in touch.

2.2 Theoretical Literature

The Human Capital Theory (HCT) emphasised the imperative of investment in education and training in order to improve workers' productivity. As propounded by Schultz (1961), the theory underscored education as an investment in human capital. Further exposition on Schultz's work was done by Becker (1964), who provided a comprehensive framework on how education and training impact productivity and earnings. The theory rests on the assumption that education and skills are highly instrumental and necessary to improve the productive capacity of a population. In short, human capital theorists argued that an educated population is a productive population. This theory emphasizes how education increases the productivity and efficiency of workers by increasing the level of cognitive stock of economically productive human capability, which is a product of innate abilities and investment in human beings (Ugwu, 2021). The provision of education is seen as an investment in human capital, which proponents of this theory have considered as equally or even more worthwhile than that of physical capital (Wuttaphan, 2017). The relevance of the HCT is that improvement in human capital skills, experiences, and education will, in the long-run results in environmentally friendly behaviour.

2.3 Empirical Review

The nexus between environmental quality and literacy in Nigeria is an intriguing area of investigation that has prompted a large body of empirical investigation, with researchers employing different markers/indicators of environmental quality and methodologies to adequately situate it. Kahomwe and Muzingili (2025) investigated the impact of climate change-induced disasters on access to education and the coping mechanisms employed by rural Zimbabwe. A qualitative approach was adopted, utilizing semi-structured and key informant interviews with 20 participants, including learners, teachers, and parents. Data were analyzed inductively to identify key themes related to the effects of climate change on education and the coping mechanisms employed. Findings revealed significant educational disruptions, including damaged infrastructure, increased school dropouts, and barriers to learning continuity as a result of climate-induced disasters. Coping mechanisms such as outdoor lessons, temporary learning shelters, migration, child labour, and limited use of technology reflected the resilience of affected communities but also exposed critical gaps in disaster preparedness and education policy. The study concludes that building climate-resilient school infrastructure, providing gender-sensitive interventions, expanding digital access, and strengthening teacher support systems are essential to ensuring equitable education in disaster-prone rural areas.

Following a recent severe drought in Southern Africa, Nordstrom and Cotton (2025) used data from a large cluster-randomized control trial involving girls and satellite data measuring drought intensity to investigate the impact of a severe drought on educational attainment and girls' school attendance and learning in Zimbabwe. Data were analysed using descriptive statistics and a difference-in-differences approach with two-way fixed effects specification as well as Standard OLS regression techniques. Findings revealed that the poorest girls tend to be disproportionately impacted as they see the largest declines in learning when exposed to the drought, illustrating how crises can perpetuate existing inequalities in learning across socio-economic groups. To the extent that shocks increase school attendance while decreasing learning gains, the paper suggests that increasing subsidies or financial incentives to support education enrolment may not result in substantial benefits.

Ucheje and Balafama (2025) investigated the impact of environmental hazards, via air pollution, noise pollution, and flooding, on the academic performance of public secondary school students in the South-South region of Nigeria. A correlational survey design targeting all principals of public secondary schools in the region was employed, while a purposive sampling technique was used to select a sample of 240 principals representing 6 states in South-South Nigeria. A questionnaire was used as an instrument of data collection, and data were analysed using simple regression techniques. Findings revealed that air pollution, noise pollution, and flooding have a significant and negative impact on students' academic performance. Air pollution was found to contribute to health issues that disrupt students' focus and school attendance, while noise and flooding interfere with the learning environment and academic activities.

Onipede and Akinlade (2025) examined how home and school environments affect secondary students' grades in Ado-Ekiti, Nigeria. Employing a descriptive survey design, a sample of 150 students was drawn from 10 secondary schools across the local government. Data were collected using a self-constructed questionnaire and analysed using inferential statistics of students' t-tests. Findings revealed that pristine learning spaces, free from environmental hazards such as noise or pollution, significantly improve academic performance and literacy.

Folayan (2025) investigated how environmental effects impact the performance of secondary schools in science subjects in Akure, Ondo state. Employing a descriptive survey and correlation design, a structured questionnaire was used to collect data from 292 students from 27 sampled public schools, while the regression technique was used for the analysis. Findings showed that the quality of the school environment has a significant relationship with the academic performance of students. Delprato and Shephard (2024) estimated the impact of climate change on education completion rates across the life-course in 2,524 communities in four sub-Saharan African countries, namely, Cameroon, Ethiopia, Guinea, and Nigeria. Using a non-parametric regression approach to account for heterogeneity of climate change-education linkage, the study found that raising temperatures, lower rainfall, aridity, and modifications on the quality

of vegetation are all related to lower education completion rates, with these impacts being more prominent in contextually disadvantaged communities. Thus, climate change as a marker of environmental quality is a trigger for low literacy rate and general low educational outcomes, suggesting the urgent need for mitigating policies.

Notwithstanding the growing body of literature examining the impact of environmental quality on literacy rate, notable gaps still exist, encompassing variables, scope, and methodology. From the perspective of variables, previous studies utilized the traditional environmental quality indicators, namely, air pollution and water pollution. This study took the investigation from a broader perspective to incorporate municipal solid waste, climate change vulnerability as an index score, as well as introducing population pressure and governance quality to succinctly situate the impact of other environmental quality covariates on literacy rate from a more holistic point of view.

From the methodological standpoint, the gap is addressed by employing the Dynamic Ordinary Least Squares (DOLS) method of analysis. Most studies in this area have utilized methodologies such as inductive (thematic) qualitative technique (Kahomwe & Muzingili, 2025); difference-in-differences approach and OLS regression (Nordstrom & Cotton, 2025); simple regression and t- test (Ucheje & Balafama, 2025; Onipede & Akinlade, 2025; Folayan, 2025); as well as non-parametric regression approach (Delprato and Shephard, 2024). While these methods have their merits, they often fall short in addressing issues of endogeneity and serial correlation comprehensively. DOLS, on the other hand, offers a robust framework for estimating long-run relationships by incorporating leads and lags of the differenced independent variables. This approach corrects for endogeneity and provides unbiased and efficient estimates, making it particularly suitable for achieving the objectives of this study.

3. Methodology

The Human Capital Theory (HCT) by Schultz (1961) forms the theoretical underpinnings of this study. The Human Capital Theory (HCT) propounded by Schultz (1961) and later expanded by Becker (1964), stressed that investment in human capital will lead to greater economic outputs and improvement in human capital skills, experiences, and education; and will, in the long-run results in environment-friendly behaviour, thus enhancing environmental quality.

The ex post facto research design was adopted for this study. Secondary data sourced from the World Development Indicator (WDI), Macro-trend, NESREA, and Notre Dame Global Adaptation Index (ND-GAIN) were employed for this study. Data were obtained on literacy rates, carbon dioxide emissions (proxy for air quality), municipal solid waste, water quality, climate change, population growth, and governance quality spanning from 1988 to 2025. Environmental quality concern in Nigeria became prominent after the

1988 Koko toxic waste dumping scandal, thus necessitating the establishment of the Federal Ministry of Environment and the Nigerian Federal Environmental Protection Agency (FEPA) (Isaac, Oripeloye & Adejo, 2024); thus, the base year of the research was 1988 when the national policy on the environment was launched with the establishment of the FEPA. Data for 2025 were extrapolated using both linear and exponential trends.

Data Source, Description, and Measurement

Table 1: Variables Description, Measurement, and Source

VARIABLES	ACRONYM	DESCRIPTION	MEASUREMENT	SOURCE
Literacy Rate	LIT	Literacy rate is the proportion of a population that can both read and write.	Measured by the average number of years of schooling received by people ages 25 and above.	Macro-trend (2025)
Air Quality	AQI	Air quality is a measure of the concentration of pollutants in the air.	Measured by the emission of Carbon dioxide (CO2) in kilotons (kt).	WDI (2023), Macro-trend (2025)
Municipal Solid Waste	MSW	This is the amount of solid waste due to open dumping and burning of waste.	Measured by waste density (kg/m³).	NESREA (2024)
Water Quality	WQI	Measured the level of biological oxygen demand (BOD) and chemical oxygen demand (COD) in rivers and lakes.	Measured by access of the population to drinking water.	Macro-trend (2024)
Climate Change Vulnerability Index	CVI	It assessed the vulnerability of an economy to variability in climatic conditions.	Measured using the climate vulnerability index by the Notre Dame Global Adaptability Index (ND-GAIN).	Notre-Dame Global Adaptability Index (ND-Gain), (2024).

Source: Authors Compilation, 2025.

Model Specification

Following the Human Capital Theory (HCT) theoretical underpinning, the model is functionally specified as:

$$LIT_t = f(AQI_t, MSW_t, WQI_t, CVI_t) \text{-----} -(1)$$

Econometrically, the model is expressed as:

$$LIT_t = \beta_0 + \beta_1 AQI + \beta_2 \ln MSW + \beta_3 WQI + \beta_4 \ln CVI + \mu_t \text{-----} - (2)$$

Where:

LIT = Literacy rate

AQI = Air quality (proxied by Carbon dioxide (CO₂) emission)

MSW = Municipal Solid Waste

WQI = Water Quality Index

CVI = Climate Change Vulnerability Index

β_0 = Intercept coefficient or autonomous parameter estimates for literacy rates.

$\beta_1, \beta_2, \beta_3$, and β_4 = slope coefficients of the variables at time t.

$\ln$ = Natural Logarithm

μ_t = Error term at time t.

A priori Expectation

In line with the study, the a priori expectation provides the signs of the parameters to be estimated in the light of economic theory. Specifically, poor air quality (Co₂ emission), municipal solid waste, and climate change are expected to harm the literacy rate. On the other hand, water quality is expected to have a positive impact on literacy rate as postulated by the endogenous growth theory. As such, the parameters (β_1, β_2 , and β_4) in equations (2) are expected to be negative (β_1, β_2 , and $\beta_4 < 0$); β_3 is, however, expected to be positive ($\beta_3 > 0$).

Justification of the Variables

In the sphere of human capital development, literacy rate is a reflection of the ability of a population to acquire information and practically apply knowledge and skills. Literacy rate is often indications of the percentage of adults who have basic literacy skills, measured by the average number of years of schooling received by people ages 25 and above, as well as the expected number of years of schooling for children of school-entry age (United Nations Development Programme, 2020). Literacy is considered a key factor in a nation's development, as it provides individuals with the knowledge and skills necessary to participate in the economy and reach their full potential (Ihemeson, 2024).

Air quality measures the concentration of the pollutant in the air. Carbon dioxide (Co₂) has been widely regarded as a universal pollutant. As noted by Aiyedogbon *et al.* (2024), air contamination as a result of Co₂ emission diminishes the quality and integrity of such essential resources.

Municipal solid waste generation in Nigeria has been increasing over the years, driven by factors such as population growth, urbanization, and economic growth. The country is facing significant environmental challenges related to waste management, including inadequate disposal facilities, poor sanitation, and environmental pollution. An increase in waste generation implies a decline in environmental quality. Waste management has been a significant challenge in Nigerian which generates an estimated 36 million tons of waste annually, with a per capita municipal solid waste generation rate of 0.55-0.58 kg/d (Switzerland Global Enterprise, 2024).

Water Quality, on the other hand, measures the level of biological oxygen demand (BOD) and chemical oxygen demand (COD) in rivers and lakes. The WHO estimates showed that 60% of Nigeria's population lacks access to clean water, which can lead to increased poverty and mortality, and thus portends a significant potential impact on educational attainment and literacy.

Climate change is one of the most pressing global challenges that threatens ecosystems, economies, and human health, with international agreements, such as the Paris Agreement, aiming to mitigate its impacts. The climate change vulnerability index (CVI) assessed the vulnerability of a region or country to the impact of climate change, including sea-level rise, extreme weather conditions, and changes in temperature and precipitation patterns. It assessed the vulnerability of an economy to variable climatic conditions. Nigeria is particularly susceptible to the climate, which has a significant impact on its human capital development trajectory (Nyong, 2023).

The investigation of the nexus between environmental quality and literacy rate in Nigeria employed a comprehensive methodological approach to ensure the robustness and policy relevance of the study. The research began with pre-estimation diagnostic tests, specifically descriptive statistics, to provide a summary of basic features in the data to enable adequate understanding of the pattern and trends, in terms of mean, median, minimum, and maximum values of the variables, among others. Unit root tests were also conducted to determine the stationarity of the data series. This crucial step is essential for verifying whether the time series data exhibit random walks (Dickey & Fuller, 1979). If non-stationarity is detected, appropriate transformations are necessary to achieve stationarity before proceeding with the estimation process. Failure to address this issue could result in spurious regression outcomes, potentially compromising the validity of the parameter estimates.

The mathematical specification for the ADF test is as follows:

$$\Delta Y_t = \delta y_{t-1} + \sum_{i=1}^n \beta_i + \varepsilon_t \quad - - - - - \quad (3)$$

Where:

Δ = First difference operator, which determines the stationarity of the series under a null hypothesis,

$H_0: \delta = 0$ (there is a unit root)

$H_1: \delta < 0$ (There is no unit root)

Y_t = Time series variable at time t

Y_{t-1} = Time series variable at lag period

n = optimum number of lag length in the dependent variable (Y_t) and it is solely determined by the parameter; and

β = Parameter.

ε_t = Stochastic error term

Decision: If the calculated ADF statistic is greater (in absolute terms) than the critical ADF values at the chosen level of significance, the study shall reject the null hypothesis that the time series data under review has a unit root. Conventionally, if the p-value at a given threshold (5%) is less than 0.05, the null hypothesis of a unit root is rejected. Otherwise, the study shall accept the null hypothesis that the time series data has a unit root.

Following the confirmation of data stationarity, the study proceeded to investigate the existence of long-run relationships among the variables. The confirmation of a long-run equilibrium relationship in the data set was further established using the ARDL Bounds Cointegration test approach.

The Bound test determines whether each of the parameters in the model has a long-term relationship (Ezie & Ezie, 2021). The hypothesis of the F-bound cointegration test is stated as

$H_0: \varphi_1 = \varphi_2 = 0$ (No cointegration exists between the variables).

$H_1: \varphi_1 = \varphi_2 \neq 0$ (Cointegration exists between the variables).

Decision Rule:

Reject H_0 if the calculated F-statistic is greater than the critical upper bounds $I(1)$

Accept H_0 if the F-statistic falls below the critical lower bounds $I(0)$

The test is inconclusive if the F-statistic falls between the critical upper and lower bounds.

To analyse the specific long-run impact of environmental quality indicators on literacy rates in terms of sign and magnitude, the Dynamic Ordinary Least Squares (DOLS) technique was employed. DOLS is particularly well-suited for this study due to its capacity to yield efficient estimates of cointegrating relationships, especially when working with small or large sample sizes and variables of similar or differing integration orders. By incorporating leads and lags of the differenced independent variables, DOLS corrects for these issues, providing unbiased and efficient estimates of the long-term relationships. Recent research by Ezie, Akanegbu, and Ene (2024) demonstrated the efficacy of DOLS in analyzing the long-run relationship among variables, underscoring its utility in policy-oriented research.

The Stock Watson method is a robust single equation approach that corrects regressor endogeneity by the inclusion of leads and lags of first differences of the regressors and for serially correlated errors by a General Least Squares (GLS) procedure.

The general form of Stock and Watson (1993) Dynamic Ordinary Least Squares (DOLS) is given as:

$$Y_t = \beta_0 + \bar{\theta}X + \sum_{j=-q}^p \bar{\theta}_j \Delta X_{t-j} + \varepsilon_t \quad \text{---(4)}$$

Y_t = dependent variable,

X = matrix of explanatory variables,

$\bar{\theta}$ = cointegration vector; that is, represents the long run cumulative multipliers or the long run effect of a change in x on y,

P =lag length,

q =lead length Lag and lead terms included in DOLS regression have the purpose of making its stochastic error term independent of all past innovations in stochastic regressors

Consequently, equation (2) was re-specified following Stock and Watson (1993), Dynamic Ordinary Least Square (DOLS) as stated in equation (4) as:

$$LIT_t = \beta_0 + \beta_1 AQI_t + \beta_2 \ln MSW_t + \beta_3 WQI_t + \beta_4 \ln CCI_t + \sum_{j=-q}^p \varphi_5 \Delta AQI_{t-j} + \sum_{j=-q}^p \varphi_6 \Delta \ln MSW_{t-j} + \sum_{j=-q}^p \varphi_7 \Delta WQI_{t-j} + \sum_{j=-q}^p \varphi_8 \Delta \ln CVI_{t-j} + \mu_t \quad \text{---(5)}$$

Where:

β_0 is the intercept parameter

$\beta_1 - \beta_4$ are the long –run parameters

$\varphi_5 - \varphi_8$ are the short-run parameter

μ_t is the error term

4. Result and Discussion

4.1 Results

Descriptive Statistics:

Descriptive statistics were used to provide an informative summary of the data so as to get a precise and succinct idea of the variables employed in the study. This is presented in Table 2.

Table 2: Descriptive Statistics

	LIT	CO2	CVI	MSW	WQI
Mean	62.3611	98287.16	138.2105	30580220	18.4897

Median	58.3000	97931.00	146.0000	29372113	17.7400
Maximum	77.6400	123750.2	163.0000	46689151	30.5000
Minimum	44.0000	72768.80	93.0000	18138057	6.0000
Std. Dev.	10.2352	14801.45	22.9655	8771999.	7.5440
Skewness	0.0357	0.1658	-1.1056	0.3020	0.0964
Kurtosis	1.8276	1.9112	2.6832	1.8404	1.6107
Jarque-Bera	2.1843	2.0510	7.9009	2.7069	3.1150
Probability	0.3355	0.3586	0.0192	0.2584	0.2107
Sum	2369.720	3734912.	5252.000	1.1609	702.6100
Sum Sq. Dev.	3876.108	8.1109	19514.32	2.8500	2105.755
Observations	38	38	38	38	38

Source: Authors' Computation using E-views 12 (2025).

The descriptive statistics in Table 2 revealed that Literacy Rate (LIT) from 1988–2025 had maximum and minimum values of 77.64% and 44.00%, respectively. With a standard deviation of 10.24%, an indication of moderate disparities in literacy across observations, and a mean of 62.36% for the period, the data indicated a 52.13% divergence from both sides of the mean, which implies consistency and absence of outliers in the data set. Median slightly lower at 58.3% than the mean (62.36%), suggesting a fairly symmetric distribution, but the lower minimum (44.00%) and moderate skewness (0.036%) reveal pockets of low literacy needing attention. CO2 emission as an indicator of Air Quality has an average of 98287.16 kilotons, with a standard deviation of 14801.45 kilotons, implying that there were 83485.71 departures from both sides of the mean. Also, the high mean (98287.16) and median (97931) with considerable range (50,981.40) and mild positive skew (0.1658) suggest most regions in Nigeria experience high emissions, while a few may be extreme outliers. Given that the standard deviation was found to be lower than the mean value, this implies a minimal fluctuation in the data set over the sample period, which further confirms initiatives towards improvement in air quality through reduction in CO2 emission.

With a magnitude of 21808221, Municipal Solid Waste (MSW) is widely spread from the mean, as indicated by its mean value and standard deviation of 30580220 and 8771999, respectively; with a minimum and maximum value of 18138057 and 46689151 in that order, indicating a measure of consistency in the data set. Also, very large mean and maximum values, with extreme positive skewness (0.3020) and kurtosis (1.8404), indicate substantial disparities in municipal waste generation linked to urban density and poor waste management.

Also, the Water Quality Index (WQI) had maximum and minimum values of 30.50% and 6.00%, respectively. With a standard deviation of 7.54% and an average value of 18.49% for the period, the data

indicated a relative 10.95% divergence from both sides of the mean, which implies that WQI is normally spread over the years. The slight positive skewness (0.0964) and substantial range (24.5%) indicate uneven access to clean water across regions in Nigeria, thus informing the imperative to expand drinking water infrastructure and enforcement of water pollution controls so as to align with broader SDG targets. Climate Change Vulnerability Index (CVI) is relatively spread from the mean, as indicated by its maximum and minimum values of 163 and 93, respectively, and mean value and standard deviation of 138.2105 and 22.96549, respectively. The 138.21 mean rank, viz-a-vis the median rank of 146, further indicates moderate to high vulnerability levels of Nigeria to climate change. The negative skewness (-1.1056) suggests some lower vulnerability outliers; however, variability is substantial in the data set.

Unit Root Test Results

The Augmented Dickey-Fuller (ADF) test was employed to check the unit root and stationarity hypotheses of the data set. The test was conducted at the 5% level of significance, and the result is presented in Table 3.

Table 3: Augmented Dickey-Fuller (ADF) Test Results

Variables	At Levels	At First (1st) Difference	5% Critical Value	P-Value	Order of Integration	Remark
LIT	-1.0988	-5.1093	-3.5403	0.0010	I(1)	Stationary
CO2	-2.8202	-6.5537	-3.5403	0.0001	I(1)	Stationary
MSW	-3.8121	1.0286	-3.5806	0.0309	I(0)	Stationary
WQI	-3.8590	-2.2005	-3.5403	0.0246	I(0)	Stationary
CVI	-1.6822	-5.7377	-3.5403	0.0002	I(1)	Stationary

Source: Authors' Computation using E-views 12 (2025).

The ADF test results in Table 3 indicated that when the variables were tested at levels, MSW and WQI were stationary, (I(0)). After first differencing, LIT, CO2, and CVI were found to be stationary (I(1)). Hence, the null hypothesis of no unit root (stationarity) was accepted at the 5% level of significance. With the mixed order of integration, the ARDL/Bounds cointegration test was employed to verify the existence of a long-run relationship among the variables as presented in Table 4.

Table 4: ARDL/Bounds Co-integration Test Result

Test Statistics	Value	K
F-statistic	19.1607	4
Critical Value Bounds		
Significance	I(0) Bound	I(1) Bound

10%	2.22	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Source: Author's computation using E-views 12 (2025).

As revealed in Table 4, the F-statistic (19.1607) is greater than the critical upper bound, I(1), value (3.49) at the (5%) significance level, thus leading to rejection of the null hypotheses no cointegration. The cointegration result implies that although the variables may drift in the short run, there is a stable and predictable long-run relationship among them. The confirmation of cointegration validates the use of Dynamic Ordinary Least Squares (DOLS) as stipulated by Stocks and Watson (1993). This is shown in Table 5.

Table 4: Dynamic Ordinary Least Squares (DOLS) Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2	0.0003	0.0002	1.6347	0.1195
MSW	-1.7206	6.2207	-2.7560	0.0130
WQI	3.3277	1.1520	2.8885	0.0098
CVI	-0.0169	0.0501	-0.3378	0.7394
D(CO2)	-4.6405	9.9005	-0.4692	0.6446
D(CO2(1))	0.0001	7.6405	1.5970	0.1277
D(CO2(-1))	-8.5505	7.3905	-1.1569	0.2624
D(MSW)	7.0205	4.8505	1.4484	0.1647
D(MSW(1))	-1.5806	5.2006	-0.3044	0.7643
D(MSW(-1))	-8.5605	6.4505	-1.3279	0.2008
D(WQI)	-2.1490	3.7054	-0.5799	0.5691
D(WQI(1))	0.5570	4.0449	0.1377	0.8920
D(WQI(-1))	-1.9552	2.9483	-0.6632	0.5156
D(CVI)	0.0005	0.0418	0.0122	0.9904
D(CVI(1))	-0.0099	0.0293	-0.3394	0.7383
D(CVI(-1))	0.0177	0.0312	0.5683	0.5769
C	40.4255	7.8342	5.1601	0.0001
R-squared	0.9837	Durbin-Watson stat	1.6277	

Adjusted R-squared	0.9693
F-statistic	68.0415
Prob(F-statistic)	0.0000

Source: Authors' Computation using E-views 12 (2025)

Starting with the long-run as indicated in Table 5, CO₂ emissions as an indicator of air quality revealed a positive (coefficient= 0.0003) and statistically insignificant effect (p-value = 0.1195) impact on literacy rate at the 5 per cent level of significance (p-value > 0.05). Thus, it showed that higher air pollution is associated with a higher literacy rate. This result is counterintuitive, but possibly reflecting more urbanized, industrialized regions where both emissions and educational access/opportunities are higher.

Municipal Solid Waste (MSW) had a negative and significant effect (coefficient -1.72, p=0.0130) on literacy rate at the 5 percent level of significance (p-value < 0.05). This suggests that increased waste generation has an adverse effect on literacy outcomes.

Water Quality (WQI) revealed a positive (coefficient 3.3277) and statistically significant (p=0.0098) long-run impact on literacy rate, (p-value < 0.05). This shows that the literacy rate is significantly influenced by access to quality water.

In addition, Climate Change Vulnerability (CVI) has a negative long-run impact on literacy rate (coefficient -0.0169). This result is, however, statistically insignificant (p=0.7394) at the 5 per cent level of significance (p-value >0.05). The result implies that vulnerability in climate, though impact literacy rate negatively in the long run, the impact is not significant.

In the short-run perspective, change in CO₂ emission, D(CO₂), together with the lagged change in CO₂ emission, D(CO₂(-1)), have a negative and insignificant effect on literacy rate. This suggests that an increase in CO₂, likely as a result of increased economic activity, rapidly disrupts educational attainment and literacy, likely due to health-related complications from CO₂ inhalation. On the other hand, the lead change in CO₂, D(CO₂(1)), has an insignificant positive effect (coefficient=0.0001, p=0.1277) on literacy rate. In addition, both the lead and the lagged change in municipal solid waste, D(MSW(1)); D(MSW(-1)), revealed negative (coefficient= -1.5800, -8.5600) and insignificant (p=0.7643; 0.2008) effect on literacy rate. However, change in Municipal solid waste, D(MSW), has a positive and insignificant effect (coefficient = 7.0200; p= 0.1647) on literacy rate.

Also in the short-run, change in climate vulnerability (D(INCVI), as well as lagged change in climate vulnerability (D(CVI(-1))), are positive (coefficient = 0.0005; 0.0177) and insignificant (p= 0.9904;

0.5769). This suggests that climate change did not disrupt educational attainment and literacy. However, the lead change in climate vulnerability, $D(CVI(1))$, is negative and insignificant (coefficient = -0.0099; $p=0.7383$), implying climate change can negatively impact literacy. Also, change in water quality, $D(WQI)$, and the lagged change in water quality, $D(WQI(-1))$, have a negative and moderately significant ($p=0.5691$; 0.5156) effect on literacy rate; an indication that water quality reduces literacy rate. Conversely, the lead change in water quality, $D(WQI(1))$, revealed an insignificant positive effect (coefficient = 0.5570; $p=0.8920$) on literacy rate, suggesting that water quality contribution to enhanced literacy outcome is insignificant.

The Adjusted R-squared of 0.9693, which provides a more accurate measure of the model's explanatory power by adjusting for the number of predictors, shows that the model still retains a significant portion of its explanatory power, suggesting that the independent variables collectively provide a meaningful explanation of the variations in literacy rates.

The F-statistic of 68.0415 and its associated probability (Prob(F-statistic)) of 0.0000 further validate the reliability of the regression model. The F-statistic tests the overall significance of the model by comparing the explained variance to the unexplained variance. In this case, the F statistic is significant at the 5 percent level ($p\text{-value} < 0.05$), indicating that the independent variables, when considered together, significantly explain the variations in literacy rates.

The Durbin-Watson statistic = 1.6277, which is a diagnostic test indicating well-behaved residuals with no incidence of multicorrelation.

Table 6: Diagnostic Test Result

Test	F-statistic	Prob. Value	Obs*R-squared	Prob. Value
Breusch-Godfrey-Serial Correlation LM Test:	1.0114	0.3287	1.9654	0.1609
Breusch-Pagan-Godfrey Heteroskedasticity Test:	1.0934	0.4243	17.2509	0.3695
Ramsey Reset Test	0.5393	0.4727	t-stat. 0.7344	0.4727
CUSUM	Within 5% bounds		The model is stable	
Normality Test	Jarque-Bera = 0.9822			
				0.6120

Source: Author's Computation, extracted from E-views 12 (2025).

From Table 6, the probability values for the Breusch-Godfrey Serial Correlation LM test and the Breusch-Pagan-Godfrey Heteroskedasticity test (0.3287) and (0.4243) are respectively greater than 0.05, hence the null hypotheses of no serial correlation and heteroskedasticity are accepted. Also, the probability values of the Ramsey Reset Test (0.4727) as well as the Normality Test (0.6120) being greater than 0.05 imply that

the model was well specified and normally distributed. In addition, the result of the CUSUM and CUSUM Square plots being within the 5% confidence bands (See Appendix A) showed that the model parameters are stable and robust over time.

4.2 Discussion of Findings

Based on the signs and magnitudes of the variables as indicated in Table 5, Carbon dioxide (CO₂) emission has a positive and insignificant impact on literacy rates in Nigeria. This finding suggests that higher CO₂ emissions, often linked to urbanization or increased industrial activities, are associated with higher literacy rates. This could be due to more developed areas having greater access to schooling and other educational activities, but also reflects complex urban trade-offs and environmental costs. Though insignificant, this outcome contradicted with the work of Ucheje and Balafama (2025), who found that increased air pollution has a significant and negative impact on students' academic performance by contributing to health issues that disrupt students' focus and school attendance in Nigeria. Similarly, Folayan (2025), who found that conducive learning spaces and quality of the school environment have a significant and positive relationship with the academic performance of students, contradicted the findings of this study.

The study also reveals that Municipal Solid Waste (MSW) has a negative and significant impact on literacy rates in Nigeria. This revelation links increased waste generation and poor waste management practices to declining educational outcomes, likely through health effects. This further suggests that literacy is lower in areas with more waste generation, which again is consistent with urbanization and competition for space. Urbanization worsens pollution and waste challenges. This finding is consistent with that of Onipede and Akinlade (2025), who reported that environmental hazards such as municipal pollution contributed to a reduction in literacy rate and poor academic records in Nigeria.

In addition, Water Quality (WQI) has a positive and significant impact on literacy rate in Nigeria within the study period. This finding implies that access to quality water by the populace is a critical factor in the determinants of literacy rate in Nigeria. Thus, poor quality drinking water has contributed to reducing the literacy rate based on the findings of this study. This can be better appreciated in rural Nigeria where women and girls travel several distances to get drinking water. This result is consistent with the findings of Eniola and Adelaja (2020), who reported that water quality positively influences literacy rates in Nigeria.

Furthermore, Climate Change Vulnerability (CVI) has a negative and insignificant long-run impact on literacy rate in Nigeria. This finding suggests that vulnerability to climate disrupts educational attainment and literacy outcomes in Nigeria. The work of Kahomwe and Muzingili (2025), which discovered significant educational disruptions, increased school dropouts, and barriers to learning continuity as a result

of climate-induced disasters, is consistent with this finding. Also, Nordstrom and Cotton (2025) reported declines in learning and diminished literacy rate when girls were exposed to drought in Zimbabwe.

5. Conclusion and Recommendation

5.1 Conclusion

This paper examines the nexus between environmental quality and literacy rates in Nigeria. The findings reveal a significant long-run impact of environmental quality indicators on literacy rates within the study period. Firstly, the positive impact of Carbon Dioxide (CO₂) emissions as a proxy for air quality on literacy rate emphasises how urbanisation and increased industrial activities can increase literacy rate. Secondly, the negative impact of Municipal Solid Waste (MSW) on literacy rate further underscores how waste generation can retard literacy rate. Thirdly, Water Quality (WQI) having a positive impact on literacy rate highlights that literacy rate is affected by access of the populace to quality drinking water. Fourthly, the negative impact of the Climate Change Vulnerability Index (CVI) suggests that the literacy rate is disrupted by a sudden shock in climate conditions.

5.2 Recommendations

In order to address the outcomes of the study, the following specific recommendations are made.

Promotion of literacy gains through sustainable urbanization. This can be done through the implementation of educational infrastructure expansion in growing urban and industrial areas while enforcing strong environmental regulations. In this regard, the Federal Ministry of Environment (FME) should establish green school certification standards by incentivizing schools to operate in an environmentally conscious manner.

Couple literacy improvement initiatives with solid waste management reforms. The National Environmental Safety and Regulation Agency (NESRA) can innovatively prioritize literacy programmes in areas with high waste generation, which often reflects higher population density and potential for rapid educational scaling. This can be done through integrating waste management education and school-based recycling clubs into primary and secondary curricula, as well as collaborating with municipal authorities to sponsor school competitions and campaigns on reducing waste and promoting clean environments, using these as literacy development opportunities.

Provision of safe water in educational environments to support literacy. The Federal Ministry of Water Resources (FMWR), in conjunction with its various counterparts, should aggressively focus on improving water infrastructure, particularly in rural or underserved schools, as an indirect pathway to better

educational outcomes and student attendance. This can be done in collaboration with the Federal Ministry of Health (FMH) to certify water safety in every school, as well as providing hygiene education workshops and installing low-cost water purification systems on school premises to support both health and learning.

School curricula and infrastructure should be designed to withstand and respond to climate disasters, ensuring continuity in education during emergencies due to climate shocks. The National Council on Climate Change (NCCC) should, as a matter of priority, establish early warning systems and disaster preparedness training for teachers and students in schools all over the country. The NCCC should equally prioritize the construction of climate-resilient schools in disaster-prone regions and include psychosocial support as part of educational recovery after crises. This will ensure that there is no considerable gap in literacy rate.

References

- Aiyedo gbon, J. O., Ogwuche, D. D., & Nanbal, J. Z. (2024). Impact of Environmental Degradation on Economic Growth: Testing the Environmental Kuznets Curve in Nigeria. *American Journal of Environmental Economics* (AJEE), 3(1), 82-92.
- Aremu, A., & Olasunkanmi, A. (2020). Environmental health and educational attainment: A intergenerational perspective. *International Journal of Environmental Research and Public Health*, 17(6), 2114.
- Badulescu, D., Simut, D., Badulescu, A. & Badulescu, A. V. (2019). The Relative Effects of Economic Growth, Environmental Pollution, and Non-Communicable Diseases on Health Expenditures in European Union Countries. *International Journal of Environmental Research and Public Health*, 16, 5115, doi:10.3390/ijerph16245115.
- Becker, G. (1964). *Human Capital*. Chicago: University of Chicago Press
- Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74, 427-431.
- Ekperiware, M. C., Olatayo, T. O. & Egbetoku, A. A. (2017). Human capital and sustainable development In Nigeria: How can economic growth suffice for environmental degradation? *Economic discussion paper, No.2017-29, Kiel Institute for the World Economy*.
- Eniola, O. A., & Adelaja, O. O. (2020). Environmental quality and human capital development in Nigeria: A position paper. *Journal of Human Resource Management*, 8(2), 60-70.
- Erondu, C. I., Nwakanma, E. (2025). Human Security and Environmental Crisis in Nigeria: Addressing Interconnected Threats to Sustainable Development. *African Journal of Social Sciences and Humanities Research* 8(1), 85-96. DOI: 10.52589/AJSSHR- GHQVMYFJ
- Ezie, O., Akanegbu, B., & Ene, J. C. (2024). Financial technology (Fintech) penetration and poverty rates in Nigeria. *A paper presented at the Nigeria Economic Society (NES) Conference, 2024*.
- Folayan, M. O. (2025). Environmental effects on the performance of secondary schools in science subjects. *International Journal of Research and Innovation in Social Science*. 8(12), 1613- 1622.
- Hassen, A., & Gebrehiwot, S. (2022). The Interrelationship of Environmental Quality and Educational Attainment in Rural Ethiopia. *Environmental Development*, 41, 100626.
- Ihemeson, C. O. (2024). *Environmental Laws and Sustainable Development in the Niger Delta Region, Nigeria*. Lap Lambert Academic Publishing, London.
- Isaac, U., Oripeloye, H., & Adejo, V. (2024). Can Faith Be the Key to Environmental Stewardship and Sustainable Development in Nigeria? *American Journal of Development Studies*, 2(2), 16 – 26.

- Nyong, A. O. (2023). Combating climate change for national security and development. *Lecture delivered on the joint 33rd and 34th convocation of the University of Jos, May 12, 2023.*
- Onipede, A. A., & Akinlade, B. K. (2025). Impact of environmental factors on students' academic performance in some selected secondary schools in Ado-Ekiti. *Social Science Education Journal*, 7(1), 34- 40
- Palacios, T. J.; Eichholtz, P.; Willeboordse, M.; & Kok, N. (2020). Indoor environmental quality and learning outcomes: protocol on large-scale sensor deployment in schools. *BMJ Open* 2020;10:e031233. doi:10.1136/bmjopen-2019-031233
- Schmidt, S. (2019). Brain Fog: Does air pollution make us less productive? *Environmental Health Perspectives*, 127(5), 052001. Doi: 10.1289/ehp4869.
- Schultz, T. W. (1961). Investment in Human Capital. *American Economic Review*, 51(1), 1-17.
- Stock, J. H. & Watson, M. (1993). A simple estimator of cointegrating vectors in higher Order integrated systems, *Econometrica*, 61, 783-820.
- Switzerland Global Enterprise (2024). Waste Management and Recycling in Nigeria. Available Online. <https://www.s-ge.com/en/pubication/fact-sheet/2023-e-clean-nigeria-ct6-recycling-waste-managemnt?ct> Retrieved 23/11/2024.
- Ucheje, O. O., & Balafama, I. W. (2025). The impact of environmental hazards on the academic performance of public secondary school students. *International Journal of Environmental and Engineering Education*, 7(1), 13-24.
- Ugwu, A. N. (2021). Human capital development for achieving Sustainable Development Goal 8 in Nigeria. *International Journal of Social Sciences and Management Review*. 4(2), 99- 110.
- United Nations Educational, Scientific, and Cultural Organization (UNESCO). (2014). *Education for Sustainable Development Goals: Learning Objectives*. Available at: <https://www.unesco.org>
- UNESCO. (2019). Literacy: What you need to know. Available at: <https://www.unesco.org>
- United Nations (2023). The sustainable development goals report 2023: Special edition. Available at <https://unstats.un.org/sdgs/2023>. Accessed 20/10/2024
- World Bank (2024). The impact of climate change on education. Available at: <https://openknowledge.worldbank.org> Accessed 15/09/205.
- Wuttaphan, N. (2017). Human capital theory: The theory of human resource development, implications, and future. *Rajabhat J. Sci. Humanit. Soc. Sci.* 18(2), 240-253.