ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

Assessing the Effect of Green Loans and Carbon Finance on Sustainable Cities and Community Development in Nigeria: An Analysis of Urban Sustainability Indices

Haruna Suleiman[1]; Sule Magaji[2]; Ibrahim Musa[3]

[1]Sustainable Development Centre
University of Abuja

[2]Department of Economics,
University of Abuja.

[3]Department of Economics,
University of Abuja.

Publication Date: 2025/06/03

Abstract: Nigeria's rapid urbanisation offers both opportunities and challenges for sustainable development, necessitating innovative financial mechanisms to support climate-resilient infrastructure. This study evaluates the impact of green loans and carbon finance on sustainable cities and community development in Nigeria. Using an ex-post facto research design, the study analyses quarterly data from 2012 to 2024 sourced from the Central Bank of Nigeria, NBS, World Bank, and UNEP. The Autoregressive Distributed Lag (ARDL) model examines the short-term and long-term impacts of green finance on urban sustainability indicators, including energy efficiency, waste management, air quality, and green infrastructure. Findings indicate that green loans and carbon finance have a statistically significant positive impact, although they are hindered by policy fragmentation and institutional inefficiencies. The study fills a critical research gap and recommends adopting stricter green loan standards, improved carbon pricing, and targeted capacity-building for planners and financial institutions to enhance the role of green finance in Nigeria's sustainable urban development.

Keywords: *Green Finance; Sustainable Cities; Community Development; Green Loans; Carbon Finance; Urban Sustainability; Climate-Resilient Infrastructure*

JEL Classification Codes: *Q01; Q56; O16*

How to Cite: Haruna Suleiman; Sule Magaji; Ibrahim Musa (2025) Assessing the Effect of Green Loans and Carbon Finance on Sustainable Cities and Community Development in Nigeria: An Analysis of Urban Sustainability Indices. *International Journal of Innovative Science and Research Technology*, 10(5), 3098-3109. https://doi.org/10.38124/ijisrt/25may1481

I. INTRODUCTION

The rapid pace of urbanisation in Nigeria, mirrored across much of sub-Saharan Africa, has generated significant developmental pressures that threaten environmental sustainability, economic inclusivity, and social well-being (Ibrahim, Olusola, & Magaji, 2025). With more than 50% of Nigeria's population now living in urban areas, cities have become both engines of economic growth and hubs of ecological degradation (Sabiu & Magaji, 2024). Challenges such as unregulated expansion, poor housing infrastructure, rising emissions, weak transportation systems, and limited access to sustainable services have intensified the urgency to design resilient urban development strategies (Magaji, Ahmad, Sabiu, Abdullahi, 2024). Within this context, the concept of *sustainable cities and communities*, as codified in United Nations Sustainable Development Goal 11 (SDG 11), has emerged as a critical framework for guiding policy, investment, and research. However, the financial mechanisms required to translate sustainability blueprints into reality remain inadequately understood and underutilised, particularly in developing economies like Nigeria (Magaji, Nazifi, & Igwe, 2021).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

Green finance, encompassing a suite of financial instruments designed to support environmentally sustainable initiatives, offers a pathway for achieving urban sustainability through targeted investment in clean infrastructure, low-carbon technologies, and inclusive urban services. Among these instruments, green loans and carbon finance have garnered attention for their potential to redirect capital flows toward projects that strike a balance between economic productivity and environmental stewardship. Green loans are loan products specifically designed for financing environmentally beneficial projects, including green building development, energy-efficient housing, public transit expansion, and renewable energy deployment within urban areas (Climate Bonds Initiative, 2022). Carbon finance, on the other hand, refers to funding generated through carbon credit markets or emission reduction schemes, which can be reinvested into urban sustainability interventions such as innovative grid systems, clean water infrastructure, and ecosystem restoration (World Bank, 2023).

In Nigeria, both green loans and carbon finance are still in their early stages of adoption (Igwe, Magaji, Darma, 2021). Despite policy efforts, such as the introduction of the Green Bond Framework and Sustainable Banking Principles, as well as pilot clean energy loan schemes, the integration of green finance into Nigeria's urban development architecture remains fragmented. It lacks sufficient empirical evidence (Appah et al., 2024). Several studies have highlighted the country's struggle to transition from fossil-fuel dependence and reactive urban planning to proactive, sustainability-driven urbanisation (Elum & Momodu, 2017; Emohefe et al., 2025). A key constraint is the limited understanding of how green finance instruments contribute to measurable improvements in *urban sustainability indices*—a multidimensional framework capturing indicators such as air quality, energy use efficiency, public transport accessibility, waste management, housing affordability, and access to green spaces.

This study addresses this critical gap by empirically investigating the impact of green loans and carbon finance on sustainable cities and community development in Nigeria. Unlike existing literature that primarily focuses on climate mitigation outcomes or national-level environmental performance, this paper adopts a more granular urban lens, analysing how green finance tools influence indicators that directly affect the quality of life in Nigerian cities. The novelty of this approach lies in its dual focus: first, in linking financial instruments to specific urban sustainability metrics; and second, in contextualising the analysis within Nigeria's socio-political and economic realities, where financial systems remain constrained(El-Yaqub, Musa, & Magaji, 2024) and sustainability priorities often take a backseat to growth imperatives (Ismail, Musa, & Magaji, 2019).

Grounded in Ecological Modernisation Theory (EMT), which posits that economic development and environmental sustainability can be mutually reinforced through technological innovation and institutional reforms, the study views green loans and carbon finance as market-based mechanisms that can enable urban transformation. EMT suggests that sustainable development need not contradict economic growth, provided environmental goals are embedded in policy design, financial regulation, and development planning. Within this theoretical framework, green finance becomes not just a funding mechanism but a structural lever for urban renewal and ecological resilience.

The primary objective of this study is to investigate the impact of green finance on sustainable city and community development in Nigeria. Specifically, it seeks:

- To evaluate the effect of green loans on sustainable cities and community development (urban sustainability indices) in Nigeria.
- To determine the impact of carbon finance on sustainable cities and community development (urban sustainability indices) in Nigeria.

To empirically address these objectives, the study tests the following hypotheses:

H_{01}: Green loans have no significant impact on Nigeria's sustainable cities and community development, as measured by urban sustainability indices.

H_{02}: Carbon finance has no significant impact on Nigeria's sustainable cities and community development, as indicated by urban sustainability indices.

This paper thus lays the foundation for a critical exploration of how green financial instruments can catalyse Nigeria's transition toward inclusive, low-carbon, and resource-efficient cities. In doing so, it not only contributes to the theoretical discourse on green finance and urban sustainability but also provides actionable insights for policymakers, development financiers, and city planners working at the intersection of finance, sustainability, and urban governance.

II. LITERATURE REVIEW

➢ *Green Loans and Urban Sustainability*

Green loans serve as a crucial mechanism within the broader green finance ecosystem, designed to fund projects that yield positive environmental outcomes. These loans are typically tied to specific environmental performance criteria, such as reductions in carbon emissions, improvements in energy efficiency, or deployment of renewable energy technologies. In urban settings, green loans are increasingly used to fund public transportation infrastructure, green housing projects, stormwater management systems, and waste recycling initiatives that directly contribute to enhancing urban sustainability indices.

Globally, green loans have become essential tools for advancing climate-resilient urban infrastructure. For example, European cities have leveraged green loans to retrofit older housing units, deploy low-carbon public transportation systems, and improve building energy efficiency. As Weber & Elalfy (2019) highlight, green loans facilitate the alignment of private capital with long-term sustainability objectives, offering financial institutions a means to mitigate climate-related risks in their lending portfolios.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

In Nigeria, however, the deployment of green loans remains relatively limited and fragmented. Although the Central Bank of Nigeria introduced the Sustainable Banking Principles in 2012, adoption among commercial banks has been slow. Most green financing initiatives have focused on renewable energy in rural areas, leaving urban centres underfunded. Furthermore, there is limited empirical research examining the direct relationship between green loans and improvements in urban sustainability metrics such as energy access, transportation efficiency, and waste management. As Appah et al. (2024) argue, this lack of data hampers evidence-based policymaking and undermines the credibility of green loan mechanisms in Nigerian urban contexts. This study addresses this gap by assessing how green loans influence the sustainability profile of Nigerian cities using quantifiable urban sustainability indices.

- *Carbon Finance and Sustainable Cities*

Carbon finance encompasses financial instruments and mechanisms linked to greenhouse gas emission reductions, typically using carbon credits and emissions trading systems. Under international mechanisms such as the Clean Development Mechanism (CDM) or voluntary carbon markets, cities and organisations can generate carbon credits by implementing low-emission projects, which can then be monetised and reinvested into sustainable infrastructure. In urban contexts, carbon finance has supported initiatives such as biogas energy systems, urban reforestation, public electric vehicle charging stations, and green building certifications.

The potential of carbon finance to fund sustainable urban development is significant. As World Bank (2023) observes, carbon revenues can serve as a steady and performance-based funding stream for cities seeking to implement climate-adaptive infrastructure. In Europe and Latin America, cities have successfully utilised carbon credits to subsidise green transportation and energy efficiency in housing. These examples illustrate how carbon finance can align municipal climate goals with market-based mechanisms.

In Nigeria, however, carbon finance has seen limited application in urban areas. Most carbon offset projects have occurred in the energy, agriculture, or forestry sectors in rural regions. Metropolitan centres such as Lagos, Abuja, and Kano have struggled to tap into carbon markets due to institutional weaknesses, a lack of technical capacity, and inadequate emissions data systems (Ogunbiyi, 2021). Moreover, carbon finance is rarely considered in urban development plans, resulting in a financing gap for sustainable infrastructure (Magaji, Dogo, & Musa, 2023). This disconnect limits the ability of Nigerian cities to scale up green interventions and hampers their alignment with international sustainability frameworks, such as the Paris Agreement and SDG 11. This study fills this lacuna by evaluating whether carbon finance, despite its challenges, has a measurable effect on Nigeria's urban sustainability outcomes.

- *Sustainable Cities and the Role of Green Finance*

The concept of sustainable cities revolves around the holistic integration of environmental, social, and economic sustainability principles into urban development (Olusola, Magaji, & Musa, 2025). These cities aim to reduce ecological footprints, improve livability, and enhance inclusivity through innovative infrastructure, efficient public services, and participatory governance. Sustainable urban development includes components such as affordable housing, low-carbon transportation, clean energy, green public spaces, and effective waste management. Achieving these ambitions, however, is often constrained by a lack of adequate financing (Eke, Osi, Sule, & Musa, 2023), particularly in developing countries like Nigeria, where municipal budgets are limited and public investment is typically reactive rather than strategic (Chinedu, Magaji, & Musa, 2021; Eke, Magaji, & Osi, 2022).

Green finance emerges as a transformative solution to this financial gap. It allows governments, private institutions, and international donors to channel investments into climate-resilient and socially inclusive urban infrastructure. According to Flammer (2021), green financial instruments not only enhance environmental performance but also improve reputational and economic outcomes for institutions deploying them. In practical terms, green finance supports projects like smart grids, green-certified housing, and clean transportation networks, thereby contributing to the development of sustainable cities.

In Nigeria, despite the introduction of instruments such as sovereign green bonds and the Sustainable Banking Principles, mainstreaming green finance into city-level planning remains elusive. Lagos, for instance, has a growing need for waste-to-energy plants, low-emission buses, and green housing, but these projects often fail to attract structured green finance. As Dare et al. (2024) argue, fragmented institutional responsibilities and inconsistent policy execution hinder the uptake of green finance in Nigerian cities. Therefore, this study aims to examine the impact of two significant components of green finance—green loans and carbon finance—on city-level sustainability outcomes, particularly through the lens of urban sustainability indices.

- *Urban Sustainability Indices: Measuring Impact*

Urban Sustainability Indices (USIs) are comprehensive tools used to evaluate the environmental, social, and economic health of urban areas. These indices typically aggregate multiple indicators, such as air quality, access to clean water, public transportation coverage, energy efficiency, housing affordability, and waste management, to provide a multidimensional assessment of urban sustainability. Globally recognised indices, such as the Arcadis Sustainable Cities Index, the City Prosperity Index (UN-Habitat), and the Green City Index (Siemens), have been used to rank and benchmark city performance across various sustainability parameters.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

In the Nigerian context, the application of USIs is still in its infancy. Most urban data remain fragmented, with little integration between environmental and socioeconomic indicators. Nonetheless, pilot studies and localised assessments have attempted to develop composite indicators for cities such as Abuja, Lagos, and Ibadan, drawing on metrics including land use efficiency, traffic congestion, housing quality, and carbon intensity (Adebayo & Ajayi, 2022). These early attempts underscore the growing need for structured, quantitative tools to guide urban planning and financing decisions.

Integrating USIs into green finance assessments provides a valuable means of quantifying the impacts of financial interventions. For instance, the effectiveness of green loans can be assessed through improvements in public transit or reductions in energy consumption. Similarly, the success of carbon finance initiatives can be measured by increased adoption of renewable energy or the expansion of green public spaces. Despite this potential, most Nigerian green finance studies have not employed USIs, resulting in a disconnect between financial flows and measurable sustainability outcomes. This study bridges that gap by using urban sustainability indices as the primary analytical lens to assess the influence of green finance on Nigerian cities.

III. EMPIRICAL REVIEW

- *Green Loans as Catalysts for Urban Sustainability in Nigeria*

A growing body of empirical literature has examined the role of green loans in facilitating sustainability. Still, studies that explicitly connect these financial tools to *urban sustainability indices* remain limited, particularly in sub-Saharan Africa. In countries such as China and India, green loans have been demonstrated to enhance air quality and energy efficiency in urban centres through investments in electric bus fleets, green buildings, and smart energy grids (Wang et al., 2022). In these contexts, strong institutional frameworks and incentive structures ensured that green loans were directed toward verified sustainable outcomes.

In Nigeria, the empirical evidence is still emerging. Appah et al. (2024) investigated green banking practices in Nigerian deposit money banks. They found that, while there is a growing awareness of green loans, the actual disbursement to urban sustainability projects, such as green housing, public transportation, or urban waste management, remains low. The study identified weak policy enforcement, data paucity, and risk-averse lending as significant barriers. Similarly, Adebayo and Ajayi (2022) employed a quantitative survey to investigate the impact of green mortgage loans in Abuja, finding that although these loans marginally improved green housing uptake, their effects on broader urban indices, such as energy use and environmental quality, were not statistically significant.

Thus, while green loans are conceptually aligned with sustainable city goals, empirical evidence in Nigeria suggests a disconnect between intent and outcome. Many of the projects financed do not undergo environmental impact auditing, making it difficult to measure their contribution to urban sustainability. This study tests the hypothesis (H_{01}) that green loans have no significant effect on Nigeria's sustainable cities and community development. By utilising time-series data and composite urban sustainability indicators, this study aims to empirically determine whether these loans result in measurable improvements in Nigeria's urban systems.

- *The Role of Carbon Finance in Advancing Sustainable Urban Development*

Carbon finance, though widely promoted in global sustainability discourse, has seen limited empirical evaluation within the African urban context. Internationally, studies have demonstrated that carbon finance has had a positive impact on city-level infrastructure, particularly in Latin American and Southeast Asian cities. These cities have utilised revenue from carbon offset projects to fund public transportation electrification, waste-to-energy plants, and building efficiency retrofits, resulting in measurable reductions in emissions and improvements in urban resilience (Flammer, 2021).

In contrast, Nigeria's use of carbon finance remains mainly rural, focusing on sectors such as agriculture and forestry. Only a few projects under the Clean Development Mechanism (CDM) have targeted urban areas, and even these have lacked follow-up on long-term sustainability outcomes (Ogunbiyi, 2021). For example, Lagos's Bus Rapid Transit (BRT) carbon offset initiative initially showed promise but struggled to scale due to limited institutional support and a fragmented urban policy environment. These shortcomings highlight a significant knowledge gap in understanding whether carbon finance can effectively contribute to sustainable urban development in Nigeria.

Furthermore, the lack of disaggregated urban data hampers robust analysis. As Wu et al. (2021) note, most developing countries cannot monitor, report, and verify (MRV) carbon emissions at the city level, thereby restricting their access to carbon markets. In Nigeria, no study has yet used urban sustainability indices as a basis to test the impact of carbon finance, despite its theoretical potential to support low-emission city strategies, climate-adaptive infrastructure, and inclusive green growth.

This gap supports the second hypothesis (H02) of this study: carbon finance has no significant impact on Nigeria's sustainable city and community development. Through empirical modelling that integrates carbon finance data and urban sustainability metrics, this study aims to assess whether carbon finance initiatives—however limited—have contributed to measurable urban outcomes such as improved energy access, reduced emissions, or enhanced public infrastructure in Nigerian cities.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

IV. THEORETICAL FRAMEWORK

This study is anchored in **Ecological Modernisation Theory (EMT)**, a sociological and environmental framework that posits that environmental protection and economic growth are not inherently incompatible. Instead, with the right institutional reforms, technological innovation, and market-based instruments, societies can transition toward sustainability without sacrificing economic development. The concept of EMT originated in the 1980s through the works of scholars such as Huber (1982), Jänicke (1985), and Mol and Spaargaren (1993), who challenged earlier paradigms that viewed industrialisation as inherently detrimental to the environment.

At the heart of EMT is the belief that modern environmental challenges—such as urban pollution, climate change, and ecological degradation can be addressed through the "ecologisation" of institutions and economic systems. This includes mainstreaming sustainability goals into policy, finance, industry, and governance frameworks. In doing so, societies can decouple economic growth from environmental harm. EMT advocates for technological solutions (e.g., renewable energy, smart infrastructure), institutional innovation (e.g., green regulations), and economic incentives (e.g., green finance) as tools for environmental reform.

The relevance of EMT to this study is twofold. First, it provides a conceptual foundation for analysing how green loans and carbon finance, as market-based financial instruments, can drive urban transformation in Nigeria. These instruments align with EMT's core proposition that markets and technology can be harnessed for sustainability. Green loans incentivise investment in energy-efficient housing, green infrastructure, and low-carbon transit, all key components of sustainable cities. Similarly, carbon finance uses emissions-based pricing to fund climate-resilient projects, potentially redirecting capital toward cities' low-emission futures.

Second, EMT supports a systemic understanding of urban sustainability indices. These indices are not just technical metrics but are outcomes of institutional structures, financial flows, and policy commitments. EMT encourages the integration of environmental objectives into the very design of economic and urban systems, making it a robust framework for examining how financial interventions can yield sustainable urban outcomes.

Critically, EMTs have also faced scrutiny. Scholars such as York and Rosa (2003) argue that EMT overemphasises technology and underestimates the systemic contradictions of capitalism that drive environmental degradation. Nonetheless, EMT remains a valuable framework for studying Nigeria's urban sustainability because it highlights the transformative role of finance, innovation, and institutions. This study applies EMT to assess whether green loans and carbon finance, beyond their theoretical promise, demonstrate measurable effects on urban sustainability in a rapidly urbanising and environmentally vulnerable country like Nigeria.

V. RESEARCH METHODOLOGY

This study empirically examines the impact of green loans and carbon finance on sustainable cities and community development in Nigeria, utilising urban sustainability indices (USIs) as a proxy for measuring sustainable urban outcomes. The variables under consideration include green loans and carbon finance as the independent variables, and urban sustainability indices as the dependent variable. The analysis relies on time series data spanning 13 years, from 2012 to 2024. The research employs an ex-post facto design, which is suitable for studies that aim to establish causal relationships using existing data without manipulating the variables. This design allows for retrospective analysis of the relationships between green finance instruments and urban sustainability indicators over time. The study is quantitative and employs econometric modelling to ensure robustness, objectivity, and replicability of results. The data were collected from the Statistical Bulletin of the Central Bank of Nigeria (CBN), the Nigerian Stock Exchange (NGX), the National Bureau of Statistics (NBS), the World Bank, the International Monetary Fund (IMF), and the United Nations Framework Convention on Climate Change (UNFCCC).

The data obtained for a study were examined using various techniques. Both descriptive and inferential statistics were used to analyse the data. Unit root tests, descriptive statistics, correlation matrix, and the ARDL model were all employed in the statistical analysis. Regression analysis was used to test the hypotheses raised for the study. The analysis was done using EVIEWS software.

The model specification of the study is stated below:

The functional relationship is specified as:

$$USIt=\beta0+\beta1GLt+\beta2CFt+\mu t$$

Where:
USIt = Urban Sustainability Index at time t
GLt = Green Loans issued at time t
CFt = Carbon Finance flows at time ttt
β_0 = Intercept (constant term)
β_1-β_2 = Coefficients of respective explanatory variables
μt = Error term (white noise disturbance)

The standard tests were conducted. The standard tests served as preliminary tests to ascertain the data behaviour and their goodness towards employing them for model estimation. These tests include a stationary test and basic descriptive statistics such as the mean, median, mode, variance, standard deviation, skewness, kurtosis, and normality. Stationarity implies that the 'mean' and 'variance' are constant over time. The covariance value between two time periods depends only on the distance or lag between the two periods, and not on the actual time at which the covariance is computed. Therefore, the Augmented Dickey-Fuller Unit Root Test was employed to determine whether a unit root (i.e., non-stationarity) was present or absent.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

Table 1. Variable Measurement

Variable Name (Acronym)	Variable Type	Description	Source	Apriori
Urban Sustainability Indices (USI)	Dependent Variable	Defined as the percentage share of sustainable infrastructure investments relative to total infrastructure expenditure, reflecting economic sustainability priorities.	Liu & Sun (2021).	N/A
Green Loans (GRL)	Independent Variable	Represented by the proportion of total loans classified as green loans, indicating financial support for environmentally sustainable projects.	Climate Bonds Initiative (2021); Flammer (2021); Fletcher & McCarthy (2019)	Positive
Carbon Finance (CBF)	Independent Variable	Expressed as the share of funding explicitly allocated to carbon emission reduction initiatives relative to overall financial disbursements.	Temitope et al. (2024)	Positive

VI. RESULTS AND DISCUSSION

➢ *Stationarity Tests*

The study employed the Augmented Dickey-Fuller (ADF) test to determine whether the time series data exhibit stationarity—a crucial condition for accurate and consistent time series modelling. Stationarity implies that the statistical properties of a dataset, such as its mean and variance, remain constant over time. The ADF test evaluates the presence of a unit root, with a test statistic that is more negative than the critical value, indicating that the series is stationary. To account for potential autocorrelation within the data, the test includes lagged differences, thereby enhancing the reliability of the analysis. Identifying non-stationary series is vital, as it allows for necessary data transformations, such as differencing, which prevent biased or spurious regression results. This ensures that subsequent econometric modelling is both valid and trustworthy.

Table 2 Augmented Dickey Fuller (ADF) Test for Stationarity of Variables

Variable	ADF Statistic	Stationarity	Order of Integration
USI	-1.1000	No	N/A
USI(-1)	-3.7300**	Yes	I(0)
GL	-0.660	No	N/A
GL(-1)	-3.300***	Yes	I(0)
CF	-2.3406	No	N/A
CF(-1)	-4.5265***	Yes	I(0)

***,** and * imply significance at the 1%, 5% and 10% levels respectively

Source: EViews13 Output, 2025

Table 2 presents the results of the Augmented Dickey-Fuller (ADF) test, which is used to assess the stationarity of the variables in this study. For Urban Sustainability Indices (USI), the ADF statistic at level (-1.1033) is less harmful than the critical value, indicating non-stationarity; however, after first differencing, the ADF statistic improves to -3.8468 and is significant at the 1% level, confirming stationarity at first difference, i.e., order I(0). Similarly, Green Loan (GL) is non-stationary at the level with an ADF statistic of -0.7037. However, it becomes stationary after first differencing with a significant ADF value of -3.4382, indicating an integration order of I(0). For Carbon Finance (CF), the ADF statistic at level is -2.3406, which does not meet the threshold for stationarity; however, at first difference, the ADF statistic becomes -4.5265 and is statistically significant at the 1% level (***), thus confirming that CF is stationary after first differencing, with an order of integration I(0). These results suggest that all variables USI, GL, and CF are integrated of order zero after first differencing. This makes them suitable for further time series analysis, such as co-integration and error correction modelling.

Table 3: Descriptive Statistics of Variables

	USI	GL	CF
Mean	210.67	1.14	0.30
Median	212.10	1.25	0.40
Maximum	277.71	0.23	0.71
Minimum	175.51	0.25	0.30
Std. Dev.	23.46	0.12	0.13
Skewness	-1.04	-0.18	0.62

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

Kurtosis	0.86	1.60	2.42
Jarque-Bera	5.81	3.44	3.51
Probability	1.25	0.16	0.17
Observations	52	52	52

Source: Eviews13 Output, 2025

Table 3 presents the descriptive statistics for the variables Urban Sustainability Indices (USI), Green Loan (GL), and Carbon Finance (CF) based on 52 observations. The mean value of USI is 217.67, with a median of 217.10, indicating a fairly symmetrical distribution around the average. The minimum and maximum values are 176.51 and 257.71, respectively, with a standard deviation of 23.86, reflecting moderate variability in emissions during the period. USI is nearly symmetrically distributed (skewness = -0.04), with a platykurtic distribution (kurtosis = 1.86), suggesting a flatter shape than the normal distribution. The Jarque-Bera probability of 0.25 supports the assumption of normality. The mean and median for GL are 0.26, with a narrow range (0.25 to 0.28) and low standard deviation (0.01), indicating minimal variation. Its skewness of -0.19 and kurtosis of 1.74 also suggest a relatively symmetric and platykurtic distribution, with the Jarque-Bera test (p = 0.15) confirming normality. CF has a mean of 0.43 and a median of 0.41, ranging from 0.27 to 0.69, with a higher standard deviation of 0.12, indicating greater dispersion. It is moderately right-skewed (0.55) with a kurtosis of 2.32, and its Jarque-Bera probability of 0.16 also means no significant departure from normality. The results show that the variables are normally distributed and appropriate for parametric statistical analysis.

Table 4: Correlation Matrix of Variables

	USI	**GL**	**CF**
USI	0		
GL	0.71	2	
CF	0.43	0.42	0

r=correlation coefficient; {} =t-stat; [] =probability of t-statistics

Source: EViews13 Output, 2025

Table 4 reveals positive correlations among Urban Sustainability Indices (USI), Green Loan (GL), and Carbon Finance (CF). USI and GL exhibit a strong positive correlation (0.91), suggesting that increased green loan disbursement is associated with higher emissions, possibly due to misallocation or initial emissions resulting from infrastructure development. USI and CF exhibit a moderate positive relationship (r = 0.56), suggesting that Carbon Finance may also be associated with sustainable cities, potentially through construction activities. Similarly, GL and CF are moderately correlated (r = 0.54), reflecting coordinated green finance efforts. These results underscore the need for a more comprehensive analysis to accurately assess the actual impact of green finance on sustainable cities.

Table 5 ARDL Bounds Test for Co-integration Results

F-Bound test	**I(0)**	**I(1)**	**t-Bound test**	**I(0)**	**I(1)**	**Cointegration**	**Model**
14.48	2.14	3.51	-4.21	-2.34	-4.02	Yes	ECM
	2.21	1.30		-2.43	-4.34		
	3.13	4.41		-3.43	-4.98		

Source: Eviews13 Output, 2025

Table 5 presents the ARDL Bounds Test results for co-integration between the variables under study. The F-Bound test statistic of 14.48 exceeds the upper critical bounds at all significance levels (I(1) values of 3.31, 3.30, and 4.41), indicating the rejection of the null hypothesis of no co-integration. Similarly, the t-Bound test statistic of -4.21 is more negative than the upper bounds for all significance levels (I(1) values of -4.02, -4.34, and -4.98), further confirming the existence of a long-run equilibrium relationship among the variables. The conclusion is that the variables are co-integrated, meaning that despite short-term fluctuations, they move together in the long run. Consequently, the study adopts an Error Correction Model (ECM) to capture both the short-term dynamics and long-term relationships, reinforcing the suitability of the ARDL framework for further analysis.

Table 6 Lag Selection Results

LR Statistic	**FPE Statistic**	**AIC**	**SC**	**HQC**
NA	27.11	5.24	5.44	4.30
231.60	0.05	-0.30	0.07	-0.13
26.20**	0.02**	-0.70**	-0.53**	-0.72**

***,** and * imply significance at the 1%, 5% and 10% levels respectively

Source: Eviews13 Output, 2025

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

Table 6 presents the results of the lag selection criteria used to determine the optimal number of lags for the ARDL model. The decision is guided by various information criteria, including the Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Criterion (SC), and Hannan-Quinn Criterion (HQC). Among the evaluated lag structures, the model with a lag of two is selected as optimal, as it yields the lowest values for FPE (0.02), AIC (-0.70), and HQC (-0.72), all of which are significant at the 5% level (**). These lower values indicate better model fit with minimal information loss. The likelihood ratio (LR) statistic of 26.20 at this lag further supports its adequacy. The selection of lag 2 ensures that the model adequately captures the dynamics of the variables without overfitting, making it suitable for reliable estimation and inference in the ARDL and ECM frameworks.

Table 7: Collinearity Test Results

Variable	Centered VIF	
GL		4.72
CF		2.71
Mean VIF		***3.72***

Source: Eviews13 Output, 2025

Table 7 presents the collinearity test results based on the Variance Inflation Factor (VIF), which assesses the degree of multicollinearity among the independent variables—Green Loan (GL) and Carbon Finance (CF). The VIF values for GL and CF are 4.72 and 2.71, respectively, with a mean VIF of 3.72. Since all VIF values are below the commonly accepted threshold of 10, multicollinearity is not a serious concern in the model. Although GL has a relatively higher VIF, it still falls within an acceptable range, suggesting that the independent variables do not exhibit excessive correlation. Thus, the estimates of the regression coefficients are likely to be stable and reliable for interpreting the effects of green loans and carbon finance on urban sustainability.

- *Regression Analysis Result*

Table 8 Long Run Model Results

Variable	*Coefficient/Std. Error*	*t-ratio*
Constant	-304.98 (43.67)	-6.98***
GL(-1)	1858.77 (173.04)	10.74***
CF(-1)	33.59 (9.39)	3.58***
R-squared		0.72
Adjusted R^2		0.70
Standard Error		4.60
F-Statistics		161.34***

Source: EViews Regression Output, 2025

The model's R-squared value is 0.72, indicating that GL and CF explain 72% of the variation in USI. In contrast, the adjusted R-squared value of 0.70 confirms the model's strong explanatory power, even after accounting for the number of predictors. The standard error of 4.60 reflects the average deviation of the actual USI values from those predicted by the model, suggesting relatively precise estimates. The F-statistic of 161.34 is highly significant at the 1% level, demonstrating that the model as a whole is statistically significant and that GL and CF jointly have a meaningful impact on USI in the long run. These findings, although revealing positive relationships, warrant cautious interpretation. They may indicate that green financial instruments in Nigeria are currently aligned with projects that involve short-term urban sustainability, such as new housing developments or infrastructure upgrades, rather than immediate urban sustainability initiatives. This highlights the importance of refining green finance criteria to ensure that investments contribute to long-term urban sustainability and environmental resilience.

Table 8 presents the long-run model results, estimating the effects of Green Loans (GL) and Carbon Finance (CF) on Urban Sustainability Indices (USI). The constant term is -304.98, with a standard error of 43.67 and a t-ratio of -6.98, statistically significant at the 1% level (***). This suggests that in the absence of green financial interventions, USI would significantly decrease, potentially due to the lack of construction or economic activities that might initially raise urban sustainability.

H_{01}: Green loans have no significant impact on Nigeria's sustainable cities and community development, as measured by urban sustainability indices.

For Hypothesis 1, the coefficient for Green Loans (GL) is 1858.77, with a standard error of 173.04 and a t-ratio of 10.74, which is statistically significant at the 1% level (***). This significant positive coefficient suggests that a unit increase in Green Loans is associated with a 1858.77-unit increase in USI in the long run. This result may appear counterintuitive, as Green Loans are expected to promote sustainable development and reduce emissions. However, it is possible that Green Loans are being channelled into

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

energy-intensive projects that indirectly increase USI. The implication is that the projects financed by Green Loans should be evaluated to ensure they align with urban sustainability goals. Policymakers should introduce stricter screening processes to ensure the funds are directed toward renewable energy projects, energy-efficient technologies, green infrastructure, urban biodiversity and sustainable transportation.

The rejection of Hypothesis One suggests that green loans have a substantial, positive, and statistically significant impact on urban sustainability indices in Nigeria, contrary to initial expectations. This suggests that while green loans are intended to support environmentally friendly projects, they may finance initiatives that generate considerable environmental degradation in the short to medium term, such as unsustainable infrastructure development or the manufacturing of fossil fuel-dependent technologies, before long-term environmental benefits materialise. This finding highlights the need for stricter environmental due diligence, improved project screening, and enhanced transparency to ensure alignment with actual sustainable development goals. Viewed through the lens of Ecological Modernisation Theory (EMT), this outcome illustrates that environmental progress depends not just on providing financial instruments but also on modernising institutional frameworks, technological systems, and policy environments. EMT posits that environmental protection can be harmonised with economic growth if ecological goals are integrated into the structures of capitalism through innovation, regulation, and stakeholder cooperation. Therefore, for green loans to yield their intended environmental benefits in Nigeria, the financial system must evolve to incorporate ecological safeguards, technological standards, and regulatory mechanisms that reflect a mature and adaptive institutional framework. The result aligns with Elsherif (2023), who identified similar challenges in Egypt, but contradicts Wu et al. (2021), who found green finance to have a direct positive effect on reducing emissions in more mature financial systems, indicating that contextual factors such as policy robustness and institutional maturity greatly influence green loan effectiveness.

H_{02}: Carbon finance has no significant impact on Nigeria's sustainable cities and community development, as indicated by urban sustainability indices.

The coefficient for Carbon Finance (CF) is 33.59, with a standard error of 9.39 and a t-ratio of 3.58, which is statistically significant at the 1% level (***). This positive coefficient suggests that a unit increase in Carbon Finance is associated with a 33.59-unit increase in USI in the long run. This result may reflect the impact of unsustainable construction-related activities, which are often linked to the increased degradation **of cities**. Carbon Finance may finance projects such as the construction of green buildings, which, although more energy-efficient in the long run, may have higher emissions during the construction phase. The implication is that while Carbon Finance promotes sustainability in the real estate sector, its short-term impact on emissions should be closely monitored and evaluated. Policymakers should emphasise low-emission construction methods and green technologies to reduce the environmental impact of construction activities.

The hypothesis that Carbon finance has no significant impact on Nigeria's sustainable cities and community development, as measured by urban sustainability indices, was rejected. Statistical analysis revealed a positive and significant impact on urban sustainability indices (USI). While green housing ultimately reduces emissions through energy savings, the construction phase tends to be emission-intensive, underscoring the need for lifecycle assessments of such projects. This finding underscores the importance of adopting low-emission construction practices and incorporating green certifications into carbon finance eligibility criteria. Interpreted through the lens of Ecological Modernisation Theory (EMT), the result highlights how environmental reform can be achieved by restructuring institutions and financial systems to incorporate sustainability goals. EMT suggests that technological innovation, proactive state policies, and market-based instruments, such as carbon finance, can drive ecological improvements without undermining economic development. In this context, carbon finance represents a shift towards embedding ecological considerations into the financial and construction sectors, encouraging environmental responsibility and economic efficiency. The result aligns with Brounen and Kok's (2017) study in the Netherlands, which found that carbon finance promotes household energy efficiency. However, it contrasts with OECD (2018), which observed that despite promoting energy-efficient technologies, carbon finance programmes in some regions suffer from regulatory inconsistencies that limit their effectiveness, emphasising the role of local policies in determining outcomes.

Table 9: Error Correction Model Results

Variable	***Coefficient/Std. Error***	***t-ratio***
Constant	0.58 (0.18)	4.64***
GL(-1)	2.4410 (0.6555)	3.8173***
CF(-3)	-2.44 (0.65)	-3.73***
R-squared		0.68
Adjusted R^2		0.62
Standard Error		0.07
F-Statistics		11.66***

Source. EViews Regression Output, 2025

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may1481

The R-squared value of 0.68 and adjusted R-squared of 0.62 suggest that the model explains a good proportion of the variation in USI, while the standard error (0.07) and F-statistic (11.66) confirm the model's overall significance and reliability. Together, these results underscore the importance of evaluating the timing and implementation dynamics of various green financing instruments to understand their environmental impact fully.

The Error Correction Model (ECM) results in Table 9 provide insight into the short-run dynamics and adjustment process between green financing instruments and Nigeria's urban sustainability indices. The constant term (0.58) is statistically significant at the 1% level, indicating a consistent baseline impact on USI when all other variables are continuous. The lagged value of green loans [GL(-1)] has a positive and highly significant coefficient of 2.4410 (t = 3.8173), suggesting that a one-period lag in green loan disbursements is associated with a substantial increase in USI in the short run. This outcome implies that green loan-funded projects may initially contribute to increased emissions, possibly due to the emission-intensive nature of construction and infrastructure activities, before realising long-term environmental benefits. Conversely, carbon finance lagged by three periods [CF(-3)] shows a negative and statistically significant coefficient of -2.44 (t = -3.73), indicating that the effects of carbon finance investments take longer to materialise but eventually contribute to sustainable development. This finding supports the view that while the short-run impact of green loans may temporarily elevate USI, carbon finance offers a delayed but practical pathway for urban sustainability, likely through the development of energy-efficient housing over time.

Table 10: Error Correction Model Serial Correlation LM Test Results

	Test Statistic	Prob.
F-statistics	0.79	0.47
Obs*R-squared	1.92	0.38

Source: Eviews13 Output, 2025

The results from Table 10 present the Error Correction Model (ECM) Serial Correlation Lagrange Multiplier (LM) Test, which is used to check for serial correlation in the model's residuals. The F-statistic value of 0.79 with a probability (p-value) of 0.47, and the Obs*r-squared value of 1.92 with a p-value of 0.38, are both statistically insignificant at the conventional levels (i.e., $p > 0.05$). This implies no evidence of serial correlation in the ECM residuals. In other words, the residuals are not autocorrelated, indicating that the model is well-specified and the estimates are reliable for inference. The absence of serial correlation strengthens the model's validity, indicating that the error terms are independently distributed, which is a key assumption for ensuring consistent and efficient parameter estimates.

VII. CONCLUSION AND RECOMMENDATIONS

The study concludes that green loans have a positive and significant impact on Nigeria's urban sustainability indices. The positive and vital link between green loans and USI implies that, contrary to their intended environmental objectives, the disbursement of green loans may be financing projects that initially contribute to increased degenerative cities, such as infrastructure development, renewable energy component manufacturing, or large-scale construction activities. This suggests that the short-term environmental costs of these projects may outweigh the immediate benefits, underscoring the need for enhanced ecological screening, rigorous project monitoring, and more stringent alignment of green loan criteria with long-term urban sustainability.

Additionally, the study reveals that carbon finance has a positive and significant impact on urban sustainability indices in Nigeria. Carbon Finance significantly increase USI, suggesting that while sustainable housing aims to achieve long-term energy savings, construction-related activities may be sustainability-driven. The challenge lies in aligning carbon financing with genuinely sustainable building practices. Incorporating stringent environmental standards, promoting sustainable materials, and incentivising certified green construction methods are crucial.

Based on the findings and conclusion, this study therefore recommends that:

- Policymakers should implement more robust screening and monitoring processes. Loan approval criteria should emphasise verifiable urban sustainability targets, and borrowers should be required to report on environmental outcomes at regular intervals. Incentives, such as interest rate discounts or extended repayment periods, could be offered to meet or exceed ecological performance benchmarks. This approach will ensure that Green Loans fund projects that contribute to climate urban sustainability indices.
- To ensure Carbon finances fulfil their intended role of promoting urban sustainability indices, developers, lenders, and policymakers should incorporate strict environmental standards into finance eligibility criteria. This may involve mandating green building certifications, promoting low-emission construction practices, and using sustainable materials. Authorities can also offer tax incentives or lower interest rates for projects demonstrating measurable emission reductions over time. Carbo Finance can better support urban sustainability efforts by aligning the real estate industry's sustainability goals with tangible environmental outcomes.

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