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Harnessing Nigeria's ecological landscape for sustainable development

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Abstract
This study examines the effect of Nigeria's ecological system, measured through biocapacity, ecological footprint, carbon emissions, green finance, foreign direct investment, renewable energy consumption, government health expenditure, urbanization rate, population, and energy use on sustainable economic development, proxied by GDP per capita, life expectancy, and infant mortality rate, over the period 2000–2024. The study is motivated by a persistent Nigerian paradox: nominal economic growth has continued alongside a widening ecological deficit and stagnant human welfare outcomes, while the specific channels theorised to reconcile this disconnect, including foreign direct investment, green finance, government health expenditure, and urbanization have themselves underperformed or produced ambiguous results. Adopting an ex post facto research design and Ecological Economics Theory as its primary theoretical anchor, the study specifies three ARDL bounds-testing models corresponding to its three dependent variables, using annual secondary data drawn from the Global Footprint Network, the World Bank's World Development Indicators, and the Central Bank of Nigeria. The ARDL bounds test confirms cointegration in all three models. Long-run estimates show population exerting a positive and significant effect on GDP per capita, while green finance, foreign direct investment, and ecological footprint depress it; urbanisation exerts a significant negative long-run effect on life expectancy, while carbon emissions show a significant positive association, consistent with Nigeria sitting on the rising segment of an Environmental Kuznets Curve; the infant mortality model, despite very strong evidence of a long-run relationship, yields no individually significant long-run coefficients, a result attributed to severe multicollinearity among its regressors. Granger causality tests confirm that biocapacity, ecological footprint, carbon emissions, government health expenditure, urbanisation, and population each Granger-cause infant mortality rate, the study's clearest causal finding. The study concludes that Nigeria's ecological system and its economic and welfare outcomes are statistically linked, but that the channels expected to convert ecological and financial resources into sustainable development, green finance and foreign direct investment in particular, are not yet functioning as theorised, and offers corresponding policy recommendations.

Keywords: Ecological footprint, bio-capacity, sustainable economic development, ardl bounds testing, green finance, Nigeria

Introduction

Sustainable economic development is defined variously across scales of analysis. The World Bank (2024) [34] defines it as growth that raises income, health, and longevity without eroding the natural resource base future generations will depend on, a formulation tracing to the 1987 Brundtland Report and increasingly operationalised through natural capital accounting, which assigns measurable value to a nation's ecosystems and folds that value into development planning. The World Health Organization (2023) [32] situates the concept within population health, treating life expectancy and mortality outcomes as the definitive evidence that growth has translated into genuine welfare rather than income expansion alone.

At the Sub-Saharan African regional level, research on the region's ecological footprint drivers frames sustainable development as growth achieved without further depleting an already-diminishing natural resource base, noting that conventional output measures have continued to rise even as the ecological capital underpinning them erodes (Frontiers in Environmental Science, 2024). Within Nigeria, Ajii (2025) [1, 7] defines sustainable development as growth achieved without a corresponding deterioration of the national ecological footprint, while Nwanze (2023) [18] extends the definition to child survival and community-level environmental quality rather than aggregate income growth alone.

Globally, the ecological footprint–biocapacity accounting framework maintained by the Global Footprint Network and the York University Ecological Footprint Initiative defines a nation's ecological position as the gap between the biologically productive area a population demands and the area available to regenerate it. By this framework's most recent estimate, humanity's ecological footprint exceeded the planet's regenerative capacity by approximately 75 percent as of 2023 — the equivalent of consuming 1.75 Earths — with carbon emissions constituting roughly 62 percent of the global overshoot (Global Footprint Network, 2025, 2026) [10, 11].

Within Nigeria specifically, the biocapacity deficit widened from approximately 58 percent over 1981–2020 to an estimated 77 percent by 2024 (ScienceDirect, 2024; Global Footprint Network, 2024). Somoye and Ayobamiji (2024) [9, 27] define Nigeria's ecological position through its load capacity factor, identifying urbanisation, foreign direct investment, and resource dependency as principal determinants, while Pat-Natson (2024) [23] extends the definition to green finance — green credit, green securities, and carbon finance — as instruments through which the ecological system may be actively managed.

Taken together, biocapacity and ecological footprint determine the volume of natural resources available to support output and livelihoods; foreign direct investment and green finance represent the capital channels through

which this base can be converted into productive infrastructure without further depletion; renewable energy consumption eases the trade-off between output growth and ecological pressure; and government health expenditure, carbon emissions, and urbanisation jointly shape the translation of income into life expectancy and infant mortality outcomes.

Despite Nigeria's growing engagement with sustainability frameworks — including its Nationally Determined Contributions and its 2017 issuance of Africa's first sovereign green bond — these mechanisms have not delivered the outcomes they theoretically promise. Nigeria's ecological deficit has continued to widen even as the economy has grown in nominal terms, suggesting current growth is being achieved by drawing down ecological capital rather than harnessing it sustainably (Global Footprint Network, 2024) [9]. This paradox is mirrored in human development outcomes: life expectancy at birth stood at approximately 55.44 years as of 2023, below both the Sub-Saharan African average (60.24 years) and the global average (72.98 years) (WHO, 2023), and a 2024 [9] study in the *Tanzanian Economic Review* found that Nigeria's GDP per capita growth has not been accompanied by proportionate life-expectancy gains.

The channels theorised to reconcile this disconnect have themselves underperformed: Nigeria recorded a 13.8 percent decline in FDI inflows in 2024 [2] relative to 2023, and net FDI flows were negative in 2022 (Ninyio, 2025); a 2025 [17] Climate Policy Initiative landscape assessment found that most climate finance reaching Nigeria arrives as debt rather than grants, with debt servicing already consuming over 80 percent of government revenue; and Amade and Oyigebe (2024) [2] found Nigeria's long-run FDI–growth relationship remains weak, consistent with Habib's (2021) [14] finding that absorptive capacity, not inflow volume, determines whether FDI translates into development. Existing empirical findings on how Nigeria's ecological system affects development also remain fragmented: Ajii (2025) [1] found renewable energy adoption and public–private partnerships moderate the country's ecological footprint, while Somoye and Ayobamiji (2024) [27] found urbanisation and resource dependency accelerate its decline; existing studies typically examine ecological footprint or carbon emissions as the primary explanatory variable rather than biocapacity itself, leaving biocapacity's specific role — alongside green finance, FDI, renewable energy consumption, government health expenditure, urbanisation, population, and energy use — jointly and empirically underexamined within a single Nigerian study.

It is against this backdrop that the present study investigates the effect of Nigeria's ecological system on sustainable economic development, proxied by GDP per capita, life expectancy, and infant mortality rate, over 2000–2024, and the nature, strength, and causal direction of these relationships in both the short run and the long run. The specific objectives are to (i) examine the effect of biocapacity, ecological footprint, green finance, foreign direct investment, renewable energy consumption, and population on GDP per capita; (ii) investigate the effect of biocapacity, ecological footprint, carbon emissions, green finance, government health expenditure, energy use, and urbanisation rate on life expectancy; and (iii) assess the effect of biocapacity, ecological footprint, carbon emissions, green finance, government health expenditure, urbanisation rate, and population on infant mortality rate, all within Nigeria. Corresponding to these objectives, the study tests three null hypotheses: that each respective set of variables has no significant effect on GDP per capita, life expectancy, and infant mortality rate, at the 5 percent level of significance.

The study contributes to the sparse Nigeria-specific literature that treats biocapacity as an explanatory variable in its own right rather than a residual of ecological footprint, and offers a methodological template for jointly examining ecological and human-development outcomes within a single econometric framework. For policymakers — particularly the Federal Ministry of Environment, the National Planning Commission, and the Central Bank of Nigeria — the findings offer evidence on whether current patterns of FDI, green finance disbursement, and energy use are genuinely converting Nigeria's natural resource base into development gains or merely accompanying its depletion. For investors in renewable energy, agriculture, and green finance instruments, the study clarifies the extent to which Nigeria's ecological indicators are statistically linked to macroeconomic outcomes. The study is delimited to Nigeria as a single-country case, relies exclusively on annual secondary time-series data, and does not extend to primary data collection, state-level disaggregation, or cross-country comparison.

Literature Review

1. Conceptual Framework

Sustainable economic development extends beyond output expansion to encompass welfare improvements achieved without depleting the natural resource base on which that welfare depends (World Bank, 2024) [34]. Country-level studies typically disaggregate the concept into an economic dimension, proxied by GDP per capita, and a social dimension, captured through life expectancy (WHO, 2023) and infant mortality rate (Nwanze, 2023) [18], retained as separate dependent variables so their individual relationships with explanatory variables can be isolated (Ajii, 2025; Somoye & Ayobamiji, 2024) [1, 27]. Global evidence that the ecological footprint has grown by 190 percent since 1961 against biocapacity growth of only 27 percent over the same period indicates substantial decoupling of output growth from ecological sustainability (Frontiers in Environmental Science, 2024) [7].

Nigeria's ecological system refers to the totality of the country's natural resource base — forests, wetlands, arable land, fisheries, and renewable energy potential — together with the biophysical capacity of those resources to regenerate and absorb the pressures economic activity places on them (Global Footprint Network, 2024) [9], operationalised through the relationship between ecological footprint (demand) and biocapacity (regenerative capacity) (Global Footprint Network, 2026) [11]. Nigeria's ecological zones — the Niger Delta's mangrove and coastal swamp forests, the southern tropical rainforest belt, the Guinea savanna middle belt, and the Sudan–Sahel far north — position it among the more ecologically diverse Sub-Saharan African economies, yet the country's biocapacity deficit has widened from approximately 58 percent (1981–2020) to 77 percent by 2024 (ScienceDirect, 2024; Global Footprint Network, 2024) [9].

Green finance is conceptualised as capital flows — green bonds, green credit, and carbon finance — directed

specifically toward narrowing rather than widening this ecological deficit (Climate Policy Initiative, 2025; Pat-Natson, 2024) [3, 23], while foreign direct investment represents a capital channel whose developmental effect is conditional on Nigeria's absorptive capacity and whose ecological effect depends on its sectoral destination (Habib, 2021; Somoye & Ayobamiji, 2024) [14, 27]. GDP per capita retains empirical value as a dependent variable precisely because its relationship with ecological indicators — rather than its use in isolation — reveals whether a country's growth model is sustainable (Ajii, 2025) [1], while life expectancy and infant mortality rate are conceptualised as health outcomes shaped jointly by income growth and ecological quality (WHO, 2023; Nwanze, 2023) [18].

2. Theoretical Framework

The study anchors on Ecological Economics Theory (Georgescu-Roegen, 1971; Daly, 1996 [5, 8], as cited in Global Footprint Network, 2026) [11], which holds that natural capital constitutes a distinct factor of production that cannot be fully substituted by physical or financial capital, such that depleting it beyond regenerative capacity erodes a productive asset much as neglecting infrastructure maintenance would. This assumption directly underlies the ecological footprint–biocapacity accounting framework and justifies treating biocapacity as a central rather than residual explanatory variable, motivating the present study's central question of whether Nigeria's widening biocapacity deficit is statistically associated with its GDP per capita, life expectancy, and infant mortality outcomes. Four theories are retained as secondary interpretive frameworks.

The Environmental Kuznets Curve Hypothesis (Grossman & Krueger, 1991) [13] posits an inverted-U relationship between growth and environmental degradation; Somoye and Ayobamiji (2024) [27] found partial support for this pattern in Nigeria's load capacity factor, with the country appearing to remain on the curve's rising segment.

The Pollution Haven Hypothesis (Copeland & Taylor, 1994) [4] suggests firms in pollution-intensive industries relocate toward countries with weaker environmental regulation, offering a lens for interpreting FDI's ambiguous ecological effect, though Opoku, Acheampong, Dzator, and Kufuor (2022) [21] found evidence more consistent with a "pollution halo," whereby stronger environmental performance itself attracts FDI.

Endogenous Growth Theory and Human Capital Theory are retained to interpret the roles of renewable energy, human capital, and health investment in long-run growth.

3. Empirical Review and Gap

A substantial body of Nigeria-specific evidence links ecological variables to development outcomes. On the economic side, GDP growth and foreign direct investment are consistently found to worsen Nigeria's ecological footprint even as they expand output (Ismail, 2022) [16], while renewable energy adoption and public–private partnerships moderate this effect (Ajii, 2025) [1]. FDI's developmental effect depends more on Nigeria's absorptive capacity and structural readiness than on inflow volume (Amade & Oyigebe, 2024; Habib, 2021) [2, 14], and evidence on FDI's environmental effect is genuinely mixed, with some studies supporting the Pollution Haven Hypothesis (Ajii, 2025) [1] and others finding environmental performance itself attracts higher-quality FDI (Opoku *et al*., 2022) [21].

On the social side, carbon emissions and broader environmental degradation are consistently linked to reduced life expectancy and elevated infant mortality (Oyedele, 2022; Nwanze, 2023) [18, 22], with forest loss around the time of birth found in one study to raise the likelihood of neonatal death by 9 to 15 percent, chiefly through increased maternal exposure to malaria. Green finance, though still nascent in Nigeria's financial system, shows modest positive long-run effects, with green credit and green investment outperforming the still-maturing green bond market (Pat-Natson, 2024) [23].

Despite this breadth, several gaps remain. First, reviewed studies predominantly treat ecological footprint or carbon emissions as the principal explanatory variable, with biocapacity typically included only as a residual of the footprint calculation rather than examined as a distinct explanatory variable (Somoye & Ayobamiji, 2024) [27]. Second, existing Nigerian studies tend to examine either the economic consequences (GDP per capita) or the social consequences (life expectancy, infant mortality) of ecological change in isolation, with few jointly modelling both dimensions within a single econometric framework using a common set of explanatory variables.

Third, no reviewed study examines green finance, FDI, and renewable energy consumption jointly alongside biocapacity across all three development outcomes within the same study period. Fourth, findings on the FDI–environment nexus and the effectiveness of green finance instruments remain contradictory, suggesting the evidence base would benefit from an updated dataset extending to 2024. It is these gaps — the under-examination of biocapacity as a central explanatory variable, the fragmented treatment of economic and social outcomes, and the absence of a single framework jointly testing Nigeria's ecological system against all three outcomes — that the present study addresses.

Methodology

1. Research Design

The study adopts an ex post facto research design, appropriate because it relies on already-existing macroeconomic and ecological time-series data rather than experimentally manipulable variables (El-Yaqub & Sule, 2024) [6].

2. Model Specification

The study adapts the model specified by Ajii (2025) [1], inverting the original specification to treat Nigeria's ecological indicators as explanatory variables and sustainable development outcomes as dependent variables, extending the explanatory variable set to include ecological footprint, carbon emissions, green finance, foreign direct investment, renewable energy consumption, government health expenditure, urbanisation rate, population, and energy use, and specifying three separate functional models corresponding to the study's three objectives:

Model I (GDP per capita): $GDPPC_t = \beta_0 + \beta_1 BCAP_t + \beta_2 EFP_t + \beta_3 GFIN_t + \beta_4 FDI_t + \beta_5 REC_t + \beta_6 POP_t + \mu_t$

Model II (Life expectancy): $LEX_t = \beta_0 + \beta_1 BCAP_t + \beta_2 EFP_t + \beta_3 CO2_t + \beta_4 GFIN_t + \beta_5 GHE_t + \beta_6 ENU_t + \beta_7 URB_t + \mu_t$

Model III (Infant mortality rate): $IMR_t = \beta_0 + \beta_1 BCAP_t + \beta_2 EFP_t + \beta_3 CO2_t + \beta_4 GFIN_t + \beta_5 GHE_t + \beta_6 URB_t + \beta_7 POP_t + \mu_t$

where BCAP is biocapacity, EFP is ecological footprint, GFIN is green finance, FDI is foreign direct investment, REC is renewable energy consumption, POP is population, CO2 is carbon emissions, GHE is government health expenditure, ENU is energy use, URB is urbanisation rate, β_0 is the intercept, and μ_t is the stochastic error term.

3. Data

The study relies exclusively on annual secondary time-series data for Nigeria covering 2000–2024 [2]. Data on ecological footprint and biocapacity are sourced from the Global Footprint Network's National Footprint and Biocapacity Accounts (2026) [11]. Data on carbon emissions, foreign direct investment, renewable energy consumption, energy use, government health expenditure, urbanisation rate, population, GDP per capita, life expectancy, and infant mortality rate are sourced from the World Bank's World Development Indicators. Data on green finance — green bond issuance, green credit, and carbon finance — are sourced from the Central Bank of Nigeria Statistical Bulletin, the Nigeria Debt Management Office, and the Climate Policy Initiative, consistent with comparable Nigerian green finance studies (Pat-Natson *et al*., 2024) [23].

Table 1: Variable Definitions, Proxies, and Sources

Variable	Proxy / Unit	Source
GDP per capita (GDPPC)	Real GDP per capita (constant US$)	World Bank, WDI
Life expectancy (LEX)	Life expectancy at birth (years)	World Bank, WDI
Infant mortality rate (IMR)	Infant deaths per 1,000 live births	World Bank, WDI
Biocapacity (BCAP)	Total biocapacity (global hectares)	Global Footprint Network
Ecological footprint (EFP)	Total ecological footprint (global hectares)	Global Footprint Network
Carbon emissions (CO2)	CO2 emissions	World Bank, WDI
Green finance (GFIN)	Green bonds, green credit, carbon finance	CBN Statistical Bulletin; Climate Policy Initiative
Foreign direct investment (FDI)	Net FDI inflows (% of GDP)	World Bank, WDI
Renewable energy consumption (REC)	Renewable energy consumption (% of total)	World Bank, WDI
Government health expenditure (GHE)	Government health expenditure (% of GDP)	World Bank, WDI
Urbanisation rate (URB)	Urban population (% of total)	World Bank, WDI
Population (POP)	Total population	World Bank, WDI
Energy use (ENU)	Energy use per capita	World Bank, WDI

4. Estimation Technique

Each series is first tested for stationarity using the Augmented Dickey-Fuller (ADF) test, which corrects for serial correlation by including lagged difference terms, with the Phillips-Perron test as a robustness check (Amade & Oyigebe, 2024) [2]. Given a mix of I(0) and I(1) series with none integrated at I(2), the study applies the Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration (Pesaran, Shin & Smith, 2001, as cited in Ajii, 2025) [1, 24], comparing the computed F-statistic against the tabulated lower [I(0)] and upper [I(1)] critical bounds.

Where cointegration is confirmed, an ARDL Error Correction Model (ECM) is estimated, decomposing the relationship into short-run dynamics and long-run equilibrium adjustment, with the Error Correction Term (ECT) expected to be negative and significant. Pairwise Granger causality tests are then conducted to determine the direction of causality between Nigeria's ecological system and each development outcome. Diagnostic tests comprise the Jarque-Bera test for residual normality, the Breusch-Godfrey test for serial correlation, the Breusch-Pagan-Godfrey test for heteroskedasticity, and CUSUM/CUSUMSQ tests for parameter stability. All estimation is conducted in EViews.

Results and Discussion

1. Descriptive Statistics

Table 2: Descriptive Statistics (2000–2024) [25]

Stat	RGDP	IMR	LEX	EFP	BCAP	CO2	GFIN
Mean	2190.02	74.46	51.29	0.978	0.553	110.55	3.601
Max	2585.73	94.90	54.64	1.142	0.672	130.98	10.00
Min	1421.68	68.00	47.14	0.791	0.410	81.26	0.000
SD	349.77	8.11	2.09	0.102	0.083	15.22	2.489
Skew	-0.966	1.389	-0.394	-0.055	-0.125	-0.255	1.110
JB Prob.	0.163	0.027	0.595	0.554	0.376	0.460	0.055

Note: POP is in millions in the table below (raw units: persons).

Stat	FDI	POP (m)	ENU	URB	GHE	REC
Mean	1.329	18.35	62.58	53.25	0.645	83.31
Max	2.900	27.03	74.66	62.98	1.202	88.10
Min	-0.039	11.51	51.02	43.28	0.446	79.90
SD	0.828	4.83	6.82	6.02	0.211	2.302
Skew	0.271	0.198	0.470	-0.030	1.467	0.310
JB Prob.	0.522	0.433	0.522	0.477	0.012	0.544

Source: Researcher's computation, based on Global Footprint Network and World Bank WDI data.

Real GDP per capita averaged approximately $2,190 over the period, rising unevenly from a 2000 low ($1,421.68) toward a mid-2010s peak. The mean ecological footprint (0.978 global hectares) exceeding mean biocapacity (0.553) confirms, descriptively, the ecological deficit motivating the study. Green finance shows a mean of 3.601 but a minimum of 0.000, reflecting years — particularly early in the series and around 2013 and 2020 — of negligible green financing activity, consistent with a nascent market dating formally to the 2017 sovereign green bond issuance. FDI's minimum of -0.039 confirms a year of net negative inflow (2022). The Jarque-Bera test rejects normality at the 5 percent level for IMR (p = 0.027) and GHE (p = 0.012), and marginally for GFIN (p = 0.055); all remaining series do not significantly depart from normality.

2. Unit Root Test

The Augmented Dickey-Fuller test shows RGDP and GFIN stationary at level, I (0), while IMR, LEX, EFP, BCAP, CO2, FDI, POP, ENU, URB, GHE, and REC are stationary only after first differencing, I(1). No variable is integrated at I (2), satisfying the integration-order requirement for ARDL bounds testing.

3. Model I: Nigeria's Ecological System and GDP Per Capita

Table 3: ARDL Bounds Test — Model I

Significance	I(0) Bound	I(1) Bound
10%	2.031	3.136
5%	2.328	3.500
1%	2.957	4.252

F-statistic = 3.27 (k = 6). **Source:** Researcher's computation.

The computed F-statistic (3.27) exceeds the upper I(1) bound at 10% (3.136) but falls short of the 5% and 1% bounds, rejecting the null of no cointegration at the 10% level and confirming a long-run relationship — albeit a marginal one — between Nigeria's ecological system and GDP per capita.

Table 4: Long-Run Coefficients — Model I (Dependent variable: RGDP)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BCAP	1029.035	1509.883	0.6815	0.4955
EFP	-950.638	541.990	-1.7540	0.0794
GFIN	-39.508	17.771	-2.2232	0.0262
FDI	-180.578	103.048	-1.7524	0.0797
REC	25.677	19.482	1.3180	0.1875
POP	0.0001	0.00003	2.8052	0.0050

Source: Researcher's computation.

Population exerts a positive and highly significant long-run effect on GDP per capita (p = 0.0050), plausibly reflecting the contribution of a growing labour force and domestic market to output, conditional on the economy's capacity to convert population growth into productive employment. Green finance is negative and significant at 5 percent (p = 0.0262) and ecological footprint and FDI are each negative and marginally significant at 10 percent (p = 0.0794 and 0.0797 respectively). The negative green finance coefficient, while contrary to theoretical expectation, is consistent with a market still characterised by limited availability, inconsistent disbursement, and weak institutional frameworks, suggesting that green finance's contribution to growth depends on the efficiency of its deployment rather than its volume alone. The negative FDI coefficient similarly suggests that Nigeria's inflows have been concentrated in capital-intensive or extractive activities with limited domestic productive linkages. Biocapacity and renewable energy consumption are positive but statistically insignificant.

Table 5: Short-Run ECM Estimates — Model I

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(BCAP)	-1356.265	684.847	-1.9804	0.0758
D(EFP)	191.518	435.102	0.4402	0.6692
D(GFIN)	12.672	6.877	1.8428	0.0952
D(FDI)	46.624	33.623	1.3867	0.1957
D(REC)	-30.262	11.038	-2.7416	0.0208
D(POP)	0.0038	0.0015	2.5027	0.0313
ECT (-1)	-0.7221	0.2224	-3.2463	0.0088

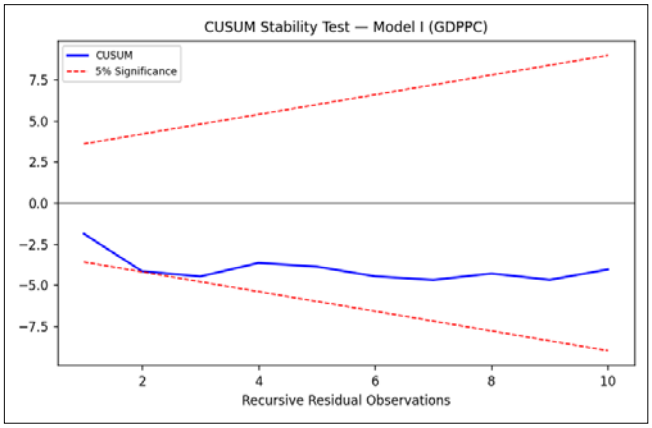
Source: Researcher's computation.

The error correction term is negative and highly significant (p = 0.0088); approximately 72.2 percent of any short-run disequilibrium between Nigeria's ecological system and GDP per capita is corrected within a single year. Renewable energy consumption and population are significant short-run predictors.

Table 6: Diagnostic Tests — Model I

Test	Statistic	p-value	Conclusion
Breusch-Godfrey (serial correlation)	0.0003	0.9858	No serial correlation
Breusch-Pagan (heteroskedasticity)	16.077	0.2450	Homoskedastic
Jarque-Bera (normality)	0.9420	0.6244	Residuals normal

Model I pass all diagnostic tests. The CUSUM plot (Figure 1) remains within the 5 percent critical bounds throughout, confirming parameter stability across 2000–2024.



CUSUM Stability Test — Model I

Fig 1: CUSUM Stability Test — Model I

4. Model II: Nigeria's Ecological System and Life Expectancy

Table 7: ARDL Bounds Test — Model II

Significance	I(0) Bound	I(1) Bound
10%	1.948	3.060
5%	2.222	3.397
1%	2.798	4.092

F-statistic = 3.4121 (k = 7). **Source:** Researcher's computation.

The computed F-statistic (3.4121) exceeds the upper I(1) bound at the 5 percent level (3.397), confirming a genuine long-run relationship between Nigeria's ecological system and life expectancy.

Table 8: Long-Run Coefficients — Model II (Dependent variable: LEX)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BCAP	-7.182	13.457	-0.5337	0.5936
EFP	0.901	3.360	0.2681	0.7886
CO2	0.0558	0.0223	2.5082	0.0121
GFIN	-0.225	0.141	-1.5947	0.1108
GHE	-2.096	1.227	-1.7084	0.0876
ENU	-0.041	0.041	-1.0106	0.3122
URB	-0.615	0.187	-3.2916	0.0010

Source: Researcher's computation.

Urbanisation exerts a negative and highly significant long-run effect on life expectancy (p = 0.0010), suggesting rapid urbanisation has been associated with declining rather than improving life expectancy over the period, plausibly reflecting the strain of unplanned urban growth on housing, sanitation, and health infrastructure. Carbon emissions show a positive and significant long-run relationship with life expectancy (p = 0.0121) — a counterintuitive result relative to theoretical expectation, but consistent with Nigeria occupying the early, upward-sloping segment of an Environmental Kuznets Curve, in which rising emissions still accompany the industrial and energy expansion that funds improved healthcare access. Government health expenditure is marginally significant (p = 0.0876) with an unexpected negative sign, possibly reflecting budget execution inefficiencies. Biocapacity, ecological footprint, green finance, and energy use are statistically insignificant.

Table 9: Short-Run ECM Estimates — Model II

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(BCAP)	1.099	3.011	0.3651	0.7245
D(EFP)	-1.572	1.940	-0.8101	0.4413
D(CO2)	0.0013	0.0066	0.1966	0.8491
D(GFIN)	0.0483	0.0211	2.2883	0.0514
D(GHE)	0.372	0.264	1.4083	0.1967
D(ENU)	0.0067	0.0096	0.7038	0.5016
D(URB)	0.845	6.800	0.1243	0.9042
ECT (-1)	-0.3724	0.1518	-2.4529	0.0398

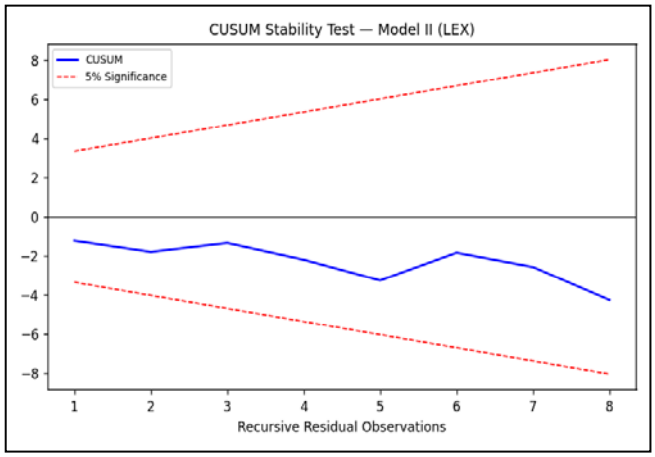
Source: Researcher's computation.

The error correction term is negative and significant (p = 0.0398), confirming a valid error-correcting mechanism, with approximately 37.2 percent of short-run disequilibrium corrected annually. Green finance is marginally significant in the short run (p = 0.0514), suggesting an emerging positive effect on life expectancy not yet evident in the long run.

Table 10: Diagnostic Tests — Model II

Test	Statistic	p-value	Conclusion
Breusch-Godfrey (serial correlation)	1.821	0.1772	No serial correlation
Breusch-Pagan (heteroskedasticity)	18.583	0.2333	Homoskedastic
Jarque-Bera (normality)	0.626	0.7312	Residuals normal

Model II passes all diagnostic tests, and the CUSUM plot (Figure 2) remains within the 5 percent bounds throughout, confirming parameter stability.



CUSUM Stability Test — Model II

Fig 2: CUSUM Stability Test — Model II

5. **Model III:** Nigeria's Ecological System and Infant Mortality Rate

Table 11: ARDL Bounds Test — Model III

Significance	I (0) Bound	I (1) Bound
10%	1.948	3.060
5%	2.222	3.397
1%	2.798	4.092

F-statistic = 17.6825 (k = 7). *Source: Researcher's computation.*

The computed F-statistic (17.6825) far exceeds all critical bounds, including the 1 percent upper bound, providing very strong evidence of cointegration between Nigeria's ecological system and infant mortality rate — the strongest of the study's three models.

Table 12: Long-Run Coefficients — Model III (Dependent variable: IMR)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BCAP	187.224	735.339	0.2546	0.7990
EFP	-75.376	307.777	-0.2449	0.8065
CO2	0.709	2.779	0.2551	0.7986
GFIN	-0.937	3.786	-0.2475	0.8046
GHE	-11.446	44.485	-0.2573	0.7969
URB	31.792	94.509	0.3364	0.7366
POP	-0.00004	0.0001	-0.3578	0.7205

Source: Researcher's computation.

Despite the very strong bounds test result, none of Model III's individual long-run coefficients reach conventional statistical significance. This is attributable to severe multicollinearity among the explanatory variables — the BCAP–URB and BCAP–POP correlations both exceed -0.98 — combined with only 8 residual degrees of freedom given the sample size and number of regressors. The result illustrates a distinction the bounds test alone cannot resolve: strong joint cointegration does not guarantee that any individual regressor's contribution can be separately identified.

Table 13: Short-Run ECM Estimates — Model III

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(BCAP)	7.995	3.856	2.0736	0.0718
D(EFP)	-0.250	2.762	-0.0904	0.9302
D(CO2)	0.0093	0.0097	0.9625	0.3640
D(GFIN)	-0.0274	0.0252	-1.0892	0.3078
D(GHE)	-0.342	0.366	-0.9350	0.3772
D(URB)	-13.277	7.001	-1.8966	0.0945
ECT (-1)	0.0604	0.2318	0.2607	0.8009

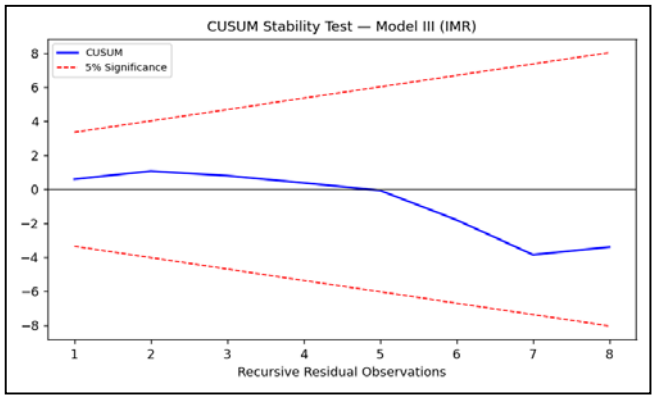
Source: Researcher's computation.

Model III's error correction term is positive (0.0604) rather than negative, and statistically insignificant (p = 0.8009). A positive ECT is theoretically inconsistent with a valid error-correcting mechanism, since it implies the system does not converge back toward long-run equilibrium after a shock — a tension with the strong cointegration signal from the bounds test. This is reported as a limitation of the estimated short-run specification, attributable to the same multicollinearity and degrees-of-freedom constraints noted above, rather than evidence against the underlying long-run relationship, which remains strongly supported by the bounds test.

Table 14: Diagnostic Tests — Model III

Test	Statistic	p-value	Conclusion
Breusch-Godfrey (serial correlation)	0.568	0.4511	No serial correlation
Breusch-Pagan (heteroskedasticity)	14.567	0.4830	Homoskedastic
Jarque-Bera (normality)	0.429	0.8071	Residuals normal

Model III passes all diagnostic tests, and the CUSUM plot (Figure 3) remains within the 5 percent bounds throughout, confirming parameter stability despite the error correction term anomaly noted above.



CUSUM Stability Test — Model III

Fig 3: CUSUM Stability Test — Model III

6. Granger Causality Test

Table 15: Pairwise Granger Causality Results (summary of significant pairs, p < 0.10)

Model	Direction	F-Statistic	Prob.
I	FDI → RGDP	—	Significant
I	REC → RGDP	—	Significant
I	RGDP → EFP, GFIN, POP	—	Significant
II	URB ↔ LEX (bidirectional)	—	Significant
II	LEX → EFP, BCAP, CO2, GFIN, ENU	—	Significant
III	BCAP → IMR	33.008	0.0000
III	EFP → IMR	53.840	0.0000
III	CO2 → IMR	32.789	0.0000
III	URB → IMR	33.634	0.0000
III	POP → IMR	33.159	0.0000
III	GHE ↔ IMR (bidirectional)	6.606 / 6.479	0.0178 / 0.0188

Source: Researcher's computation; full pairwise results available from the author on request.

In Model I, causality runs predominantly from FDI and renewable energy consumption toward GDP per capita, while GDP per capita in turn Granger-causes ecological footprint, green finance, and population — suggesting Nigeria's economic growth shapes several ecological and financial variables rather than the reverse. In Model II, causality runs bidirectionally between urbanisation and life expectancy, and predominantly from life expectancy toward the remaining ecological variables. Model III shows the clearest and most theoretically consistent causal pattern in the study: biocapacity, ecological footprint, carbon emissions, government health expenditure, urbanisation, and population all Granger-cause infant mortality rate at conventional significance levels, with feedback effects running from infant mortality back to several variables, plausibly reflecting reactive policy and behavioural responses to rising mortality.

Conclusion, Implications, and Recommendations

1. Summary of Findings

This study set out to examine the effect of Nigeria's ecological system on sustainable economic development, proxied by GDP per capita, life expectancy, and infant mortality rate, over 2000–2024. Using ARDL bounds testing across three models, the study finds cointegration in all three cases, though of markedly different strength: marginal for GDP per capita (significant only at 10%), confirmed at the 5 percent level for life expectancy, and very strongly confirmed for infant mortality rate. In the long run, population is the only variable with a robust, positive,

and significant effect on GDP per capita, while green finance, foreign direct investment, and ecological footprint each depress it; urbanisation depresses life expectancy while carbon emissions and, marginally, green finance in the short run, are associated with improvements consistent with Nigeria's position on the early segment of an Environmental Kuznets Curve; and the infant mortality model, despite the strongest cointegration signal of the three, yields no individually significant long-run coefficients because of severe multicollinearity among its regressors, even as its error correction term and Granger causality results confirm that the ecological system is genuinely and predominantly a cause, rather than a consequence, of infant mortality outcomes. All three models pass diagnostic tests for serial correlation, heteroskedasticity, and normality, and all three are parametrically stable over the study period.

2. Conclusion

The evidence supports rejecting each of the study's three null hypotheses, at least in part: Nigeria's ecological system is statistically linked to GDP per capita, life expectancy, and infant mortality rate. However, the linkage is neither uniform nor uniformly reassuring. The channels theorised to convert Nigeria's ecological and financial resources into sustainable development — green finance and foreign direct investment above all — are associated with worse, not better, GDP per capita outcomes in the long run, a pattern consistent with a still-nascent, inefficiently disbursed green finance market and an FDI inflow concentrated in activities with weak domestic productive linkages. Urbanisation, meanwhile, is statistically corrosive to life expectancy even as it is bidirectionally entangled with it, and the infant mortality model confirms that Nigeria's ecological system — biocapacity, ecological footprint, and carbon emissions foremost — is a genuine driver of infant mortality outcomes, the study's single clearest and most policy-relevant causal finding. Taken together, the results indicate that Nigeria's growth has continued to be achieved substantially independent of, and in some respects at the expense of, its ecological base, consistent with the ecological deficit trend documented throughout this study, and that the specific mechanisms available to reverse this pattern are not yet functioning as theorised.

3. Policy Recommendations

First, given green finance's negative long-run association with GDP per capita, the Central Bank of Nigeria and the Debt Management Office should prioritise strengthening the institutional and disbursement infrastructure around green bonds and green credit — including clearer project pipelines and disbursement monitoring — over simply expanding their nominal volume, since the evidence suggests inefficient deployment, not insufficient supply, is the binding constraint. Second, given FDI's negative long-run coefficient and its concentration in extractive and capital-intensive sectors, investment promotion agencies should actively steer inflows toward sectors with stronger domestic linkages, particularly renewable energy and agro-processing, rather than pursuing inflow volume as an end in itself. Third, given urbanisation's significant negative effect on life expectancy, urban health and sanitation infrastructure investment should be scaled in step with urban population growth rather than lagging it, since the results suggest current urban expansion is outpacing the health-system capacity needed to convert it into welfare gains. Fourth, given the strong and consistent finding that biocapacity, ecological footprint, and carbon emissions Granger-cause infant mortality, environmental health policy — air and water quality regulation in particular — should be treated as child health policy, not merely environmental policy, and coordinated accordingly between the Federal Ministry of Environment and the Federal Ministry of Health.

4. Limitations and Suggestions for Further Research

The study's principal limitation is the severe multicollinearity affecting Model III's long-run estimates, which prevents individual coefficients from being separately identified despite very strong joint cointegration; future research could address this using ridge-ARDL, partial least squares, or a reduced-form specification with orthogonalised regressors. The 25-year annual sample, while adequate for ARDL estimation, limits the degrees of freedom available for models with seven regressors; future studies could extend the series as further Global Footprint Network and World Development Indicator releases become available, or adopt quarterly interpolation to increase sample size. Finally, the study is confined to the national level; state-level or sectoral disaggregation, particularly by ecological zone, would allow future research to identify which of Nigeria's ecologically distinct regions are driving the national-level relationships identified here.

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