



BOOK OF PROCEEDINGS

**INTERNATIONAL VIRTUAL CONFERENCE OF
THE DEPARTMENT OF URBAN AND REGIONAL PLANNING
FACULTY OF ENVIRONMENTAL STUDIES
UNIVERSITY OF NIGERIA, ENUGU CAMPUS**

**THEME: ADVANCING THE SUSTAINABLE DEVELOPMENT
GOALS THROUGH ENVIRONMENTAL PLANNING,
DESIGN AND LAND GOVERNANCE**

DATE:

22nd - 23th APRIL, 2026

VENUE:

VIRTUAL (ZOOM)

University of Nigeria Enugu Campus (UNEC)

WELCOME ADDRESS BY THE HEAD, DEPARTMENT OF URBAN & REGIONAL PLANNING, UNIVERSITY OF NIGERIA, NSUKKA | APRIL 22, 2026.

It is with great pleasure and a deep sense of responsibility that I extend warm greetings to you all on the occasion of this important professional conference themed “Advancing the Sustainable Development Goals through Sustainable Environmental Planning, Design, Geospatial Innovation, and Land Governance.” This gathering comes at a critical time in our global and national journey toward achieving the Sustainable Development Goals (SDGs). The challenges confronting our environment—ranging from rapid urbanization and climate change to land degradation and governance inefficiencies—require not only urgent attention but also innovative, interdisciplinary, and sustainable solutions.

As a department, we recognize that environmental planning and design are no longer conventional practices; they are dynamic tools for shaping resilient, inclusive, and sustainable communities. The integration of geospatial innovation into planning processes has opened new frontiers for data-driven decision-making, improved resource management, and effective monitoring of development outcomes. Equally, sound land governance remains central to ensuring equity, transparency, and sustainability in land use and administration. This conference, therefore, provides a valuable platform for intellectual exchange, collaboration, and the sharing of cutting-edge research and practical experiences. I am confident that the deliberations, presentations, and interactions that will take place here will not only enrich our knowledge but also inspire actionable strategies toward sustainable development.

I commend the organizers for their dedication and vision in bringing this event to fruition, and I encourage all participants to actively engage, share insights, and build meaningful networks that will extend beyond this conference. On behalf of the department of Urban & Regional Planning, I warmly welcome you all and wish you a productive, insightful, and impactful conference.

Thank you.

Prof. Nwachukwu Maxwell.

WELCOME ADDRESS BY PROF. OBINNA UBANI, CHAIRMAN, CONFERENCE PLANNING COMMITTEE, DEPARTMENT OF URBAN & REGIONAL PLANNING , UNIVERSITY OF NIGERIA, ENUGU CAMPUS

To the glory of God, It is my great honor and privilege, as Chairman of the Conference Planning Committee, to warmly welcome you all to the second edition of this International Virtual Conference hosted by the Department of Urban & Regional Planning, University of Nigeria, Enugu Campus. This conference begins today, April 22, 2025, and will conclude tomorrow.

A tremendous amount of time, energy, and careful planning has gone into making this event a success, and we are truly delighted to have such a distinguished gathering of scholars, professionals, and thought leaders assembled here today. I would like to express my heartfelt appreciation to our eminent resource persons for their invaluable contributions to this conference. First, I acknowledge our Chief Host, the Vice Chancellor of this great university, for his unwavering support. I also extend sincere gratitude to our Keynote Speaker, the first female Professor of Urban & Regional Planning in Africa, Prof. (Mrs.) Joy Ukamaka Ogbazi (FNITP), and to the Dean of the Faculty, Prof. Donald Okeke. I further recognize and appreciate the contributions of Emeritus Prof. H. C. Mba, Prof. K. C. Ogboi, and Prof. V. Onyebueke, whose efforts have significantly enhanced the success of this conference. To all conference participants and paper presenters, you are most welcome. Please feel free to share your research findings and actively contribute to the discussions.

At this juncture, I wish to specially appreciate the Head of Department of Urban & Regional Planning, UNN, Prof. Nwachukwu Maxwell Umunna, for his consistent support and encouragement. I also commend the dedicated members of the Conference Organizing Team—Asso. Prof. U. Jiburum, Asso. Prof. N. Ezeadichie, Dr. G. Chukwura, Dr. C. Anierobi, Mrs. C. John-Nsa, Mrs. N. Kanu, Mr. O. Okoli, and Mr. J. Oma—whose tireless efforts have made today a reality. Your commitment and teamwork are truly admirable.

This conference represents more than just an event; it is a platform for meaningful dialogue, collaboration, and the exchange of innovative ideas within our field. Over the course of this gathering, we will engage in insightful discussions, share valuable experiences, and explore solutions to the pressing challenges and opportunities in urban and regional planning.

To our speakers and facilitators, thank you for dedicating your time and expertise to enrich this program. To our participants, your presence gives this conference its true value. I encourage you to actively engage, ask questions, network, and make the most of every session. As we formally begin, I wish you all a productive, enlightening, and rewarding experience.

Once again, you are most welcome, and thank you.

Prof. Ubani O. J

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Protocol:

- The Vice Chancellor, University of Nigeria, Nsukka, **Prof. Simon Uchenna Ortuanya.**
- The Deputy Vice Chancellor, University of Nigeria, Enugu Campus, **Prof. Josaphat U.J. Onwumere.**
- The Dean, Faculty of Environmental Studies, University of Nigeria, Enugu Campus, **Prof Donald Okeke.**
- The Head, Department of Urban & Regional Planning, UNN, **Prof. Nwachukwu Maxwell**
- The Conference Chairman, Tpl. **Prof. Obinna Ubani**
- Esteemed Colleagues & Scholars
- All Conference Participants.
- Ladies and Gentlemen

I am delighted to be a part of this second international virtual conference on "Advancing the Sustainable Development Goals through Environmental Planning, Design, Geospatial Innovation, and Land Governance", hosted by the Department of Urban & Regional Planning, University of Nigeria, Enugu Campus, and to deliver the keynote address. It is both an honour and a privilege to address this distinguished gathering of thought leaders, professionals, and innovators committed to shaping a more sustainable and equitable future. Today's conference theme is not only timely but profoundly critical in the face of escalating global challenges.

We convene at a defining moment in human history: a moment characterized by rapid urbanization, climate change, environmental degradation, land conflicts, and socio-economic inequalities. The Sustainable Development Goals, adopted as a universal call to action, provide a comprehensive framework to address these interconnected challenges. However, the realization of these goals depends heavily on how effectively we integrate knowledge, technology, policy, and practice within the domains of environmental planning, design, geospatial science, and land governance.

I would also like to appreciate the Head of Department, Prof. M. Nwachukwu for organizing the second edition of this virtual conference and inviting me to deliver the keynote address. This conversation is timely as it presents an opportunity for speakers to share valuable insights and engage with a distinguished array of policymakers, policy

analysts, researchers, academia, and numerous like-minded individuals, all united by the common objective of achieving sustainable development.

1. Sustainable Development Goal II: An Overview

The general theme of this conference, *Sustainable Development Goals II* started last year when the first edition of the conference was held with similar theme, *Sustainable Development Goals and National development I*, and this year's edition seems to be a continuation of what was unfinished in the last year's conference. The importance of the discourse on these goals cannot be overemphasized. The Sustainable Development Goals (SDGs) were born at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. The objective was to produce a set of universal goals that meet the urgent environmental, political and economic challenges facing our world. The SDGs replace the Millennium Development Goals (MDGs), which started a global effort in the year 2000 to tackle the indignity of poverty. The MDGs established measurable, universally-agreed objectives for tackling extreme poverty and hunger, preventing deadly diseases, and expanding primary education to all children, among other development priorities.

For 15 years, the MDGs drove progress in several important areas: reducing income poverty, providing much needed access to water and sanitation, driving down child mortality, and drastically improving maternal health.

They also kick-started a global movement for free primary education, inspiring countries to invest in their future generations. Most significantly, the MDGs made huge strides in combating HIV/AIDS and other treatable diseases such as malaria and tuberculosis.

The legacy and achievements of the MDGs provide us with valuable lessons and experience to begin work on the new goals. But for millions of people around the world the job remains unfinished. We need to go the last mile on ending hunger, achieving full gender equality, improving health services and getting every child into school beyond primary.

The SDGs are also an urgent call to shift the world onto a more sustainable path. The SDGs are a bold commitment to finish what we started, and tackle some of the more pressing challenges facing the world today. All 17 Goals interconnect, meaning success in one affects success for others. Dealing with the threat of climate change impacts how we manage our fragile natural resources; achieving gender equality or better health helps eradicate poverty; and fostering peace and inclusive societies will reduce inequalities and help economies prosper. In a nutshell, this is the greatest chance we have to improve life for future generations.

For emphasis, Sustainable Development refers to a holistic approach that ensures the provision of critical needs of the current generation without undermining the ability of future generations to meet their needs (Brundtland Commission, 1987). Sustainable development is also defined as an “approach to social, economic, and environmental planning that seeks to balance the social and economic needs of present and future human generations with the imperative of preserving or preventing undue harm to the natural environment” (Kulik, 2025).

Many factors influence sustainable development. For one, Kanie and Biermann (2017) emphasised the importance of protecting and conserving natural, environmental, and ecosystem resources for sustainable development. Sustainable development cannot occur without the preservation of these resources. Accordingly, current and future production and consumption activities must incorporate sustainable practices that avert the depletion of exhaustible natural resources, prevent the overexploitation of inexhaustible resources, and mitigate climate change. Another important approach to ensure sustainable development in Africa is to restrict the unabated increase in population growth (Mensah, 2019). Unsustainable population growth mounts excessive pressure on scarce economic, natural, and environmental resources, which can lead to overexploitation of limited resources and irreversible damage to natural and environmental resources.

2. The Imperative of Environmental Planning and Design

Environmental planning and design lie at the heart of sustainable development. They provide the tools and frameworks for organizing human activities in ways that respect ecological limits while enhancing social and economic wellbeing. Urban areas, especially in developing countries, are expanding at unprecedented rates. Without proactive planning, this growth leads to informal settlements, environmental pollution, traffic congestion, and infrastructure deficits. Sustainable environmental planning offers a pathway to: promote compact and resilient cities, integrate green infrastructure and ecosystem services, enhance climate adaptation and mitigation strategies and improve public health and quality of life.

Design, in this context, is not merely aesthetic. It is functional, adaptive, and transformative. Sustainable design principles such as passive cooling, energy efficiency, water-sensitive urban design, and inclusive public spaces directly contribute to SDGs such as **Goal 11 (Sustainable Cities and Communities)** and **Goal 13 (Climate Action)**.

3. Geospatial Innovation as a Catalyst for Transformation

Geospatial technologies have revolutionized how we understand, monitor, and manage our environment. From Geographic Information Systems (GIS) to remote sensing, satellite imagery, drones, and spatial data analytics, geospatial innovation provides evidence-based

insights for informed decision-making. These tools enable us to: map urban growth and land-use changes, monitor environmental degradation and biodiversity loss, assess disaster risks and enhance resilience planning and optimize infrastructure development and service delivery. In the African context, including Nigeria, geospatial innovation presents immense opportunities to bridge data gaps and support sustainable planning. Accurate spatial data is essential for tracking SDG indicators, ensuring accountability, and guiding policy interventions. Moreover, the integration of geospatial technologies with artificial intelligence and big data analytics is opening new frontiers in predictive modelling, smart city development, and real-time environmental monitoring.

4. Land Governance: The Foundation of Sustainable Development

Land is a fundamental resource—economically, socially, and environmentally. Effective land governance ensures that land resources are managed transparently, equitably, and sustainably. However, many regions face persistent challenges, including: insecure land tenure systems, Land-use conflicts and disputes, weak institutional frameworks and inefficient land administration processes. Strengthening land governance is essential for achieving multiple SDGs, particularly **Goal 1 (No Poverty), Goal 2 (Zero Hunger), and Goal 15 (Life on Land)**.

Key priorities in land governance include: securing land tenure and property rights, enhancing land registration and cadastral systems, promoting equitable access to land resources, integrating customary and formal land systems and leveraging digital land administration systems. Transparent and accountable land governance not only reduces conflicts but also stimulates investment, supports agricultural productivity, and promotes environmental stewardship.

5. The Role of Academia, Professionals, and Policymakers

Achieving the SDGs requires collective action. Each stakeholder group has a critical role to play:

1. Academia must generate relevant research, develop innovative methodologies, and train the next generation of professionals.
2. Practitioners must translate theory into practice through sustainable design and planning solutions.
3. Policymakers must create enabling environments through sound policies, regulations, and institutional frameworks.

4. Private sector and civil society must collaborate to drive innovation and ensure inclusivity.

Capacity development, interdisciplinary collaboration, and knowledge exchange platforms, such as this conference, are essential for bridging gaps between theory and practice.

6. The Way Forward.- As we look ahead, several strategic directions are critical:

1. *Enhancing Land Governance Systems:* Digitize land administration and improve transparency. The integration of technology, especially Geographic Information Systems (GIS), is a key tool for better data handling and decision-making in land governance (Fanfani et al., 2022). Technological solutions can simplify land registration, enhance transparency, and encourage community participation. Adopting modern technology can greatly improve the overall effectiveness and efficiency of spatial planning.
2. *Focus on Environmental Sustainability:* Incorporating environmental sustainability metrics into land use planning is crucial for sustainable development. Findings emphasize the importance of considering ecological factors, conducting environmental impact assessments, and using multi-criteria decision-making frameworks to guide planning towards environmentally responsible outcomes (Gaudry et al., 2022). States can benefit from policies that prioritize ecological health alongside urbanization and economic growth.
3. *Encouraging Participation:* Engage communities in decision-making processes to ensure inclusivity and ownership. Public participation has become essential for effective governance and spatial planning. Engaging stakeholders—including local communities, civil society, and government actors—ensures diverse perspectives are considered. Participatory models from various global case studies highlight the potential for community empowerment, fostering support for land use decisions and leading to more equitable results.

Conclusion

Distinguished participants, ladies and gentlemen, as I round up my keynote address, let us return to the timeless charge of the University of Nigeria, Nsukka: **“To Restore the Dignity of Man”**. These words are not relics of the past; they are a compass for our future and the guiding light of this institution for generations. Dignity is not given, it is built.

Finally, the journey toward achieving the Sustainable Development Goals is complex but achievable. It demands vision, commitment, innovation, and collaboration. Environmental planning and design provide the blueprint. Geospatial innovation provides the intelligence. Land governance provides the structure. Together, they form a powerful triad capable of transforming our cities, safeguarding our environment, and improving the quality of life for present and future generations. Let us use this conference as a platform to exchange ideas, challenge assumptions, and forge partnerships that will drive meaningful change. The future we seek is sustainable, inclusive, and resilient; and it begins with the decisions we make today.

Thank you for this opportunity and your attention.

God bless you

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An Assessment of the Participatory Methods Adopted Over the Years by Oil and Gas Companies Operating In the Niger Delta Region, Nigeria

By

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Abstract

There has been various degrees of environmental related crisis and protests in most oil producing communities in Nigeria. Whenever an Environmental Impact Assessment (EIA) exercise was to be carried out by multinational companies, some groups of people from host communities would complain of not being carried along in the entire EIA process. This has often led to disagreements between oil companies and their host communities, which consequently has resulted to loss of lives and properties. This study has been carried out to identify the participatory methods adopted over the years by Oil and Gas companies operating in the Niger Delta Region with a view to assessing how e-participation can be adopted to bridge any spotted participatory gap. Purposive sampling technique was employed to select 357 respondents from three states of the region, namely, Imo, Rivers and Bayelsa. The respondents comprise management staff of Oil and Gas Companies operating in the area, as well as knowledgeable members of the host communities of the States involved. Of six (6) identified as channels of information for EIA projects carried out in the area, newspaper notices stood out as the key channel (62%). The study also revealed low input of the respondents in host communities (34%) in EIA processes. This was considered a negative trend that can be attributed to gaps in proper communication. The study, therefore, recommends the institutionalization of the social media (e-participation) as a notification tool which will bring about sustainable participation in the EIA processes, rather than obscure newspaper notices.

Keywords: Environmental Impact Assessment, E-participation, Host-communities, Niger Delta Region, Social Media.

1.0 Introduction

E-participation is the use of information and communication technologies (ICTs) to enable citizens to incorporate their concerns, needs and values in government decision making (Lai & Beh, 2025). From this perspective, the literature claims that e-participation can expedite citizen engagement and participation, particularly among marginalized groups (Nnah & Frank, 2023). Although social media platforms and other government websites prove to be more efficient, effective, and practical, some governments still grapple, whilst some appear to be advancing with desirable online presence, which in turn often affects the number of citizens taking part in decision-making processes through online platforms (Taako Andama & Kiemo, 2023).

In Africa, South Africa demonstrates its regional lead with a rank of 39 (0.8356) of 193 as opposed to the rank of 61 in the 2024 e-participation index globally (Santamaría & Wimmer (2018). This suggests that South Africa has enhanced its e-participation presence across African countries thus far followed by Mauritius, Tunisia Egypt and Kenya coming 2nd, 3rd, 4th and 5th respectively (Ajiboye & Awe, 2020)

In Nigeria, the Federal Government (FG) Nigeria has implemented various e-governance initiatives to improve transparency, accountability, and service delivery. For instance, the Federal Ministry of Communications, Innovation and Digital Economy has implemented initiatives like the Government Service Portal (GSP) and the Government Contact Centre (GCC) to improve citizen access to government services and information (Maria, 1996). In the United Nations' 2024

E-Government Development Index (EGDI), Nigeria ranks 144th out of 193 countries of the World. This places Nigeria in the "medium" rating class (MEGDI). Nigeria's EGDI value for 2024 is 0.4815 (Lai & Beh, 2025)

Traditionally, paper based participatory approaches such as workshops, public meetings, displays among others has been used to notify the public and interested parties on issues that affects them. Debates suggest that these face-to-face participatory approaches have not met the need of stakeholders due to distance, conflicting schedules and other factors thereby limiting their effectiveness (Yao & Xu, 2021).

However with advancement in technology, new participatory approaches have emerged to engage the public during impact assessment exercises to address problems associated with paper based participatory system. This new online participatory platform is referred to as e-participation.

The advantages e-participation have over face-to-face form of participation are enormous and includes but not limited to, bridging access to relevant information (Zainab, Sharifa & Muhammad, 2020), encourage feedback mechanism (Uduak (2011), improves democratic processes and transparency (Johnstone, Charles & Florence, 2016), ability to penetrate into more remote areas and gathering of more volume of data at reduced cost and time (Luke, 2019), engage younger people into more decision making processes and improves effectiveness of public participation in impact

Many researchers (Niger Delta HD Report, 2006, Santamaría & Wimmer, 2018 and Richard, 2021) postulate that despite the numerous benefits associated with online participatory processes, e-participation also has its inherent limitations and some of these includes but not limited to; problem of digital divide, lack of digital infrastructures in remote areas, poor quality of network connectivity. Also, citizens with a more social capital, most influential and powerful and those

with a more internet savvy, younger, more educated, richer, and environmental NGOs engage more in e-participation platforms than others (Richard, 2021).

The study is aimed at identifying the type of participatory methods adopted over the years by oil and gas companies operating in the Niger Delta Region in the engagement of their host community members during EIA exercises. Importantly, the question of the type of participatory methods adopted over the years by oil and gas companies operating in the Niger Delta Region was answered in this study and if recommendations are implemented would reduce conflict between multinationals operating in various host communities leading to a smooth and cordial relationship and sustainability of oil and gas facilities. Hence this study examined at identifying the type of participatory methods adopted over the years by oil and gas companies operating in the Niger Delta Region in the engagement of their host community members during EIA exercises.

1.2 Past studies

Combining E-participation with traditional participatory approaches in EIA

Empirical studies that have studied successful e-participation initiatives over time emphasize the importance of offline activities to support e-participation. This was already noted a decade ago. Most defendants of ICT-based public participation systems (Panopoulou, Tambouris & Tarabanis, 2014; Kato & Inunkiwere, 2020) stressed that these should not replace current participatory practices; rather, ICT should be seen as a way to enhance participatory practices as it creates opportunities for more people to participate (Wenshu, Tao Feng, Harry, Timmermans & Ming Zhang, 2020). Several studies (Panopoulou, Tambouris & Tarabanis, 2014; Shell Petroleum Development Company, 2015; Taako Andama & Kiemo, 2023) claim that there is a connection between e-participation and offline participation and that strengthening e-participation will increase offline participation over the long-term (Adlifatin, Shu, Satria & Mohammad, 2015).

Around 30% of initiatives employ non-electronic channels combined with electronic (Mariani, Marzia, Francesca & Alessandro, 2025), usually for dissemination and promotion purposes in well-established media like radio, TV, press or towards special symposiums and conferences.

ICTs make existing participatory arrangements easier to implement and provides alternative, cheaper ways of eliciting participation. In particular, the introduction of Web 2.0 has introduced new possibilities for participation. Specifically, it has decreased the costs of providing information electronically; opened new channels for doing so; and its functionalities have allowed for interaction that does not need to be synchronous or physically limited to one place. Compared to traditional participation mechanisms, this allows governments to reach out and receive feedback from more people. For example, setting up consultations on policy drafts by making them available for comment on a public platform is in theory a low-cost activity, compared to holding in-person consultation meetings or using other systems to disseminate the draft and elicit, collect and compile comments (Bagui, Weimann & Johnston, 2016; Daramola & Olowoporoku, 2021).

Hence, within the same legal and institutional context, ICTs create additional opportunities for interaction between governments and citizens. However, many e-participation mechanisms are digital versions of pre-existing mechanisms or processes. For instance, consultations and participatory budgeting existed prior to the internet; e-voting or m-voting is either a complement to traditional ballot casting or a more convenient way to vote; etc. On the other hand, ICTs have opened genuinely new ways of doing participation, both in terms of channels for participation and of outputs of participatory processes. This is particularly evident for products or services that rely on the aggregation of individual, voluntary inputs made by many citizens acting in a decentralized fashion. Collaborative mapping, as applied to real-time disaster and hazard maps, feedback on public services, and other applications, were made possible by the combination of geographic

information systems (GIS) and mobile technologies including video, text messaging and internet access. The boundary between “old” and “new” participation tools is not always clear-cut, however. For example, today’s “citizen science” based on crowdsourcing has ancestors well back into the 19th century. In many cases, making a participation practice digital mostly allows for doing more, faster and cheaper (He, Boas, Mol, & Lu, 2017).

Combining online and offline activities is a widespread practice. E-participation initiatives have adopted “packages” of offline and online activities in different fields such as e-rulemaking, environmental impact assessments, participatory initiatives for climate change action and participatory budgeting (Ge, Elna & Jia, 2022). Activities that are often found in support of e-participation include: advertising the initiatives and having outreach plans (both offline and online); alternating electronic and physical meetings; providing educational material on the issues being discussed; and making linkages with other programs or initiatives.

According to Iheriohanma (2016) a channel combination is an important process/strategic decision for any e-Participation initiative. It has been revealed from the literature that most of the e-Participation initiatives rely severely on traditional internet access via private PCs and laptops. However, there is a 50% of e- Participation initiatives research that report at least one additional online or offline channel, though one third described that they synchronized online with offline channels. There are several citizens that cast their votes online but there are also citizens that choose mobile voting or performing their elections in the dedicated kiosks. Another common example of improving publics’ participation is over merging online consultation/deliberation tools with offline meetings and workshops. In general, there has been an encouraging lesson from the countries that did use a mixture of two or more channels, while others were found at the process of expanding

their doings to more channels apart from the typical internet access (Daramola & Olowoporoku, 2021).

1.3 The study area

The Niger Delta basin of Nigeria is situated on the continental margin of the Gulf of Guinea in equatorial West Africa between latitude 4° 00' to 7° 00' N and longitude 5° 00' to 8° 00' E covering an area of about 108,900km² and facing the Atlantic Ocean, refer to Fig 1 below (SPDC, 2015).

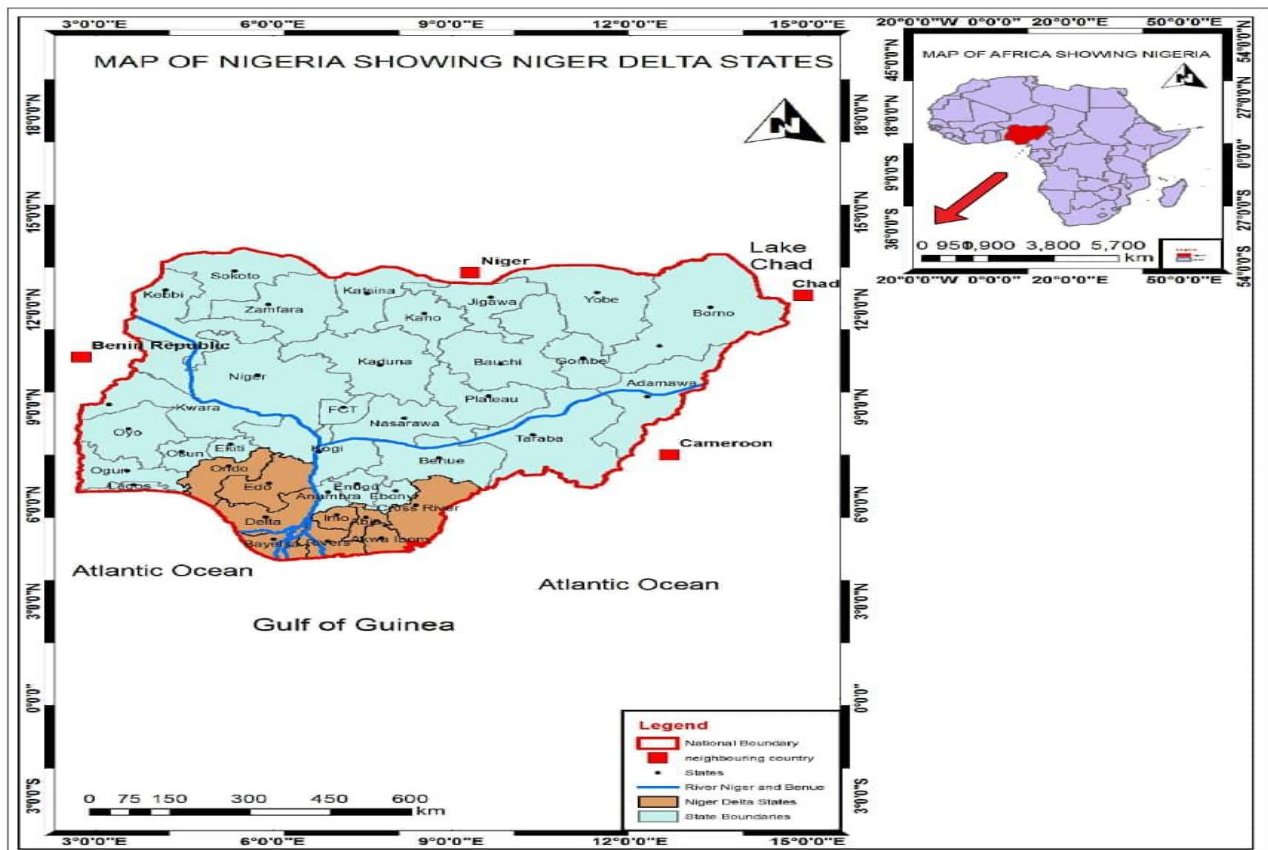


Fig 1: Map of Africa showing Nigeria and map of Nigeria showing Niger Delta States.

Source: Geography and information System (GIS) laboratory of Department of Urban and Regional Planning (URP), Abia State University, Uturu (ABSU), Abia State, 2025.

1.4 Research Methods

The study employed survey research design. Purposive sampling technique was employed to select 357 respondents from three states of the region, namely, Imo, Rivers and Bayelsa states. The respondents comprise management staff of Oil and Gas Companies operating in the area, as well as knowledgeable members of the host communities of the States involved. Data were collected with the use of questionnaire and interview with respondents. Both descriptive and inferential statistics were employed - frequencies, percentages, charts and mean scores were used. One-way ANOVA was used to test whether there is significant difference between participatory methods adopted over the years by oil and gas companies operating in the Niger Delta region and the demerits of the methods. Data processing and analysis for the current study were conducted whilst utilizing the Statistical Package for Social Sciences (SPSS) version 25 for Windows. In utilizing the variables, the identified variables were transformed from ordinal into numerical scales thereby making them fit for the study.

1.5 Hypothesis testing:

Hypothesis (Ho) that the sample means are the same was presented as follows: Ho: $M1=M2=M3$.

For the hypothesis, the independent variable is the demerits and the dependent variables is the E-participatory methods adopted. ANOVA was used to test whether there is significant difference between participatory methods adopted over the years by oil and gas companies operating in the Niger Delta region and the demerits of the methods. ANOVA analytical technique was used because it investigates differences between means and allows

multivariate comparison of means. It also calculates the significance of the association for more than one predictor variable at a time.

The formula for ANOVA was given below:

$$SST = \frac{\sum X^2}{N} - \frac{(\sum X)^2}{N} \dots\dots\dots (2)$$

$$SSb = \frac{(\sum X_1)^2}{N} + \frac{(\sum X_2)^2}{N} + \frac{(\sum X_3)^2}{N} + \frac{(\sum X_4)^2}{N} \dots\dots (3)$$

$$SSw = SST - SSb \dots\dots\dots (4)$$

Where

SSt = Total variation (Total sum of squares)

SSb = Variation between groups (Sum of squares between)

SSw = Variation within groups (Sum of squares within).

For this hypothesis, the statistic F was employed for the null hypothesis in an ANOVA table.

The data was analyzed on 0.05 level of significant. Hence, if from the ANOVA output, the probability ratio was less than 0.05, the null hypothesis was rejected and vice versa.

i. Gender of the Respondents

The table below showed the gender of the respondents in the study area. The result of the analyses showed that males dominated the females with 85% as against 15% of the total respondents in the host communities. This analysis portrays the patriarchal systems being experienced in the society where males are preferred more to female when it comes to leadership positions and headship of families.

Table 1: Gender of the Respondents

S/N	Option	Frequency	Percentage
1	Male	302	85
2	Female	55	15
	Total	357	100

Source: Researcher's Survey, 2025

ii. Age of the Respondents

In table 2 below, it was revealed that the age of the respondents showed differing results for each category of respondents. For members of the host communities, the analyses showed that majority (69%) of the respondents were 50 years and above signifying maturity, exposure and experience. 18% of the respondents from the host communities were between 40-49 years while 13% were between 30-39 years. This result therefore implies that advanced age signified wisdom, experience and robust leadership quality and counted more for the host communities.

Table 2 Age of the Respondents

S/N	Options (years)	Frequency	Percentage
1	18-29	-	-
2	30-39	48	13
3	40-49	63	18
4	50 and above	246	69
	Total	357	100

Source: Researcher's Survey, 2025

iii. Highest Educational Qualification of the Respondents

Table 3 showed the educational qualification of the respondents in the study area. For the members of the host communities, the analyses revealed that majority (42%) attained secondary education; 28% possessed higher education degrees, 15% had diploma certificates, 14% had Masters and above degree while 3% obtained other educational qualifications (like weathering and woodwork).

From the analysis, it can be deduced that the respondents where knowledgeable and educational sound to provide accurate information as regarding the study.

Table 3: Highest educational qualification of the respondents

S/N	Options	Frequency	Percentage
1	Secondary	151	42
2	Diploma	54	15
3	Degree	99	28
4	Masters and above	50	14
5	Others	3	1
Total		357	100

Source: Researcher's Survey, 2025

1.6 Testing of hypothesis

Ho: There is no significant difference between participatory methods adopted over the years by oil and gas companies operating in the Niger Delta region and the demerits of the methods.

In order to effectively test this hypothesis, the values from table 4 and 5 were inputted into the computer with the SPSS software and the result in Appendix I was obtained.

2.0 Results:

The result of the hypothesis using ANOVA indicated that there is significant difference between the participatory methods adopted over the years by oil and gas companies operating in the Niger Delta region and the merits of the methods ($F = 366.061$, p . Sig = 0.00001, p . sig < 0.05). Since the p . significance (0.0001) was less than the level of significance which is 0.05, therefore, the null hypothesis is rejected.

Furthermore, and Eta and Eta Square score of 0.950 and 0.905 respectively indicated and extremely strong relationship, where 90.5% of the total variance in the dependent variables (here

being participating method) is accounted for by the independent variable (being the demerits). This result therefore showed that a more advanced participatory method like social media and webinars would yield fewer demerits than methods currently being used.

Table 4 and Figure 5 indicated how respondents in the host communities liked to be informed about EIA projects and meetings. From the analysis, majority (62%) of the respondents in host communities indicated to receive information on EIA projects and meetings via text messages. 15% indicated social media platforms (like WhatsApp); 9% indicated Email; 6% indicated online surveys; 5% indicated online forums while 3% indicated webinars. The result however demonstrates a significant shift from traditional mechanisms of information dissemination to digital methods which ensures maximum reach due to technological advancements like mobile phones and the internet.

Table 4: Response on information channels for EIA projects and meetings

S/N	Option	Frequency	Percentage
1	Email	32	9
2	Text Messages	221	62
3	Social Media Platforms	53	15
4	Online surveys	22	6
5	Online forums	20	5
6	Webinars	9	3
	Total	357	100

Source: Researcher's Survey, 2025

Table 5 showed that percentage demerits to the adoption of E-participation in the EIA process in the study area. From analysis in table 5, results showed that majority (28%) of the respondents

indicated low literacy level, language and distance barrier as the major factor hindering the adoption of E-participation in the study area. Also, 16% of the respondents indicated how to integrate opinions of diverse users; 12% indicated how to effectively use technology to foster genuine and sustainable community engagement; 10% indicated lack of political will or legal framework; 9% indicated insufficient resources to deploy ICT tools; 8% indicated high implementation and maintenance costs; 6% indicated inadequate ICT infrastructures; 5% indicated digital divide due to lack of access to ICT tools and digital literacy issues; 4% indicated how to maintain security and transparency of information from the public while 2% indicated how to address the issue of resistance to change by members of host communities.

Table 5: Response on the percentage demerits on using e-participation in the EIA process

S/N	Demerits of E-participation to EIA	Frequency	Percentage
1	Low literacy level, language and distance barrier	102	28
2	How to integrate opinions of diverse users	57	16
3	How to effectively use technology to foster genuine and sustainable community engagement	42	12
4	Lack of political will or legal framework	37	10
5	Insufficient resources to deploy ICT tools	32	9
6	High implementation and maintenance costs	27	8
7	Inadequate ICT infrastructures	21	6
8	Digital divide due to lack of access to ICT tools and digital literacy issues	18	5
9	How to maintain security and transparency of information from the public	13	4
10	How to address the issue of resistance to change by members of host communities	8	2
Total		357	100

Source: Researcher's Survey, 2025

Table 6 analysed the types of e-participation platforms used to engage with host communities during projects and activities. Result from Table 6 showed that majority (72%) of the respondents in oil and gas company's utilised social media as the main e-participation platform for engaging with host communities. This was followed by other platforms including online surveys, online forums and webinars (16%); Email and websites with 6% each of the total respondents in oil and gas companies in the study region. The result further gives credence to the huge role e-participation play in enhancing communication between project organizers and members of the public.

Table 6: Response on the type of e-participation platforms

S/N	Option	Frequency	Percentage
1	Email	2	6
2	Social media	23	72
3	Websites	2	6
4	Others: online surveys, online forums and webinars	5	16
Total		32	100

Source: Researcher's Survey, 2025

2.2 Discussion

The study focused on identifying the participatory methods adopted over the years by oil and gas companies operating in the Niger Delta region of Nigeria. The result of the analysis was presented and analyzed in line with the study objective. The result as presented in tables 1 to 6 showed that majority signifying 85% of the respondents were male as against 15% that were female out of the total respondents in the host communities. On age, the result showed that majority representing (69%) of the respondents were 50 years and above signifying maturity, exposure and experience. Meanwhile, 18% of the respondents from the host communities were between 40-49 years while 13% were between 30-39 years. For educational attainment, the analyses revealed that majority

(42%) attained secondary education; 28% possessed higher education degrees, 15% had diploma certificates, 14% had Masters and above degree while 3% obtained other educational qualifications (like weathering and woodwork).

The result of the hypothesis using indicated that there is significant difference between the participatory methods adopted over the years by oil and gas companies operating in the Niger Delta region and the merits of the methods ($F = 366.061$, $p. \text{Sig} = 0.00001$, $p. \text{sig} < 0.05$).

Table 4 and Figure 5 indicated how respondents in the host communities liked to be informed about EIA projects and meetings. From the analysis, majority (62%) of the respondents in host communities indicated to receive information on EIA projects and meetings via text messages. 15% indicated social media platforms (like WhatsApp); 9% indicated Email; 6% indicated online surveys; 5% indicated online forums while 3% indicated webinars. The result however demonstrates a significant shift from traditional mechanisms of information dissemination to digital methods which ensures maximum reach due to technological advancements like mobile phones and the internet. This result also corroborates with that of Taako Andama & Kiemo (2023) who stated that current EIA practices has experienced a paradigm shift from traditional and paper based to a more sophisticated electronics processes. E-participation is a vital tool to enhancing the EIA process. Similarly, the study also collaborated with the findings of Chassin & Ingensand (2022) who posited that e-participation enhances e-voting processes.

On the percentage demerits to the adoption of E-participation in the EIA process in the study area, results showed that majority (28%) of the respondents indicated low literacy level, language and distance barrier as the major factor hindering the adoption of E-participation in the study area. Also, 16% of the respondents indicated how to integrate opinions of diverse users; 12% indicated how to effectively use technology to foster genuine and sustainable community engagement; 10%

indicated lack of political will or legal framework; 9% indicated insufficient resources to deploy ICT tools; 8% indicated high implementation and maintenance costs; 6% indicated inadequate ICT infrastructures; 5% indicated digital divide due to lack of access to ICT tools and digital literacy issues; 4% indicated how to maintain security and transparency of information from the public while 2% indicated how to address the issue of resistance to change by members of host communities.

The types of e-participation platforms used to engage with host communities during projects and activities by Oil and Gas companies operating in the areas were analysed and result showed that majority (72%) of the respondents in oil and gas company's utilised social media as the main e-participation platform for engaging with host communities. This was followed by other platforms including online surveys, online forums and webinars (16%); Email and websites with 6% each of the total respondents in oil and gas companies in the study region. The result further gives credence to the huge role e-participation play in enhancing communication between project organizers and members of the public. These findings are in tandem with that of Nnah & Frank (2023) who averred that e-participation platforms used to engage host community members in contemporary EIA exercises are social media like whatsapp, video conferences etc. Also, Yao & Xu (2021) stated that the most utilized E-participation platforms included text messages, social media, online forums, online surveys and webinars.

2.3Conclusion

Environmental Impact Assessment (EIA) as an instrument and management tool continue to garner support as it stands as a cornerstone for entrenching sustainable development. This ensures that the potential consequences (Environmental, Economic and Social) of major projects are

understood, recorded and addressed before decisions are finalized. However, the study highlighted the significant role E-participation has on the EIA process as it is no longer just a supplementary tool but is becoming a core component especially in the post-pandemic digitally driven beyond 2020.

The results of the study highlighted the E-participatory methods adopted over the years by oil and gas companies in the Niger Delta region of Nigeria to include text messages which still fall short of the desired E-participatory framework where social media and webinars account as desirables. The study also analyzed the benefits of E participation to include it leads to more robust democratic decision making while for oil and gas companies, it results in the identification of adverse potential environmental impact and alternative solutions.

The study also revealed that the demerits of adopting E-participation in EIA to host communities included low literacy level, language and distance barrier, how to integrate opinions of diverse users, how to effectively use technology to foster genuine and sustainable community engagement, lack of political will or legal framework, insufficient resources to deploy ICT tools, high implementation and maintenance costs, inadequate ICT infrastructure, digital divide due to lack of access to digital tools and digital literacy issues, how to maintain security and transparency of information from the public and how to address the issue of resistance to change by members of host communities. Demerits to adopting E-participation to oil and gas companies in the study area included lack of political will or legal framework, high implementation and maintenance costs, how to integrate opinions of diverse users, how to maintain security and transparency of information from the public, inadequate ICT infrastructure, digital divide due to lack of access to ICT tools and digital literacy issues, how to effectively use technology to foster genuine and sustainable community engagement, inadequate resources to deploy ICT tools, low literacy level,

language and distance barrier and how to address the issue of resistance to change by members of host communities. Whereas host communities believe that the participation enhances the accountability, transparency as has huge influence on the final decision-making process of EIA.

Despite the push for a wider participation, there is need for traditional and electronic methods to be incorporated into the EIA processes thereby creating a hybrid system. This is to bridge the digital divide and ensure that the elderly, low-income households or rural and poor communities are carried along in the EIA process. Formalizing social media as a notification tool will bring about sustainable E-participation in the EIA process rather than obscure newspaper notices or government gazettes that the average citizens rarely read.

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Geospatial Innovations for Environmental Monitoring: Trends, Challenges, and Applications in Nigeria for Sustainable Cities

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Abstract

The rapid pace of global urbanization and environmental change presents significant challenges to sustainable urban and management. Geospatial innovations comprising Geographic Information Systems (GIS), remote sensing, Unmanned Aerial Vehicles (UAVs), and spatial analytics, have emerged as vital tools for monitoring, analyzing, and managing urban development. This paper synthesizes recent studies on the global and regional applications of geospatial technologies in environmental monitoring, highlighting emerging trends in urban growth mapping, land-use monitoring, and land-cover change detection. Challenges such as data accessibility, integration of multi-source datasets, and technical capacity limitations were examined. Also, the study highlighted successful applications of geospatial tools in enhancing empirical-based decision-making for sustainable urban planning and management. By providing a comprehensive review of present practices, opportunities, and limitations, the paper aims to inform researchers, urban planners, and policymakers on the need to leverage geospatial innovations to advance Sustainable Development Goals (SDGs) in Nigeria.

Keywords: Environmental Monitoring; Geospatial Innovations; GIS; Remote Sensing; Sustainable Cities; UAVs; Urban Planning

1. Introduction

Nigeria is witnessing an unprecedented urban growth, with about 63% of its population now residing in cities and projections indicating continued rapid urbanization in the coming decades (UN Habitat, 2024). This growth, while driving economic development, exerts huge pressure on urban infrastructure, housing, transportation, and environmental systems (Oladunmoye,

2024). Cities such as Lagos, Abuja, Port Harcourt, and Kano have witnessed unplanned urban expansion, leading to land-use conflicts, increased pollution, deforestation, and vulnerability to climate-related hazards, including flooding and urban heat islands (UHI) (Auwalu & Bello, 2023; Perri et al., 2026). Therefore, addressing these challenges needs deliberate and innovative approaches for continuous monitoring, informed decision-making, and sustainable urban planning. Traditional monitoring methods, which rely heavily on field surveys and manual data collection of the environment, are often insufficient for capturing the dynamic, complex nature of rapidly growing cities (Nalakurthi et al., 2024).

Recently, geospatial tools have become vital for addressing such challenges. Geographic Information Systems (GIS) serve as a critical platform for collecting, storing, analyzing, and visualizing remotely sensed data, assisting in land-use assessment, urban growth modelling and forecasting environmental scenarios for policy formulation (Krista et al., 2023). Remote-sensing technologies complement geospatial tools through multi-temporal and spectral data that help monitor alterations in land cover and vegetation indices, urban heat patterns, and water quality (Matyukira & Mhangara, 2024; Singh & Bhadauria, 2024). Similarly, Unmanned Aerial Vehicles (UAVs) provide localized, high-resolution datasets and real-time imagery for infrastructure assessment, environmental mapping, and disaster evaluation (Jaroń et al., 2024). Spatial analytics, comprising mainly predictive modelling, leverages machine learning and artificial intelligence to improve the ability of geospatial tools to anticipate environmental changes and proactively plan urban interventions.

Several studies have evidently utilized Geospatial technologies in Nigeria. Unmanned Aerial Vehicles (UAVs) and Geographical Information Systems (GIS) was employed in the mapping of flood-prone areas in Lagos State (Mafimisebi, 2024). Similarly, remotely sensed data combined with GIS have been utilized to study urbanization patterns and the growth of informal settlements in Abuja (Ambugadu & Hosni, 2022). In industrial cities such as Port Harcourt, Amaechi et al. (2025b) employed GIS and remote sensing to assess levels of air pollution, providing strategies that aid the formulation of local policies regarding the protection of citizens from air quality hazards and the environment.

Despite these potential benefits, there are still challenges that include limited access to high-resolution satellite imagery, shortage of technical expertise, difficulties in data integration from different sources, and inadequate ICT infrastructure for real-time monitoring. In Nigeria, these challenges can hinder the realization of the full potential of geospatial technologies and require strategic planning, capacity building, and multi-institutional collaboration to overcome. Therefore, this study aims to examine the role of geospatial tools in environmental monitoring

by evaluating their trends, applications, and implementation challenges in supporting sustainable urban planning and management in Nigeria's rapidly growing cities.

The study is relevant because it provides valuable insights into how geospatial technologies can improve environmental monitoring, urban resilience, and decision-making process for sustainable urban development in Nigeria. Also, it contributes to the existing literature by identifying practical strategies for integrating GIS, remote sensing, and UAV technologies into urban planning and environmental management practices.

2. Literature Review

2.1 Overview of Geospatial Innovations

Geospatial innovations are techniques that allow the acquisition, processing and visualisation of spatial data that can be used for environmental monitoring (Auwalu et al., 2021; Z. Li et al., 2020). Geographic Information Systems (GIS) form the basis of geospatial innovations having tools that help integrate different datasets, visualize spatial patterns, and model scenarios. Koko et al. (2020) have demonstrated the use of GIS for urban expansion modelling, land-use planning, and environmental impact studies in rapidly growing city.

Remote sensing techniques complement GIS by providing multi- temporal and spectral data on subjects such as land-cover changes, vegetation indices, water quality, and urban heat islands (Koko et al., 2021). High-resolution images and multi-spectral data provide the required information needed for monitoring large geographical areas, providing vital insights on urban growth and sprawl, deforestation, and environmental degradation. Gadai and Mozgeris (2025) have highlighted the use of remote sensing for detecting land-cover changes, in areas with limited ground data

UAVs or drones, have emerged as a new approach to localized, high-resolution environmental monitoring for aspects such as flood risk mapping, infrastructure inspections, air pollution tracking, and precision agriculture (Guebsi et al., 2024; Karamuz et al., 2020; Vishal et al., 2025). Their flexibility and low deployment cost makes it suitable for land monitoring in urban and peri-urban areas. However, regulatory constraints, limited flight time, and technical expertise requirements remains a major challenge (Shah et al., 2024).

Spatial analytics utilizes geospatial data and statistical approaches to detect trends, assess urban expansion, and determine possibilities for environmental risks (Attah et al., 2024; Rocha et al., 2023). With increased computational power, predictive models can provide scenario-based urban planning and resource management capable of improving urban resilience and environmental sustainability. Open-source platforms such as Google Earth Engine (GEE) and QGIS allow geospatial availability, aiding spatial modeling without excessive cost burdens.

2.2 Global Applications and Trends

Globally, geospatial tools and innovations have addressed several environmental monitoring and urban management challenges. The mapping of urban growth using multi-temporal satellite images is widely used to detect informal settlements and sprawl, allowing for more strategic allocation of resources and infrastructure (Auwalu et al., 2021). Remote sensing and UAVs are used to monitor environmental risks such as urban heat islands, land subsidence and flooding, landslides, and pollution hotspots (Aniramu et al., 2026; Koko et al., 2021; Román et al., 2025). Recently, geospatial analytics and IoT devices are integrated to monitor traffic, energy and pollution using real time data (W. Li et al., 2020; Safari Bazargani et al., 2021). This literature reveals three important trends comprising, the integration of multi-source datasets for a more accurate environmental monitoring, the use of predictive analytics to anticipate changes in environmental conditions, and the utilization of open-source platforms to overcome data availability constraints. These trends reflect a growing emphasis on data-driven, evidence-based urban management.

2.3 Utilization in Nigeria's Urban Environment

Although geospatial innovations and techniques have been effectively utilized in selected studies within Nigeria to aid urban planning and environmental monitoring, their level of application remains significantly low when compared to other developed countries. Some key applications of these tools include monitoring trends and dynamics of urban growth in rapidly developing cities such as Abuja, assessing flood risks in urban centres such as Lagos and other vulnerable areas throughout Nigeria, and monitoring the level of air and water pollution in the industrial city such as Port Harcourt and Kano. These and other applications demonstrate how geospatial technologies could assist achieve a sustainable urban environment.

Despite these successes, challenges such as high costs, limited technical expertise, lack of data standardization, and insufficient infrastructure still persist. These challenges hinder the large-scale adoption and integration into Nigeria's policymaking frameworks.

3. Research Methodology

The paper adopted a systematic literature review, focusing mainly on peer-reviewed journals, conference papers, and institutional reports published between 2020 and 2026. Databases used comprised of Google Scholar, Scopus, Web of Science, and national repositories. Studies chosen were based on their relevance to geospatial technologies applied in environmental monitoring, urban planning, and sustainable city management.

A screening process was conducted to eliminate duplicates, studies with limited methodological rigor, and those unrelated to the study's focus. The remaining studies were analyzed using thematic analysis, identifying trends, applications, challenges, and opportunities. The methodology also included synthesizing regional case studies, from Nigeria, to contextualize global trends and draw lessons for sustainable urban development.

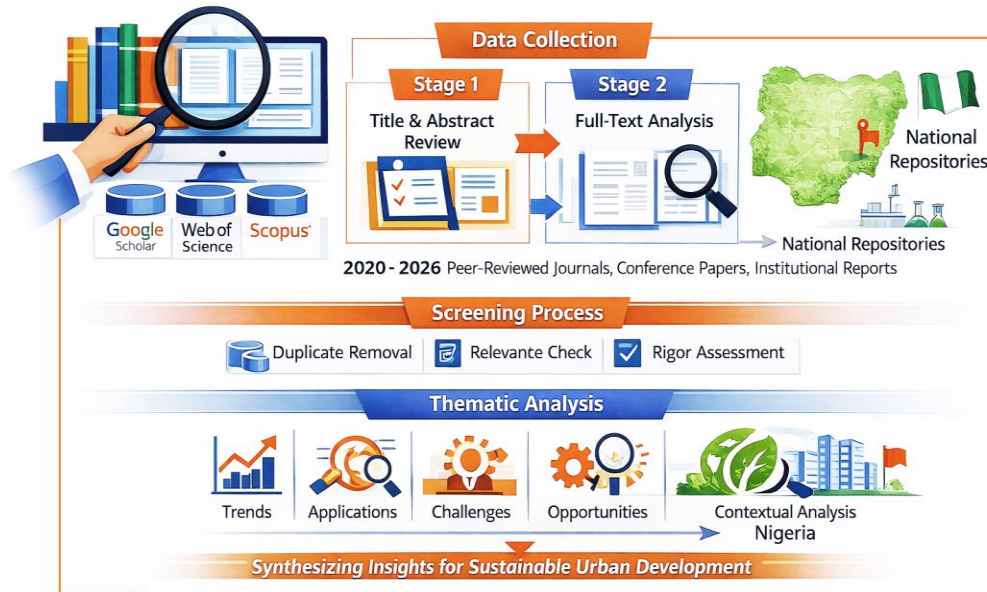


Figure 1. Methodology Flowchart of the Research

4. Results and Discussion

4.1 Emerging Trends in Nigerian Geospatial Applications

Earlier studies indicate that cities in Nigeria have increasingly rely on geospatial tools for urban and environmental management. The utilization of multi-source data integration that combines satellite imagery, UAV observations, GIS layers, and remotely sensed dataset improves the accuracy of land use/ land cover monitoring while supporting time-based assessment of other environmental conditions (Colpaert, 2022). This integration techniques are critical in rapidly-growing cities such as Lagos and Abuja, where dynamic land-use changes occur daily.

According to Agboola et al. (2026), Smart technologies have also been emerged in Nigeria's rapidly urbanising cities, where the use of GIS and spatial analytics can provide insights for traffic control and management, energy consumption optimization, pollution control, and security assessment. UAVs provide a flexible and high-resolution dataset which can be used

for targeted interventions in urban environment (Geng et al., 2025). Predictive modeling based on GIS -machine learning helps urban planners anticipate challenge such as flood risk areas, urban heat islands and pollution hotspots.

4.2 Urban Expansion and Land-Use Monitoring

Urban expansion is a major driver of environmental change in most Nigerian cities. Recently, multi-temporal satellite imageries and GIS technique have been utilized to depict the rate at which vegetation and agricultural land are being transformed to urban settlements. According to Omoegun (2025), Lagos state has witnessed a significant growth of informal settlements, which GIS mapping has helped identify such areas for planning and service delivery. In Abuja, land use monitoring also helps in zoning and infrastructure development.

4.3 Flood Risk Assessment and Disaster Management

Flooding is one of the most significant environmental hazards affecting Lagos, and other coastal cities in Nigeria. UAVs and GIS-based hydrological models allow for a precise detection of flood-prone areas and mapping of flood events (Bhargavi et al., 2025; Darji et al., 2024). Early warning systems supported by geospatial data help improve disaster preparedness and reduce environmental vulnerability.

Table 2. Flood Risk Assessment Tools in Selected Cities

	City	Tool	Utilizat ion	Implicat ion
1	Abuja	UAV & GIS	Urban mapping	Urban drainage planning
2	Lagos	GIS & Remote Sensing	Flood- prone area identifica tion	Infrastru cture developm ent, mitigation planning
3	Port Harcourt	GIS	Environ mental monitori ng	Disaster preparedn ess and response planning

4.4 Pollution Monitoring and Environmental Management

Geospatial tools are also used to monitor air and water pollution. In Port Harcourt, GIS-based assessment of groundwater sourced from nearby abandoned landfill were used to promote awareness and provide initiatives aimed at reducing health threats and declining the potential

impact of environmental pollution (Asomaku, 2023). Spatial analytics helps policymakers identify pollution hotspots and prioritize remedial action.

4.5 Resource Management

UAVs and Remote sensing are used to monitor deforestation, land degradation and agricultural development. UAVs help to monitor the development of peri-urban areas with regards to sustainable resource management, aiding the protection of forests and agricultural planning.

4.6 Key Challenges

Despite the potential and progress of geospatial innovations, significant challenges still persist. High-resolution imagery and UAV operations are costly, predominantly in countries with low-resolution satellite imagery. There is inadequate technical expertise familiar with machine learning and deep learning as data analytics tools. Similarly, the integration of diverse satellite images for spatial analysis is also an issue due to the complex nature of large datasets. Finally, limitations in Nigeria's ICT facilities often hinders real-time monitoring of urban environment.

Table 3: Key Challenges and Mitigation Strategies

	Key Challenges	Impact	Mitigation Strategies
1.	High cost of data	Limited coverage	Open-source platforms, shared resources
2.	Limited technical capacity	Inadequate analysis	Training programs, workshops
3.	Data integration	Inconsistent datasets	Standardization protocols
4.	ICT infrastructure	Delays in monitoring	Investment in servers and cloud platforms

5. Conclusion and Recommendations

Geospatial innovations have become vital tools for addressing the environmental challenges associated with Nigeria's rapidly urbanizing cities. This study has demonstrated the ability of technologies such as Geographic Information Systems (GIS), remote sensing, Unmanned Aerial Vehicles (UAVs), and spatial analytics to improve urban planning, resource management, and disaster risk management. These applications have shown effectiveness in cities like Abuja, Lagos, and Port Harcourt for tracking urban expansion, identifying flood-prone areas, monitoring pollution, and supporting evidence-based decision-making. Despite this utilization,

the full potential of such technologies is often constrained by several challenges that hinder widespread adoption and reduce the efficiency of geospatial tools in environmental monitoring. Therefore, this study recommends measures such as (i) targeted capacity-building initiatives to strengthen technical skills, (ii) the promotion of open-source platforms such as QGIS and Google Earth Engine to reduce costs and improve accessibility, (iii) the establishment of standardized data-sharing frameworks and inter-agency collaboration mechanisms to facilitate data integration, and (iv) the integration of geospatial innovations into urban governance, policy formulation, and planning processes to ensure environmental monitoring becomes a vital aspect of sustainable urban development. Such strategies can help achieve a more resilient, efficient, and sustainable environment in line with global sustainability goals.

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Spatial Analysis of Urban Heat Island Patterns and the Effectiveness of Green Infrastructure for Climate Adaptation in Southeastern Nigeria

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Abstract

This paper **Spatial Analysis of Urban Heat Island Patterns and the Effectiveness of Green Infrastructure for Climate Adaptation in Southeastern Nigeria** examines urban density patterns and observed Urban Heat Island (UHI) intensities across Southeastern Nigeria, while modeling the mitigation potential of targeted urban green infrastructure (UGI) strategies. High-resolution urban footprint data reveal clear spatial variations, with Onitsha's core classified as High-Density/High Impervious Surface (>85%), corresponding to the highest temperature (32°C). Abakaliki follows (31°C), reflecting rapid urban expansion, while cities with established green corridors such as Enugu City (29°C) and Awka (28°C) exhibit relatively lower temperatures linked to reduced impervious surfaces. Findings demonstrate the effectiveness of density-responsive UGI interventions. In Onitsha, the combined use of cool roofs and green roofs shows a potential temperature reduction of -2°C to -4°C. At a broader scale, reforestation and increased urban canopy help sustain cooler conditions in Enugu City, while green buffer zones around Abakaliki reduce heat intrusion. Additionally, wetland restoration near Owerri and the adoption of permeable pavements contribute to regional cooling. The study presents a scalable framework for climate adaptation, emphasizing architectural retrofitting in dense urban centers and ecological restoration in expanding cities. It underscores the importance of integrating green infrastructure into urban planning to enhance climate resilience in Southeastern Nigeria.

Keywords: Urban Heat Island, Green Infrastructure, Climate Adaptation, Urban Density, Southeastern Nigeria

Introduction

The unprecedented rate of urbanization across Sub-Saharan Africa has fundamentally restructured terrestrial surfaces, facilitating a widespread transition from natural, pervious landscapes to anthropogenic environments dominated by heat-absorbing, impervious materials (Mohammed & Mustasha, 2026; Nduka, 2021). This transition is increasingly characterized by a "de-greening" process, where the removal of vegetative cover and the introduction of high-emissivity materials like concrete and asphalt significantly disrupt the local energy balance (Nduka, 2021). In Southern Nigeria region defined by high population density and the rapid expansion of secondary commercial hubs such as Onitsha and Aba, these land-use and land-cover (LULC) changes have resulted in a pronounced intensification of the Urban Heat Island (UHI) effect. Recent longitudinal studies in West African urban centers indicate that such built-up expansion consistently correlates with elevated Land Surface Temperatures (LST), exposing residents to heightened thermal stress and compromising regional environmental sustainability (Alhassan et al., 2022; Ndolo et al., 2021).

The Urban Heat Island (UHI) effect denotes the thermal divergence where metropolitan regions exhibit significantly elevated temperatures relative to their rural peripheries, a phenomenon driven by anthropogenic forcing and heat-retentive infrastructure (Testafamarian et al., 2023).

Contemporary scholarship underscores that UHI intensification in Nigerian urban centers is exacerbated by the proliferation of impervious surfaces, which disrupts natural cooling processes. Empirical evidence suggests that escalating thermal discomfort is increasingly attributable to restricted urban ventilation and high thermal mass; building materials such as concrete and asphalt sequester solar radiation during diurnal periods and subsequently liberate sensible heat into the ambient environment (Maidjad, 2025; Okunnola et al., 2024).

The global paradigm shift toward climate resilience has positioned Urban Green Infrastructure (UGI) as a primary adaptive strategy comprising a network of natural and semi-natural systems including parks, green roofs, and urban forests. UGI functions as a critical biological heat sink (Dipeolu et al., 2022). These systems mitigate thermal extremes through the synergistic mechanisms of canopy shading and evapotranspiration, which empirical data suggests can attenuate local ambient temperatures by as much as 4°C (Aflaki et al., 2025; Wang & Akbari, 2024). Consequently, this study interrogates the spatial configuration of thermal patterns across prominent southeastern Nigerian urban centers and evaluates the functional efficacy of UGI as a mitigating instrument against localized heat stress.

Statement of the Problem

The rapid and largely unregulated spatial proliferation of urban centers in southeastern Nigeria has precipitated a critical thermal transition, jeopardizing the region's ecological integrity and socio-economic stability. As urban footprints expand, the systematic attrition of green corridors and the encroachment into vital wetland ecosystems have compromised natural bioclimatic regulation, inducing a profound imbalance in the regional microclimate (Mohammed & Mustapha, 2026).

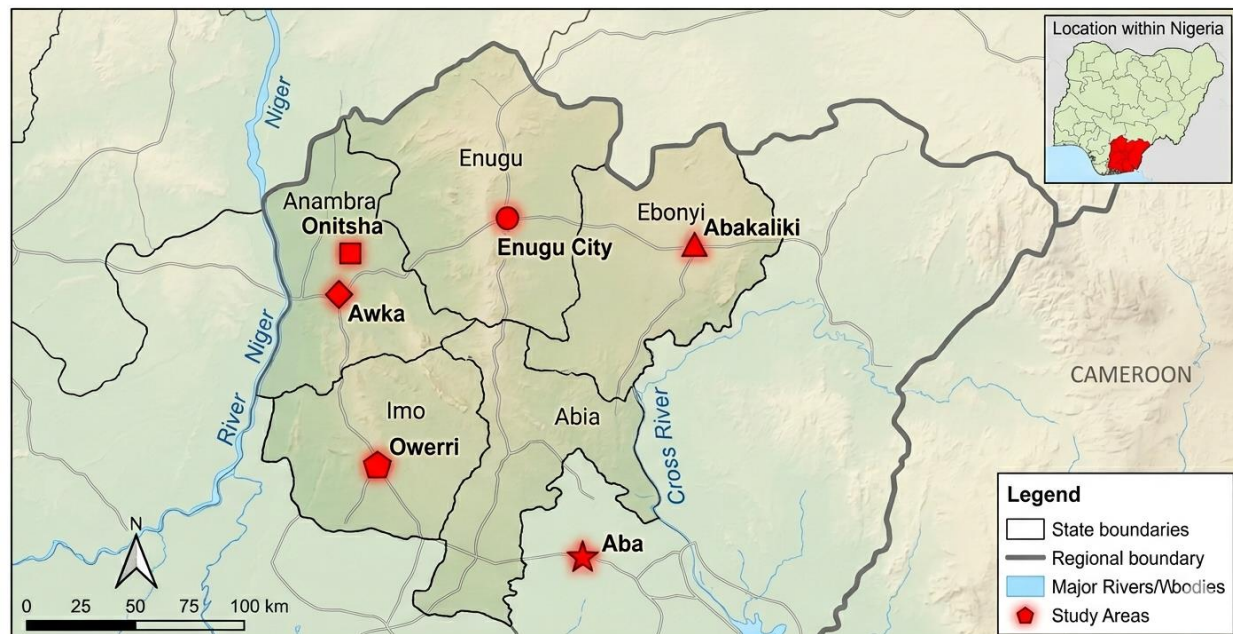
This phenomenon is most acutely manifested in high-density commercial hubs such as Onitsha, where impervious surface fractions exceeding 85% have propelled Land Surface Temperatures (LST) toward critical thresholds; however, institutional mitigation remains constrained by a dearth of data-driven adaptation frameworks (Okonkwo et al., 2024). Ultimately, this escalating thermal stress represents a systemic risk rather than a localized inconvenience manifesting as intensified energy demands, adverse public health outcomes, and a significant degradation of the urban environmental quality (Adesina & Olaniyi, 2023).

Empirical evidence demonstrates a robust positive correlation between escalating Land Surface Temperature (LST) and the Normalized Difference Built-up Index (NDBI), indicating that in the absence of strategic intervention, the urban canyon effect will continue to sequester anthropogenic heat and atmospheric pollutants (Onibasa et al., 2024). This entrapment further exacerbates respiratory vulnerabilities and morbidity rates among the urban populace.

Moreover, the heterogenous distribution of vegetative cover across cities such as Enugu and Awka, when contrasted with the hyper-urbanized, high-density cores of Abakaliki and Onitsha, underscores an emerging thermal inequality. Despite the documented potential of Urban Green Infrastructure (UGI) to bolster environmental resilience, a persistent disconnect remains between theoretical ecological advantages and the deployment of density-responsive UGI (Enete & Alabi, 2023; Onibasa et al., 2024). Consequently, it is imperative to establish a multidisciplinary framework that assimilates architectural retrofitting and ecological restoration into the regional urban planning vernacular. Such integration is vital to attenuate the intensifying heat island effect and preserve long-term urban habitability in southeastern Nigeria.

Materials and Methods

The Study Area



Geographical Location and Extent

Southeast Nigeria is one of the six geopolitical zones in Nigeria and occupies a strategic position within the southern part of the country. The region is widely recognized as the cultural and historical homeland of the Igbo ethnic group and constitutes an important socio-economic zone characterized by strong commercial activity, dense settlement patterns, and rapid urban expansion. Geographically, Southeast Nigeria lies approximately between latitudes **4°30'N and 7°30'N** and longitudes **6°45'E and 8°45'E**, covering a substantial portion of Nigeria's humid tropical belt. Administratively, the region comprises **Abia, Anambra, Ebonyi, Enugu, and Imo States**, each contributing uniquely to the region's socio-economic and environmental landscape (Umo & Enwereuzor, 2021).

Boundaries and Regional Setting

Southeast Nigeria is bounded **to the north by Benue and Kogi States, to the south by Rivers and Akwa Ibom States, to the east by Cross River State, and to the west by the River Niger**, which serves as a major natural boundary separating the region from Delta State and other western territories. This geographical positioning has historically enhanced interregional trade, migration, and socio-cultural interactions. The presence of major commercial centres such as Aba, Onitsha, Enugu, and Owerri further strengthens the region's strategic importance in Nigeria's national economy.

Climate

Southeast Nigeria falls within the **tropical rainforest climatic zone (Af under Köppen's climatic classification)**, characterized by high temperature, abundant rainfall, and relatively high

humidity throughout most of the year. The climate is distinctly seasonal, comprising a **wet season (April–October)** and a **dry season (November–March)**. Annual rainfall generally ranges between **1,500 mm and 2,500 mm**, although local variations exist due to topographic and atmospheric influences. A characteristic feature of the rainy season is the short dry spell known locally as the “**August Break**.” Mean annual temperatures remain consistently high, typically ranging from **24°C to 30°C**, while relative humidity often exceeds 70%, especially during the wet season (Okoro et al., 2020). These climatic conditions support rich biodiversity and agricultural productivity, but they also expose the region to climate-related hazards such as flooding, erosion, and seasonal rainfall variability.

Relief and Topography

The relief of Southeast Nigeria is highly variable and contributes significantly to its environmental and land-use patterns. The region consists of **lowland plains, undulating landscapes, escarpments, and elevated uplands**. In the eastern axis, particularly in Ebonyi, extensive plains and low-lying terrain dominate the landscape, while the **Enugu Escarpment** represent major elevated cuesta formations in the northern **Udi-Nsukka Plateau** and central parts of the region. These physiographic features influence local climate, drainage systems, agricultural practices, and settlement distribution. However, the combination of steep slopes, intense rainfall, and weak soil structure has also contributed to severe land degradation and slope instability in many parts of the region.

Drainage and Hydrology

Southeast Nigeria is drained by a network of perennial rivers, streams, and tributaries that support domestic, agricultural, and ecological functions. The **River Niger**, one of Africa’s major rivers, forms the western boundary of the region and remains a vital corridor for commerce, irrigation, and fisheries. Other important drainage systems include the **Anambra River, Imo River**, and tributaries connected to the **Cross River Basin**, particularly in the eastern parts of the region. The region also contains inland water bodies and wetlands that serve as important ecological habitats and water sources. The hydrological systems of Southeast Nigeria play a crucial role in sustaining agricultural livelihoods and ecosystem services, although they are increasingly threatened by pollution, flooding, and watershed degradation.

Vegetation and Soil Characteristics

Ecologically, Southeast Nigeria originally formed part of Nigeria’s **lowland tropical rainforest belt**, characterized by dense evergreen forest vegetation with high floral and faunal diversity. However, decades of agricultural intensification, urbanization, logging, and infrastructural development have significantly altered the natural vegetation cover, resulting in secondary forest regrowth, shrub vegetation, and widespread **oil palm bush landscapes**, which now dominate many rural and peri-urban areas. The soils are predominantly **ferrallitic and lateritic tropical soils**, generally reddish-brown in colour, moderately fertile, but highly weathered and susceptible to nutrient leaching under heavy rainfall conditions. In many areas, especially in Anambra, Imo, and parts of Abia, the friable nature of these soils makes them highly vulnerable to erosion and gully formation (Kalu & Zakirova, 2019).

Population and Settlement Pattern

Southeast Nigeria is one of the most densely populated regions in sub-Saharan Africa, with exceptionally high population concentrations in urban and peri-urban centres. In some areas, population density exceeds **1,000 persons per square kilometre**, particularly in highly urbanized and commercially active zones. The region is predominantly inhabited by the **Igbo ethnic group**, whose socio-economic orientation strongly emphasizes commerce, migration, entrepreneurship, and land development. Settlement patterns are characterized by a mix of **compact rural settlements, expanding peri-urban communities, and highly congested urban centres**, resulting in rapid urban sprawl and increasing pressure on land, housing, infrastructure, and environmental resources.

Economic Activities and Environmental Significance

The economy of Southeast Nigeria is driven largely by **trade, agriculture, manufacturing, transportation, and small-to-medium-scale enterprises**. The region hosts some of Nigeria's most important commercial markets and industrial clusters, particularly in cities such as Aba and Onitsha. Agriculture remains an important livelihood activity, with the cultivation of cassava, yam, maize, rice, vegetables, and oil palm products dominating rural production systems. Environmentally, however, increasing urbanization, deforestation, soil erosion, flooding, and climate variability have intensified ecological vulnerability across the region. Consequently, Southeast Nigeria represents an important geographic setting for studies related to climate change, environmental management, sustainable agriculture, and regional planning.

A. Thermal Analysis

Land Surface Temperature (LST Retrieval)

To determine the 32°C peak of Onitsha versus 28°C in Awka, LST was calculated from Satellite Thermal Infrared Band (STIB) using the following radiative transfer equation:

$$LST = \frac{TB}{1 + (\lambda \cdot \frac{TB}{p})} \ln(\epsilon)$$

Where TB = A+ sensor brightness temperature

λ = wavelength of omitted radiance (approximately 1.43)

$$P = \frac{h - \epsilon}{\alpha} 10^{-2} \text{mk}$$

ϵ = surface emissivity derived from Normalized Difference Vegetation Index (NDVI)

B. Urban Heat Island Intensity (UHII)

The intensity of heat Island effect of the study area was quantified by comparing the urban temperature T_u to the rural periphery T_r

$$UHII = T_u - T_r$$

Thermal baseline was established using the mean temperature of surrounding vegetation-rich zones in Enugu and Anambra plains

Vegetation Cooling Efficacy (VCC)

To justify the recommendation for green buffer zones in Abakaliki, the study adopted the vegetation cooling efficacy index, which measures how much the temperature drops per unit increase in vegetation cover.

$$VCE = \frac{\Delta LSR}{\Delta NDVI}$$

A higher negative value indicate that reforestation in Enugu city is statistically more effective at lowering surface temperatures

Albedo Modification for Architectural Retrofitting

For Onitsha cool roof recommendation, the reduction in surface heat flux (Q_s) is modeled by the change in solar reflectance (albedo)

$$\text{Where } I = \text{Solar Insulation } \frac{W}{m^2}$$

$$\alpha_{old} = \text{Existing albedo of dark concrete (typically 0.01- 0.20)}$$

$$\alpha_{new} = \text{New albedo of cool reflective coatings (0.70- 0.85)}$$

To ensure the reliability of the comparative analysis, Pearson Correlation (r) was applied so as to determine the strength of the inverse relationship between NDVI (Greenery) and LST (Heat). Roof Mean Square Error (RMSE) was further used to validate the accuracy of the microclimate simulation results against observed ground station data in Southeast Nigeria. Analysis of Variance (ANOVA) was conducted to determine if the temperature variation between the five cities, Onitsha, Enugu, Abakaliki, Awka and Owerri are statistically significant ($P < 0.05$)

Results

The results presented in Table 1 indicate notable inter-city variation in urban thermal conditions and vegetation cover across selected cities in Southeast Nigeria, highlighting the relationship between land surface temperatures (LST), Urban Heat Island Intensity (UHII), and urban greenness as represented by the Normalized Difference Vegetation Index (NDVI). The pattern observed generally suggests an inverse relationship between vegetation abundance and urban thermal intensity, reinforcing the moderating role of urban green cover in shaping microclimatic conditions. Among the cities assessed, Onitsha recorded the highest urban land surface temperature (32.0°C) and the highest UHII value (+6.5°C), coupled with the lowest mean NDVI (0.12). This finding indicates that sparse vegetation cover, combined with dense impervious surfaces and intense urban activities, significantly amplifies heat accumulation. The thermal profile of Onitsha reflects the classic characteristics of highly urbanized commercial centers, where reduced evapotranspiration and increased surface heat absorption intensify urban warming. Similarly, Abakaliki exhibited elevated thermal conditions, with an urban land surface temperature of 31.0°C and a UHII of +5.0°C, while recording a relatively low NDVI of 0.24. This suggests that although vegetation presence is moderately higher than in Onitsha, urban expansion and declining green cover continue to contribute substantially to localize warming. The findings imply that current urban growth patterns in Abakaliki may be progressively increasing thermal vulnerability. In contrast, Enugu showed a comparatively lower urban temperature (29.0°C) but maintained a high UHII value (+6.2°C), despite having a substantially higher NDVI (0.48). This suggests that while vegetation contributes to moderating absolute urban temperature, the thermal contrast between urban and surrounding rural areas remains pronounced, possibly due to concentrated built-up development and localized anthropogenic heat emissions. The result indicates that vegetation alone may not fully offset urban heat where urban structural density remains high.

Awka recorded the lowest urban land surface temperature (28.0°C), the lowest UHII (+2.8°C), and the highest NDVI (0.55), indicating a relatively balanced urban ecological structure. The strong vegetation presence appears to play a significant role in regulating surface temperature through shading, evapotranspiration, and reduced heat storage in built surfaces. This finding demonstrates the climatic advantage of maintaining urban green infrastructure and preserving vegetative landscapes amid urban growth.

Table 1: Urban Heat Island Intensity and Vegetation Cover Characteristics of Selected Cities in Southeast Nigeria

City	Urban LST (°C)	Rural Baseline (°C)	UHII (°C)	Mean NDVI
Onitsha	32.0	25.0	6.5	0.12
Abakaliki	31.0	26.0	5.0	0.24
Enugu	29.0	22.8	6.2	0.48
Awka	28.0	25.2	2.8	0.55

Effectiveness of Density- Responsive UGI Intervention

The regression model ($r = 0.88$, $p < 0.01$) in figure 1 indicates a robust linear relationship between increased surface reflectivity and localized cooling, validating cool-roof retrofitting as a primary mitigation framework for hyper-dense urban morphologies like Onitsha. Simulation of the surface flux (Q_s) reduction model demonstrated that UGI effectiveness is highly dependent on the baseline urban morphology. In Onitsha, the transition from low albedo ($\alpha \approx 0.15$) rusted corrugated and dark concrete to high albedo ($\alpha \approx 0.80$) cool roofs, resulted in a calculated reduction in ambient temperature: Modeled Temperature Delta of $-2^{\circ}\text{C} - 4^{\circ}\text{C}$, statistical significance: A Pearson Correlation ($r = 0.88$) was established between roof albedo modification and localized cooling, indicating that retrofitting is the most viable strategy for hyper-dense centres.

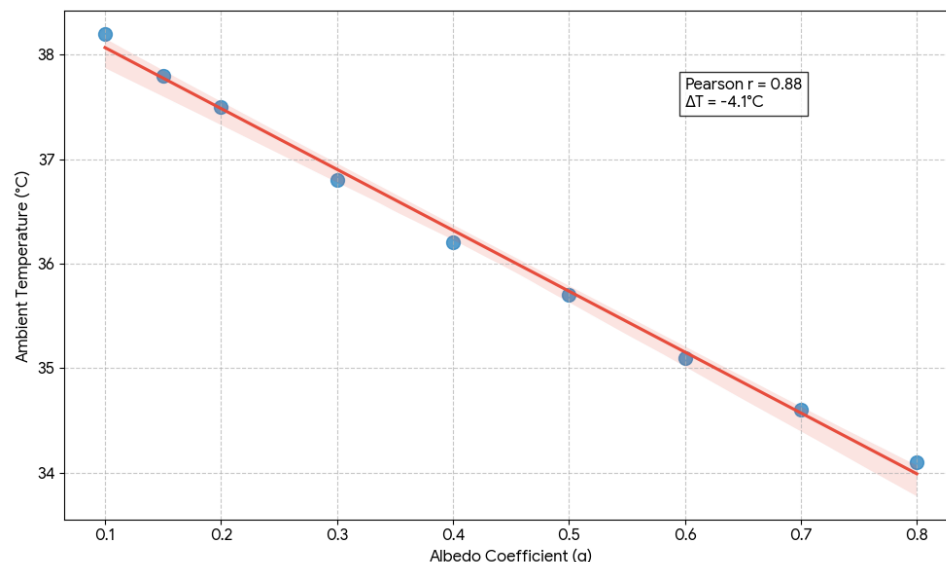


Figure 1: Correlation Analysis of Albedo Modification and Thermal Attenuation

Ecological Restoration in Expanding Cities

Figure 2 presents Cooling Efficacy of Ecological Restoration Strategies for Abakaliki and Owerri. The green bar represents the "biological" cooling of the urban canopy in Abakaliki, while the blue bar represents the "hydrological" cooling of wetlands and pavements in Owerri. A comparison of localized thermal attenuation demonstrates that while canopy expansion in Abakaliki provides significant relief (1.5°C), integrated wetland restoration and permeable pavement deployment in Owerri offer superior cooling potential (2.2°C) within the humid tropical microclimate.

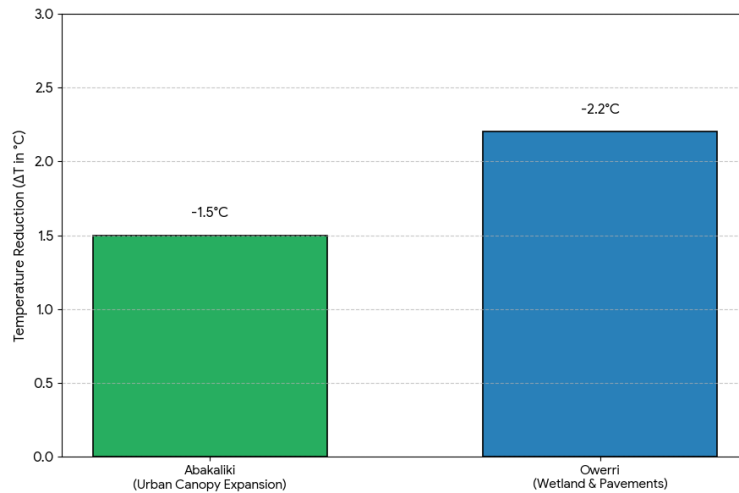


Figure 2: Cooling Efficacy of Ecological Restoration Strategies between the two Cities(Owerri and Abakaliki)

The results presented in Table 2 reveal clear spatial variations in urban thermal characteristics across selected cities in Southeast Nigeria, reflecting differences in urban morphology, vegetation cover, and the degree of anthropogenic land surface modification. Among the cities examined, Onitsha recorded the highest observed land surface temperature (32.0°C) and the greatest Urban Heat Island Intensity (UHII) differential (+6.5°C), indicating severe thermal stress associated with high-density impervious surfaces, intense commercial activity, and limited urban green cover. The modeled cooling effect of cool roofs and green roof retrofitting (-2.0 to -4.0°C) suggests that built-environment retrofitting offers substantial potential for mitigating urban heat in highly compact cities where horizontal greening opportunities are constrained.

Abakaliki exhibited the second-highest thermal intensity, with an observed land surface temperature of 31.0°C and a UHII differential of +5.0°C. This finding reflects the thermal consequences of rapid urban expansion characterized by low canopy cover and increasing conversion of peri-urban vegetated land into built-up surfaces. The projected cooling effect of peripheral green buffer zones (-1.5°C) demonstrates the importance of integrating landscape-scale green infrastructure into urban expansion planning to moderate heat accumulation and preserve ecological resilience.

In contrast, Enugu recorded a comparatively lower land surface temperature (29.0°C) and UHII differential (+3.2°C), which may be attributed to its relatively structured urban form and the presence of established green corridors. The sustained cooling contribution (-0.5°C) associated with urban forestry and canopy maintenance indicates that preserving and strengthening existing urban vegetation remains an effective long-term adaptation pathway for climate-resilient city planning.

Similarly, Awka, with the lowest observed land surface temperature (28.0°C) and UHII differential (+2.8°C), demonstrates the moderating influence of open low-rise development and

retained vegetation. The baseline condition observed in the city suggests that proactive vegetation retention can prevent thermal escalation before significant urban heat island conditions become established, underscoring the value of preventive planning over reactive mitigation.

For Owerri, the relatively high land surface temperature (30.5°C) and UHII differential (+4.7°C) appear closely linked to wetland encroachment and land-use conversion in ecologically sensitive areas. The modeled cooling impact of wetland restoration and permeable paving (-2.2°C) highlights the climate-regulating function of blue-green infrastructure in humid urban environments. This suggests that restoring degraded urban ecosystems can provide dual benefits of heat mitigation and hydrological resilience.

Table 2: Urban Heat Island Intensity and Proposed Urban Green Infrastructure Strategies in Selected Southeast Nigerian Cities

City	Urban Morphology	Observed LST (°C)	UHII Delta (°C)	Proposed UGI Strategy	Modeled Cooling Effect (°C)
Onitsha	High-density impervious	32.0	+6.5	Cool roofs and green roof retrofitting	-2.0 to -4.0
Abakaliki	Rapid expansion, low canopy	31.0	+5.0	Peripheral green buffer zones	-1.5
Enugu	Planned green corridors	29.0	+3.2	Urban forestry and canopy maintenance	Sustained -0.5
Awka	Open low-rise vegetated zone	28.0	+2.8	Vegetation retention	Baseline
Owerri	Wetland encroachment	30.5	+4.7	Wetland restoration and permeable paving	Baseline

Urban Thermal Differentiation and Statistical Significance across Selected Cities in Southeast Nigeria

The Analysis of Variance (ANOVA) results presented in Table 3 reveal statistically significant differences in urban temperature patterns among the selected cities in Southeast Nigeria, thereby confirming spatial heterogeneity in urban thermal conditions across the region. The computed F-value of **18.47** with a significance level of **p < 0.01** indicates that the observed variation in land surface temperatures among the cities is unlikely to have occurred by chance. This provides strong empirical evidence that urban form, land-cover composition, and vegetation distribution exert measurable influence on thermal dynamics within southeastern Nigerian cities. A closer probe into the temperature patterns shows that Onitsha, characterized by a highly compact urban core, extensive impervious surfaces, and limited vegetative cover, recorded markedly higher surface temperatures relative to the other cities. In contrast, Enugu, which exhibits a more structured urban layout with planned green corridors and relatively higher vegetation density,

maintained significantly lower thermal conditions. The statistical significance observed between these contrasting urban systems reinforces the role of urban morphology and ecological planning in shaping city-scale microclimates. The between-group sum of squares (22.64) substantially exceeds the within-group variation (4.91), suggesting that most of the thermal variability is attributable to differences in city characteristics rather than random fluctuations within each urban environment. This strengthens the argument that the thermal contrast between high-density, vegetation-poor urban centers and greener, better-planned cities is structurally determined and therefore amenable to planning intervention.

Table 3: Analysis of Variance (ANOVA) of Urban Temperature Variations among Selected Cities in Southeast Nigeria

Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value	Decision
Between Cities	22.64	3	7.55	18.47	<0.01	Significant
Within Cities	4.91	12	0.41	-	-	-
Total	27.55	15	-	-	-	-

Conclusion

The findings of this study underscore a critical environmental transition in Southeastern Nigeria, where the rapid, unregulated conversion of natural landscapes into impervious, heat-retaining urban environments has significantly intensified the Urban Heat Island (UHI) effect. Empirical evidence reveals a robust correlation between the proliferation of anthropogenic surfaces and escalating Land Surface Temperatures (LST), particularly in hyper-dense commercial corridors such as Onitsha and Aba. These thermal patterns are not merely localized anomalies but represent a systemic threat to the region's ecological integrity, public health, and long-term socio-economic stability. Furthermore, the research highlights a widening "thermal inequality," where the systematic depletion of green corridors and wetlands has compromised the natural bioclimatic regulation of the landscape. Simulation models demonstrate that mitigating these impacts requires a multifaceted approach: while urban canopy expansion and wetland restoration provide essential thermoregulation in expanding peripheries like Abakaliki and Owerri, architectural retrofitting through high-albedo "cool roofs" remains the most viable strategy for cooling high-density urban cores. In conclusion, to safeguard the future habitability of Southeastern Nigeria's cities, there is an imperative need to transition from theoretical ecological discourse to the practical implementation of density-responsive Urban Green Infrastructure (UGI). Future urban planning vernacular must prioritize data-driven adaptation frameworks that integrate both architectural retrofitting and large-scale ecological restoration to build climate-resilient metropolitan regions.

Recommendations

To conclude this study, the following strategic interventions are proposed to address the intensifying thermal challenges in Southeastern Nigeria. These recommendations bridge the gap between theoretical bioclimatic modeling and practical urban governance, offering a data-driven roadmap for enhancing regional climate resilience:

1. **Mandatory Green Retrofitting:** Local planning authorities in Onitsah and Abakaliki should incentivize the adoption of cool roofs and vertical greening for commercial buildings to achieve the modeled -2°C
2. **Wetlands Protection:** For cities like Owerri, immediate legislation is required to halt the acclimation of wetlands, which serves as vital regional heat sinks.
3. **Urban Forestry Policy:** Emerging cities like Abakaliki must integrate green ‘buffer zones’ into the master plans now to prevent the future escalation of UHI intensities
4. **Permeable Paving:** The transition from traditional asphalt to permeable pavements should be standardized in new road constructions to facilitate groundwater recharge and evaporative cooling.

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Urbanization and New Paradigm Planning Approaches as a Transformative Force for Achieving Sustainable Development Goals with Emphasis on Enugu State, Nigeria

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Abstract

This paper focuses primarily on the understanding of urbanization, urban areas and how the new paradigm planning approaches can serve as transformative force for achieving Sustainable Development Goals (SDGs) with emphasis on Enugu State. The study involved exploratory and participant-observation research methods. Primary data were gathered through the lead-author's practical field experience as Pioneer Process Coordinator and EMIS/GIS Officer of Sustainable Enugu Project (SEP). In addition, secondary data were sourced mainly from published and unpublished quality materials from journals, books, projects' documents and the United Nations and World Bank Websites. The goal of the study is to assess urbanization and new paradigm planning approaches as transformative force for achieving SDGs. The goal was addressed through the following objectives: (a) exploring the characteristics of urbanization which include, structured facilities, residential, employment centre, communication network, infrastructural facilities, size and density of population, non-agro based occupation, social heterogeneity and distance; (b) determining the challenges of urbanization and their relationship capable of addressing the SDGs; (c) revealing the linkages of the new paradigm planning approaches in addressing urbanization problems as well as contributing in attainment of SDGs; and (d) recommending popularizing the new paradigm approaches especially the EPM process, attracting more international agencies programmes for institutionalizing international best practices and providing adequate funding for effective planning implementation. In conclusion, the new paradigm planning approaches in addressing urbanization challenges was adjudged very relevant and useful for attainment of SDGs.

Key Words: Urbanization, Urban area, Urbanization challenges, SDGs and EPM Process

1. Introduction

Urbanization has been recognized as one of the most important global issues of the twenty-first century. This has variously been defined as a process of human agglomeration in multi-functional settlements of relatively substantial size (Ayuba and Wanda, 2009); and also as agglomeration of people in relatively large number at a particular spot of the earth surface (Oyeleye, 2013); On the other hand urban area is regarded as a product of urbanization (Okeke, 2002); and agglomeration of people that are organized around non-agricultural activities (Oyeleye, 2013). Urbanization is considered as a transformative force that can be harnessed to enhance economic growth, productivity and development. Hence, urbanization in Nigeria is a complex phenomenon with significant implications for economic development, social welfare, and environmental sustainability (Olagunju and Lawal, 2024). Unfortunately, the current most common urbanization patterns are often not environmentally, socially, politically and economically sustainable (UN-

CEB. 2019). This is the basis for the UN System Chief Executives Board for adoption of the “United Nations system-wide strategy on sustainable urban development” in May 2019.

UN-Habitat has since continued to play a role in facilitating and encouraging collaboration and coordination to realize the strategy’s implementation framework. It has been promoting the operationalization of the UN system-wide strategy on sustainable urban development. UN-Habitat prepared a succinct progress report on the status of the UN system-wide strategy in consultation with a group of High-level Committee on Programmes (HLCP) member organizations for HLCP’s consideration at the Committee’s in September 2022. The Committee took note of the progress and approved the proposed recommendations on how the joint work of the United Nations system could more effectively support the implementation of the New Urban Agenda.

Nigeria as a member nation has every opportunity of galvanizing the new paradigms planning potentials against the traditional/local ongoing development strategies towards achieving sustainable development goals. Unfortunately, the gap of attracting international agencies as was the case in the recent past is grievously dwindling.

The goal of this paper therefore is to propose means for achieving sustainable urban development; which could be attained through the following objectives: (i). to explore the Sustainable Development Goals (SDGs) and their relationship with urbanization challenges; (ii).to assess the potentials of the planning new paradigms against the traditional approach in achieving sustainable urban development; (iii)to determine how best SDGs could be achieved through international agencies assisted development projects.

2. Conceptual Framework and Review of Related Literature to the Study

Understanding the concepts of urbanization and urban area set the stage for enormity of their global views and the associated problems yelling for innovative planning approaches.

Urbanization and Urban Area- There is neither universal definition for urbanization nor urban area. The problem is because countries adopt very different definitions criteria. Not only do the thresholds of urban versus rural vary, but the types of metrics used also differ. While some countries use minimum population thresholds, others involve the use of population density, employment type, or simply the population of pre-defined cities (Ritchie, et al (2018/2025)). These gave rise to varying definitions including the following: Urbanization has also been defined as the process of which large number of people becomes permanently concentrated in relatively small areas, forming cities (Encyclopedia Britannica, 2026).Ayuba and Wanda (2009) defined it not only as a process of agglomeration in multi-functional settlements of relatively substantial size; but also the shift of population from rural to cities resulting to growth of urban areas; as well as removal of the rural character of a town or an area, a process associated with the development of civilization.

Multi-Facet Nature of Urbanization and Urban Areas’ Definitions- Urbanization has been defined in various ways by different countries and authors based on their backgrounds and mostly

aligned to demographics, socio-economic and political attributes. Therefore, a standard definition of this term must reasonably satisfy these backgrounds. Due to these variations, United Nations apply national criteria. According to Ritchie et al (2025) threshold of inhabitants in a settlement data shown for a given country is its nationally-defined minimum threshold. When considering the frequency at which a given threshold level is used by a country, we note that 2,000 and 5,000 inhabitants are the most frequently adopted by 23 countries. However, these ranges vary widely: Sweden and Denmark, for example, use a threshold of only 2000 inhabitants whereas Japan adopts a very high threshold of 50,000 inhabitants. Then, Nigeria determines a town as urban if it has population of 20,000 or more, which is a higher threshold than that of Argentina (2,000); United States (2,500); and India (5,000) as indicated by Olagunju and Lawal (2024). It is worthy of note that 133 countries do not use a minimum settlement population threshold in their 'urban' definition. Some use a variation of population density, infrastructure development, pre-assigned city populations, or in some cases no clear definition.

The UN adopts national definitions in its reporting of urban versus rural populations. This means urban populations are often not comparable across countries. Global urbanization trends also encounter this issue: world urban population is reported as the sum of nationally defined urban populations (therefore summing metrics/thresholds that are not directly comparable). The 2020 recommendation of the “Degree of Urbanization” is a first step toward a harmonized definition of cities and urban and rural areas that can enable comparability among different countries across the globe. For this purpose, the European Union, the Food and Agriculture Organization of the United Nations (FAO), the International Labor Office (ILO), the Organization for Economic Co-operation and Development (OECD), UN-Habitat and the World Bank joined forces to develop a new people-based, global definition of three categories.. The 51st Session of the United Nations Statistical Commission endorsed this new definition called “Degree of Urbanization” to delineate cities, towns, and villages for international statistical comparison.

The project, Global Human Settlement Layer (GHSL), combines high-resolution satellite imagery with national census data to derive its estimates of cities, towns, and villages (Ritchie, 2025:P7).

The European Commission, also according to Ritchie (2025: P7) applied a harmonized definition attempt of settlements across all countries as follows:

- **Cities:** must have a minimum of 50,000 inhabitants plus a population density of at least 1500 people per square kilometer (km²) or density of build-up area greater than 50%.
- **Towns:** must have a minimum of 5,000 inhabitants plus a population density of at least 300 people per km² (Ritchie, 2025: P7).
- **Villages:** fewer than 5,000 inhabitants.

Using these definitions, GHSL estimates that about 45% of people live in cities and a further 35% live in towns. The remaining 20% live in villages. This means that the total urban share was around 80% in 2020 (more than 6.2 billion people).

This method recommends reporting figures across three distinct categories—cities, towns, and villages—rather than using a simple urban-rural dichotomy. This approach recognizes urbanization as a continuum, acknowledging that towns occupy a unique position, differing significantly from both cities and villages in their characteristics and needs.

The European Commission's estimates are also not without its critics. It is on record that researchers at the Marron Institute of Urban Management (New York University) challenged these figures as a gross overestimation.

The Sustainable Development Goals (SDGs) -This was adopted by all the United Nations members in 2015, as 2030 agenda which has 17 goals. This was adopted by all United Nations Member States as a shared blueprint for peace and prosperity for people and the planet, now and into the future (UN-SDG, 2015; Eze, 2025). The SDGs emerged with 17 Goals from decades of work by countries and the UN, including the UN Department of Economic and Social Affairs as follows:

- In June 1992, at the Earth Summit in Rio de Janeiro, Brazil, more than 178 countries adopted Agenda 21, a comprehensive plan of action to build a global partnership for sustainable development to improve human lives and protect the environment.
- Member States unanimously adopted the Millennium Declaration at the Millennium Summit in September Open Working Group2000 at UN Headquarters in New York. The Summit led to the elaboration of eight Millennium Development Goals (MDGs) to reduce extreme poverty by 2015.
- The Johannesburg Declaration on Sustainable Development and the Plan of Implementation was adopted at the World Summit on Sustainable Development in South Africa in 2002. This reaffirmed the global community's commitments to poverty eradication and the environment, and built on Agenda 21 and the Millennium Declaration by including more emphasis on multilateral partnerships.
- During the United Nations Conference on Sustainable Development (Rio+20) in Rio de Janeiro, Brazil, in June 2012, Member States adopted the outcome document "The Future We Want" in which they decided, inter alia, to launch a process to develop a set of SDGs to build upon the MDGs and to establish the UN High-level Political Forum on Sustainable Development. The Rio +20 outcome also contained other measures for implementing sustainable development, including mandates for future programmes of work in development financing, small island developing states and more.
- In 2013, the General Assembly set up a 30-member to develop a proposal on the SDGs.
- In January 2015, the General Assembly began the negotiation process on the post-2015 development agenda. The process culminated in the subsequent adoption of the 2030 Agenda for Sustainable Development, with 17 SDGs in September 2015.
- The 2015 was a landmark year for multilateralism and international policy shaping, with the adoption of several other major agreements which included:
 - ✓ Sendai Framework for Disaster Risk Reduction (March 2015)
 - ✓ Addis Ababa Action Agenda on Financing for Development (July 2015)
- Transforming our world: The 2030 Agenda for Sustainable Development with its 17 SDGs was adopted at the UN Sustainable Development Summit in New York in September 2015.

These global 17 goals (UN-SDG, 2023).are aimed at transforming the world, and presented as follows:

Goal 1: End poverty in all its forms everywhere – This has target of eradicating extreme poverty for all people everywhere by 2030 as a pivotal goal of the 2030 Agenda for Sustainable Development. Extreme poverty was defined as surviving on less than \$2.15 per person per day at 2017; Sustainable Development Summit (UN-SDG, 2023).

Goal 2: Zero Hunger – It is all about achieving a world free of hunger by 2030. The global Hunger and food insecurity has been on an alarming increase since 2015, a trend exacerbated by a combination of factors including the pandemic, conflict, climate change, and deepening inequalities.

Goal 3: Good Health and Wellbeing – Health is wealth; and as such accorded priority attention in project implementation.

Goal 4: Quality Education – Education is power. In fact, education is the hallmark of every development. Therefore, the quality of education determines the quality and extent of development of a nation.

Goal 5: Vulnerable and Gender Sensitivity – The activities and programmes of the project involves every sectors of the populace including the aged, youths, women, widows and widowers for the purpose of inclusiveness. Others are:

Goal 6: Clean Water and Sanitation: Ensure availability and sustainable management of water and sanitation for all.

Goal 7: Affordable and Clean Energy: Ensure access to affordable, reliable, sustainable and modern energy for all.

Goal 8: Decent Work and Economic Growth: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation;

Goal 10: Reduced Inequality: Reduce inequality within and among countries

Goal 11: Make cities inclusive, safe, resilient and sustainable - The world's population reached 8 billion on 2022 while over half living in urban areas. This figure is expected to rise, with 70 per cent of people expected to live in cities by 2050; while approximately 1.1 billion people currently live in slums or slum-like conditions in cities.

Goal 12: Responsible Consumption and Productivity: Ensure sustainable consumption and production patterns.

Goal 13: Climate Action –This is targeted at taking urgent actions to combat climate change and its impacts. Every person in every country in every continent is certain to be impacted in some shape or form by climate change. There is a climate cataclysm looming, and we are underprepared for what this could mean. Climate change is caused by human activities and threatens life on earth as we know it. With rising greenhouse gas emissions, climate change is occurring at rates much faster than anticipated. Its impacts can be devastating and include extreme and changing weather patterns and rising sea levels. If left unchecked, climate change will undo a lot of the development progress made over the past years. It will also provoke mass migrations that will lead to instability and even wars (UN-SDG, 2023). Other remaining goals are as follows:

Goal 14: Life below Water: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Goal 15: Life on Land: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 16: Peace, Justice and Strong Institutions: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels; and

Goal 17: Partnership for the Goals: Strengthen the means of implementation and revitalization of the global partnership for sustainable development (UN-SDG, 2023: 1-27).

The Concept of Sustainable Development Based on Systems Approach

Sustainability interpretation is usually taken as the starting point of the consensus reached by the World Commission on Environment and Development (WCED 1987), which defined sustainable development as: “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. However, despite the universal approval of

the WCED definition of sustainability, opinions still vary on how this goal can be attained. According to Barbier and Burgess (2017) in Sustainable Development Goals and the systems approach to sustainability, the first attempts in economics was the systems approach, which characterizes sustainability as the maximization of goals across environmental, economic and social. This approach is attributed to Barbier (1987), who first identifies three systems as basic to any process of development: the environmental or ecological system, the economic system and the social system. The UN agenda emphasizes that the inter-linkages and integrated nature of the SDGs are of crucial importance in ensuring that sustainable development is realized. As we show here, each SDG can in fact be identified as primarily an economic, environmental, or social system goal. Thus, collectively the UN's SDG targets can be considered a representation of the systems approach to sustainable economic development.

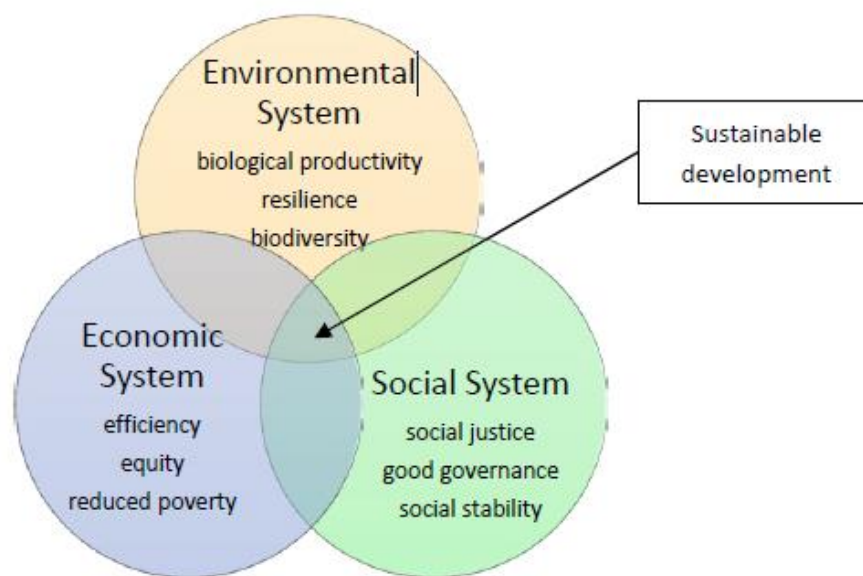


Figure 1: The Concept of Sustainable Development as Applied in System Approach

Source: Adapted from Barbier Figure 1(1987); Barbier and Burgess Figure 1(2017);Eze and Ozuomba (2025)

Concept of Urbanization in Relation to Population Size, Industrialization and Infrastructure

Urbanization on the other hand is a global issue such that addressing it has much implication for attainment of sustainable development goals. In order to appreciate the extent SDGs can be addressed through sustainable urban plan, it becomes appropriate to define the term clearly. Urbanization has simply been defined as agglomeration in multi-functional settlements of relatively substantial size (Ayuba and Wanda, 2009). The size urban area here points to demographic factor (population) which is determined in different countries with varying standards that change over time. Although the United Nations once recommended that countries should

regard all places with more than 20,000 inhabitants living close together as urban; but in real terms, countries use different statistical standards. The United States, for instance, considers urban area to mean any locality with more than 2,500 living together. However, in Nigeria, it involves places with 5,000 people and all local government headquarters. More important to this is the idea that such area is where settlers are not mostly engaged in agricultural activities but industrials. It invariably means living in town rather than rural area. This implies that industrialization is an essential aspect of urbanization. This is because various factors of industrialization are attributes of urbanization. Another important aspect of the urban area is infrastructure which is a basic requirement for industrial development as well as improving urban standard of living. In fact, urban infrastructure is an incentive for establishment of industries and expansion of existing ones. The location factors of the industries include labor, power, market, transport, site, raw materials, and other infrastructure services. This gradually gives way to modernization. Modernization is a process of change from obsolete technological development to a preferred one. This is regarded as a transformation from traditional, rural agrarian society to a secular, urban industrial one.

As earlier expressed that population is a very important index of urbanization, which attracts infrastructure services to enhance living standard; it is important to express factors that trigger such urbanization process. These include population from net migration, natural population increase, and rural areas with special rapid rate of development.

Urbanization Challenges and the Sustainable Development Goals Relationships

Urbanization, especially in developing countries like Nigeria has directly or indirectly affected the structure and functions of the various social institutions like the family, economy, polity, religion, health and education. In the same vein, industrialization and modernization that are intertwined with urbanization have led to the diminished functions of these various institutions in Nigerian urban centers (Oyeleye, 2013). In fact, urbanization has raised the poverty level of the urban areas due to their alarming population growth and which has further aggravated unemployment, underemployment, a decrease in real wages due to persistent inflation and uncontrolled migration (Oyeleye, 2013: 79-96). These challenges of urbanization are common in almost all aspects of urban centers. The challenges also have so much in common with the development goals. They include the following:

(i).Poverty – This is a serious issue in Nigerian urban centers because of inadequate job opportunities, infrastructural facilities and services that do not satisfy the demands of the urban areas. This problem is central to the number one (1) of SDGs, which also is struggling hard to satisfy the SDGs, number eight (8).

(ii).Food Insecurity – This is directly related to the zero hunger, which is the SDG number two (2).

(iii).Unemployment/Underemployment – Rural to urban migration is the main reason for this high rate; which must continue as long as there is no solution for providing decent work and economic growth.

(iv).Housing – This is a common issue in urban areas and SDG number six (6): clean water and sanitation are important components of this outstanding urban problem; and both affect the SDG number (3): health and well-being strongly.

(v).High Crime Rate and Insecurity – This is at its worst level in the country which to the extent of receiving attentions of other nations. This is majorly a product of greed, corruption, reduced inequality (Goal 10) as complicated by failure to provide Goal 16: peace, justice and strong institutions.

(vi).Climate Change – This is the SDG number thirteen (13): Climate action, which is making wave across the globe.; targeted at taking urgent actions to combat climate change and its impacts. If unchecked, every person in every country in every continent is certain to be impacted in some shape or form by climate change (UN-SDG, 2023). .

3. Methodology

The study applied exploratory and participant-observation research methods (McCall, 1975; Rubinstein, 1973). Primary data were gathered through the lead-author's practical field experience as Pioneer Process Coordinator and EMIS/GIS Officer of Sustainable Enugu Project (SEP) of UN-Habitat sponsored Sustainable Cities Programme (SCP). The secondary data were sourced majorly from the SCP Source Book Series, UN-Habitat/UNEP and the World Bank Websites.

The urbanization characteristics were explored; its challenges and the linkages in addressing SDGs through new paradigm planning approaches were investigated. Through these approaches, the relevant recommendations for attainment of SDGs were provided.

4. The Traditional Planning Practices and Need for Adoption of the New Paradigm

The conventional land use planning approach has long been found to be inadequate for being in form of blue print/too rigid, non-participatory, inadequate technical skill/financial resources, absence of proper legal and administrative framework, plans based on unrealistic assumptions among other issues (Falade, 2003: 13). However, this received an added impetus from the 1992 Earth Summit in which all countries are signatory to the commitment reached in the conference. The Human Settlements Chapter of the Agenda 21 particularly urges planners globally to review settlements planning approaches for better results. The challenges of land use planning are not only how to contain urban growth but also includes how to coordinate human, financial and technical resources to ensure that social, economic and environmental needs are added within

urban growth. In the same manner, Habitat Agenda provided in the global plan of action on what planning actions to take for the purpose of achieving sustainable human settlements development and management. These innovations have come over the years especially through international agencies like United Nations and the World Bank supported projects.

There are common features associated with the New Approaches to Urban Land Use Planning which include the following:

- (a). Ability of planning authorities to forge partnership among stakeholders – This involves private sectors and community organizations in various aspects of land use planning and management. The partnership formation requires a move away from control to land use enablement. Thus, planning is regarded less as development control and more as encouraging and supporting the multiplicity of private sector initiatives from citizen groups, NGOs, local, national and international enterprises that make the settlements viable.
- (b). Emphasis is placed on integration of social, economic and environmental goals in settlements planning and with tangible results.
- (c). Greater emphasis is also placed on capacity building of planning authorities by the international community in settlements planning and management, direct support and promotion of global programmes in urban management.

The UN-Habitat (1996) following reactions from the shortcomings of the traditional land use master plan approach, a number of innovative approaches emerged. This new paradigm could be classified as follows:

- (i). Structure Plan Making;
- (ii). Strategic Planning;
- (iii). Action Planning;
- (iv). Environmental Planning and Management (EPM).

- **Structure Plan Making**

Britain setup Planning Advisory Group in 1967, which reviewed their planning system that was based on the conventional land use planning approach and found it inadequate. Adoption of the 'structure plan approach' was recommended. It was backed up by a new planning legislation: 1971 Town and Country Planning Act in England that replaced the 1968 Act 'novel act on the innovation' (Falade, 2003). Unfortunately, Nigeria is yet to drop the 1946 Town and Country Planning Act designed after the much earlier British law; by failing to adopt/domesticate the Nigerian Urban and Regional Planning Act of 1992 by most of the states including Enugu State.

The structure plan approach focuses on introducing a framework strategic planning and policies to guide the social, economic and physical development of urban areas. It usually consists of written

statements accompanied by diagrams and illustrations, which provides the basis for preparation of detailed local plans or subject plans or action plans. This has interesting advantages over the traditional land use master plan approach. The advantages include being comprehensive in approach in terms of considering the various socio-economic factors that can influence development; more flexible in approach such that allows opportunity to adopt the plan to changing circumstances; and better response to community needs and aspirations through public participation in planning process.

- **Strategic Planning**

Strategic planning is outstandingly considered as a participatory approach to integrated urban development. It is targeted at achieving growth management and carrying out necessary remedial actions, both at the citywide and local level. The resultant products of action planning are not just a physical development plan for the city but a set of interrelated strategies for city development (including land, infrastructure, finance and institutions).

Some key characteristics of the strategic planning approach include the following:

- Cross-sectoral coordination and integration;
- Financial feasibility;
- Comparative advantages of public and private sectors in urban development and management agreement;
- Enabling role of public sector in support of private sector;
- Inter and intra –sectoral choice mechanisms;
- Linkages to and from national policy issues;
- Concern with rural-urban relationships;
- Resolution of conflicts among participants; and
- Regular monitoring, evaluation/review.

- **Action Planning**

Action planning is an implementation type of process for solving problems at the local level. It has the quality of resolving issues in a very short, direct manner with minimum application of data collection and traditional planning procedures. Community participation allowed is the key for successful action planning whether physical or socio-economic issue is being addressed.

- **Environmental Planning and Management (EPM) Process**

Environmental Planning and Management (EPM) process is a special innovate approach of Sustainable Cities Project (SCP) sponsored by UN-Habitat/UNEP in so many countries all over the world. The SCP is a practical response to the universal search for sustainable development (SCP, Undated). It is the leading technical cooperation programme in the field of urban environmental planning and management and is the principal activity of the United Nations system

for operationalizing sustainable urban development and thus contributing to implementation of the globally-agreed Agenda 21 and Habitat Agenda (UN-Habitat/UNEP, 2000). The SCP recognizes sustainable cities as being fundamental to social and economic redevelopment and maintains that urbanization builds diversified and dynamic economies which raise productivity, creates jobs and wealth, provide essential services, absorb population growth, and become the key engines of economic and social advancement (UN-habitat/UNEP, 1997, 2000).

In Nigeria, it was demonstrated in Ibadan as Sustainable Ibadan Project (SIP) and replicated in Kano and Enugu as Sustainable Kano Project (SKP) and Sustainable Enugu Project (SEP) respectively. The EPM process as applied these Projects is an articulated analytical framework and logical structure which facilitates better understanding of the dynamism of urban development and environmental issues that helps in evolving guidelines and strategies for intervention.

The aims of the EPM process are to identify urban environmental issues in time, agree on strategies and actions to resolve the issues, and implement strategies through public and private actions. When properly and successfully executed, the process would eventually improve health and productivity; reduce environmental hazards; and protect natural resources and for economic and social development.

The Basic Attributes and key Elements of the EPM Process

These important attributes as presented in the SCP general information are as follows:

- Bottom-up planning approach;
- Anchored on participation and commitment of stakeholders;
- Mixes up planning and action;
- A systematic approach for better planning and effective management of urban development;
- Powerful tool for communication and information sharing; and
- Facilitating and strengthening of local capacity to plan.

The key elements of the EPM process can conveniently be summarized into four steps:

- Identification of Urban Environmental Issues and Involvement of Stakeholders in Issue Assessment and Priority setting;
- Formulating Urban Environmental Management Strategies;
- Formulating and Implementing Environmental Action Plans; and
- Institutionalizing the Environmental Planning and Management (EPM).

5. Summary of Findings and Discussions

i. Issues in Defining Urbanization/Urban Area - There is no universal definition of what constitutes an 'urban area'. Definitions of an urban settlement vary widely across countries, among organizations, authors and authorities both in terms of the metrics used to define them, and their

threshold level. Considering the UN World Urbanization Prospects (2018) database, it is on record that threshold levels mostly used by countries are 2000 and 5000 inhabitants adopted by 23 countries. Beyond this criterion, one wonders the acceptable population density, the level of non-agro based occupation, availability of industries and infrastructures. In Enugu State of Nigeria, there is a new trend of designating urban areas to some entire L.G.As which originally only their headquarters were considered as urban areas. Unfortunately, this is done without considering the remoteness, rural nature and non-industrialized nature of most of such communities and poor nature of their infrastructural base. If nothing is done to reposition such new status, there will be confusion of land use contradictions, new level of poverty generation, and strange new level of urbanization challenges.

ii. Urban Populations are known to be having Higher Living Standards - Information are abound which suggest that, on average, living standards are higher in urban populations than in rural ones. Typical examples available in our-world-in-data include that: in almost all countries electricity access is higher in urban areas than in rural areas; improved in urban areas; improved in urban areas; access to clean fuels for cooking and heating is higher in urban areas; and child malnutrition is lower in urban settings.

iii. Poor Legal Foundation of the New Land Use Regulations –The new land use regulations currently declared for Enugu State in particular amounts to a new wine in an old wine-skin. This is because the new regulations are dependent on the outdated 1946 Land Use Acts since the Nigerian Urban and Regional Planning Act of 1992 is yet to be domesticated in the State.

iv. Urbanization Challenges Highlighted are direct Issues in Sustainable Development Goals –Proper planning, management and implementation of urbanization challenges are direct solutions to attainment of SDGs.

v. Adoption of the New Planning Paradigm as Reliable Solution for Attainment of the SDGs -The new paradigm highlighted inform of Structure Plan Making, Strategic Planning, Action Planning and Environmental Planning and Management (EPM) are proven approaches for urban growth and development.

vi. Attraction of more International Agencies' Projects Applying New Planning Paradigm as Models for Harnessing Urbanization Potentials and Sure way for Attainment of the SDGs – Experiences have shown that each of the International Agencies sponsored projects left indelible marks of model urban planning approaches worthy of replication and attracting new ones.

6. Recommendations and Conclusion

Recommendations -The following recommendations are made based on the findings:

i. Standardization of the terms urbanization and urban Area–Efforts should be strengthened through international agencies for universally acceptable meaning and criteria for defining the terms.

ii. Domestication of the Enabling Law(s) – The essential legal framework for effective urban planning should be provided. For instance, the Nigerian Urban and Regional Planning Law of 1992 is long overdue for domestication in all the states. Also, the relevant portions of the Law, like the skeletal Environmental Impact Assessment (EIA) aspect that contradicts the provisions of the EIA Law of 1992 should be reviewed.

iii. The Potentials of Urbanization should be harnessed through the New Paradigm of Urban Planning –This should be done by implementing and institutionalizing the international best planning practices demonstrated by the relevant agencies' projects.

iv. Designation of Urban Areas should not be without due Considerations to Infrastructural and Industrial provision - Any area designated as urban should be accompanied with a viable and sustainable plan necessary for such new status.

v. Efforts to Attract more International Agencies' Sponsored Projects should be Intensified – Considering the benefits of various international agencies' projects and programmes not only in development but also in capacity building and encouraging international best practices, greater efforts should be made to attract more. Most importantly, when such projects are available, the new paradigm approaches that are introduced through such projects should be institutionalized and sustained even at the close of the project(s).

In conclusion, urbanization is a global issue and important one in development planning. The urbanization in human society is inevitable through urban growth and development, modernization, political actions and industrialization. It is like a two-edged sword which has adverse challenges of concerns to SDGs. However, such challenges can be addressed through the new paradigm planning approaches. This, therefore, can serve as a valuable transformative force for harnessing urbanization potentials and attainment of the SDGs.

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Examination of the Spatial Pattern of Primary Health Care Facilities in Enugu Urban, Enugu State-Nigeria.

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Abstract

This study identify the existing spatial distribution of primary health care facilities in Enugu urban, from 2003 to 2023, using GIS with a view to providing policy guidelines for future location decision. The hypothesis stated that the existing primary health care facilities in Enugu Urban areas are not equitably distributed. The study adopted the exploratory research design and image geo-referencing. The research gathered data from a survey involving 1,300 residents from a sample frame of 161,881 households in the Enugu urban using the Williams (1978) sample size determination formula and only 1,210 residents were used. Employing a questionnaire method, both qualitative and quantitative data were collected using multi-stage sampling techniques which consist of clustered, systematic and simple random sampling techniques. The study area was clustered into three administrative local government areas (Enugu East, Enugu South and Enugu North). Then simple random sample technique was used to select the neighbourhoods from each of these local government areas. 3, 5 and 7 neighbourhoods were selected from Enugu East, Enugu South and Enugu North respectively. Buffer zone analysis, multiple linear regression, and Nearest Neighbour Analysis were used in study to further analyze the data. The results revealed that the existing PHCFs in Enugu Urban areas are not equitably distributed since the Nearest Neighbour Index (R_n) values for Enugu East ($R_n = 0.655$, $z = 3.9952$, $p = 0.000322$), Enugu North ($R_n = 0.714$, $z = 3.8355$, $p = 0.00012$) and Enugu South ($R_n = 0.867$, $z = 1.63$, $p = 0.10$) were below 1, thus, indicating an uneven and clustered distribution. The study established some areas in Enugu urban are located outside of the 2-kilometre accessibility zones to the PHCFs especially in the western and northern parts of Enugu urban and that the population without access to services amounts to was 317,937 people. The shortage in health centers represents approximately 22 PHC facilities. PHCF should be regularly distributed as opposed to the existing cluster distribution or centrally located in the study area. The distribution should be adequate to ensure minimum travel cost for households. This will offer an innovative approach to reducing gaps in healthcare access and subsequently enhance the efficient and effective delivery of healthcare services in Enugu State at large.

Keywords: *G I S, Primary Health Care, Spatial Distribution, and Spatial Pattern*

1 Introduction

Public services and facilities play a crucial role for residents in cities around the globe, especially in developing countries where the demand often outstrips what's available. To meet rising public

expectations, governments have been taking a closer look at how these services are provided, aiming to enhance both their quality and reach (Alabi, 2011). Assessing how effective public services are is a complex task, involving various factors like geographic and financial accessibility, availability, quantity, distribution, service quality, and user satisfaction. Among these, the way services are spread out geographically has become a key issue. In recent years, the spatial analysis of how public services are distributed has gained a lot of attention from geographic and environmental experts (Oluwayinka, 2023). These ties closely to the idea of spatial equity in urban public facilities, which is part of a larger movement toward achieving spatial justice. A detailed evaluation of the current state of a public service is vital for making informed decisions about where to place new facilities to improve availability and accessibility (Isma'il et al., 2014). In this regard, Geographic Information Systems (GIS) are essential tools for conducting spatial analysis. This study zeroes in on the distribution of Primary Health Care Facilities (PHCFs).

Health is widely seen as a basic human right and a top social and political priority. Since the 1970s, the strong link between poverty and poor health has been recognized (Peters et al., 2008). As a result, many developing countries embraced the “Health for All” strategy, which was bolstered by the 1978 Alma-Ata Declaration (Hall & Taylor, 2003). Despite significant government efforts and international backing, access to medical services in many developing nations is still lacking, causing some people to skip essential care (Atuoye et al., 2015; O'Donnell, 2007; Peters et al., 2008).

The United Nations' Sustainable Development Goal 3 (SDG 3) aims to ensure that everyone, regardless of age, can lead a healthy life and enjoy well-being. However, there are significant challenges due to inequalities in access to healthcare based on geography. These disparities make it tough to reduce maternal and neonatal mortality rates and to fight diseases like HIV/AIDS, malaria, hepatitis B, and tuberculosis (Lawal & Anyiam, 2019; George & Sahadevan, 2019). To truly achieve SDG 3, we need to focus on improving access to healthcare facilities, especially Target 3.8, which highlights the importance of universal health coverage, financial risk protection, and access to essential health services, medicines, and vaccines. Given how closely health and development are intertwined, it's crucial for governments and development partners to invest consistently in the health sector.

Nigeria recognizes the right to health and has pledged to uphold it through both international treaties and local laws (Isreal & Sunday, 2009). Before the economic downturn in the mid-1980s, Nigeria's health sector was thriving, thanks to robust government funding and support from international donors. During that time, free healthcare services were readily available in public hospitals and clinics, especially in urban areas. Unfortunately, by 1985, this progress took a hit due to economic struggles and political instability, including extended military rule (Fadahunsi et al., 2017). These issues have led to ongoing systemic challenges that still impact healthcare delivery in Nigeria (Ubochi et al., 2019).

Healthcare planning and Geographic Information Systems (GIS) are two fields that are closely intertwined, relying heavily on spatial data. Key information like the locations of facilities, population distribution, and patient demographics is essential for effective local health planning (Loucks & Van Beek, 2017). Access to healthcare services is a vital part of a well-functioning health system and has a direct effect on the disease burden in developing countries.

The use of GIS in healthcare analysis really boosts how we interpret data by allowing us to visualize complex spatial patterns and relationships (Oppert & Simon, 2012). By mapping these patterns, we can clearly see a spatial disparity, which in turn supports evidence-based decision-making.

In Enugu Urban, early observations indicate that the distribution of Primary Health Care Facilities (PHCFs) doesn't align well with the population size or land area across the three local government areas—Enugu North, Enugu South, and Enugu East. This noticeable mismatch points to potential inadequacies and uneven access to these facilities. In many neighborhoods, women often have to walk long distances just to reach maternity services offered by these facilities. This situation might highlight a lack of clear planning criteria for where these facilities are placed, especially since there's limited existing literature on the spatial distribution of PHCFs in Enugu State.

Looking at the bigger picture, health services in Enugu State, particularly in Enugu Urban, aren't evenly distributed. The distance and travel time between communities and health facilities create significant barriers to access and are crucial indicators for assessing how well these services are located. This study aim to identify the existing spatial distribution of primary health care facilities in Enugu urban, from 2003 to 2023, using GIS with a view to providing policy guidelines for future

location decision and ensuring healthy lives. The relevance of this study lies in its contribution to health policy, urban planning, and equitable access to healthcare in Enugu urban. This study is being conducted within that important context.

2 Review of Literature

Spatial Distribution of healthcare facilities

There are scattered accounts on accessibility, distribution and utilisation of primary health facilities with regard to other states of Nigeria aside Enugu State, particularly Bayelsa, Edo, Osun and Oyo. Onokerhoraye (1999), Omofonmwan (2003), Ogunjumo, Omisore, & Amusam, (2005) and Owoola (2002) carried out the study on some of the factors that determine the location of healthcare facilities in their chosen study areas and drew some conclusions based on their findings..

In his studies of access and location of healthcare facilities in the petroleum-producing region of Nigeria, the case study of Bayelsa State, Onokerhoraye (1999) employed the Central Place Theory of Walter Christaller to analyze the healthcare delivery system in Nigeria and Bayelsa State. In order to achieve this, he postulated that the hierarchical system of Christaller reflected in space, the geographical arrangements of service outlets in which a particular area tends to have numerous primary health facilities and very few tertiary facilities, if at all. He further summarised that for efficiency to be attained in the provision of healthcare facilities in any locality, the threshold population must exist within the range of that category of healthcare service. He also observed that the capability of any geographical area to satisfy the threshold requirements for the provision of a particular category of healthcare facility will depend on the pattern of population density.

In this study, Onokerhoraye discovered a glaring disparity in the distribution of health facilities in Bayelsa state. There were six functioning tertiary and secondary health facilities in Bayelsa state in 1999. These establishments which are made up of one tertiary health centre and five secondary centres are located in four of the eight local government areas. These facilities were located in the eastern part of the state, while the western part has none located in it. In like manner, there are 29 functioning primary health establishments in the state in 1999. However, there is the concentration of most of them in the northern part of the state while the south with a greater population density, has fewer primary health centres. He also discovered in this study that within the individual local government areas, respondents in settlements where primary health establishments are located

indicated the use of these facilities compared with those in communities where there are no such establishments. Thus, he reeled off the factors influencing the utilization pattern of modern healthcare facilities in Bayelsa state to include the level of formal education, level of income, cost of the services, facilities available in the health establishments, availability of alternative medical attention in the locality, perception of the attention received in the modern health establishments and the distance to the centres in terms of travel cost and time of reaching the health centre. Accordingly, Onokerhoraye emphasized that one of the most important determinants of the use of modern health establishments is their accessibility to the people. He concluded that the petroleum-producing communities have the poorest healthcare services in the country largely because of inadequate attention given to the area in terms of the allocation of resources despite the fact that the region produces most of the wealth of the country. Further, the inaccessibility of the vast majority of the population in Bayelsa state to modern healthcare services has contributed to the prevailing attitude of the people towards modern healthcare services. However, it is pertinent to note that the prevailing pattern of the location and distribution of healthcare facilities in Bayelsa state is influenced by the geographical and environmental characteristic of the state. Local government areas closer to the mainland areas attract more attention in the provision of healthcare facilities than those in the riverine because they are more accessible. The litany of criticisms on this theory particularly on the difficulty to operationalise it makes it apparently inoperable as a basis for the location of healthcare facility in EnuguState. However, the political/administrative principle might have variously influenced the location decisions of existing healthcare facility in the study area.

Omofonmwan (2003) used the Nearest Neighbour Analysis Model in the study of spatial distribution of health services in Esan area of Edo state. The study revealed that there are six general hospitals in the area in addition to a specialist/teaching hospital located within the region. According to him, six hospitals yielded a theoretical mean access radius of 13 kilometres per unit. This working radius surpasses the World Health Organization (WHO) standard of 16 kilometres per hospital. Also, there are 36 PHCF distributed hexagonally in the region. The working distance per unit is 5.4 kilometres. The study according to him shows that 31 additional units are required to meet the WHO standards of 4 kilometres access radius per PHCF. Omofonmwan concluded based on this deduction that some of these units may be economically unviable, health services are

most basic of the human needs, and as such economic considerations should not be allowed to outweigh the welfare consideration of health service delivery.

This conclusion is fraught with some shortcomings. First, the economic viability of location of healthcare facilities should be tied together with their locational feasibility. This is because it is wasteful to arbitrarily locate facilities that will be functionally obsolescent. Second, the utility of the services provided by healthcare facilities will be most appreciated by the users if it is demand-driven and location-guided by Pareto Optimality. Third, the study did not explain the parameters that informed the location of existing health facility.

Owoola (2002) carried out a study of three local government areas (LGA) in the northern part of Oyo state based on the title: Between Policy and Practice: A Spatial Decision Support System-Based (SDSS) Assessment of Facility Location Planning in Nigeria. In this study, he concentrated on Kajola, Iseyin and Ifedapo LGAs. The three LGAs constitute the Oke Ogun area of the state. It is an area perceived as being deprived of basic facilities and infrastructure compared to other parts in the state. In 1985, there were 40 dispensaries in 31 settlements representing only 6.2 percent of the settlements but containing 71.8 percent of the total population in the study area. In 1996, 8 more dispensaries were built in 6 settlements in the study area. Out of these 6 settlements, 2 were already dispensary locations, increasing the number of settlements with dispensaries to 35. These settlements contain 72.1 percent of the total population in the study area. Thus, by 1996, the dispensary to population ratio improved to 1:17 433. Owoola inferred that in terms of absolute level of geographic coverage defined as actual population and settlements served with services, it was obvious that government had not considered the dispersed nature of settlement distribution in the study area in locating these services. He stated that whereas 72.1 percent of the population has access to dispensaries, this figure represented 7.04 percent of the settlements served with these facilities and more so with little or no spread in the locations chosen as service centres even when new facilities were being established. Owoola concluded that 93 percent of the settlement has no dispensary; a situation which has made location accessibility more or less fixed in the study area and therefore negated the objective of equity in facility distribution. To justify and statistically validate this assertion, he hypothesized that the distribution of health facilities does not follow the dispersed pattern of population distribution. Using the product moment correlation coefficient (r) between the number of dispensaries located and the population size of settlements for the two

periods, r values of 0.73 and 0.84 were obtained respectively. The test of significance of r at 0.05 levels indicates that the critical t of 1.96 is less than the calculated t of 23.88 and 34.42 for dispensary services in the two periods respectively. The t tests of significance indicate that the observed association between size of settlements and the number of facilities located in them is too significant to be adduced to chance. Thus, he further concluded that the distribution of health facilities in the study area is deliberate action of government to locate them in areas of high population concentration. This tendency according to him negates the claims that government is concerned with providing an equitable pattern of service delivery. The use of SPSS in the assessment of facility location planning is limited by the fact that it lacks the capacity of incorporating other relevant physical and socio-economic variables that are important in the holistic analysis of location planning.

Ogunjumo, et al (2005) in their study of Bivariate Analysis of factors of location of healthcare facility in Osun state identified the problem of dichotomy in the location of public healthcare facilities in favour of urban areas. Further, they highlighted the observed uncoordinated location and multiple siting of these facilities far away from the residences of the patrons. The study also revealed that the dominant factors influencing the location of public healthcare were distance of public healthcare facilities from patients' residence, patients' mode of transport and transport cost incurred by patients patronizing these facilities. Other factors that influenced the use of facilities were affordable cost of treatment, efficient medical personnel, nearness to residence and availability of medical facilities. However, they further discovered that the choices of doctors by patients were influenced by acceptability, continuity of care, geographical proximity/accessibility, and similar gender/religion. All these determine the patronage pattern. This study did not lay emphasis on the importance of catchment population/density in location decisions and therefore population was not considered as a relevant location parameter. It also did not suggest the possible reason for the dichotomy/differential in the location of health facility in the study area.

Adeyemo (2005) appraised the performance of local governments (LGA) in health care delivery in Nigeria with particular reference to Ife-East local government area of Osun state. He identified major contradictions in the management of primary healthcare implementation orchestrated by shortage of qualified personnel and finance, inadequate transportation, inaccessibility of healthcare delivery to communities, lack of maintenance culture, political instability and incessant turnover

of leadership. Adeyemo contended that these factors accounted for inconsistencies in health care policy decisions at the LGA levels being the tier of government responsible for the management of primary healthcare services delivery. He however suggested some panacea that would ensure the sustainability of healthcare service delivery at the grass root level to include increased financial allocation, community mobilization, improved health education, policy consistency and provision of qualified health workers.

On location of medical facilities, numerous factors of public facilities have been given. Reid [1984] observed that in recent times, the issues of access, equity and efficiency criteria that consider the distributional aspect of public facilities have been receiving attention. Filani [1991] shares the same idea when he asserted that accessibility questions had assumed greater importance among researchers and policy makers in recent years. Implying that, location on a transport network is an important determinant of the availability of public facilities (medical services inclusive). Looking at the geo spatial distribution of primary health care, Agaja [2012] using Germain GPS to capture the Co-ordinates of the health centres with the aid of Arc Map 9.3 (ESRI) GIS software applied multivariate technique to show that the nearest neighbour value for Warri South Local Government, Nigeria, was clustered in pattern of distribution while Ughelli South LGA showed random distribution rather than clustered pattern.

Omosho [2010] studied the location distribution of rural medical services for effective development in Ekiti State, Nigeria and found out a high incidence of morbidity and mortality resulting from the prevalence of preventable and infectious diseases due to uneven distribution of facilities in the area. Adebayo [2013] in their web-based spatial approach to the distribution of health care facilities observed that the distribution of Information System in Nigeria showed that stakeholders were able to visualize the distribution of tertiary hospitals in Nigeria, and make useful inferential decisions with ease.

Similarly, Aliyu [2013] undertook a mapping of the spatial distribution of post primary schools in Yola North Local Government Area of Adamawa State, Nigeria using nearest neighbor analysis and discovered that random distribution pattern existed in the location of the schools.

Furthermore, Alabi [2011], conducted a study on the assessment of spatial distribution of health centers in Ilo-Ilo, Nigeria and discovered that an output of 0.99228, an indication of weak randomness, because it exceeds the Z-scoreable value of -0.723417 which is indicative of

insignificant accessibility and submitted that the scenario is a microcosm of state of health facility distribution in typical Nigerian cities where health facility distributions do not adhere to any particular pattern or criteria.

Ali [2014], observed in his study on health care financing in Ethiopia: an implications on access to essential medicines that Revenue retention by health facilities, systematizing the fee waiver system, standardizing exemption services, outsourcing of nonclinical services, user fee setting and revision, initiation of compulsory health insurance among others in Ethiopia. Although limited, the evidence shows that there is increased health care utilization, access to medicines, and quality of services as a result of the reforms.

Nigeria National Health Policy

The Nigeria National Health Policy (NHP) 2016 focuses on strengthening the overall health system, with a particular emphasis on primary health care. It aims to achieve universal health coverage, improve quality and accessibility of healthcare, and ensure that services are affordable for all Nigerians. Prior to the development of this National Health Policy document, Nigeria had developed and implemented two National Health Policies in 1988 and 2004. The policy also addresses emerging health challenges like epidemics and the impact of globalization and climate change on the health system.

Its core objectives and Strategies: were the strengthening Primary Health Care, universal Health Coverage, Addressing Emerging Challenges, Improved Data and Information, Stakeholder Engagement and National Strategic Health Development Plans. However, before the NHP, there was the existence of the National Health Act 2014: The 2016 policy is designed to be aligned with the provisions of the National Health Act 2014, which provides a framework for the regulation, development, and management of the health system. A National Health Policy (NHP) 2016 provides the compass for the country's health system; while the National Health Act (2014) provides a framework for the regulation of the health system. In general, the National Health Policy 2016 was designed to promote and sustain equity, efficiency, accessibility and quality in healthcare provision. This policy seeks to improve the overall health system, strengthen primary health care in Nigeria and enable efficient, accessible, and affordable health system

Minimum standards for primary health care in Nigeria

The Federal Republic of Nigeria operates a 3 tier system of Government: the Federal, State and Local Government levels. Similarly the Nigerian health system operates along those lines,

operating primary health care at the Local Government Level, secondary health care at State level and tertiary health care at Federal level. Primary Health Care (PHC) is the cornerstone of the health policy in Nigeria and is the first point of contact for most Nigerians with the health care system. Standards must therefore be set in order to effectively manage health services and achieve good quality of care. The purpose of setting health standards according to the World Health Organization is to serve as a tool in health services management; and to strive towards achieving the highest possible quality of care within the resources available.

The Minimum Standards for Primary Health Care in Nigeria document was developed by the National Primary Health Care Development Agency through a collaborative process involving all major stakeholders in health; Agencies and individuals from the Federal Ministry of Health, academia and public health experts, development partners, including the UN agencies – WHO, UNICEF, UNFPA, the World Bank, PATHS2, FHI and other organizations.

The need to ensure equity in the delivery of health care services and improve access, informed the development of the Ward Minimum Health Care Package in 2007. There was also a need to define and declare a set of Minimum Standards in the areas of health infrastructure, human and financial resources and provision of essential drugs and commodities for primary health institutions in Nigeria, which informed the development of this Minimum Standards for Primary Health Care in Nigeria document. Health standards are tools which are designed as a platform to strive towards achievement of the highest quality of care possible within the resources available

The overall goal of this the Minimum Standards for PHC is to uniformly define for the various levels of fixed health facilities in Nigeria, the Minimum Standards for PHC structures (systems, staffing, equipment and service delivery) at Local Government level in order to improve access and quality of services. It is also intended as a vital tool for effective supervision, monitoring and evaluation and to aid effective planning, development and delivery of PHC services.

This Minimum Standards for PHC defines a set of Minimum Standards in the following areas:

- a. Health infrastructure: Types/Levels of PHC facilities including recommended infrastructure dimensions, furniture and equipment
- b. Human resources for health: Minimum recommended staff number and cadre for each type of health facility

- c. Service provision: Recommended minimum PHC services for each facility type including the minimum requirement of medical equipment and essential drugs (From the National essential Drugs list) required to achieve these services

It is expected that these Standards would be used to guide the further development of PHC in terms of infrastructure, human resource availability and service provision as well as for the provision of qualitative PHC services and in ensuring equity in the availability and provision of the PHC services. It should be noted that this manual defines Minimum Standards at the different Primary Health Care levels, to which additional indices can be added.

The National Primary Health Care Development Agency (NPHCDA) provides support for the implementation of the National Health Policy in all matters relating to primary health care (PHC) in Nigeria. Within the policy, PHC is identified as the 'main focus for delivering effective, efficient, quality, accessible and affordable health services to a wider proportion of the population'. Subsequent to this mandate, one of its core functions is the development of effective systems of supervision, monitoring and evaluation of PHC based on national guidelines and standards.

Ideally, Primary health care (PHC) is the foundation of the health care system. For most Nigerians, PHC is the first point of contact with the health care system. It is the level at which short-term, uncomplicated health issues should be resolved. It is also the level at which health promotion and education efforts are undertaken, and where patients in need of more specialized services are connected with secondary care.

The four basic approaches to PHC in Nigeria are to: (i) Promote community participation in planning, management, monitoring and evaluation; (ii) Improve inter-sectoral collaboration in primary health care delivery; (iii) Enhance functional integration at all levels of the health system and (iv) Strengthen managerial processes for health development at all levels.

3 Materials and Methods

For this study, both primary and secondary data were gathered. Due to the nature of the research and the purpose of the study, an exploratory research design was employed to explore accessibility of primary health care. The case study method under the exploratory design was employed to examine the spatial distribution and accessibility of healthcare facilities in Enugu residential urban area. This type of research design was used to gain an in-depth and better understanding of access

to primary health care in Enugu neighbourhoods. This research design is the most appropriate for this study because it helps gain a concrete, contextual, and in-depth understanding of accessibility to health care (Creswell, 2014).

Out of 1,300 copies of questionnaire distributed through face-to-face administration in the various neighborhoods in the study area, 1,219 of them were properly filled and used for the study. The sample size of 1,300 was scientifically determined using Williams (1978) sample size determination formula, based on a household population of 161,881 in Enugu urban. This ensured that the number of respondents was statistically representative of the study population while remaining manageable for fieldwork.

This study made use of multi-stage random sampling. The use of this procedure was informed by the fact that the multi-stage random sampling procedure allows for an effective and fairly even representation of all the units within the studied area. The sampling procedure was carried out in stages, and the peculiar characteristics were taken into consideration at all the sampling stages to ensure equal representation.

- Stage One: The three local government areas that made up the administrative Enugu urban were chosen, namely Enugu East, Enugu South, and Enugu North.
- Stage Two: Neighbourhoods were selected from each of these LGAs. Specifically, three neighbourhoods were chosen from Enugu East, five from Enugu South, and seven from Enugu North. These numbers were selected because they met the criteria of being urban in character, having significant residential density, and representing the spatial spread of the city.
- Stage Three: Within each neighbourhood, streets/roads were selected using simple random sampling. The names of the streets in each selected neighborhood were written on pieces of paper, placed into lucky-dip bags (one per neighbourhood), and drawn without replacement. From these selected streets, households were randomly chosen where questionnaires were administered.

In addition to the questionnaire survey, georeferencing instruments such as GPS and GIS were employed to capture the spatial coordinates of primary health care facilities and sampled households as shown in map 1, 2 and 3 below. This ensured accurate mapping, spatial analysis,

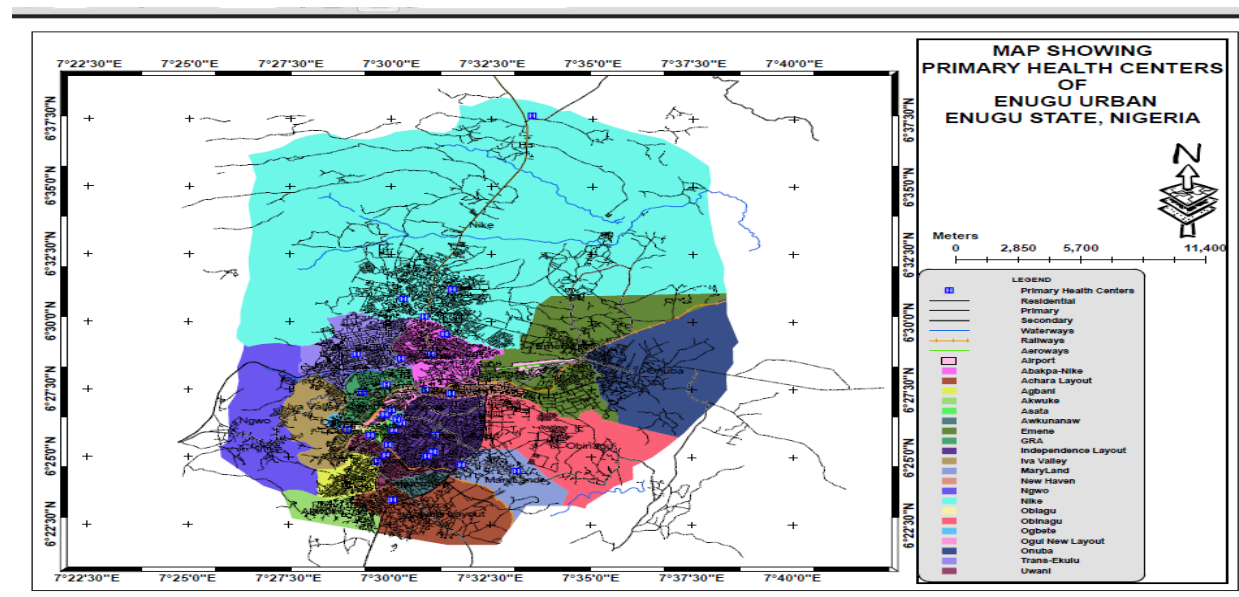
and visualization of accessibility patterns across Enugu urban. The integration of these geospatial tools was critical in identifying clustered distributions, accessibility gaps, and areas underserved by health facilities.

4 Results and Discussion

The spatial pattern of primary health care facilities in the study area indicated an irregular clustered pattern of distribution of these facilities in Enugu. This revelation from the study was the clustered distribution of health services, which led to the difficulty in accessing some of these facilities by residents outside the catchment areas for their services. As there are areas in Enugu urban which have health care services and others do not have. It was revealed with the aid of the GIS techniques to the geographical distribution of this PHCF that they are clustered irregularly this resulted that there are no balance between the administrations of the services. The planners and decision makers should consider the obtained results to achieve fair and better distribution of public services. The result on GIS Maps of 1, 2, 3, below show that the distribution of health care facilities in the area was clustered in a particular section or pole in the study area. This corroborates with the Nearest Neighbourhood analysis result. It was observed that the clustering was most in Enugu East with the R_n of 0.655. This could be attributed to the presences of many PHCF in some areas like Abakpa Nike that has not less than 5 PHCFs. Again, Enugu North experienced also a cluster distribution with R_n 0.714. However, Enugu South which also depicts cluster distribution although not as the other LGAs had R_n of 0.867. It was tilting towards random distribution which statistically starts from 0.09. This implies a high level of inequity in the facilities' distribution. It also had an important implication for facility planning and management. The inequity implied that neighbourhoods at the core like Abakpa Nike, Obiagu, uwani etc enjoyed closer proximity to the location of medical facilities while other settlements were at farther proximities away from the facilities. In the area where population is not evenly distributed, the mean centre of population distribution is calculated as the "demand", which forms the origin of location. The facility location point is considered as destination points or "supply". In other words, it was discovered that that the pattern of distribution of PHCF in the metropolis is generally clustered and uneven, and as one moves away from the center, the sparser the PHCF become. Neighborhood analysis of the areas gives values less than 0.09, as such, ascertains the clustering in the distribution of the PHCF in the metropolis. Furthermore, the clustering distribution of PHCF in the study area revealed that the existing distribution was not patterned by any policy guideline (Umezuruike, 2016, Alabi, 2011).

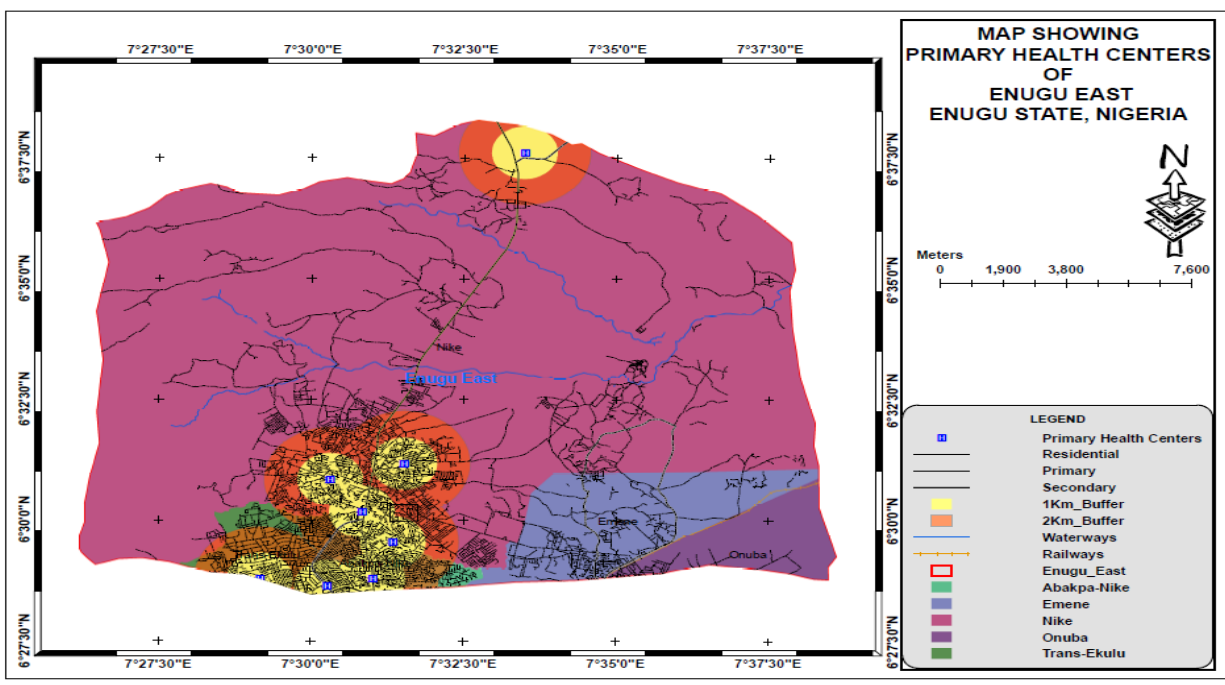
Accordingly, most areas in Enugu urban have inadequate distribution of PHCF. The result of the spatial distribution of PHCF in Enugu metropolis shows an uneven distribution of PHCF in the metropolis and revealed that the concentration of the PHCF is in the central part of the area. This means that there is uneven spatial distribution of health facilities. This finding is not surprising since a study conducted by Blanford et al. (2012) on accessibility to hospitals, maternity and integrated health centers in Niger concluded that there is significant geographic variation in access to health facilities in Niger. Yin et al. (2018) also affirm that there is poor spatial accessibility of healthcare facilities in China. The concentration of the PHCF within the central area cannot be explained by the Christellars central place theory, which explains that, the location of services is base on seize of community, population, accessibility and proximity putting into consideration, threshold and range. This further shows that the distribution pattern of all the PHCF in all the study areas in Enugu metropolis was cluster. There was no difference in their distribution pattern.

Maps 1 Showing the Spatial Distribution of the PHCFs in Enugu Urban



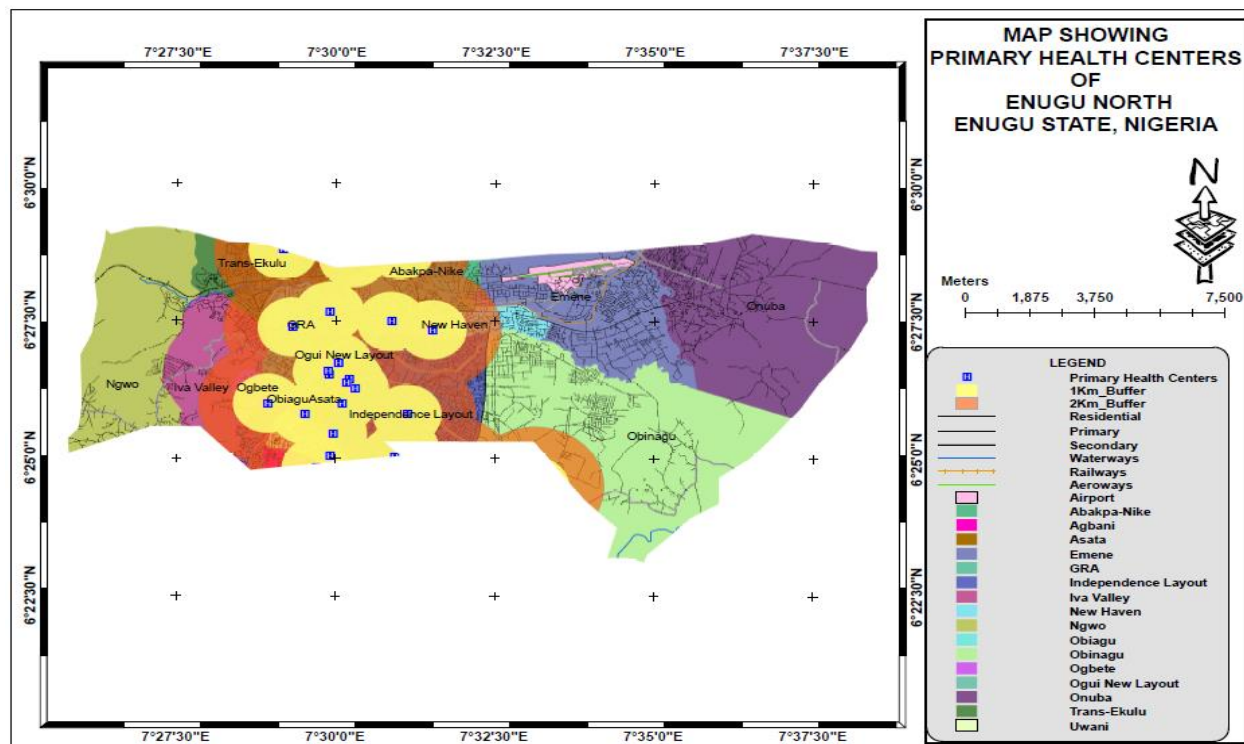
Source: GIS Result, 2023

Maps 2: Shows the buffer Zone analysis of the PHCF in Enugu East LGA



Source: GIS Result, 2023

Maps 3: Shows the buffer Zone analysis of the PHCF in Enugu North LGA



Source: GIS Result, 2023

5. DISCUSSION

The spatial pattern of primary health care facilities in the study area indicated an irregular clustered pattern of distribution of these facilities in Enugu. This revelation from the study was the clustered distribution of health services, which led to the difficulty in accessing some of these facilities by residents outside the catchment areas for their services. As there are areas in Enugu urban which have health care services and others do not have. It was revealed with the aid of the GIS techniques to the geographical distribution of this PHCF that they are clustered irregularly this resulted that there are no balance between the administrations of the services. The planners and decision makers should consider the obtained results to achieve fair and better distribution of public services. The result on GIS Maps of 5.1, 5.2, 5.3, 5.4 shows that the distribution of health care facilities in the area was clustered in a particular section or pole in the study area. This corroborates with the Nearest Neighbourhood analysis result. It was observed that the clustering was most in Enugu East with the R_n of 0.655. This could be attributed to the presences of many PHCF in some areas like Abakpa Nike that has not less than 5PHCFs. Again, Enugu North experienced also a cluster distribution with R_n 0.714. However, Enugu South which also depicts cluster distribution although not as the other LGAs had R_n of 0.867. It was tilting towards random distribution which statistically starts from 0.09. This implies a high level of inequity in the facilities' distribution. It also had an important implication for facility planning and management. The inequity implied that neighbourhoods at the core like Abakpa Nike, Obiagu, Uwani etc enjoyed closer proximity to the location of medical facilities while other settlements were at farther proximities away from the facilities. In the area where population is not evenly distributed, the mean centre of population distribution is calculated as the "demand", which forms the origin of location. The facility location point is considered as destination points or "supply". In other words, it was discovered that that the pattern of distribution of PHCF in the metropolis is generally clustered and uneven, and as one moves away from the center, the sparser the PHCF become. Neighborhood analysis of the areas gives values less than 0.09, as such, ascertains the clustering in the distribution of the PHCF in the metropolis. Furthermore, the clustering distribution of PHCF in the study area revealed that the existing distribution was not patterned by any policy guideline. (Umezuruike, 2016, Alabi, 2011). Accordingly, most areas in Enugu urban have inadequate distribution of PHCF. The result of the spatial distribution of PHCF in Enugu metropolis shows an uneven distribution of PHCF in the metropolis and revealed that the concentration of the PHCF is in the central part of the area. This

means that there is uneven spatial distribution of health facilities. This finding is not surprising since a study conducted by Blanford et al. (2012) on accessibility to hospitals, maternity and integrated health centers in Niger concluded that there is significant geographic variation in access to health facilities in Niger. Yin et al. (2018) also affirm that there is poor spatial accessibility of healthcare facilities in China. The concentration of the PHCF within the central area cannot be explained by the Christallers central place theory, which explains that, the location of services is based on size of community, population, accessibility and proximity putting into consideration, threshold and range. This further shows that the distribution pattern of all the PHCF in all the study areas in Enugu metropolis was cluster. There was no difference in their distribution pattern

6 Conclusion

This study explored the use of GIS for analyzing the spatial distribution and accessibility of the health care delivery system in Enugu metropolis. It was revealed that Primary healthcare facilities have been provided but not equally distributed and not readily accessible. Healthcare planning is a challenging field that depends on spatial data such as location and characteristics of health center demand. GIS was used to analyze the center catchment as well as study of the spatial distribution of the PHC in the area. The study concluded that the existing health facilities is not marching the available demand because most of these facilities were clustered within the radius of the city centre and on the other hand area the periphery were neglected. It could be said that there is inequality in the distribution of primary healthcare in Enugu metropolis. The developed map indicates the uneven distribution of health facilities. This study found that Primary health Care facilities are poorly distributed spatially which has had negative implications on access to primary health care.

7. Recommendation

Based on the analysis and findings in this study, this study recommends the following:

1. The urgent improvement of the health care delivery system in Enugu metropolis for the benefit of the general public should be conducted by providing new health care facilities,
2. Improvement should be made on healthcare provision in Enugu urban by having a standardized regulation for establishing primary healthcare facilities. This could be considered when the identified determinants of the locational distribution of primary health care facility in Enugu State are considered in future location decisions of PHCF. These determinants are: number of PHCF in the community/area, population density, household size, household income, travel cost, age of respondents and decision to locate PHCF (political/economic

factor). The study established a significant relationship between spatial accessibility of these health centres and these determinants. This adaptive relationship would inform the basis for facility location decisions.

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Development of a Composite Urban Flood Vulnerability Index Using Drainage Condition and Household Exposure Data in Uyo, Nigeria

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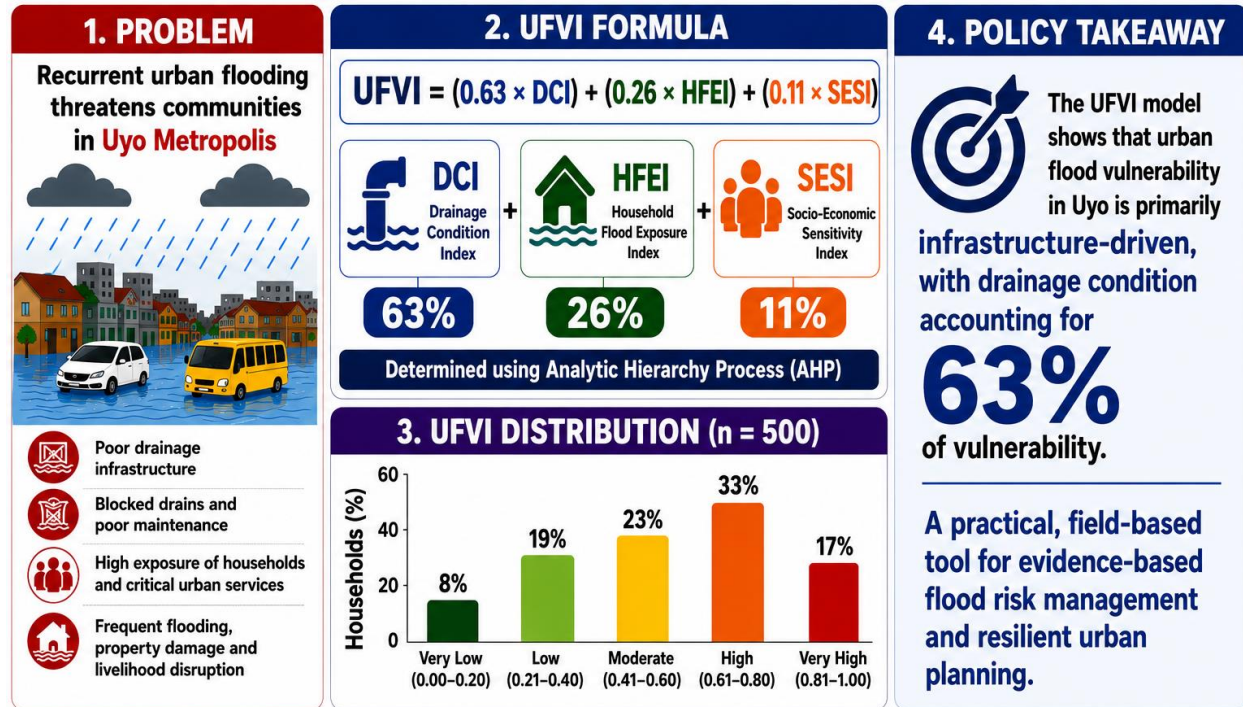
Abstract

Urban flooding has become a persistent environmental and infrastructure challenge in rapidly urbanising cities across sub-Saharan Africa, where weak drainage systems and uncontrolled urban growth intensify flood risk. In Nigeria, recurrent flooding increasingly reflects infrastructure deficiencies and poor urban management rather than extreme climatic conditions alone. Despite growing scholarly attention, many flood vulnerability studies rely heavily on GIS-based approaches that are often data-intensive and difficult to implement in low-resource planning environments. This study develops and validates a Composite Urban Flood Vulnerability Index (UFVI) using field-based drainage condition and household exposure data in Uyo Metropolis, Nigeria. A cross-sectional design involving 500 household surveys and structured drainage infrastructure audits was adopted across ten flood-prone neighbourhoods. Three vulnerability dimensions, Drainage Condition Index (DCI), Household Flood Exposure Index (HFEI), and Socio-Economic Sensitivity Index (SESI) were integrated using the Analytic Hierarchy Process (AHP). Descriptive statistics, correlation analysis, and multiple regression analysis were employed to determine the dominant drivers of vulnerability. Results indicate a mean UFVI of 0.61, with 50% of households classified under high vulnerability. Drainage condition emerged as the strongest determinant of vulnerability, contributing 63% of the composite index weight, followed by household flood exposure (26%) and socio-economic sensitivity (11%). The findings demonstrate that urban flood vulnerability in Uyo is primarily infrastructure-driven. The study provides a practical and replicable framework for flood vulnerability assessment, infrastructure prioritisation, and resilient urban planning in data-constrained environments.

Keywords: Urban flooding; Composite vulnerability index; Drainage infrastructure; Flood exposure; urban resilience; Uyo Metropolis

Graphical Abstract

DEVELOPMENT OF A COMPOSITE URBAN FLOOD VULNERABILITY INDEX (UFVI) USING DRAINAGE CONDITION AND HOUSEHOLD EXPOSURE DATA IN UYO, NIGERIA



1. Introduction

Urban flooding has become one of the most persistent environmental challenges confronting rapidly urbanising cities across sub-Saharan Africa. Increasing rainfall variability, uncontrolled urban expansion, and inadequate drainage infrastructure have intensified flood occurrence and vulnerability within many developing urban centres (IPCC, 2022; UNDRR, 2023). In most African cities, rapid conversion of permeable surfaces into built-up areas has significantly increased stormwater runoff, while weak planning and infrastructure maintenance systems continue to worsen flood impacts.

In Nigeria, recurrent urban flooding now affects several cities including Lagos, Port Harcourt, Ibadan, Aba, and Uyo. Existing studies identify poor drainage systems, indiscriminate waste disposal, weak development control, and infrastructure deterioration as major drivers of urban flooding (Adelekan, 2016; Komolafe *et al.*, 2015). Beyond environmental damage, flooding

increasingly disrupts transportation, housing, public health, livelihoods, and economic activities within rapidly growing urban areas.

Recent flood vulnerability studies have largely relied on GIS and remote sensing techniques for flood susceptibility mapping and hazard assessment (Ajin *et al.*, 2013; Ouma & Tateishi, 2014). Although these approaches provide important spatial insights, they are often data-intensive and technically demanding, limiting their applicability within many resource-constrained planning environments. In addition, several existing studies focus mainly on physical flood susceptibility while paying limited attention to drainage infrastructure condition and household-level vulnerability.

Contemporary resilience literature increasingly recognises that urban flood vulnerability is multidimensional and shaped by the interaction between environmental exposure, infrastructure systems, and socio-economic conditions (Birkmann *et al.*, 2022; Meerow *et al.*, 2016). Consequently, composite vulnerability indices have emerged as practical tools for integrating multiple indicators into unified assessment frameworks capable of supporting evidence-based planning and infrastructure prioritisation.

Despite growing research on urban flooding in Nigeria, limited studies have developed field-based composite vulnerability models integrating drainage condition, household flood exposure, and socio-economic sensitivity within a single framework. This gap is particularly evident in Uyo Metropolis where recurrent flooding continues to affect mobility, infrastructure, and residential environments. Therefore, this study develops and validates a Composite Urban Flood Vulnerability Index (UFVI) using field-generated data and the Analytic Hierarchy Process (AHP) to support resilient urban planning and flood management in Uyo, Nigeria.

1.1 Statement of the Problem

Urban flooding has increasingly become a major infrastructure and environmental management challenge across rapidly growing Nigerian cities. In many urban centres, rapid physical expansion has outpaced drainage infrastructure development, resulting in blocked drainage channels, increased impervious surfaces, and recurrent surface flooding (Adelekan, 2016; World Bank, 2022). In Uyo Metropolis, several neighbourhoods frequently experience flooding, road inaccessibility, property damage, and disruption of socio-economic activities during rainfall events.

Field observations indicate that poor drainage maintenance, waste blockage, inadequate hydraulic capacity, and weak development control significantly contribute to the persistence of flooding within the city.

Despite the growing severity of urban flooding, existing flood vulnerability studies in Nigeria remain dominated by GIS-based and remote sensing approaches that often require advanced datasets, geospatial expertise, and technical infrastructure that are not readily available to many local planning institutions (Ajin *et al.*, 2013; Ouma & Tateishi, 2014). Furthermore, several existing studies focus mainly on flood susceptibility mapping while giving limited attention to drainage infrastructure condition, household flood exposure, and socio-economic sensitivity within integrated vulnerability assessment frameworks. Consequently, there remains limited empirical evidence on practical field-based approaches capable of supporting local-level flood management and infrastructure prioritisation in rapidly urbanising cities such as Uyo.

Without context-specific and operationally feasible vulnerability assessment tools, flood management in Uyo remains largely reactive and infrastructure-deficient. Therefore, there is a critical need for a field-based composite flood vulnerability framework capable of integrating drainage condition, household flood exposure, and socio-economic sensitivity into a unified analytical model. This study addresses this gap by developing and validating a Composite Urban Flood Vulnerability Index (UFVI) using the Analytic Hierarchy Process (AHP) to support evidence-based planning, infrastructure prioritisation, and resilient urban flood management in Uyo Metropolis.

1.2 Aim and Objectives

Aim

The aim of this study is to develop and validate a Composite Urban Flood Vulnerability Index (UFVI) integrating drainage infrastructure condition, household flood exposure, and socio-economic sensitivity for effective urban flood risk assessment and planning in Uyo Metropolis, Nigeria.

Specific Objectives

1. To assess the physical condition and functional efficiency of drainage infrastructure within selected neighbourhoods in Uyo Metropolis.

2. To evaluate household flood exposure in terms of flood frequency, depth, duration, and associated impacts.
3. To examine socio-economic factors influencing household vulnerability to urban flooding.
4. To develop a weighted Composite Urban Flood Vulnerability Index (UFVI) using the Analytic Hierarchy Process.
5. To determine the dominant drivers of urban flood vulnerability using inferential statistical analysis.
6. To classify and rank neighbourhoods based on flood vulnerability for planning and infrastructure prioritisation.

1.3 Theoretical Framework

This study is anchored on the Vulnerability Framework advanced by Blaikie *et al.* (1994) and further refined by Turner *et al.* (2003). The framework conceptualises vulnerability as the interaction between exposure, sensitivity, and adaptive capacity. Unlike hazard-centred models, the framework recognises that disasters emerge from the interaction between environmental processes, infrastructural conditions, and socio-economic realities.

Within the context of this study:

- Household Flood Exposure Index (HFEI) operationalises exposure;
- Socio-Economic Sensitivity Index (SESI) captures sensitivity and adaptive capacity;
- Drainage Condition Index (DCI) reflects infrastructure-mediated vulnerability.

The framework provides a suitable theoretical basis for integrating infrastructural and socio-economic indicators into a unified flood vulnerability assessment model.

2. Literature Review

2.1 Urban Flood Vulnerability and Infrastructure Failure

Urban flood vulnerability has increasingly become a major focus within climate resilience and urban sustainability research. Earlier studies predominantly concentrated on hydrological and topographical determinants of flooding using GIS and remote sensing techniques (Ouma & Tateishi, 2014). Although these approaches effectively delineate flood-prone zones, they often underrepresent infrastructure performance and household-level vulnerability.

Recent studies increasingly acknowledge that urban flood vulnerability is multidimensional, shaped by infrastructure condition, socio-economic resilience, governance effectiveness, and environmental exposure (Birkmann *et al.*, 2022; de Brito *et al.*, 2018). Lamond *et al.* (2012) observed that deteriorating drainage systems significantly intensify urban flooding in rapidly urbanising cities. Similarly, Meerow *et al.* (2016) emphasised that resilience of urban infrastructure systems constitutes a critical determinant of adaptive capacity.

Within Nigeria, several scholars have identified drainage blockage, poor waste management, and weak development control as central drivers of urban flooding (Adelekan, 2016; Komolafe *et al.*, 2015). In many urban areas, drainage infrastructure has failed to expand proportionately with urban growth, thereby increasing stormwater accumulation and neighbourhood exposure.

2.2 Composite Vulnerability Indices and Flood Assessment

Composite vulnerability indices have become increasingly popular in environmental risk assessment because of their ability to integrate multiple indicators into unified decision-support systems. Balica *et al.* (2012) developed a flood vulnerability index integrating exposure, susceptibility, and resilience indicators for urban flood assessment. Similarly, de Loyola Hummell *et al.* (2016) argued that composite indices provide flexible and scalable approaches for evaluating multidimensional vulnerability within data-constrained environments.

Compared with conventional GIS-based models, composite indices are often more adaptable to local planning contexts because they combine quantitative and qualitative dimensions of vulnerability. They also provide practical frameworks for policy prioritisation, especially where geospatial infrastructure remains limited.

2.3 GIS-Based Models versus Field-Based Approaches

GIS-based flood vulnerability models remain dominant within flood risk literature because of their spatial analytical capabilities. Studies by Ajin *et al.* (2013) and Ouma and Tateishi (2014) demonstrated the effectiveness of GIS and remote sensing for flood susceptibility mapping. However, these approaches are highly dependent on geospatial datasets, digital elevation models, and advanced technical expertise.

In contrast, field-based approaches emphasise direct assessment of infrastructure conditions, household experiences, and socio-economic realities. Such approaches are particularly suitable for

rapidly urbanising cities where reliable geospatial data are limited or inaccessible. Field-driven frameworks also provide stronger representation of lived vulnerability experiences and infrastructure performance.

Despite growing interest in integrated vulnerability assessment, limited studies within Nigerian cities have developed field-based composite vulnerability models integrating drainage infrastructure condition, flood exposure, and socio-economic sensitivity using weighted multi-criteria techniques. This study contributes to addressing this methodological gap.

3. Methodology

3.1 Study Area

The study was conducted in Uyo Urban, Akwa Ibom State, Nigeria, located between latitudes 4°52'N and 5°07'N and longitudes 7°47'E and 8°03'E. Uyo is characterised by low-relief topography, high annual rainfall, and rapidly expanding urban development. Increasing impervious surfaces and inadequate drainage systems have intensified surface runoff and recurrent urban flooding.

The study focused on ten flood-prone neighbourhoods which are Ekpri Nsukkara, Ekom Iman, Aka Itiam, Paul Bassey, Urua Ekpa/Ikpa Road, Nkemba/Abak Road, Ekamba Nsukkara, Atiku Abubakar, Ikot Akpan Abia, and Ifa Ikot Idang. These neighbourhoods were selected based on recurrent flooding history, drainage deficiencies, and evidence from preliminary reconnaissance surveys, and are presented in figure 1.

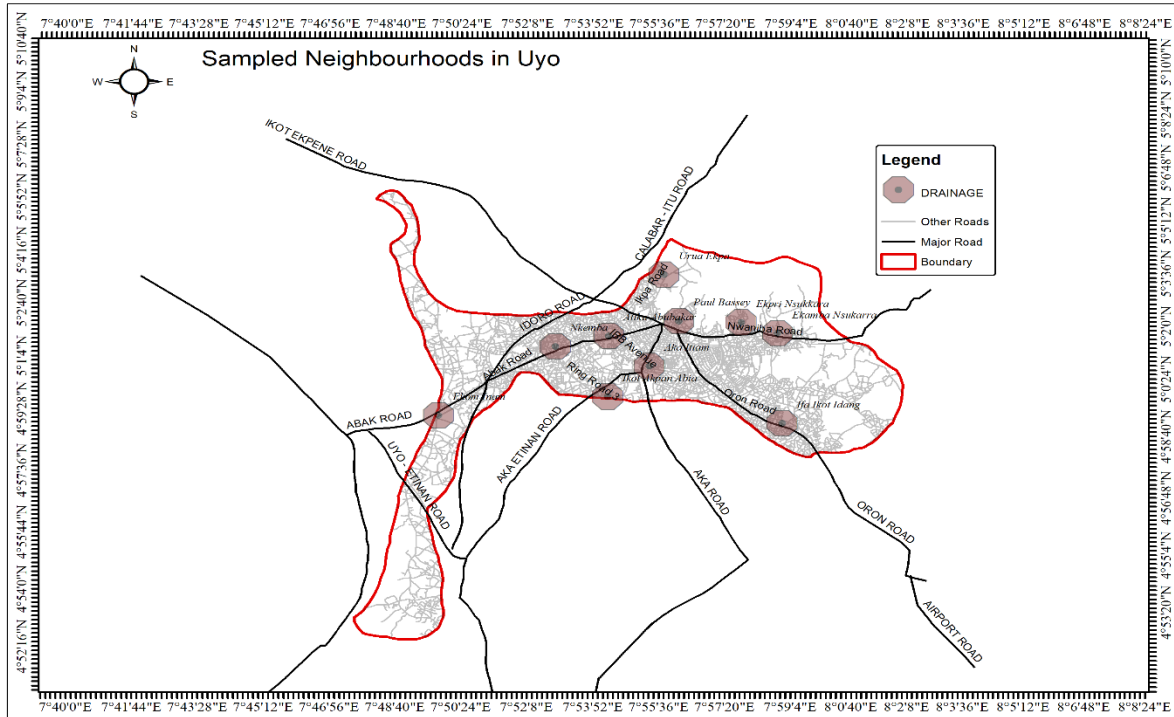


Figure 1. Sampled Neighbourhoods in Uyo

3.2 Research Design

The study adopted a cross-sectional empirical research design integrating household surveys with field-based drainage infrastructure audits. The design enabled simultaneous assessment of infrastructural, environmental, and socio-economic dimensions of flood vulnerability.

3.3 Sample Size Determination

The sample size was determined using Cochran's formula for large populations:

$$n_0 = \frac{Z^2 p(1 - p)}{e^2}$$

Where:

- $Z = 1.96$ (95% confidence level)
- $p = 0.5$
- $e = 0.05$

The computed sample size yielded 384 households. To improve statistical reliability and account for incomplete responses, a 20% adjustment was applied, resulting in approximately 480 respondents. The final sample size was rounded to 500 households.

3.4 Sampling Procedure

A multi-stage sampling technique was adopted. First, ten flood-prone neighbourhoods were purposively selected. Second, systematic household sampling was conducted within each neighbourhood. Only households with prior flood experience were included.

Drainage audits were conducted across major drainage segments within sampled neighbourhoods. Audit procedures involved direct field observation of drainage blockage, hydraulic adequacy, waste accumulation, structural condition, vegetation growth, and maintenance status.

3.5 Questionnaire Pretesting and Data Quality Control

The questionnaire instrument was pretested using 30 households outside the sampled neighbourhoods to evaluate clarity, reliability, and response consistency. Feedback from the pretest informed refinement of question wording and sequencing.

Incomplete questionnaires representing less than 5% of total responses were excluded from final analysis. Data cleaning procedures included consistency checks, missing value screening, and outlier assessment.

3.6 Construction of Vulnerability Indices

Three sub-indices were developed:

Drainage Condition Index (DCI)

Indicators included: blockage level, structural condition, hydraulic adequacy, waste accumulation, vegetation/siltation, maintenance frequency.

Household Flood Exposure Index (HFEI)

Indicators included: flood frequency, flood depth, flood duration, property damage, displacement, road inaccessibility, health impacts.

Socio-Economic Sensitivity Index (SESI)

Indicators included: income level, household size, education, occupation, housing quality, preparedness level, insurance coverage.

All variables were measured using standardised 0–5 scales.

3.7 Data Normalisation

Min-max normalisation was applied:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}}$$

This standardised all indicators to a 0–1 scale.

3.8 AHP Weighting Procedure

The Analytic Hierarchy Process (AHP) developed by Saaty (1980) was employed to derive criterion weights. Pairwise comparisons among DCI, HFEI, and SESI were conducted using expert judgment.

Five experts comprising two urban planners, one environmental scientist, one civil engineer, and one hydrologist participated in the pairwise comparison process. Judgments were aggregated using mean comparison values.

Saaty's 1–9 scale was used to evaluate relative importance. Consistency of judgments was assessed using the Consistency Ratio (CR). The computed CR value of 0.08 was below the acceptable threshold of 0.10, indicating acceptable consistency.

Figure 2 presents the analytical framework adopted for the development of the Urban Flood Vulnerability Index (UFVI) alongside the Analytic Hierarchy Process (AHP) pairwise comparison matrix used for criterion weighting. The figure illustrates the integration of drainage condition, household flood exposure, and socio-economic sensitivity indicators within the composite vulnerability assessment framework.

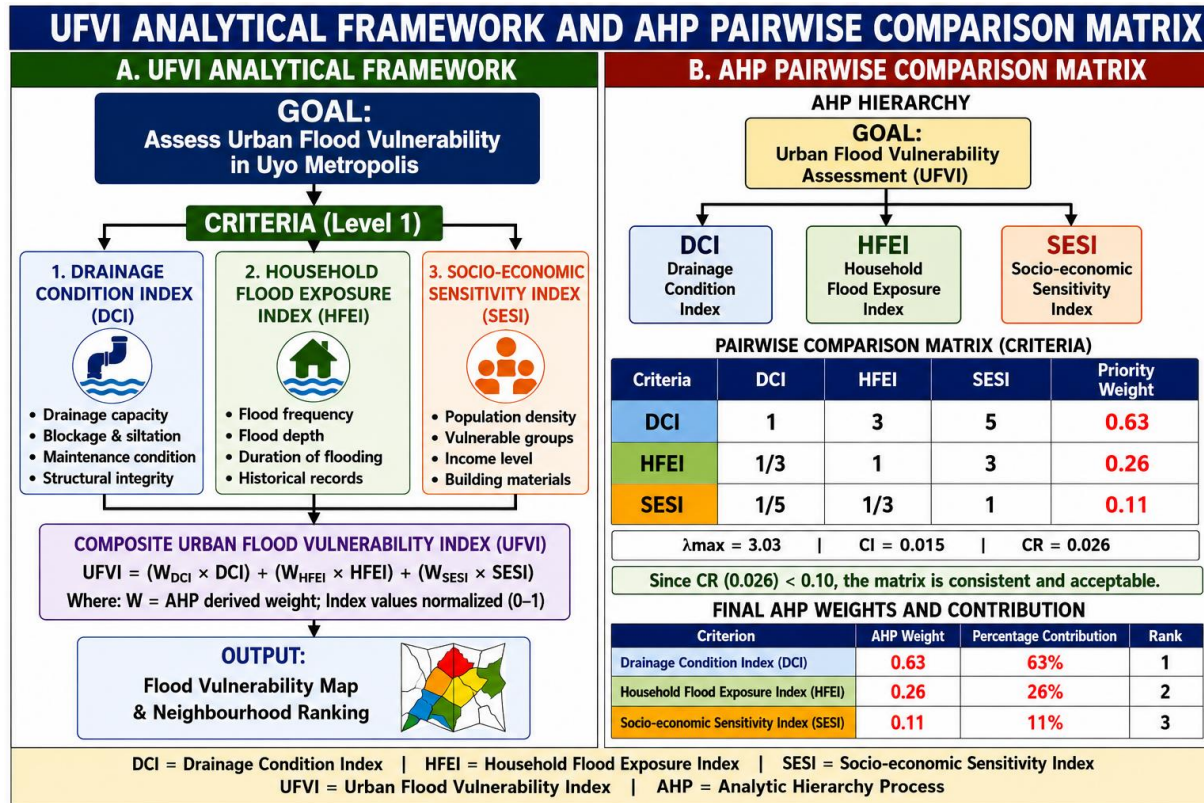


Figure 2: UFVI Analytical Framework Diagram and AHP Pairwise Comparison Matrix

The analytical framework demonstrates the systematic integration of infrastructural, environmental, and socio-economic indicators into the composite flood vulnerability model. The AHP pairwise comparison matrix further illustrates the weighting process used to determine the relative contribution of each vulnerability component. The results indicate that drainage condition received the highest priority weight, confirming its dominant influence on urban flood vulnerability within Uyo Metropolis. The acceptable consistency ratio further validates the reliability of the weighting procedure and the robustness of the UFVI model.

The final weights obtained were:

- DCI = 0.63
- HFEI = 0.26
- SESI = 0.11

3.9 Statistical Analysis

Descriptive statistics including means, frequencies, and percentages were computed. Pearson correlation analysis was conducted to evaluate relationships among indices.

Multiple regression analysis was further employed to determine the relative influence of DCI, HFEI, and SESI on overall flood vulnerability.

The regression model was specified as:

$$UFVI = \beta_0 + \beta_1DCI + \beta_2HFEI + \beta_3SESI + \varepsilon$$

Reliability analysis was conducted using Cronbach's Alpha.

4. Results and Discussion

4.1 Socio-Economic Characteristics of Respondents

Analysis revealed that over 60% of respondents earned below ₦100,000 monthly, indicating generally low-income conditions across sampled neighbourhoods. Household sizes ranged between three and nine persons with an average household size of 5.2 persons. Approximately 68% of respondents resided in semi-permanent or poorly serviced housing. Preparedness capacity was generally low, with less than 30% of households reporting access to formal flood warning systems or insurance mechanisms. Table 1 presents the socio-economic characteristics of sampled households within the study area, including income level and housing condition.

Table 1: Socio-Economic Characteristics of Respondents

Variable	Category	Frequency	Percentage
Monthly Income	< ₦50,000	145	29.0
	₦50,000–₦100,000	165	33.0
	₦100,000–₦200,000	120	24.0
	> ₦200,000	70	14.0
Housing Type	Temporary	110	22.0
	Semi-permanent	230	46.0
	Permanent	160	32.0

The results indicate that a large proportion of respondents belong to low- and middle-income categories and reside in semi-permanent housing conditions, suggesting limited adaptive capacity and increased vulnerability to urban flooding.

4.2 Drainage Condition Assessment

Field-based drainage audits revealed widespread infrastructural deficiencies across sampled neighbourhoods. The mean DCI value of 3.42 indicates generally poor drainage performance.

Blockage by solid waste and sediment accumulation was particularly severe within Urua Ekpa/Ikpa Road, Ekpri Nsukkara, and Nkemba/Abak Road. Structural deterioration including cracks and collapsed channel sections was observed in several drainage segments. Table 2 shows the assessment of drainage infrastructure condition across the sampled neighbourhoods based on blockage level, structural condition, hydraulic adequacy, and maintenance status.

Table 2: Drainage Condition Assessment

Indicator	Mean Score	Interpretation
Blockage Level	3.80	High obstruction
Structural Condition	3.25	Moderate deterioration
Hydraulic Adequacy	3.60	Undersized
Waste Accumulation	3.70	High
Maintenance Frequency	3.50	Poor
Vegetation/Siltation	3.00	Moderate
Overall DCI	3.42	Poor condition

The findings reveal generally poor drainage performance characterised by high blockage levels, inadequate hydraulic capacity, and weak maintenance practices, confirming the significant role of infrastructure failure in urban flood occurrence. The findings reinforce arguments by Lamond *et al.* (2012) that infrastructure failure significantly amplifies urban flood vulnerability.

Figure 3 presents the severity distribution of drainage infrastructure conditions alongside the conceptual pathway through which infrastructure deficiencies contribute to urban flooding in Uyo Metropolis. The figure integrates empirical drainage assessment results with the broader infrastructure failure process driving urban flood vulnerability.

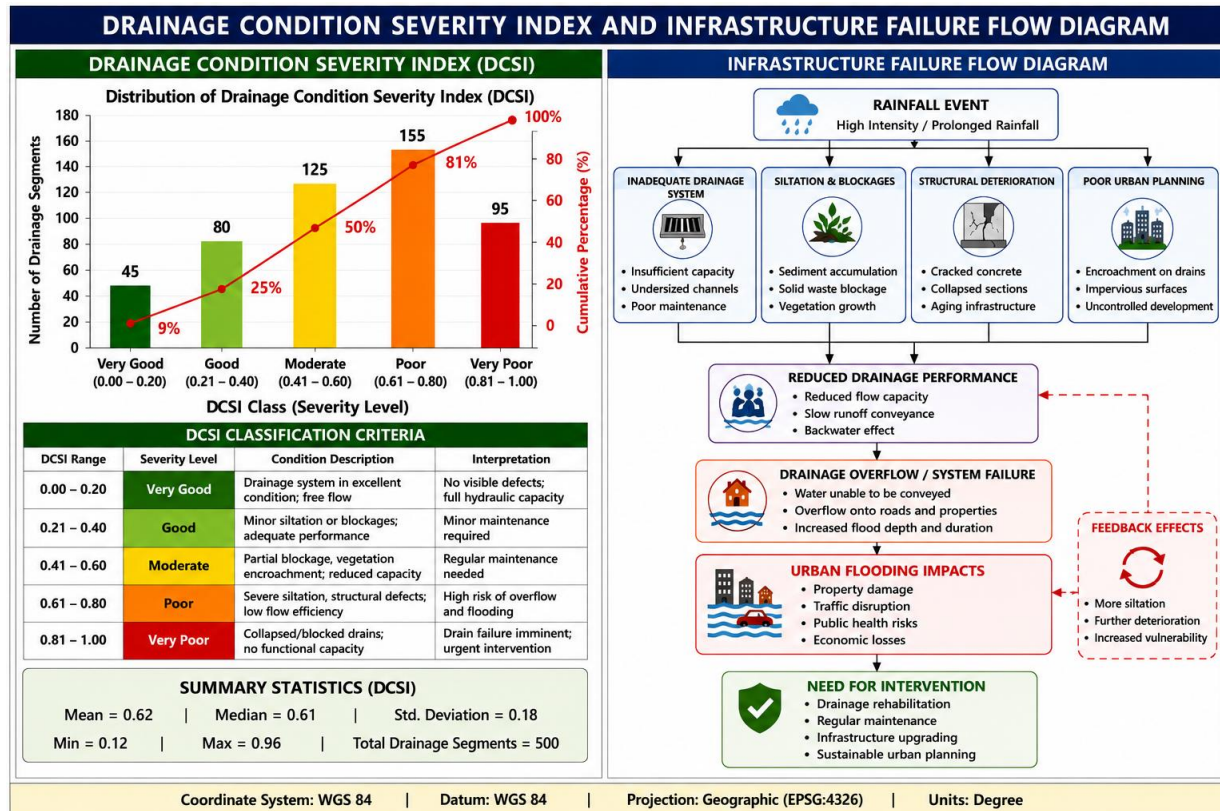


Figure 3: Drainage Condition Severity Index and Infrastructure Failure Flow Diagram

The figure indicates that a substantial proportion of drainage segments within the study area fall within poor and very poor condition categories, reflecting widespread infrastructural deterioration, blockage, and inadequate hydraulic performance. The infrastructure failure flow diagram further demonstrates how rainfall events interact with drainage deficiencies, sediment accumulation, structural deterioration, and poor urban planning to reduce drainage efficiency and intensify flood occurrence. The conceptual pathway reinforces the study's finding that urban flood vulnerability in Uyo is fundamentally linked to infrastructure failure and weak maintenance systems.

4.3 Household Flood Exposure

The HFEI recorded a mean value of 2.87, reflecting moderate to high exposure. More than 70% of households experienced flooding at least twice annually. Flood depths commonly reached knee to waist level, while property losses frequently exceeded ₦50,000 per event. Table 3 presents household flood exposure characteristics including flood frequency, depth, duration, property damage, and accessibility disruption.

Table 3: Household Flood Exposure Characteristics

Indicator	Mean Score	Interpretation
Flood Frequency	3.10	Frequent
Flood Depth	2.95	Moderate–High
Flood Duration	2.80	Moderate
Property Damage	3.20	High
Road Inaccessibility	3.00	Frequent
Health Impacts	2.50	Moderate
Overall HFEI	2.87	Moderate–High

The results demonstrate that households within the study area experience recurrent and disruptive flooding, with substantial impacts on mobility, residential properties, and daily socio-economic activities.

4.4 Socio-Economic Sensitivity

The SESI recorded a mean value of 2.15, indicating moderate vulnerability. Low incomes, high dependency ratios, limited insurance coverage, and weak preparedness systems intensified household vulnerability.

4.5 Composite Urban Flood Vulnerability Index

UFVI values ranged from 0.22 to 0.89, with a mean value of 0.61. Table 4 presents the classification of households based on the computed Urban Flood Vulnerability Index (UFVI).

Table 4: UFVI Classification

Vulnerability Level	Range	Frequency	Percentage
Low	0.00–0.30	52	10.4
Moderate	0.31–0.60	198	39.6
High	0.61–1.00	250	50.0

The high proportion of households within the high vulnerability category confirms the structurally vulnerable nature of urban systems within Uyo. The distribution indicates that half of the sampled households fall within the high vulnerability category, reflecting the widespread and systemic nature of urban flood vulnerability within Uyo Metropolis.

Figure 4 presents the distribution of households across Urban Flood Vulnerability Index (UFVI) categories alongside the relative contribution of the AHP-weighted vulnerability components used in the composite model. The charts illustrate both the overall vulnerability structure and the dominant factors influencing flood vulnerability within Uyo Metropolis.

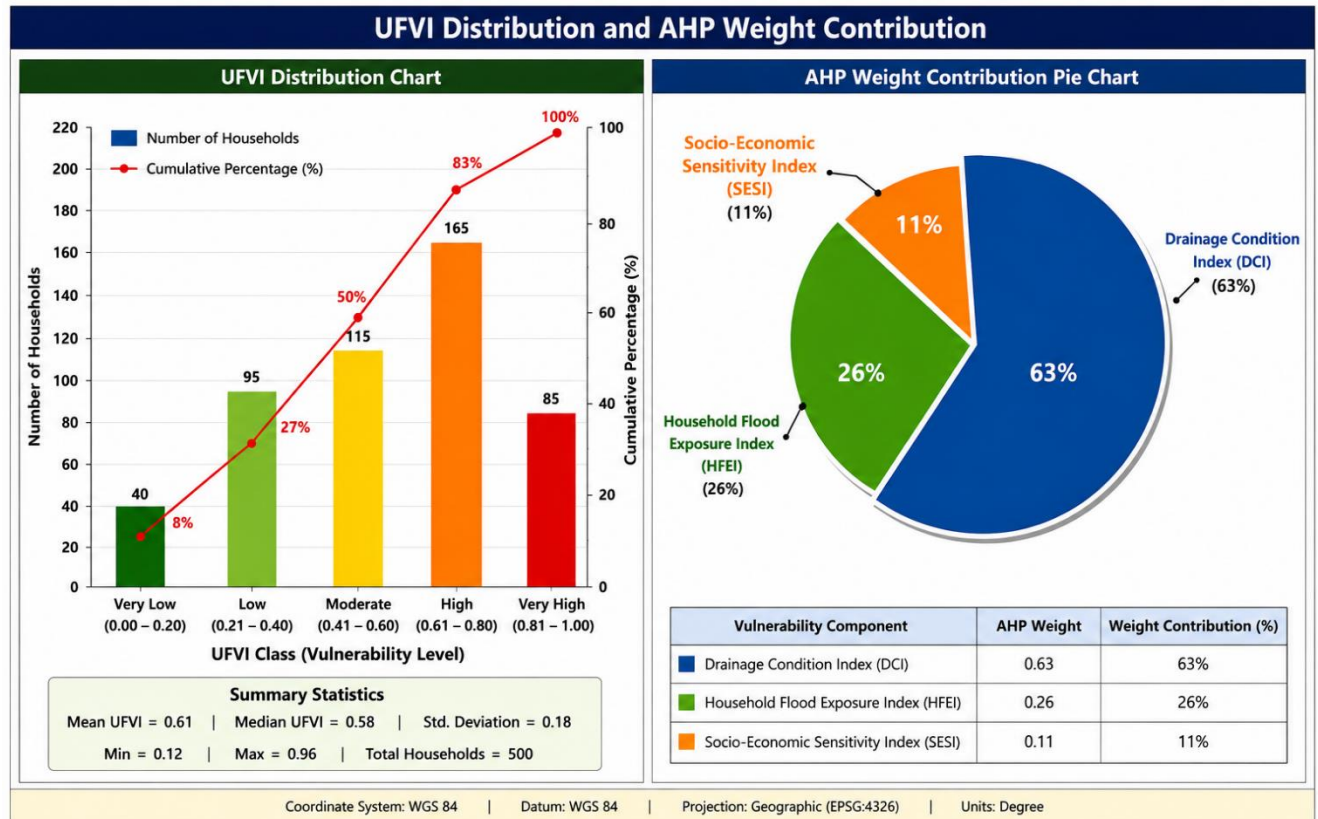


Figure 4: UFVI Distribution and AHP Weight Contribution

The UFVI distribution chart indicates that a substantial proportion of households fall within the moderate to high vulnerability categories, reflecting widespread exposure to urban flood risk within the study area. The AHP weight contribution chart further demonstrates that drainage condition constitutes the most influential component of the composite vulnerability model, contributing 63% of the overall index weight, followed by household flood exposure (26%) and socio-economic sensitivity (11%). The findings reinforce the conclusion that urban flood vulnerability in Uyo is primarily infrastructure-driven.

4.6 Neighbourhood Vulnerability Ranking

Table 5 presents the ranking of sampled neighbourhoods according to their computed Urban Flood Vulnerability Index scores.

Table 5: Ranking of High Vulnerability Neighbourhoods

Rank	Neighbourhood	UFVI Score
1	Urua Ekpa/Ikpa Road	0.89
2	Ekpri Nsukkara	0.86
3	Nkemba/Abak Road	0.84
4	Ifa Ikot Idang	0.82
5	Ekamba Nsukkara	0.79
6	Aka Itiam	0.76
7	Paul Bassey	0.73
8	Atiku Abubakar	0.69
9	Ikot Akpan Abia	0.65
10	Ekom Iman	0.58

The ranking identifies Urua Ekpa/Ikpa Road, Ekpri Nsukkara, and Nkemba/Abak Road as the most vulnerable neighbourhoods, highlighting areas requiring urgent infrastructure intervention and flood management prioritisation. Figure 5 presents the spatial distribution and neighbourhood ranking of urban flood vulnerability across Uyo Metropolis based on the Composite Urban Flood Vulnerability Index (UFVI). The heat map illustrates the intensity of flood vulnerability, while the ranking map classifies sampled neighbourhoods according to their relative vulnerability levels.

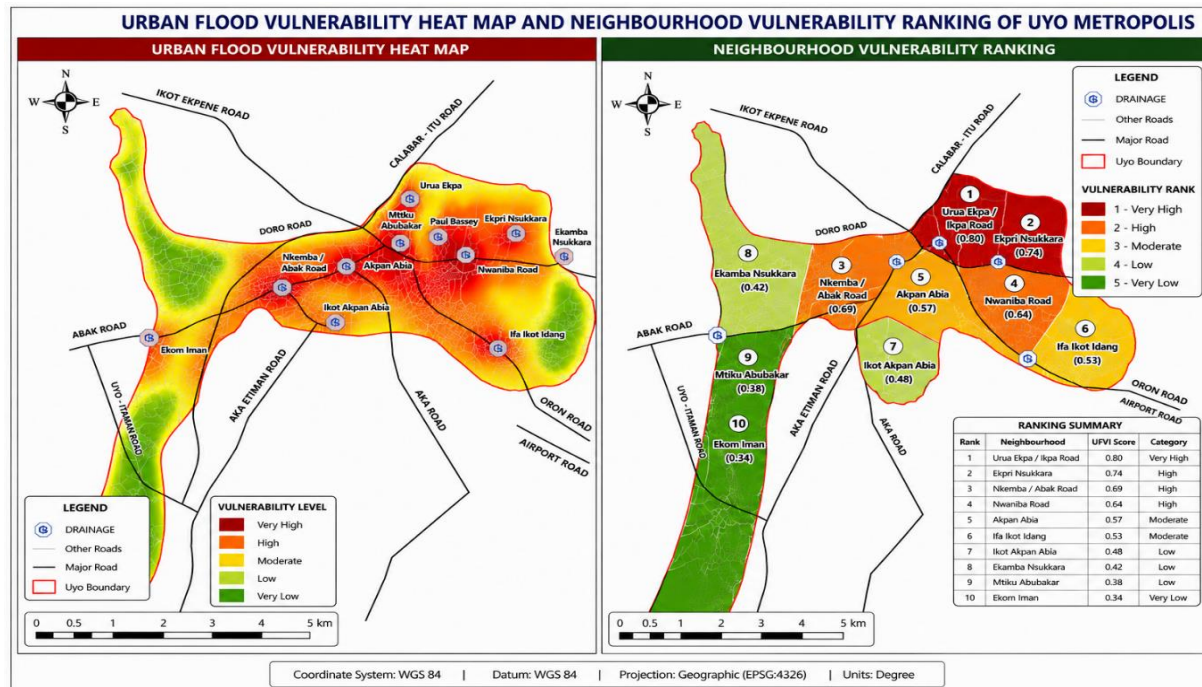


Figure 5: Urban Flood Vulnerability Heat Map and Neighbourhood Vulnerability Ranking

The figure reveals clear spatial disparities in urban flood vulnerability across the study area. Urua Ekpa/Ikpa Road, Ekpri Nsukkara, Nkemba/Abak Road, and the Nwaniba Road axis exhibit high to very high vulnerability levels associated with poor drainage conditions, recurrent flood exposure, and increased socio-economic sensitivity. In contrast, peripheral neighbourhoods such as Ekom Iman and Ekamba Nsukkara display comparatively lower vulnerability levels. The spatial pattern highlights priority areas requiring urgent drainage rehabilitation, infrastructure upgrading, and targeted flood resilience interventions within Uyo Metropolis.

4.7 Correlation Analysis

Table 6 shows the Pearson correlation relationships among drainage condition, household flood exposure, socio-economic sensitivity, and overall flood vulnerability.

Table 6: Correlation Matrix

Variable	DCI	HFEI	SESI	UFVI
DCI	1.00	0.62	0.31	0.84
HFEI	0.62	1.00	0.40	0.71
SESI	0.31	0.40	1.00	0.52
UFVI	0.84	0.71	0.52	1.00

Drainage condition exhibited the strongest correlation with overall vulnerability. The analysis reveals strong positive relationships between drainage condition and overall vulnerability, indicating that deteriorating drainage infrastructure significantly increases urban flood risk.

Figure 6 presents the statistical relationships and severity patterns associated with urban flood vulnerability in Uyo Metropolis. The figure combines regression coefficient analysis, correlation structure among vulnerability variables, and household flood exposure severity distribution to provide a comprehensive understanding of the dominant drivers of urban flood risk.

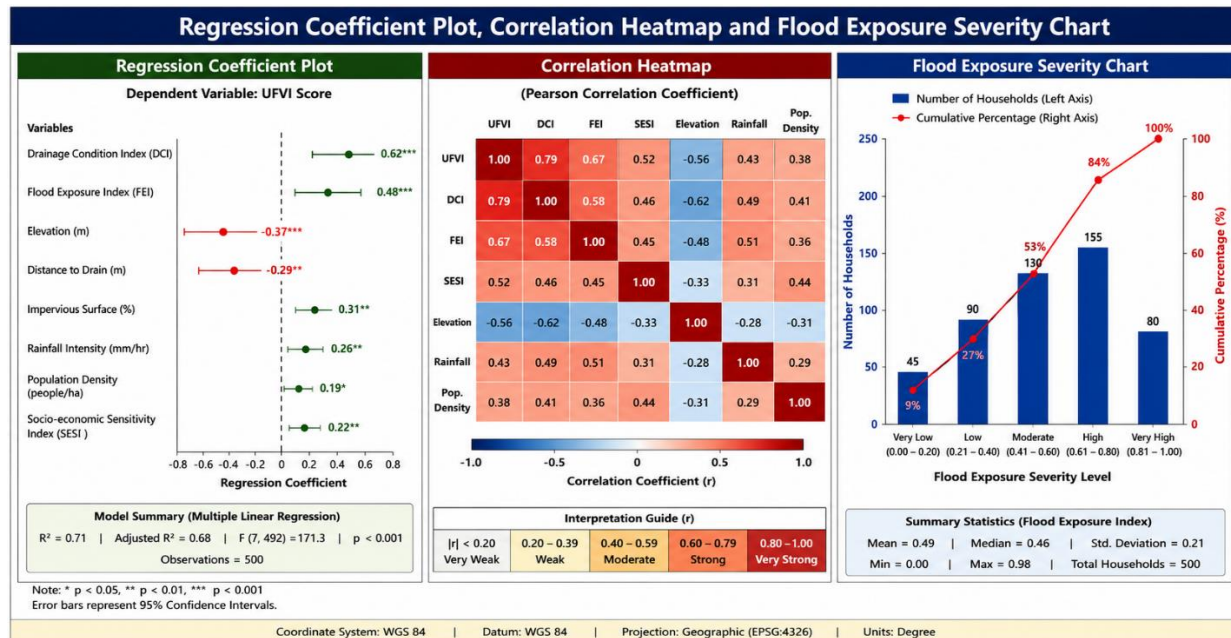


Figure 6: Flood Vulnerability Statistical Analysis

The figure demonstrates that drainage condition and household flood exposure exert the strongest positive influence on overall urban flood vulnerability within the study area. The correlation heatmap reveals strong positive associations among drainage condition, flood exposure, and the Urban Flood Vulnerability Index (UFVI), while the regression coefficient plot further confirms drainage infrastructure as the dominant predictive variable. The flood exposure severity chart also indicates that a substantial proportion of households experience moderate to high flood severity conditions, reflecting the widespread nature of flood impacts across sampled neighbourhoods. Together, the findings reinforce the conclusion that urban flooding in Uyo is primarily infrastructure-driven and spatially concentrated within highly urbanised corridors.

4.8 Regression Analysis

Table 7 presents the multiple regression analysis showing the relative influence of drainage condition, household flood exposure, and socio-economic sensitivity on overall flood vulnerability.

Table 7: Multiple Regression Results

Variable	Beta Coefficient	t-value	Significance
DCI	0.68	9.84	0.000
HFEI	0.29	5.31	0.002
SESI	0.14	2.62	0.018

The regression results confirm that drainage condition exerts the strongest predictive influence on urban flood vulnerability, reinforcing the argument that flooding in Uyo is primarily infrastructure-driven.

4.9 Reliability Analysis

Cronbach's Alpha coefficient of 0.82 indicates strong internal consistency and reliability of the composite vulnerability model.

4.10 Discussion of Findings

The findings demonstrate that urban flood vulnerability within Uyo is fundamentally infrastructure-driven. Drainage blockage, inadequate hydraulic capacity, and weak maintenance systems emerged as dominant vulnerability drivers across sampled neighbourhoods. These findings align with recent resilience scholarship emphasising the central role of infrastructure systems in shaping urban adaptive capacity (Meerow *et al.*, 2016).

The dominance of drainage condition within both weighted and inferential analyses suggests that urban flooding within rapidly urbanising Nigerian cities is often less a consequence of extreme hydrological conditions and more a reflection of infrastructure governance failure. Weak enforcement of development control regulations, encroachment along drainage corridors, indiscriminate waste disposal, and poor maintenance culture collectively intensify vulnerability.

The findings further reveal important socio-economic dimensions of vulnerability. Although SESI contributed less strongly to overall vulnerability relative to drainage condition, low-income households experienced disproportionately higher impacts because of limited coping capacity, weak preparedness systems, and poor housing quality.

Importantly, the study demonstrates the effectiveness of field-based composite vulnerability modelling within data-scarce planning environments. Unlike highly technical GIS-driven approaches, the UFVI framework provides a practical and operationally feasible tool for local planning institutions.

5. Conclusion and Recommendations

5.1 Conclusion

This study developed and validated a Composite Urban Flood Vulnerability Index integrating drainage infrastructure condition, household flood exposure, and socio-economic sensitivity

within Uyo Metropolis. Findings reveal that urban flood vulnerability is primarily infrastructure-driven, with deteriorating drainage systems constituting the dominant driver of flood risk. While socio-economic factors amplify household susceptibility, the persistence and severity of flooding are fundamentally linked to drainage inadequacy, weak maintenance systems, and uncontrolled urban development. The study further demonstrates that field-based composite vulnerability modelling provides a practical, scalable, and policy-relevant alternative for flood assessment in data-constrained urban environments. The UFVI framework therefore offers a robust decision-support tool capable of guiding infrastructure prioritisation, resilience planning, and proactive urban flood management.

5.2 Recommendations

Urban flood management within Uyo Metropolis requires an immediate transition toward infrastructure-led and data-driven planning interventions. Priority should be given to rehabilitation, expansion, and routine maintenance of drainage systems, particularly within highly vulnerable neighbourhoods such as Urua Ekpa/Ikpa Road, Ekpri Nsukkara, and Nkemba/Abak Road. The Akwa Ibom State Ministry of Environment, Uyo Capital City Development Authority, and local planning agencies should institutionalise periodic drainage inspection and maintenance programmes supported by dedicated infrastructure budgets.

Development control enforcement along drainage corridors should be strengthened to prevent encroachment and obstruction of stormwater pathways. Community-based waste management initiatives and environmental awareness campaigns should complement infrastructural interventions to reduce drainage blockage.

Figure 7 presents the proposed urban flood governance framework and strategic intervention priority structure for sustainable flood risk reduction in Uyo Metropolis. The framework integrates governance coordination mechanisms with prioritised flood management interventions aimed at improving urban resilience and infrastructure sustainability.

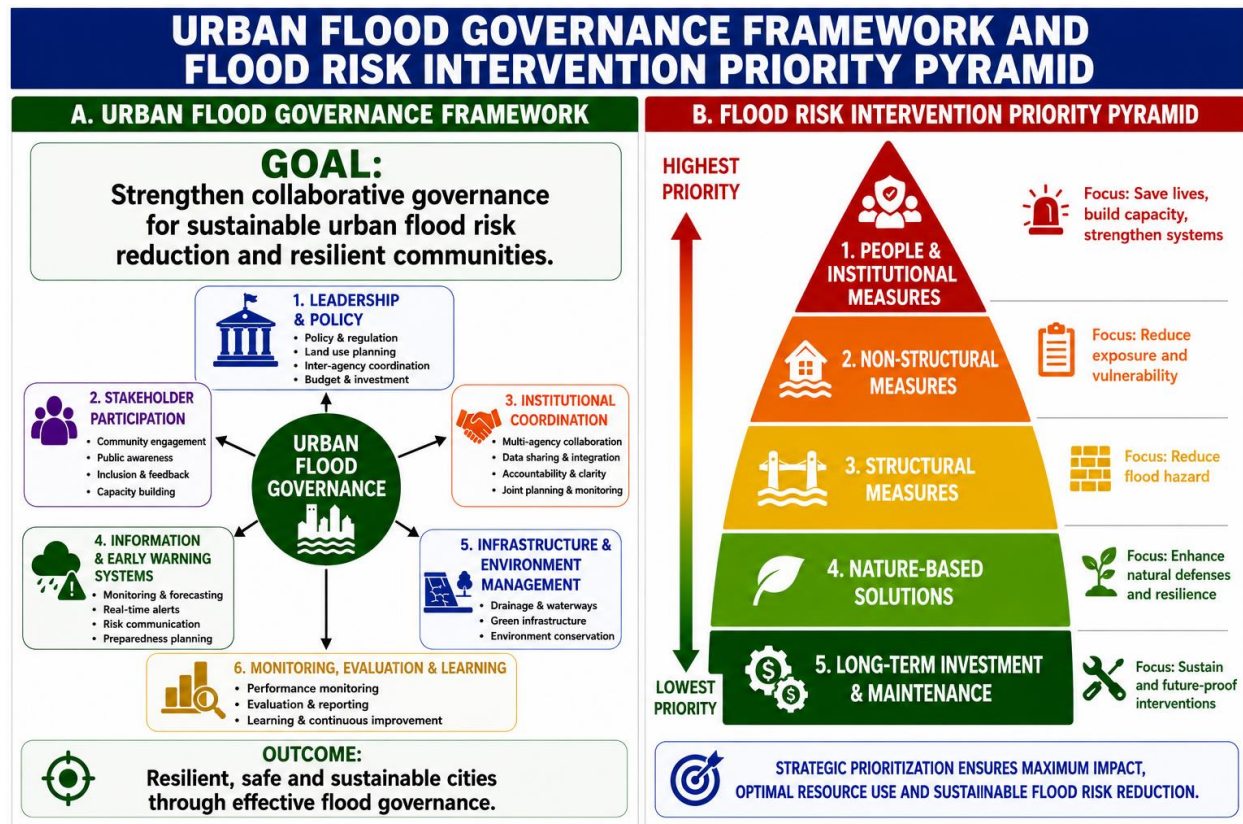


Figure 7: Urban Flood Governance Framework and Flood Risk Intervention Priority Pyramid

The figure highlights the importance of coordinated governance, institutional collaboration, infrastructure management, and community participation in effective urban flood mitigation. The intervention priority pyramid further demonstrates that sustainable flood management requires a combination of structural measures, non-structural planning approaches, ecosystem-based solutions, and long-term infrastructure investment. Together, the framework provides a practical pathway for strengthening urban flood resilience and improving adaptive planning capacity within rapidly urbanising environments.

The UFVI framework should be integrated into municipal planning and budgeting processes as a decision-support tool for vulnerability ranking and infrastructure prioritisation. Long-term resilience strategies should further incorporate socio-economic support mechanisms, household preparedness programmes, and climate adaptation planning.

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REVIEW OF INTERNATIONAL LEGISLATION AND POLICIES ON HOME BASED
ENTERPRISE: PLANNERS' PERSPECTIVE ON NIGERIAN CONTEXT

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Abstract

Home-based enterprises (HBEs) have emerged as a significant component of the informal economy, particularly in rapidly urbanizing societies like Nigeria. This study explores international legislative and policy frameworks regulating HBEs, with the goal of drawing insights applicable to Nigeria's urban planning and economic development. Through a qualitative analysis of global best practices including instruments such as the ILO Convention No. 177, Thailand's Homeworkers Protection Act, and regional declarations like the Kathmandu Declaration this paper highlights how HBEs have been integrated into planning, zoning, and labor systems in various countries. Findings reveal a stark contrast between the formal inclusion of HBEs in the Global North and their marginalization in the Global South, especially Nigeria, where rigid planning regimes and outdated zoning laws inhibit their potential. The research underscores the need for a national HBE policy framework in Nigeria, emphasizing inclusive zoning reforms, legal recognition, and participatory governance. By drawing lessons from international models, this study advocates for the reimagination of planning paradigms to formally integrate HBEs as legitimate urban actors, thereby enhancing employment, spatial equity, and sustainable urban development.

Keywords: *Home-Based Enterprises, Urban Planning, Informal Economy, International Policy, Legislation*

Introduction

Nigeria, similar to most developing countries, has experienced urbanisation that has jump-started the spread of informal economic practices, which have taken the form of home-based entrepreneurship (HBEs). The factors that promote this development are population growth, rural-urban migration, and the economic impact of structural adjustment programmes (Obilor et al., 2024; Umar, 2023). Nigerian informal sector is a wide range of unchecked, often neglected

economic activities, and it has been growing significantly in connection to the high unemployment rates and poor opportunities in the formal economy (Enyoghasim et al., 2023; Onyebueke and Geyer, 2012). The rise of HBEs is an example of adaptation techniques used by the individuals in search of economic survival in the times of both the public sector cutbacks and city living.

HBEs have not just diversified livelihood strategies, but they are also significant employers and contributors to local economies in urban areas (Najm & Al-Karkhi, 2025).

These enterprises although informal and running throughout the urban landscapes have little implications to urban planning, yet they are rather unstudied and lack regulations. Even as HBEs have been seen to play significant roles in the economy of countries across the borders, they are still regarded as peripheral to the formal planning systems in Nigeria. The need of conducting this research is based on the disconnection - the acknowledgment of the economic and social benefits caused by HBEs, presented in opposition to their invisibility in the context of the planning and policies (Ezeadichie, 2012; Najm and Al-Karkhi, 2025).

Regardless of the spread of HBEs and its economic significance in Nigeria, there remains an urgent research gap on the issue of HBEs in urban planning (Ezadaichie and Opedu, 2023; Ayo-Odifiri et al., 2022). As a result, profitability of these enterprises will be legal grey zone, which will make them susceptible to evictions, harassment, and future punishments because of the lack of regulation or existing regulation (Onyebueke and Geyer, 2012; Enyoghasim et al., 2023). The lack of harmonized national or local policies on the spatial and environmental aspects of HBEs limits their possibilities to be developed in an organized way. Moreover, there is the issue of developing international models of policy involvement in the informal sector, which have not been properly adjusted to the Nigerian environment, which led to the need to research successful experiences of other countries and their presence in the country.

The objectives of the proposed study will be as follows: (i) the policies and legislation existing globally in relation to home-based businesses; (ii) how a legislated approach to HBEs may be utilized positively in urban planning in Nigeria; and (iii) policy suggestions based on international experience of how HBEs may be absorbed into the town planning framework of Nigeria.

This overall research objective is to explore the international laws and policies governing HBEs with the view of presenting a strategic policy framework that suits the urban planning requirements of Nigeria. Particularly, it will seek to pinpoint applicable global policy frameworks, outline the planning loopholes within the Nigerian scenario, as well as, provide workable recommendations that can be scaled down to suit the local context to enable and govern the HBEs. The area of the proposed study is restricted to the analysis of international law and policy frameworks related to the HBEs on the informal sector, and the scope with which they can be used to inform the Nigerian planning and policy formulation in urban areas. It is important because it tackles a historical blind spot in the development literature and practice namely the lack of an official consultation with

HBEs when it comes to urban planning endeavours in Nigeria. Through insights gathered by relying on practices in other regions of the world, such a study aims at giving actionable ideas to planners, policymakers, and other stakeholders in the urban development that can bring about positive change in urban economies and social welfare, making HBEs valid economic units (Najm and Al-Karkhi, 2025; Ezeadichie, 2012).

Literature Review

Home-based enterprises (HBEs) have recently grabbed the interest of scholars and policy makers as strong additions to informal economy due to their resilience in a wide variety of economic environments around the world. HBEs can be broadly understood as the business that are operated on or near residential homes, although this activity includes a variety of activities, including craft and garment sewing, food production, digital platforms, and consultation (Ezeadichie, 2023; Thulare et al., 2021). Although the historical context of HBEs is pre-industrial home production, modern HBEs have become part of the modern global value chains but at times operate as subcontracted nodes of large global supply networks (Ezeadichie et al., 2018; Al-Karkhi and Najm, 2025). This development highlights the idea that HBEs are not part of the past, being the main participants in the contemporary economy, and digital infrastructure is in the process of destroying the boundaries between residential and professional spheres (Vorley and Rodgers, 2014). Empirical investigation in the Global North reveals that HBEs grow in the suburban and semi-urban environments, where affordability, residential area, and distance to consumers all contribute to feasibility of business (Orkpeh and Adedire, 2024; Zenkteler et al., 2022). Further studies also confirm a correlation between the growing ageing, flexible work-life programs, and the revitalisation of home-based work (Vorley and Rodgers, 2014; Zenkteler et al., 2022). Inclusive zoning reforms and live-work-space have become a policy tool to accommodate this population group as they perform both residential and economic roles. On the contrary, the Global South is more of a survivalist context, with HBEs regularly being the main sources of income in the absence of formal work avenues. Case studies of other settings like Kampoeng Pandean, Indonesia, demonstrate that HBEs are critical to economic sustainability and community development (Banks et al., 2019; Thulare et al., 2021). In spite of such contributions, HBEs often do not have essential technical infrastructure and legal protections, making them more vulnerable (Ezeadichie et al., 2018). Still, they can be applied to a high degree affecting poverty alleviation, especially to women and households having low incomes (Al-Karkhi and Najm, 2025; Banks et al., 2019; Hadjri et al., 2024).

Increased urbanisation has boosted the growth of informal economies around the world. The formal sector of the building sector, which is strongly represented in developing economies such as those in Nigeria, has not been able to accommodate the number of people that migrate into the urban areas, the changes in population structure, and economic restructuring (Tacoli et al., 2015; Heintz, 2012). This job gap is filled by the informal sector, consisting of unregistered and unregulated economic activities, the HBEs form an actively expressive subset of the informal sector (ILO, 2002; Al-Karkhi and Najm, 2025). Operators are usually family, self-employed or

casually employed workers and are motivated by need and entrepreneurial ambition because of fragile access to formal credit and regulatory insurance and social safeguards (ILO, 2002; Heintz, 2012). Modernization efforts have not eradicated urban informality, which has instead become structural as opposed to a transition phase in development (Banks et al., 2019; Orkpeh and Adedire, 2024). Since the challenge of increasing urban population is faced by the cities, the remote reworking of residential areas into workplaces is a key livelihood practice, especially in the case of low-income neighbourhoods (Ezeadichie, 2023; Reuschke, and Mason, 2015). Such intersection of residential and commercial utilization poses some unconventional regulatory and infrastructure difficulties particularly in regard to zoning, sanitation, and city planning. The presence of HBEs in the urban landscape world over has triggered re-evaluation of the planning norms globally. Traditional planning systems based on strict zoning and formal licensing often omit HBEs or term them as nuisances. But modern practice is moving towards more energized permissive frameworks that also respect the legitimacy and potential of HBEs (Ezeadichie and Opedu, 2023; Zenkteler et al., 2022). Mixed use zoning, decentralisation, and participatory planning that have been tried out by cities have led to economic inclusion and city liveliness to be reported (Orkpeh & Adedire, 2024). The situation is particularly risky in Nigeria. Housing or residential land is being regularly reclaimed by commercial purposes like tailoring, petty trade, and maintenance and repair. HBEs are rarely integrated into formal city planners, despite their pervasiveness partly because master plans are nonexistent or poorly implemented in most of the Nigerian cities (Ezeadichie et al., 2023; Adeokun and Ibem, 2016).

This unregulated land use transformation disputes the ideals of urban planning as well as causes infrastructural insufficiency, spatial chaos, and conflicts of official authorities and non-official actors. However, planning failures also lie in the continuity of informalisation. The acute shortage of housing in Africa, high unemployment rates, weak municipal governance structures have provided good grounds where HBEs have triumphed though under legal and geographical uncertainty. The tradition of town planners embraces exclusionary practices; they do not consider involving HBEs to local development (Ezeadichie, 2012; Enyoghasim et al., 2023; Ezeadichie et al., 2022). Therefore, it is urgent that new planning paradigms based on local realities were developed.

Other frameworks and movements around the world have aimed at formalizing and empowering home based workers. In 1996, the change came with the ratification of the Convention No. 177 (C177) by the International Labour Organization acknowledging the rights of the homeworkers to fair wages, safe working conditions, as well as, the rights of all other workers. Even though it is currently ratified in ten countries only, it serves as a model of the inclusion of labor (HomeNet International, 2024; WIEGO, 2023). The achievement of such conventions to motivate national laws through working to ensure transparency of contracts, safety, and gender equity has been evidenced by Thailand Homeworkers Protection Act passed in 2011. Other statements including Kathmandu Declaration (2000) and Delhi Declaration (2015) have also served to stimulate debate on HBEs in the Global South. These documents encourage governments to acknowledge the role

of HBEs as legitimate economic actors and enhance their access to credit and services and national development plans. Examples of Pakistan and Sri Lanka demonstrate that specific policy frameworks can legitimize HBEs as sources of poverty alleviation and pro-poor economic development (Ezeadichie et al., 2018; Al-Karkhi and Najm, 2025).

HBEs in Nigeria have been very restricted and do not have any form of legislation or policy infrastructure to assist them in getting into the formal urban systems (Adeokun and Ibem, 2016; Ezeadichie and Opedu, 2023). HBEs are marginalised by restrictive zoning act, absence of spatial planning enforcement, and inconsistency in response by the municipalities notwithstanding the fact that they are widespread across all geopolitical zones. The relevance of the informal sector has been further enhanced by the national economic situation characterized by unemployment, shortage of houses, and an overstretched formal sector. Research notes that Nigerian HBEs have a vital contribution to household income, particularly among women and the unemployed, and often recycle residential areas with little customization (Ezeadichie, 2023; Morakinyo et al., 2023; Nwaka & Ike, 2024). Nevertheless, there are many difficulties among the operators: the inability to attract funds, inadequate power supply, the lack of properly developed infrastructure, the indifference of the bureaucracy (Enyoghasim et al., 2023; Fapohunda, 2012). Moreover, the rigidity of Nigerian planning doctrine has remained mostly colonial, as they have not adapted to the dynamics of the changing realities of the urban environment (Orkpeh & Adedire, 2024). There has been haphazard policy intervention. Despite agencies like the Central Bank of Nigeria and NISER acknowledging the role of the informal sector, very little has been done in that regard, regarding spatial or legal planning. The enabling regulation provides HBEs with a legal face of legal ambiguity, legal acceptance where it suits to the client, legal oppression in cases of conflict. The mismatch of international policy models with the local realities in Nigeria are vivid. Using models like ILO C177 and acting local in implementing their canons might be the basis of inclusion in the cityscape reform. Accepting HBEs as indispensable agents instead of regulatory liabilities can be a way to socially set up, economically dynamic, and spatially receptive cities.

Methodology

This study adopted a qualitative research design, leveraging secondary data to explore the regulatory environment and planning implications surrounding home-based enterprises (HBEs). Since HBEs are heterogeneous and informal, especially when dealing with Nigeria, quantitative precision application was limiting. The paper, therefore, predetermined the analytical approach of interpretation, uniting diverse cases and sources of data in explaining the nuances of policy approaches and regulatory barriers (Creswell and Poth 2018).

The data used in the research were sourced primarily from existing literature, public policy documents, government and non-governmental reports, and previous academic studies. The key sources included the International Labour Organization (2002), HomeNet (HomeNet International, 2024) and research reports by Chen (2004), Kellett and Tipple (2000), Onyebueke (2001), and

Ezeadichie and Opedu (2023). Moreover, reports issued by planning bodies, legislations, and even comparative case studies of other countries which have implemented the HBE-friendly policies formed the crucial part of the data corpus. These sources provided us with knowledge on the structural environments in which HBEs exist and the legislative processes through which they can either be placed in formal planning regimes or not.

Limitations of the study stemmed largely from the scarcity of consolidated, empirical data on HBEs within Nigeria and inconsistencies in the documentation of sub-national urban policies. Additionally, whereas international policy frameworks were incorporated into the study, their irrelevance to the Nigerian context can be limited because of variations in governance networks and socio-economic conditions. Still, the research provides a strong foundation to the policymaking change and contributes to deeper knowledge base desperately needed in the effort to achieve more accommodative urban planning activities (Morakinyo et al. 2023; Tipple 2005).

Findings and Discussion

Over the last few years, there has been an establishment of a row of legislative and institutional frameworks to enable house-based entrepreneurship (HBEs), specifically those involved in the sector of informality. Such frameworks often focus on labor protection, social security and economic empowerment, although most of them are not successful in covering the spatial and environmental integration of the HBEs with the overall urban planning framework. Significant documents are the Convention No. 177 of the International Labour Organization (ILO C177), Kathmandu Declaration (2000), and national policy documents in Ghana, Pakistan, or the United States that all present the argument that home-based workers should be formally recognized (ILO, 1996; HomeNet International, 2024; Darkwah and Tsikata, 2021). Additionally, the Maricopa County Ordinance in Arizona, USA, is a more developed solution that includes planning and zoning and thus has made some classes of HBEs authorized to work under well-specified urban circumstances (WIEGO, 2023).

Selected Examples of International HBE Policies

Country / Region	Key Legislation / Policy	Focus Areas	Gaps Noted
Ghana	Labour Act (Act 651), Constitution of 1992	Equal work rights, pensions, social protection	Minimal distinction between formal and informal
Pakistan	National Policy for Home-Based Workers	Rights, market access, training, capacity development	Weak enforcement and limited urban planning linkage
South Asia (Regional)	Kathmandu Declaration (2000)	Protection, recognition, policy advocacy	Non-binding, limited implementation
USA (Maricopa County)	Model Home-Based Business Ordinance	Zoning compliance, environmental compatibility	Localized policy, not widely replicated
Global (ILO C177)	Homework Convention (1996)	Legal protection, fair wages, social rights	Low ratification rate, limited enforcement mechanisms

These examples reflect varied efforts to formalize HBEs, yet only a few incorporate spatial planning mechanisms that could guide zoning, infrastructure support, or housing regulations.

Despite the evident expansion of HBEs across Nigerian cities, there is no national legislation specifically addressing their regulation or integration into the urban economy. The unrecognized status predisposes the operators to eviction, insecurity, and shortage of communal infrastructure (Ezeadichie and Opedu, 2023; Morakinyo et al., 2023). The current urban planning and zoning regulations in Nigeria are mostly based on colonial regulations that specify a precise division between commercial and residential land activities (Kellet & Tipple, 2000; Al-Karkhi and Najm, 2025). These inflexible models do not explain what such an HBEs as what is known as the nuanced spatial hybridity. At the same time, the national housing and employment policies overlook the economic potential of home-based work and do not suit the changing live-work processes in the urban settlements (Ezeadichie, 2023; Adeokun and Ibem, 2016).

Perceptions of Urban Planners

The planners of Nigeria urban areas recognize the importance of HBEs in alleviating unemployment especially in informal settlements. Based on the synthesis of the literature and empirical interviews, the planners suggest beneficial policies incorporating HBEs into local development models without intentionally neglecting the environmental standards (Onibokun, 1995; Onyebueke, 2001; Ezeadichie and Opedu, 2023). Whereas HBEs are not always benign, one of the aspects that are being considered a socio-economic need among the planners is the home-based work, particularly to women and the poor living households (Moser, 1995). Their thought is

based on a pragmatic planning strategy that would facilitate benign HBEs and control disruptive ones by supporting and participating in zoning of communities, and not by enforcing uniform bans (Simon, 1992; Al-Karkhi and Najm, 2025).

Planning Conflicts and Integration Needs

The main cause of conflicts is the occupation of residential areas by HBEs without authorization of financial planning. The multi-in purpose or, as it has also been referred to as, the multi-purpose of space brings tension between man and the authorities (UNCHS/ILO, 1995). The informal structures that are constructed to support HBEs like outdoor kiosks and workshops (also known as kibandas) are usually not regulated which exposes them to legal threat and affects the aesthetics or infrastructure of the environment. However, the adaptations are a logical economic reaction to the restricted access to formal jobs and housing. Planners point out the fact that zoning codes should be revised to allow conditional mixed-use in low-income neighborhoods, especially where HBEs form the core of community-based economies (Rogerson, 1996; Ezeadichie and Opedu, 2023). Other suggestions are focused on the need to include planning in its true sense where HBEs are not thought of as a vice but a source in need of assimilation by allowing an urban structure and design criteria (Simon, 1992; Moser, 1995).

Comparative Analysis: Global South vs. Global North

There is a marked difference in the way HBEs are treated in the Global South and the Global North. The HBEs in the Global North are becoming a part of the flexible economy, which in many cases is conditional on digital tools and official policies (Reuschke & Mason, 2015). They are supported by zoning reforms, live-work housing models, and business incubation schemes which operate within obvious legal frameworks. Conversely, in the Global South and Nigeria is no exception, often HBEs are informal and marginalized despite their economic irreplaceability. There are inflexible regulatory systems, inefficient urban planning tools and inadequate informal settlements (Onyebueke, 2001; Al-Karkhi and Najm, 2025). As a result, there are ongoing spatial conflicts, poor investment and poor infrastructure outcomes of HBE operators.

Dimension	Global North	Global South
Policy Integration	Formalized in planning codes	Largely excluded from urban policies
Zoning Flexibility	Mixed-use zoning permits HBEs	Rigid zoning restricts live-work options
Institutional Support	SME programs, training, digital services	Minimal access to state programs
Social Protection	Enforceable labor rights, benefits	Fragmented or non-existent coverage
Public Perception	Viewed as entrepreneurial innovation	Often seen as informal nuisance

The formalization of HBEs is less about mirroring international models and more about adapting principles to Nigeria's context: inclusive zoning, pragmatic enforcement, and recognition of spatial informality as a legitimate urban form.

Conclusion

The empirical evidence reveals that HBEs are important livelihood strategies among low-income households, women, and marginalized groups, thus playing significant roles in improving the levels of productivity in the economy, employment in the locality, and community sustainability. However, even after being regarded as acceptable and widespread in Nigeria, HBEs are still not adequately represented in the formal planning and legal system (Onibokun, 1995; Onyebueke, 2001). The international tools like ILO convention 177 and regional declarations (e.g., Kathmandu declaration) give strong guidelines under which states have strived to justify and give support to HBEs through specific legislations, by using space accommodation, and through social protection (ILO, 1996; UNIFEM/WIEGO, 2000; UN-Habitat, 2020).

The justification of introducing legislation in relation to HBEs in Nigeria is pegged on the need to move them out of their informal peripheral position to be mainstreamed in agenda as part of urban planning. Formal status would provide a legal structure on land-use management, ensure better working environments, and the HBEs would be incorporated in the mainstream economic development policies. Devoid of this recognition, HBEs are prone to eviction, uneven regulation, and structural exclusion (Tipple et al., 2002; Al-Karkhi and Najm, 2025). HBEs legislation also contributes to the achievement of the goal proposed by the United Nations Sustainable Development Goals, which is to make cities inclusive, safe, and resilient (UN-Habitat, 2020).

The role of urban planners is central to it, being experts as well as policy-makers. Their expert knowledge of land use, environmental management, and spatial equity place them in a vanguard position with regard to conception of responsive planning structures. Importantly, the redefinition of planning paradigms can be facilitated by planners through introduction of mixed current development, flexible zoning, and incremental upscale infrastructure improvements that would support operations of HBE within residential areas (Simon, 1992; Moser, 1995; Ezeadichie and Opedu, 2023). They will be able to promote the spirit of community ownership and coordinate spatial planning with current socioeconomic conditions by use of participatory planning and local decision-making territories.

Following the empirical results, the following strategic proposals are established to be used as the basis of policy and planning reforms in Nigeria:

- **Establish a National HBE Policy Framework:** Nigeria must create a framework of HBE policy based on legal acceptance and spatial amalgamation. Based on the ethos of ILO C177, the policy will need to be able to protect the rights of home-based workers, an act that, at the same time, should undertake urban infrastructure and land-tenure issues. Such

framework must justify HBEs as part and parcel of urban economy instead of classifying them as planning offenses.

- **Reform Urban Planning Instruments:** Master plans, zoning ordinances, and building regulations: These plans should be updated to include new mixed-use categories of zoning that allow certain forms of HBEs to be lawfully operated in residential areas. The reform must also ensure that building designs are such that they are adapted to live-work setups, especially in the low-income neighbourhoods.
- **Promote Localized Planning and Governance:** Decentralised Planning Processes based on local communities decision-making can be more responsive to local needs. Planning authorities are expected to work with neighbourhood associations to determine the appropriateness of certain HBEs, safety standards, and conflict resolution. This strategy is consistent with the principle of subsidiarity, and it enhances regulatory legitimacy.
- **Adopt Global Best Practices with Local Adaptation:** Nigeria can also take an advantage of adopting international models, which include South Asian models of local training programs, Thailand models of Homeworkers Protection and Arizona of conditional-use models to their local urban and institutional contexts. These models prove that it is possible to regulate HBEs formally without affecting their operating flexibility and economic sustainability.
- **Strengthen Social and Infrastructure Support:** HBEs also require similar support with infrastructure investments such affordable transport, water provisions, electricity, and access to broadband among others, and occupational health and safety education. The urban improvement plans must be capable of foreseeing the functional spatial requirements of HBEs and establishing an equal service provisions to informal settlements where HBEs are most prevalent.

Finally, institutionalizing HBEs into the formal planning system does not only consider their socio-economic values but also balances the urban path of Nigeria with the values of inclusive and sustainable growth. By using laws, adaptive planning, and by integrating global and local knowledge, HBEs will be able to shift their positions as marginalised player on the outskirts of city to recognised drivers of urban resilience and opportunity.

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TOWNSCAPE ASSESSMENT OF ABUJA CITY MASTER PLAN

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The original urban design concept for the Abuja city was initially conceptualized by International Planning Associates (IPA) in 1979 as a pilot concept that would create a standardized series of urban design ideas across the country's capital city. These original concepts were intended to guide indigenous firms in formulating ecologically and environmentally conscious urban designs for the remaining districts. However, current status reveals a city that is degenerating aesthetically beyond the original concepts owing to rapid population growth, master plan contraventions and land use regulation defaults, thereby necessitating the wave of current reviews and updates by development authorities. This study aims to identify the implications of factors like land-use alterations, physical development contraventions, absence of green spaces, poor urban landscaping and proliferation of unregulated activities on the environmental and urban aesthetics of major districts in the city. It adopted a study methodology that is based on Townscape Assessment (utilizing a five-point scale) which includes a series of indicators/features like environmental conditions, land-use disposition, green spaces, water elements and urban furniture. These features were evaluated using field surveys and visual assessment analysis of significant districts covered in the Phase-1 of the Abuja master-plan developed by International Planning Associates. The result from the study highlights the significance of integrating urban aesthetics into urban planning processes in order to ensure the sustainability of attractive urban spaces. It further recommends the adoption of this assessment process as a component for monitoring the performance of urban districts with major focus on improving the quality of urban environments.

Keywords: cityscape theory, environmental aesthetics, townscape, urban aesthetics, urban design,

1. Introduction

The structure of urban streets is considered an integral element to the attractiveness of cities. Urban streets are the primary spaces for interactions between residents and visitors within the urban environment. This therefore makes the urban street ambience a significant indicator of the total aesthetic quality of a city. The character of cityscapes have been known to deeply influence perceptions of urban attractiveness and thus seen as significant to urban identity. Urban attractiveness is an integral component of sustainable urban planning and its many benefits includes enhancing urban health through high quality green spaces and iconic architectural designs, which in turn contributes to city branding and enrichment of resident's mental health (Chen *et al.*, 2024). Studies suggest that visual attractiveness, especially with regards to the urban visual appeal, plays a key role in promoting economic development through the attraction of tourists and investors as well as enhancing overall quality of life for residents and visitors. With the presence of scenic streets and iconic landmarks, visitors are drawn in swarms to these environments which further contribute significantly to the development of hospitality industries, real estate and cultural attractions (Zhou, *et. al*,

2025). Findings indicate that visually compelling urban environments not only boosts the image of a city on a global scale, but also strengthens its economic competitiveness (Zawadzka, 2021). Planners and designers of cities are often tasked with the role of balancing between urban aesthetics and the critical roles of infrastructure development, coupled with the provision of satisfactory quality of life for its inhabitants. This task also stretches into the harmonization of land uses, preservation of open spaces, environmental protection, maintenance of ecological aesthetics and promotion of social diversity (Davison, 2017). Urban planning goals are often attained through the adoption of measures like land use acts, zoning laws, building codes and guidelines. These measures are fundamentally established to manage urban development as well as control disorderly growth and ultimately configure the visual and functional character of cities, for the purposes of protecting public welfare and orderly/attractive urban environments (Okimiji, *et. al*, 2025).

Historically, urban planning restrictions were established to regulate building development relative to urban aesthetics which may include restrictions that impact on alteration of land-uses as well as alteration of building and city plans that would require consultation with local authorities (Bashua, *et. al*, 2025). However, this is often not the case in emerging cities of third world countries like Nigeria, where issues of physical development contraventions are rife (Ibrahim, 2020). With its rapidly growing population, rundown infrastructure, poor waste management and weak regulatory structures, the aesthetic values of Nigerian cities are declining (Abubakar & Doan, 2017). Factors mostly regarded as responsible for this decline includes uncontrolled commercialization, land-use encroachment into public spaces, and absence of green spaces, poor urban landscaping policies and the proliferation of unregulated activities like street trading, which contribute to the loss of the visual appeal of these cities (Okonkwo *et. al*. 2025). Studies further show that informal settlements and lack of adequate enforcement of urban zoning laws contributes to this decline in urban beautification (Dhanaraj & Angadi, 2022), whereas proper planning and adherence to regulations ensures a successful urban development, while maintaining safety, usability, and urban aesthetic standards (Arimah , 2000). Instances of cities like Kigali in Africa and Singapore in Asia, demonstrates that the adoption of global best practices improve the value of urban aesthetics when governments make sustainable development policies a priority in urban development (UN-Habitat, 2020). Based on these tenets, this paper aims at studying the effects of these factors responsible for the decline of urban aesthetic values in Abuja City. The major objectives of the study are as follows:

- To identify the districts that are mostly impacted by physical development contraventions in Abuja
- To examine the key factors influencing urban aesthetics in the city
- To analyze the effects of informal land-use and alterations on the urban aesthetic values within selected districts in Abuja using Townscape

1.1 *Review of the Townscape Theory*

Developed by Gordon Cullen, Townscape Theory is an urban design philosophy that emphasizes the visual and emotional experience of cities (Gordon, 1961). The townscape concept can be regarded as a basis for architects and planners to channel the emotional focus of observers to the appearance of the city (Damayanti, *et. al*, 2020). The concept comprehends that the physical form of urban spaces is influenced and determined by the shape and mass of the buildings and ambience of its environment. The concept creates a nexus which is only perceived psychologically and physically by the observer relative to the shape and arrangement of urban spaces (Reeve, *et. al*, 2007). The theory emphasizes the establishment of a sense of place through

organized placement of spaces, buildings and streets, by adopting elements like focal points, the serial vision (which reveals views in sequentially pattern as seen in Figure 1) and comprehension of how people perceive places in order to evoke emotion that transform cities into more meaningful and engaging environments (Buchanan, 1994), (Nute, 2021).

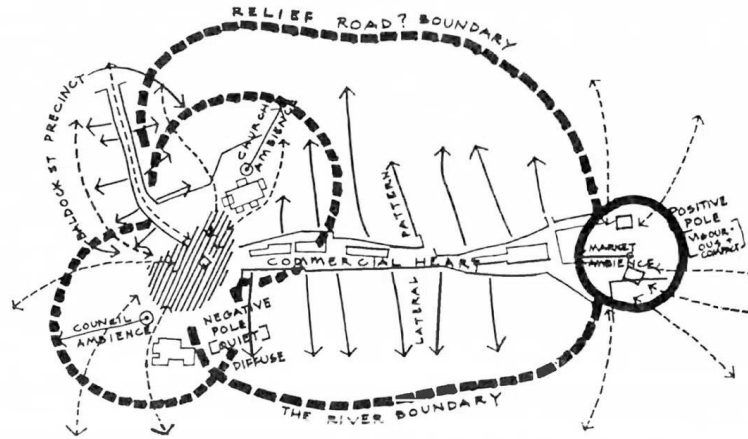


Figure 1. Diagrammatic analysis of space for Vivat Ware (a sketch by Gordon Cullen), Image source: *Urban Design Quarterly* (Galloway, 1986)

In the book *Concise Townscape*, Gordon Cullen emphasized the key contexts for experiencing urban centers as: Optics, Place, and Content (Damayanti, et. al, 2020). While 'Optics' is associated with human visual ability to enjoy scenic views, beautiful sequences and movements, they can also feel these experiences while walking through spaces in the streets, 'Place' relates to the quality of urban spaces and feelings of the environment. 'Content' on the other hand relates to the details of urban space with regards to elements like color, texture, style, scale and distinctiveness.

Studies by Anthony Raynsford, in the text "Urban contrast and Neo-Toryism", which centered on the social and political symbolism of Townscape campaign by Architectural Review, traced the roots and growth of Townscape ideologies chronologically as a political and social project that is linked to the history of British planning theories (Raynsford, 2015). The study contended that Townscape theorized an anti-collectivist society model that is bound together through composite ecology of personalized differences that are developed according to individual distinctive cultural character or bias rather than through a consensus of viewpoints. It posited that the Townscape ideologies naturalized these differences and biases through a tripartite model that links social classes with a symbolic construct of society expressed as nature. Acknowledging the significance of these political and social symbolisms permits the redefinition of Townscape's restructuring of social complexities (Andrew, 2004). The theoretical constructs drawn from Townscape ideology, forms a collection of approaches applicable in urban design studies that originates from the human visual perception to solving urban spatial problems. In urban planning process, townscape character assessments leads to the understanding of a city's value, by providing ideal indicators for evaluation and managing development. These indicators range from architectural styles, street features, landmarks, green spaces and environmental appeal which contribute to people's perception of the city (Ricardo da Costa, et. al, 2025). Further studies identified such indicators for scoring townscape quality in Townscape Assessment (TA) as environmental awareness, street furniture, green spaces (vegetation), building character, building maintenance, selected features like water bodies and water spaces, play grounds,

public eating facilities, public toilets, sky lines, street quality, boundary maintenance, functional diversity, pedestrian environment, community compliances etc. (Reeve, *et. al*, 2007).

2. Description of Study Area

Nigeria is composed of 36 states and one capital territory. Its first capital city was Lagos (a megacity) which is the most populous city in Nigeria and the largest urban area in Africa (World Urbanization Prospect, 2025). The administrative status of Lagos was replaced with Abuja on the 12th of December 1991 owing to the city's overpopulation and weakened infrastructure (Wapwera, 2015). According to United Nation's urbanization data, Abuja city is regarded as one of the fastest growing cities in the world (World Urbanization Prospect, 2025). The city is strategically located at a geographical center within the region dubbed the Federal Capital Territory (FCT). While the city functions primarily as the seat of the Nigerian government, it also houses the country's key national institutions, buildings and landmarks which spread across the 50 districts within the FCT region. The FCT administration in 1976 established a federal capital development authority (FCDA) to oversee the general development of Abuja. The International Planning Associates (IPA), was commissioned in 1977 by the FCDA and went ahead to design the Abuja city master plan in 1979.

The city's master plan was designed to reflect the modern global trends in urban planning and development. The major considerations in the master plan as produced by IPA (1979) include:

- Land Use plan, which detailed the zoning groups into governmental areas, residential and commercial as seen in Table 1.
- Infrastructure plan, which developed guidelines for transportation networks, public services and utilities
- Environmental concerns, which focused on sustainable development, sanitation as well as designation of areas for parks and green spaces.

Table 1. Abuja Master plan Land use summary. Source: Jiriko (2015).

LAND USE ZONES	TOTAL AREA (Ha.)	PERCENTAGE AREA (%)
Residential	12,500	48.7
Commercial and Business District	561	2.2
Industrial/Public Service	891	3.5
Industrial/Research/Training	920	3.6
Transportation	1,700	6.6
National Government	500	2
Parks and open spaces	160	0.6

Sports and recreation	8,400	32.9
TOTAL	25,700	100

Since its establishment, Abuja city has experienced exponential growth in population and urban agglomeration. The city's master plan was originally projected to accommodate about 3.1 million on a land area of 8,000 km² (Iwalaiye, et. al, 2024), however recent data shows a rise to about 4.2 million in 2025 (Abuja's 2025 Population). The initial concept of the master plan considered that the city's growth will occur in stages, thus the planned area was set across four major phases for the purposes of organized development as seen in Figure 2 (AGIS, 2024). This study is focused on the Phase-1, comprising of ten districts which includes the Central Business District (CBD), Asokoro, Garki-1, Garki-2, Guzape, Maitama-1, Maitama-2, Wuse-1, Wuse-2 (A07) and Wuse-2 (A8). The major justification for selection of this area (for the urban aesthetics research) is due to the developed status of the Phase-1, which is almost fully developed compared to other phases in Abuja.

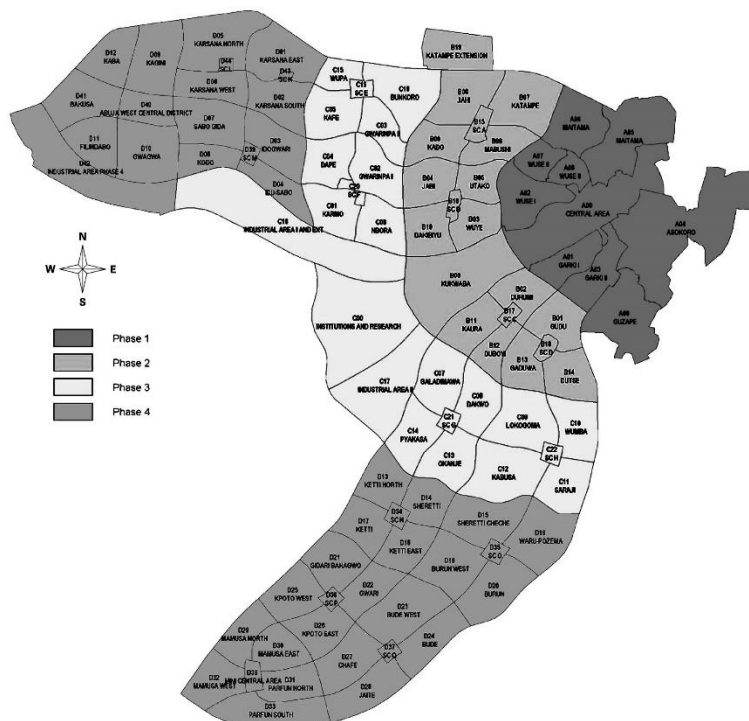


Figure 2. Abuja city (FCT area) Showing the four main phases of development
(Source: AGIS, 2024)

3. Research methodology

This study adopts the use of indicators that are derived from Townscape theories by combining such indicators for scoring Townscape quality in Townscape Assessment (TA) as environmental awareness, street furniture, green spaces (vegetation), selected features (water spaces, play grounds, public eating

facilities, public toilets), community compliances. For this study, a total of five distinctive indicators for scoring townscape quality was adopted. These selected indicators are described as follows:

Environmental conditions

The context of environmental awareness in cities is relevant in establishing a holistic consciousness of environmental conditions and its impacts due to human activities on the natural environment (Zhou, 2024). In this study, the value of environmental compliance is measured through the analysis of reports derived from interviews and interactions with the relevant departments/staff of the AEPB in the Abuja Municipal Area Council (AMAC) office.

Land use Disposition

While urban Land use refers to the general context of land management by way of zoning of different activities that involves the categorization of land functions into commercial, industrial, institutional, residential, recreational, transportation and agricultural (Brown, 2016), its broader definition also encompasses the deliberate reservation of undeveloped areas for purposes of conservation and ecological sustenance (FAOUN, 2017). For the purpose of this research work, Land use contraventions within the Phase-1 districts are recorded through surveys and interview of the Development Control department in the FCDA office. The level of contraventions in each district is studied and adopted for measuring the compliance values across the Phase-1 districts.

Green Spaces

Areas in urban environments (with vegetation) reserved for activities like recreation, beautification and landscaping form part of the most significant features for environmental sustainability in cities. In this study, the sustenance of green spaces within the Phase-1 districts in the Abuja master plan was measured using physical survey of individual districts and reports gotten from interviewing the staff of the Department of Parks and Gardens.

Water Elements

Water features in urban environments embodies nature and therefore adds to the ecological aesthetics dimension of the urban landscape. This study measured the presence and value of water elements in the Phase-1 districts using physical surveys and visual assessment in order to determine the impact of the water elements on the city's aesthetics value.

Urban Furniture

The presence of urban furniture serve practical functions like seating, lighting, waste management, and vehicular and pedestrians guidance, as well as enhancing the aesthetic value

of urban areas. This study measured the presence and value of urban furniture in the Phase-1 districts using physical surveys and visual assessment in order to determine the impact of urban furniture on the city's aesthetics value.

4. Data Collection and Analysis

4.1 Environmental Compliance

The Abuja Environmental Protection Board (AEPB) enforces the city's environmental laws, abatement of environmental nuisance, degradation as well as the impact of physical development on the city's ecosystem. The Data for this study was obtained from interviews with relevant staff of AEPB under the Abuja Municipal Area Council (AMAC) office. Three management-level respondents each from the departments of waste management, sanitation, enforcement and finance were interviewed and provided responses on the performance of the districts covered. The performance factors were derived from twelve parameters set for the tenement owners/occupiers within the ten districts, covering the following:

- Keeping of lawns, flowers and hedges (**P1**)
- Maintenance of drains running through tenement areas (**P2**)
- Controlling vegetation (trees and shrubs) within permitted (8 meters radius) tenement areas (**P3**)
- Regulation of illegal structures like batchers, kiosks and sheds within permitted (8 meters radius) tenement areas (**P4**)
- Regulation of waste disposal in approved AEPB waste disposal containers (**P5**)
- Regulation of noise pollutions (**P6**)
- Regulation of unsightly displays (**P7**)
- Regulation of farming and animal breeding (**P8**)
- Regulation of construction waste within construction sites (**P9**)
- Regulation of encroachment into river valleys (**P10**)
- Regulation of sewer lines (**P11**)
- Payment of waste management tenement rates (**P12**)

The performance of individual districts on the above enumerated factors is recorded using a five-point scale ranging from 1 to 5 (where the number '1' represents the lowest performance value and '5' represents the highest performance value). The summary of the Environmental compliance in the ten districts is presented in Table 2.

Table 2. Summary of Environmental compliance in the Phase-1 districts. Source: Author's fieldwork

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Total (Average)
D1	2.7	3.7	4	3.7	4.3	3.3	3.3	3.7	4	4	4	3.7	3.7
D2	2.7	4	3	2.3	3.3	2.7	3.7	3.3	3.7	3.7	3.7	3.3	3.3

D3	2.3	2.7	3	2.3	2.3	2	3	2.3	2.7	4	3.7	3	2.8
D4	2	2.3	2.3	2	2.3	2	2.3	2.3	2.7	4	3.3	2.7	2.5
D5	2	2	2.3	2	2.3	2	2.7	2.3	2.7	4	3.3	2.7	2.5
D6	3.7	4	4	3.7	4	4.3	3.7	4.3	4	4.3	5	4.3	4
D7	3	4	3.7	3.7	4.3	4.3	4	4	4	5	5	4.3	4
D8	2.3	2.3	3	2.7	2.3	2	2.3	2.3	2.7	3.7	3.3	3.7	2.7
D9	2.7	3	3	3	3	3.3	3.3	2.7	3	3.7	4	3.3	3.2
D10	3	3	3	3.3	3.3	4	4	3	3.7	4	4`	3.3	3.5

4.2 Land use Compliance

The Department of Development Control (DDC) and Abuja Geographic Information Systems (AGIS) within the Federal Capital Development Authority (FCDA) regulate compliance of land use activities in the FCT. The Data for this study was collected from interviews with relevant staff of the DDC and AGIS in the FCDA office. Three management-level respondents each from the AGIS, DDC, Monitoring and inspection departments were interviewed and provided responses on the performance of the districts covered. The performance factors were derived from five parameters set for the tenement owners/occupiers within the ten districts, covering the following:

- Regulation of conversion of approved land uses (**P1**)
- Regulation of conversions of flood plains and green areas (**P2**)
- Regulating development of slums and squalid settlements (**P3**)
- Regulation of Illegal Building conversion (**P4**)
- Regulation of construction guidelines (building heights, setbacks and designed function) (**P5**)

The performance of individual districts on the above enumerated aspects is recorded using a five-point scale ranging from 1 to 5 (where the number '1' represents the lowest performance value and '5' represents the highest performance value). The summary of the Land-use compliance in the ten districts is presented in Table 3.

Table 3. Summary of Land use compliance in the Phase-1 districts. (Source: Author's fieldwork)

	P1	P2	P3	P4	P5	Total (Average)
D1	4	2.7	3.3	3.7	4	3.5
D2	3.7	3.7	3.3	4	4	3.7
D3	3.3	3	3	2.7	3.3	3
D4	3.3	2.7	2.3	2.3	3.3	2.8

D5	3	2.7	2.3	2.3	2.3	2.5
D6	4	3.7	4	3.3	4	3.8
D7	4	3.7	4	3.3	4	3.8
D8	3.3	3	3.3	3	3.3	3.2
D9	3.7	3	4	3.3	3.7	3.5
D10	4	4	4	3.7	4.3	4

4.3 Green Spaces

Surveys identified that significant green spaces within the districts were either unkempt or outrightly abandoned. This study therefore evaluated the aesthetic attention employed in the maintenance of green space using a five-point rating in order to ascertain the green landscaping quality of each district. The summary of the green space utilization is presented in Table 4.

Table 4. Summary of Green space utilization in the Phase-1 districts of Abuja City (using a 5-point scale).

Source: Author's fieldwork

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Availability of designated Green Space for development	yes	yes	yes	yes	non	yes	yes	yes	yes	yes
Rate of Green area development	2	3	5	3	0	1	4	4	3	5

4.4 Water Elements

The original master plan of the Abuja FCT Phase-1 area recommended the use of water bodies to serve the function of dams/irrigation, beautification and recreational, however, only a handful of the districts have fully developed these water bodies which comprise of the following:

- i. Streams
- ii. Natural Lakes
- iii. Artificial Lakes (water parks)

Field Survey identified that the locations of these water bodies and the extents of their development/utilization within the districts. The availability of water elements and levels of utilization within each district is measured using a five-point scale, where the number '1' represents low utilization and '5' represents highest utilization. The summary of the water element utilization in the ten districts is presented in Table 5.

Table 5. Summary of Water element utilization, natural (N) and artificial (A) in the Phase-1 districts of Abuja City (using a 5-point scale). Source: Author's fieldwork

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Availability of Water bodies	yes	yes	non	non	non	yes	yes	yes	non	non
Category of Water bodies	N	A	0	0	0	0	N	N	0	0
Rate of development of Water elements	1	5	0	0	0	0	1	5	0	0

4.5 Urban Furniture

This study grouped the identified urban furniture elements into four major categories namely Street furniture (traffic lights, street lights, street signage) Parks (comprising of outdoor game areas, picnic spots, cultural zones, pedestrian ways), Squares and monuments (comprising of Street resting spaces, neighborhood squares, sitouts) and Sporting environments (comprising of Stadiums, outdoor sporting courts, street workout amenities). The levels of development of these elements for community utilization within each district is measured using a five-point scale, where the number ‘1’ represents low utilization and ‘5’ represents highest utilization. The quality of urban furniture development for community utilization is presented in Tables 6 to 9.

Table 6. *Quality of Street furniture development in the Phase-1 districts of Abuja City.*

Source: Author's fieldwork

DISTRICTS		STREET LIGHTS	TRAFFIC LIGHTS	SIGNAGE	TOTAL (AVERAGE)
D1	CENTRAL BUSINESS DISTRICT	3	4	3	3.3
D2	ASOKORO	3	3	3	3
D3	GARKI-1	2	2	2	2
D4	GARKI-2	2	2	2	2
D5	GUZAPE	2	2	2	2
D6	MAITAMA-1	3	3	3	3
D7	MAITAMA-2	3	3	3	3
D8	WUSE-1	2	3	2	2.3
D9	WUSE-2 (A07)	3	2	2	2.3
D10	WUSE-2 (A08)	3	3	2	2.7

Table 7. *Quality of Recreation Park development in the Phase-1 districts of Abuja City.*
Source: Author's fieldwork

DISTRICTS		OUTDOOR GAMES	PEDESTRIAN WAYS	PICNIC SPOTS	TOTAL (AVERAGE)
D1	CENTRAL BUSINESS DISTRICT	2	2	2	2
D2	ASOKORO	2	2	1	1.7
D3	GARKI-1	3	2	2	2.3
D4	GARKI-2	2	2	1	1.7
D5	GUZAPE	2	2	2	2
D6	MAITAMA-1	1	2	2	1.7
D7	MAITAMA-2	3	2	3	2.7
D8	WUSE-1	2	2	1	1.7
D9	WUSE-2 (A07)	2	2	2	2
D10	WUSE-2 (A08)	2	2	2	2

Table 8. *Quality of Squares and monuments development in the Phase-1 districts of Abuja City*
Source: Author's fieldwork

DISTRICTS		SQUARES	SITOUTS	SCULPTURAL GARDEN	TOTAL (AVERAGE)
D1	CENTRAL BUSINESS DISTRICT	3	1	2	2
D2	ASOKORO	2	1	0	1
D3	GARKI-1	1	2	0	1
D4	GARKI-2	2	2	0	1.3
D5	GUZAPE	2	3	0	1.7
D6	MAITAMA-1	1	3	2	2
D7	MAITAMA-2	2	3	1	2
D8	WUSE-1	2	2	1	1.7
D9	WUSE-2 (A07)	2	2	0	1.3
D10	WUSE-2 (A08)	1	2	0	1

Table 9. *Quality of Sporting environment development in the Phase-1 districts of Abuja City*

Source: Author's fieldwork

	DISTRICTS	STADIUMS	OUTDOOR ARENAS	STREET WORKOUT	TOTAL (AVERAGE)
D1	CENTRAL BUSINESS DISTRICT	2	2	1	1.7
D2	ASOKORO	0	2	1	1
D3	GARKI-1	0	2	1	1
D4	GARKI-2	0	1	1	0.7
D5	GUZAPE	2	1	0	1
D6	MAITAMA-1	0	1	1	0.7
D7	MAITAMA-2	0	1	1	0.7
D8	WUSE-1	0	2	1	1
D9	WUSE-2 (A07)	0	2	1	1
D10	WUSE-2 (A08)	0	1	1	0.7

5. Results and Discussion

Through the filed surveys and analyses as indicated above, this study revealed a number of outcomes through which the Urban Aesthetics values of Abuja city can be distinguished. The summary of the five townscape factors which demonstrates the urban aesthetic value for each of the districts are calculated and presented using a bar chart showing the comparison of attractiveness of the districts. With reference to the Linkert-type five (5) point scale for quality, the number “3” represents the average score at which a condition is regarded as normal or acceptable. Correspondingly, values below the number “3” are regarded as unsatisfactory (hence substandard), while values above the number “3” are regarded as remarkable (Koo *et. al*, 2025, Vogt, 1999). Therefore from the values in Table 11, the Asokoro district which scored the highest cumulative mean value of 3.6 can thus be described as the most attractive district with the best aesthetic feature in Abuja. This is followed closely by Wuse-1 with cumulative mean value of 3.4, then Wuse-2 (A08) with mean value of 3.0. The other districts scored below 3 in the 5-point scale average, with Guzape district scoring the lowest at 1.4. The low performance observed in these districts could be attributed to the poor quality or unavailability of the Townscape Assessment (TA) components.

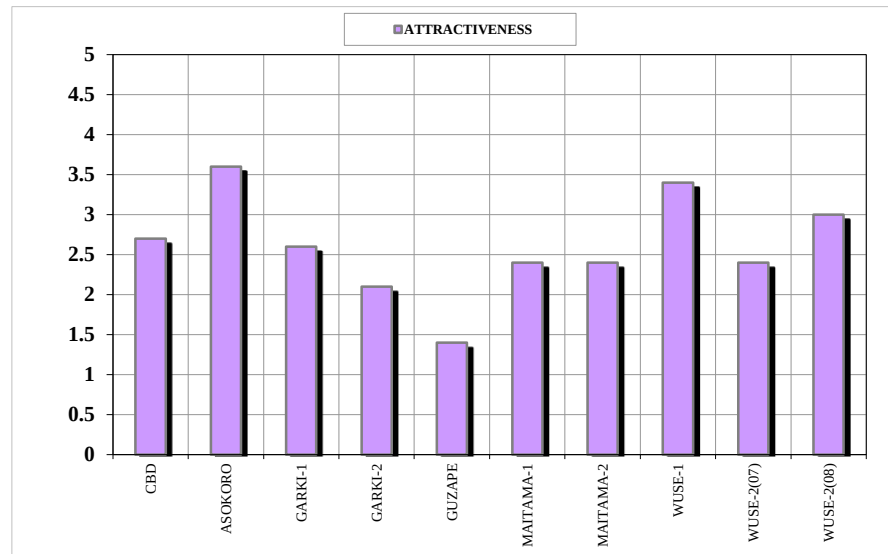


Figure 9. Comparison of attractiveness of the Abuja city Phase-1 districts

6. Conclusion

This study perused the status of Abuja city master plan using Townscape Assessment (TA). The selected indicators includes environmental and land use conditions, green spaces, water elements and urban furniture. The findings revealed that the Phase-1 districts were generally low on all aspects of the Townscape Assessments. It also revealed the specific conditions with the best and least TA performance as well as the districts that are mostly affected. The result from the study highlights the significance of integrating Townscape assessment into the urban planning processes in order to ensure the sustainability of attractive urban spaces. This study further recommends the adoption of this assessment process as a component for monitoring the performance of urban districts with major focus on improving the quality of urban environments. Government agencies and local administrators may adopt streamlined versions of Townscape Assessment methods, which may be tailored to suit the intended objectives of city or regional authorities.

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ANALYZING THE HOUSING TREND AND DEMAND IN ENUGU URBAN, ENUGU STATE

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ABSTRACT

The study's aim is to analyse the housing trend and demand in Enugu Urban, Enugu State with objectives of examining the trend in housing demand in Enugu Urban from 2006 to 2025 and analysing the socioeconomic factors that contribute to increasing housing demand in the study location. The survey research was adopted. Questionnaire and face-to-face interview with town planners and the 250 permanent staff members of Enugu State Housing Development Corporation (ESHDC) constituted the data collection instruments. Frequencies, percentages and means were employed in analyzing the study's data while PCA was employed to reduce and determine the major socioeconomic factors that contribute to increasing housing demand in Enugu Urban. Findings revealed that housing demand increased from 169,422 to 321,901 between 2006 and 2025 showing a difference of 152,479. The study also revealed that housing price; income of household; land availability/cost among others constituted the factors that contribute to the increased demand for housing in Enugu Urban. The study found that the initial assumption of the study was rejected as they identified factors contributed to 99.99% of the factors that cause housing shortage in Enugu Urban. For the hypothesis test, the model accounted for 99.99% with Factor One (Income of household) having the greatest influence with an Eigen Value of 37.353. This is followed by household size (2.649%), employment status (0.873%), maintenance culture (0.442%) and household housing preference (0.219%). The study suggested that new planning schemes should be initiated by the government with help of town planners to open up new areas for housing development with strict adherence to planning regulations.

Keywords: Demand, Enugu Urban, Household Income, Housing, Trend

1.1 Background to the Study

One of man's three basic requirements is housing. After the availability of food, it is the most crucial element for human physical life (Ogbuna, 2023). Human health, welfare, and productivity can all be significantly impacted by a housing shortage. Without it, man would not be able to survive. Housing includes everything that surrounds a home to promote healthy living, not only its structure, amenities, and contents. For housing to serve its fundamental functions, it must be both numerically and qualitatively sufficient (Aderamo and Ayobolu, 2024).

In the UK, poor demand for housing including, in its most extreme form, the "abandonment" of homes is not a recent occurrence (Bramley and Pawson, 2021). There are historical instances of entire settlements being abandoned and depopulated. According to Burrows (2018), the low demand for housing in the UK can be attributed to current cohorts of stable, elderly renters who are projected to leave the industry in increasing numbers due to aging and death, which will increase the supply and decrease the stability of social rental estates.

Between the 1960s and 1989, Enugu State and Enugu Urban in particular experienced two housing-related issues as a result of the growing rate of urbanization and industry. The first was the lack of affordable housing, and the second was the rising cost of such housing (Ononugbo et al., 2021). Low-income households in Enugu found it more and more difficult to maintain a decent quality of living due to the lack of affordable housing and the growing cost of existing units, which forced them to live in slums where they wreaked havoc on the environment.

In Enugu Urban, there exist various forms of human settlement problems which depicts the standard of living and lack of affordable housing. A successful city is one which meets multiple goals like adequate housing, working environment for her dwellers, water supply, and provision for sanitation, garbage collection/disposal, paved roads, and other forms of infrastructural services essential for healthy achievement.

In Enugu Urban, the lack of housing to meet demand is manifested in two main ways. Firstly, is the decay or depreciation of housing stock over time through natural disaster and lack of maintenance. The second is a result of an increase in housing demand generated through a population increase, combined with positive changes in social and economic factors. The deficits in housing demand in Enugu Urban have resulted in numerous problems like overcrowding, reduction in the vacancy rate, high room occupancy rates, proliferation of informal settlements and slums like Ugwu Aaron, Ugbo Odogwu, Ugwu Bottle among others, pressure on the existing housing stock, pressure on existing infrastructure, deterioration of the infrastructural facilities, inadequate basic amenities, poor spatial arrangement, and deteriorated

environment. Others are high rents, increase in housing prices, lack of adequate and affordable housing and decrease in Marginal propensity to save (MPS) of the household as greater part of the income is spent on rent.

Consequently, the Enugu State Government through the Enugu State Housing Development Corporation (ESHDC) embarked on several programmes aimed at improving housing supply to meet the demand. These programmes include site and services scheme, direct housing construction, core housing scheme among others. It is therefore to note that these efforts have not yielded the desired result because housing shortages still persist in Enugu Urban. This has been attributed to the inability of the policy makers to identify all the factors that are responsible for phenomenal growth in the housing demand, which have made all efforts in tackling housing provision ineffective. Existing housing demand estimate were based on population alone thereby neglecting other factors that are crucial for the estimates. The situation was due to the absence of the national and state data on housing (Ademiluyi, 2017).

From the above scenario, the focus of this study was to analyze housing demand with a view to identify all the factors that influenced housing demand in Enugu Urban. The outcome of this study is capable of enhancing efforts towards meeting housing needs of the residents of the study area, Enugu State and Nigeria at large. The study further hypothesizes that the socioeconomic factors influencing the increasing demand of housing in Enugu Urban, Enugu State, Nigeria are not statistically significant.

2.0 Literature Review

2.2.1 Concept of a House

A house is a perfect representation of the social structure that gives rise to it and an evolutionary product of human civilization. According to Adeleye and Ogunshakin (2023), it is a three-dimensional geometric structure that is externally expressed, physically projected on the geographic region, and internally organized and split into distinct but closely connected and communicating functional spaces. Regardless of its level of intrinsic architectural interest, a house can be viewed as a place where people live, whether it is

a simple hut or a complex mansion. In actuality, a house serves as a focal point for daily life and offers shelter.

2.2.2 Concept of Housing Demand

Quigley (2024) expanded the theoretical analysis of housing demand to include the choice of home type and the spatial dimension (and thus, the residential location selection). We specifically discuss the choice of residential location and style of dwelling in a metropolitan area that may contain many workplaces. The spatial distributions of the stocks of different home types are provided in this short-run analysis. The theoretical model shows the relationship between housing choices and systematic differences in the relative costs that households must pay for the same kinds of residential dwellings. The model indicates that these prices, in turn are heavily dependent on the interaction of work place location, the spatial distribution of the stock of housing, and the characteristics of the urban transport network.

Desire housing demand and effective housing demand are not the same. A desire to purchase a home that is supported by the means to pay for it is an example of effective housing demand. Conversely, the term "desire housing demand" refers to a consumer's eagerness to purchase a home despite their lack of financial means. Such housing demand has not become effective housing demand until there is the financial means to purchase the housing unit (Alison, 2024).

2.3 Empirical Review

Recent studies have been conducted by several authors on housing and its demand over the years. This subsection reviews some of these literatures.

Halicioglu (2020), in a study of the demand for housing in Turkey; found out that housing demand is determined by economic and demographic factors. The findings of the study showed that the most significant factor in determining the level of housing demand was real income which was positively related

to demand for housing, followed by house prices that showed a negative relationship and level of urbanization. The estimated private housing demand function revealed a stable long-run relationship between independent and dependent variables and a relatively stable housing demand function.

Bynoe et al. (2021), in a study of the demand for housing in Barbados found out that income, the price of non-housing items and interest rates largely explained the pattern of demand for housing in Barbados, with interest rates apparently having a positive impact on the demand for housing through their effect on mortgage credit availability. This indicated the primacy of individuals' ability to service their mortgage in their housing decisions.

Idoko and Ezeodili (2021) investigated urbanization and housing development in Enugu State. The findings from the study showed that urbanization positively affects housing characteristics in Enugu state, urbanization affects house rents and choice of settlement in the state and urbanization had a significant effect on housing quality in Enugu state. As a result, the study recommended among others that; government need to check rural-urban migration by providing even development policies that provide for equitable development between rural and urban centres. The study concluded that the demand for affordable and quality housing in Enugu is very high and growing steadily owing to rapid urbanization.

Ogbuna (2023) analyzed housing demand in Enugu Metropolis, Enugu State, Nigeria from 1980 to 2013. The result from the housing trend analysis showed that housing demand differed significantly over the years ($p < 0.05$) in Enugu metropolis. The housing demand was highest (172,844 housing units per annum) during the third (2000-2013) decade and it was followed in descending order by second (1990-1999) and first (1980-1989) decades with housing demand of 123,713 and 93,841 housing units per annum respectively. There was a significant relationship ($p < 0.05$) between housing demand and the determinant factors (Population growth, Income, Institutions, Public utilities, Security and Household size). This implies that the six identified afore-mentioned factors are the determinants of housing demand in Enugu metropolis. Housing demand differed significantly ($p < 0.05$) among various income groups (high, medium and low) in Enugu metropolis. The low-income group has the highest housing demand (88,406 housing units per

annum) and it was followed in descending order by medium – income (31,835 housing units per annum) and high-income (14,917 housing units per annum) groups. There was a significant difference ($p < 0.05$) in residents' perception of the housing demand in Enugu metropolis. The study recommends among other things the inculcation of the identified factors in determining housing demand in Nigeria.

The reviewed literature revealed that studies focusing on the housing trend and demand in Enugu Urban is non-existent and therefore the current study will try to fill this gap in literature. Also, the current study will try to analyze and determine the influence of socioeconomic factors on housing demand in Enugu Urban. This will make for informed decision-making as regards housing provision for the residents of the study area especially the low-income earners.

3.0 Materials and Methods

3.1 Study Area

The capital of the southeast Nigerian state of Enugu is Enugu City. Geographically, it is situated at latitude 6° 27' 9.6"N and longitude 7° 30' 37.2"E. The city is 113 km² in size and has a population density of 6,400 people per km². The elevation is 202 meters above sea level. It is bordered to the east by Nkanu East Local Government Area, to the west by Udi Local Government Area, to the north by Igbo-Etiti and Isiuza Local Government Areas, and to the south by Nkanu West Local Government Area (see image 1).



Image 1: Map of Enugu State
Source: Google Map (2025)

3.2 Methodology

The survey research was adopted to facilitate reach to the respondents in the study area. Data sources for this study were grouped into two. These are primary and secondary data. Both sources of data were extensively used for the purpose of drawing an empirical conclusion for proper analysis of the study so as to come up with objective findings. Questionnaire and face-to-face interview with residents, town planners and staff members of Enugu State Housing Development Corporation (ESHDC) constituted the data collection instruments. Utilizing the sample size calculator (<https://www.calculator.net/sample-size-calculator.html>), a sample size of 384 was obtained from a total population of 421,049 (NPC, 2006 population figure for Enugu Urban and projected to 2025). Purposive and simple random sampling techniques were adopted for the research in determining the sample population and the residential densities to be selected for the study. In applying purposive sampling technique, sampling was required from the

three local government areas that make up the city, that is, Enugu North, Enugu South and Enugu East LGAs. Secondly, the urban area was delineated into two strata using the two purposively identified densities, that is, high and medium. The high-density areas comprised Abakpa, Iva valley, Asata, Camp, Ogbete, Ogui New layout Achara layout, Ogui, Uwani. Medium densities include Awkunanaw, Idaw River, New era, New Haven, Trans-Ekulu, secretariat quarter and Udi Siding. Applying the simple random sampling technique, one neighborhood was drawn at random from each of the two strata or densities from the three local government areas. On this while, respondents from Abakpa (94), Trans Ekulu (58), Ogui (58), New Haven (50), Achara Layout (66) and Awkunanaw (58) were chosen for the study. To ensure the reliability of the study instrument, the instrument was prepared with help from the students' supervisor, statistician and other authorities in the built environment. Trial questionnaires administration was conducted to ascertain adequate coverage of scope and topic. A calculated coefficient of 0.7 using Spearman Brown Formula was obtained and revealed a statistically reliable p-value. Frequencies, percentages, chart and means were employed in analyzing the study's data while Principal Component Analysis (PCA) was employed in analyzing the study's hypothesis.

4.0 Findings

4.1.1 Analyzing Objective One

The Trend in Housing Demand in Enugu Urban from 2006 to 2025

In achieving this study objective, data from NPC (2006) on housing census was obtained and projected to 2025. In projecting the housing figure from 2006 to 2025, the average growth rate of 3.2% for Nigeria was used as dictated by the National Population Commission (NPC, 2023). In projecting the population, the formula is given in the equation below.

$$N_t = P e^{r \cdot t}$$

Where:

N_t = Housing Projection from 2006 to 2025

P = Present Housing

e = the base of natural logarithms (2.71828)

r = growth rate (3.2% or 0.032)

t = time period involved (n years)

The projected housing figure for Enugu Urban is detailed in table 1. The housing demand for Enugu Urban according to NPC (2006) was put at 169,422.

Table 1 and Figure 1 reveals the housing demand in Enugu Urban from 2006 to 2025. From the analysis, the trend in housing demand continued to move upwards from 169,422 to 321,901 showing a housing demand difference of 152,479. The result shows the high housing lag in the city.

Table 1: Trend of Housing Demand in Enugu Urban, 2006-2025

Year	Housing Demand	Year	Housing Demand
2006	169,422	2017	249,050
2007	174,505	2018	257,521
2008	179,587	2019	265,993
2009	186,364	2020	274,464
2010	193,141	2021	282,937
2011	198,224	2022	291,406
2012	205,001	2023	301,571
2013	211,778	2024	311,736
2014	218,554	2025	321,901
2015	233,802		
2016	240,579	Deficit = 152,479	

Source: NPC, 2006 and Researcher's Calculation, 2026

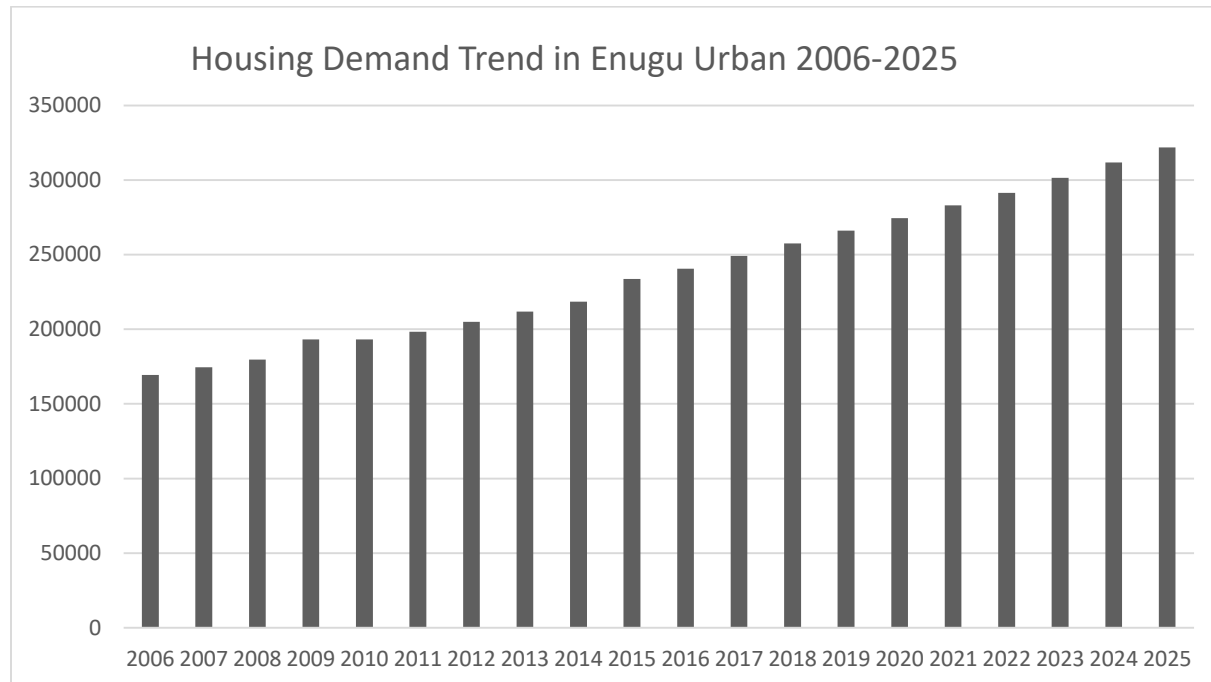


Figure 1: Housing Demand Trend in Enugu Urban 2006-2025

Source: Field Survey, 2026

4.1.2 Analyzing Objective Two

Socioeconomic Factors that contribute to increasing Housing Demand in Enugu Urban

Table 2 showed the contributory factors to the increasing housing demand in Enugu Urban. From the analysis, the identified 17 factors were accepted as they recorded mean scores above 1.49 with a grand mean of 2.70. Notable among these factors include housing price (m= 2.90); income of household (m= 2.90); land availability/cost (m= 2.80); lack of access to finance (m= 2.80); inadequate infrastructure (m= 2.80); high construction cost (m= 2.80); long period in obtaining planning permit (m= 2.80); household size (m= 2.70); the housing quality (m= 2.70); high unemployment (m= 2.70); high cost of building material (m= 2.60); increasing population (m= 2.50); poor maintenance of existing housing (m= 2.50); sanitary condition (m= 2.50); Land Use Act (m= 2.50); interest rate volatility (m= 2.50) and the housing quantity (m= 2.40). The result from this analysis is evident in the study area as people continue to flow into the city in search of employment, education and trade.

Table 2: Analyzing situation influencing increased Housing Demand in Enugu Urban

S/N	Situations	Sig.	Indff.	Not Sig	Mean X	Remark
1	Interest rate volatility	235	95	54	2.50	Accepted
2	Income of household	328	56	-	2.90	Accepted
3	Increasing population	295	69	20	2.50	Accepted
4	Household size	302	67	15	2.70	Accepted
5	Housing price	328	56	-	2.90	Accepted
6	Land availability/cost	319	59	6	2.80	Accepted
7	Lack of access to finance	301	75	8	2.80	Accepted
8	High cost of building material	265	99	20	2.60	Accepted
9	The housing quantity	209	120	55	2.40	Accepted
10	The housing quality	298	55	31	2.70	Accepted
11	Inadequate infrastructure	304	69	11	2.80	Accepted
12	Poor maintenance of existing housing	216	128	40	2.50	Accepted
13	Sanitary condition	232	127	25	2.50	Accepted
14	High unemployment	293	79	12	2.70	Accepted
15	Land Use Act	208	150	26	2.50	Accepted
16	High construction cost	299	77	8	2.80	Accepted
17	Long period in obtaining planning permit	312	65	7	2.80	Accepted
	Grand Mean				2.70	Accepted

Key: Sig=Significant; Indff.= Indifferent; Not Sig= Not Significant

Source: Field Survey, 2026

4.3 Hypothesis Testing

The socioeconomic factors influencing the increasing demand of housing in Enugu Urban, Enugu State, Nigeria are not statistically significant.

Table 3: Output of PCA Reduction

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	.951
Bartlett's Test of Sphericity Approx. Chi-Square	18837.881
df	378
Sig.	.000

Source: SPSS, 2023

Results from the factor analysis, the factors were grouped into five categories. Results showed that the Kaiser-Meyer-Olkin (KMO) (.951) which is more than 0.7 indicated that the sampling was adequate. Also,

the Bartlett's Test of Sphericity (0.000) was less than the significance level of 0.05 which implies that the variables were strongly correlated and suitable for the study.

For the categories of factors, the categories explained 99.99% of the socioeconomic factors influencing the increasing demand of housing in Enugu Urban, Enugu State, Nigeria. The identified predominant categories of socioeconomic factors influencing the increasing demand of housing in Enugu Urban, Enugu State, Nigeria included the income of households (95.815%), household size (2.649%), employment status (0.873%), maintenance culture (0.442%) and household housing preference (0.219%).

4.4 Discussions

The discussions were carried out in line with the findings of the study. On the housing demand in Enugu Urban, Table 1 and Figure 1 reveals that the trend in housing demand continued to move upwards from 169,422 to 321,901 from 2006 to 2025 respectively showing a housing demand difference of 152,479. The result therefore goes a long way to show the high housing lag in the city. The above result therefore calls for urgent intervention from government and private organization to increase the supply of housing to meet demand in the city. This result is in lie with that of Ogbuna (2023) and Idoko and Ezeodili (2021) who averred that housing demand continues to rise following migration and population increase into the urban area.

On the socioeconomic factors that contribute to increasing housing demand in Enugu Urban, the result as presented in table 2 included housing price (m= 2.90); income of household (m= 2.90); land availability/cost (m= 2.80); lack of access to finance (m= 2.80); inadequate infrastructure (m= 2.80); high construction cost (m= 2.80); long period in obtaining planning permit (m= 2.80); household size (m= 2.70); the housing quality (m= 2.70); high unemployment (m= 2.70); high cost of building material (m= 2.60); increasing population (m= 2.50); poor maintenance of existing housing (m= 2.50); sanitary condition (m= 2.50); Land Use Act (m= 2.50); interest rate volatility (m= 2.50) and the housing quantity (m= 2.40). The result from this analysis is evident in the study area as people continue to flow into the city in search of employment,

education and trade. This result conforms to that of Bynoe et al (2021) who averred that housing demand is fueled by factors ranging from interest rates, household size, housing price, housing quality and sanitary condition among others. From the study result also, it goes to show that until these factors are addressed, housing demand will continue to increase in Enugu Urban while the resources and land to meet the demand continue to diminish as evidenced by the falling crude oil prices, high inflation and insecurity in Nigeria.

5.0 Conclusion and Recommendations

5.1 Conclusion

The study had analyzed the housing trend and demand in Enugu Urban. The study successfully projected the housing demand trend from 2006 to 2025 showing a difference of 132,149. The study also observed that factors influencing the increase in housing demand were accepted in the study area including housing price; income of household; land availability/cost; lack of access to finance; inadequate infrastructure; high construction cost; long period in obtaining planning permit among others. The study therefore concludes that adequate measures must be taken to increase housing production and that existing stock should be adequately maintained. The study also recommends that further studies be conducted on whether housing supply has equaled demand in Enugu Urban. This will enable policy makers to intensify efforts in housing delivery for the residents of Enugu Urban, Enugu State and Nigeria in general

5.2 Recommendations

From the findings and conclusion of the study, the following recommendations were put forward for immediate adoption and implementation to curb the continued housing shortage being experienced in the study area.

1. There is urgent need to ensure that private organizations and individuals are granted permission to embark on mass housing development in Enugu Urban. This is to be supported by the government with tax waivers, lower interest rates among other.

2. Adequate rehabilitation of dilapidated housing stock is urgently needed to meet the growing housing need in the city.
3. Modern housing delivery strategies like housing subsidies, capital grants to access mortgage finance, shelter micro-finance among others be employed to effectively address the housing shortage currently experienced in Nigeria.
4. Provision of finance with lower interest rates through the Nigerian Mortgage bank and other financial institutions should be intensified to developers. This will hasten the housing delivery efforts in the city.
6. New planning schemes should be initiated by the government with help of town planners to open up new areas for housing development with strict adherence to planning regulations. This will help curb slum proliferation, reduce crime and ensure that buildings are adequately maintained for future occupants.

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**Intra-Urban Land Surface Temperature Variability of Aba, South-East, Nigeria
(1986-2025)****Madumere, Kingsley Onyekachi (Ph.D.)**

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ABSTRACT

Globally, rising urbanization has contributed to increasing Land Surface Temperature (LST), altering urban microclimates and creating environmental challenges that require mitigation. While many studies compare rural and urban LST, limited attention has been paid to intra-urban variations. This study examined LST variability across neighbourhoods in Aba, South-East Nigeria, between 1986 and 2025. The objectives were to identify neighbourhoods, classify them by development density, quantify their LST, and assess temporal changes. GIS and remote sensing techniques were employed using thermal satellite datasets from Landsat 5 and 9 from the United States Geological Survey Earth Explorer platform. Only images with less than 10% cloud cover were selected. Twenty neighbourhoods were classified using dwelling units per hectare (du/ha) into urban-core (50–100+ du/ha), transitional-urban (20–50 du/ha), and suburban (<20 du/ha). LST was derived through conversions from thermal digital numbers to top-of-atmosphere radiance, brightness-temperature, vegetation-proportion, and surface-emissivity. Findings revealed that urban-core neighbourhoods consistently recorded the highest LST, while transitional and suburban areas showed lower values, indicating a strong relationship between development density and increased temperature. However, suburban neighbourhoods experienced the fastest thermal growth over time, reflecting urban expansion and weak planning controls. In contrast, the urban-core remained a persistent heat zone with relatively stable fluctuations. Statistical analysis showed a strong positive correlation (0.94) and a significant difference between 1986 and 2025 LST values ($t = 21.24 > 2.09$). The study concludes that urbanization in Aba is shifting thermal risk outward, making suburban areas increasingly vulnerable and underscoring the need for climate-responsive planning strategies.

Keywords: GIS analysis, Intra-urban variability, Land Surface Temperature, Neighbourhood density, Remote sensing, Thermal climate change, Urbanization,

1.0 Introduction:

Urban areas significantly influence local thermal regimes, often generating distinct land-surface temperature (LST) patterns and urban heat island (UHI) effects. These phenomena arise primarily from the replacement of vegetated surfaces with impervious materials, reductions in

evapotranspiration, and increased anthropogenic heat emissions, which ultimately alter the urban energy balance at micro-scales (Oke, 1982). Intra-urban LST variability reflects the heterogeneous distribution of land cover and urban form, and capturing such variability is crucial for heat-resilience planning (Zhao, *et al.*, 2021).

In West African secondary cities, empirical studies have begun to document the evolving relationship between urban expansion and LST. For instance, Ukanwa, *et al.*, (2024) used Landsat 8 imagery to analyze the impact of land-use/land-cover (LULC) changes on LST in Imo State, Nigeria, highlighting marked variations in thermal responses across built-up, vegetation, and water-covered areas. Similarly, Ikuemonisan *et al.*, (2025) assessed heatwave dynamics in Lagos State, demonstrating that rapid increases in built-up area corresponded with rising LST trends, particularly inland where urban expansion was most intense. Onuegbu (2024) observed a strong positive correlations between normalized difference built-up index (NDBI) and LST in Abakaliki,, indicating that the densest urban zones experienced the most pronounced surface warming.

More broadly, multi-decadal assessments confirm that rapid urbanization is often accompanied by increasing LST and diminished cooling from vegetation. Ishaya, *et al.*, (2025) documented rising areas of high and extreme LST across Greater Karu Urban Area, attributable to conversion of vegetated or agricultural land into built-up surfaces between 1992 and 2022. In Kano Metropolis, Bernard and Bilal (2023) used Landsat MSS, ETM+ and OLI/TIRS data spanning 1984–2022 and reported that urban expansion, coupled with declining vegetation, resulted in substantial LST increases, especially in highly urbanized core zones.

Despite the above valuable contributions, there remains a gap in detailed, neighbourhood-scale LST assessments in rapidly growing cities like Aba, South-eastern Nigeria. Many studies rely on bulk LST categorization or city-wide averages against the adjoining rural areas, limiting

insights into micro-scale variations. Furthermore, few incorporate dwelling-density metrics, such as dwelling units per hectare (du/ha) to classify neighbourhood density and examine its relationship with thermal outcomes. More often, neighbourhoods are classified along traditional lines; low-density areas for high-income groups, medium-density for middle-income groups, and high-density for low-income earners. However, this approach clearly limits a deeper understanding of the interactions and complex interplay between development density and urban heat dynamics.

This study addresses that gap by conducting an intra-urban LST analysis of Aba for two snapshot years, 1986 and 2025. The specific objectives of the study were to identify neighbourhoods, classify them by development density, quantify their LST, and assess temporal changes. Landsat 5 and 9 thermal imageries obtained from the USGS Earth Explorer platform were used. Only scenes with minimal cloud cover (<10%) were considered fit for the study. By linking high-resolution, time-area-specific satellite thermal data with neighbourhood-level density stratification, this research delivers fine-scale understandings into how urban densification and morphology influence thermal regimes in a typical south-east Nigerian city. The outcomes are directly relevant for land-use policy, heat-mitigation strategies, and urban adaptation planning in similar cities undergoing rapid, unplanned growth/expansion.

2.0 Study Area:

Aba Urban, made up of Aba North and Aba South Local Government Areas (LGAs), is the largest urban center in Abia State, South-east, Nigeria. It is also known as Enyimba (Elephant) City. Aba was founded by Mr. Aba Amaku (from where it derived its name) before the colonial era. Covering approximately 65.03km², it lies between 07°20'–07°26'E and 05°02'–05°08'N, and is bounded by Osisioma Ngwa LGA at its north-west, Obingwa LGA at its north-east, Ugwunagbo LGA at its south east, and Ukwu West LGA at its south-west.

Aba was designated a second-class town in 1917 and has since then witnessed rapid population growth, rising from 531,340 in 2006 (NPC, 2006) to about 961,700 by 2025, at a 3.2% growth rate annually. This growth, mainly driven by commerce, industry, education, and rural–urban migration, has significantly contributed to the development density of Aba, transforming it into an active and expanding socio-economic hub in South-eastern Nigeria with attendant LST rises and variations in its different neighbourhoods.



Figure 1: Map of Nigeria, showing Abia State,

Source: GIS Lab., Department of Geography, University of Nigeria, Nsukka (2018)
https://www.researchgate.net/figure/Map-of-Nigeria-showing-Abia-State-Source-GIS-Lab-Department-of-Geography-University_fig1_339611484



Figure 2: Map of Abia State Showing Aba North & South LGA's

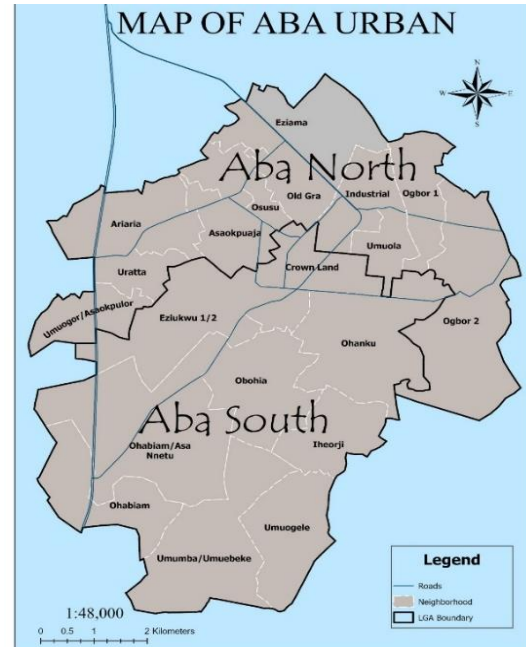


Figure 3: Map of Aba Urban (The Study Area)
Source: Researcher's Study, 2026

3.0 Materials and Methods:

3.1 Data Collection: The study utilized secondary spectral and thermal satellite datasets remotely derived from Landsat 5 and 9 sensors from the United State Geological Survey (USGS) Earth Explorer website for the years/epochs 1986 and 2025 respectively. The Area of Interest (AOI i.e Aba Urban) was defined using the site's map tools. The date range was set to 1986 and 2025 while filtering for Landsat 5 and 9 scenes. Scenes with minimal cloud cover ($<10\%$) were prioritized and that informed the selection of epochs. Data derived were digitized thereby making them quantifiable for statistical analysis.

Table 1: Image Data Acquired

DATA	YEAR	SENSOR ID	DATE ACQUIRED	PATH / ROW
LANDSAT 5	1986	TM	17 – 01 - 1986	186 / 057
LANDSAT 9	2025	OLI_TIRS	17 – 12 -2025	188 / 56

Source: USGS, 1986, 2025

3.2 Data Analysis: Recall the objectives of the study were: to identify neighbourhoods in Aba urban, classify them by their development density, quantify their LST and examine temporal variations between the two epochs (1986 and 2025) as well as amongst the neighbourhoods. List of neighbourhoods sourced from Aba North and Aba South Town Planning Authorities indicated twenty (20) neighbourhoods. They were delineated and classified by their development densities using number of dwelling units per hectare (du/ha) matrix: urban core/high-density neighbourhoods (50–100+ du/ha), transitional urban/medium-density neighbourhoods (20–50 du/ha), and suburban/low-density neighbourhoods (< 20 du/ha). GIS-based zonal analyses were then applied to extract mean LST for each neighbourhood for the quantification of intra-urban variability across the forty-year interval.

$$\text{Development density} = \text{No of dwellings (buildings)} / \text{Area (Ha)}$$

The LSTs of the various neighbourhoods of the two epochs (1986 and 2025) were derived through a sequence of conversions from thermal digital numbers to top-of-atmosphere radiance, brightness temperature, vegetation proportion (NDVI-based), and surface emissivity by the application the procedures and formulae tabulated below.

Table 3: Summary of the LST Analyses and Formula

Analysis	Formula	Definition

DN to Top of atmospheric reflectance (TOA)	$L\lambda = ((L\_MAX - L\_MIN) / (Q\_CALMAX - Q\_CALMIN)) \times (Q\_CAL - Q\_CALMIN) + L\_MIN$	$L\lambda$: Spectral radiance ($W/m^2 \cdot sr \cdot \mu m$) QCAL: Digital number (DN) value LMAX, LMIN: Max and min radiance for Band 6 (from metadata) Typical metadata values for Band 6 (Landsat 5 TM): LMAX=15.600 $W/m^2 \cdot sr \cdot \mu m$ LMIN=1.238 $W/m^2 \cdot sr \cdot \mu m$ QCALMAX = 255, QCALMIN=1: max and min pixel DN value Q_{cal} = Quantized and calibrated standard product pixel values (DN)
TOA to brightness temperature (BT) conversion	$(K_2 / \ln(K_1 / L_\lambda + 1)) - 273.15$	K_1 = Band-specific thermal conversion was constant from the metadata (607.76) K_2 = Band-specific thermal conversion was constant from the metadata (1260.56) $L\lambda$: TOA spectral radiance ($W/m^2 \cdot sr \cdot \mu m$) $\ln$ = Natural logarithm To obtain the results in Celsius, the radiant temperature is adjusted by adding the absolute zero (approx. -273.15 °C)
Proportion of vegetation (PV)	$((NDVI - "NDVI \text{ min} ") / (NDVI\_max - NDVI\_min))^2$	The minimum and maximum values of the NDVI image can be displayed directly in the image
Land surface emissivity (ϵ)	$0.004 \cdot P_v + 0.986$	P_v = Proportion of vegetation The value of 0.986 corresponds to a correction value of the Equation
LST	$(BT / (1 + (\lambda * BT / C2) * \ln(\epsilon)))$ i.e $("Brightness\_Temperature" / (1 + (0.00115 * BT / 1.4388) * \ln(\epsilon)))$	BT = Top of atmosphere brightness temperature (°C) λ = Wavelength of emitted radiance (0.00115) $C2 = h \cdot c / s = 1.4388 \times 10^{-2} mK = 14,388 mK$ H = Planck's constant = $6.626 \times 10^{-34} Js$ S = Boltzmann constant = $1.38 \times 10^{-23} JK$ C = Velocity of light = $2.998 \times 10^8 m/s$ E = Land surface emissivity

Furthermore, to statistically evaluate the relationship between development density and LST across the neighbourhoods, a simple linear regression analysis was conducted with

significance assessed at the 0.01 level. In addition, the student's t-test (paired two-sample for means) was employed at a 0.05 significance level to examine temporal variations in LST across neighbourhoods between the two epochs (1986 and 2025).

4.0 Results and Discussions

4.1 Neighbourhoods and Density Classifications: The study identified twenty (20) neighbourhoods, with a total land area of 6,502.87 hectares and 115,947 buildings (shown on table 3 below). The identified development densities (using the dwelling/buildings per hectare matrix) for 2025 were transitional urban/medium-density neighbourhoods (20–50 du/ha), and suburban/low-density neighbourhoods (<20 du/ha). LST values ranged from 30.15°C to 31.41°C. Notably, there were no urban core/high-density neighbourhoods, suggesting a relatively moderate urban structure and a dominance of low-density areas, though several medium-density zones exist.

Table 3: Development Density and LST of Aba Neighbourhoods for 2025

<i>S/N</i>	<i>Neighbourhoods</i>	<i>Area (Ha)</i>	<i>No of Buildings</i>	<i>Dev. Density</i>	<i>Density Class</i>	<i>LST (Celcius)</i>
1	Ariaria	346.45	6,962	20.10	Medium	31.34
2	Asaokpuaja	205.33	5,503	26.80	Medium	31.36
3	Crown Land	298.45	6,263	20.99	Medium	31.40
4	Eziama	378.55	7,339	19.39	Low	31.19
5	Eziukwu 1/2	496.94	11,555	23.25	Medium	31.21
6	Iheorji	238.18	3,690	15.49	Low	30.80
7	Industrial	116.88	1,831	15.67	Low	31.22
8	Obohia	352.96	7,886	22.34	Medium	31.27
9	Ogbor 1	213.20	3,968	18.61	Low	31.05
10	Ogbor 2	652.55	12,510	19.17	Low	31.03
11	Ohabiam	308.47	1,558	5.05	Low	30.64
12	Ohabiam/Asa Nnentu	780.63	10,932	14.00	Low	30.93
13	Ohanku	518.89	16,637	32.06	Medium	31.41

14	Old GRA	159.28	2,958	18.57	Low	31.34
15	Osusu	154.10	4,145	26.90	Medium	31.37
16	Umumba/Umuebeke/Nnentu	534.32	2,915	5.46	Low	30.27
17	Umuogele	323.47	1,186	3.67	Low	30.15
18	Umuogor/Asaokpulo	186.78	3,118	16.69	Low	31.06
19	Umuola/Crown Land 2	119.89	2,781	23.20	Medium	31.24
20	Uratta	117.55	2,210	18.80	Low	31.14
21	Total	6502.87	115,947			

Source: Researcher's Study, 2026

4.1 Relationship Between Density and LST: From Table 3 above, it can be observed that LST values showed moderate variation (about 1.26°C difference between the highest LST and lowest LST). Note that this range is still meaningful in urban climate studies especially when assessed through the Universal Thermal Climate Index (Climate-adapt.eea.europa.eu. (2020). The highest LST values were recorded for Ohanku (31.41°C), followed by Crown Land (31.40°C), then Osusu (31.37°C) and Asaokpuaja (31.36°C) neighbourhoods – all within the medium-density category, while the lowest LST values were recorded at Umuogele (30.15°C), followed by Umumba /Umuebeke/ Nnentu (30.27°C) and Ohabiam (30.64°C) neighbourhoods – all within the low-density neighbourhoods. This indicates localized heat concentration (UHI) in certain neighbourhoods.

Interestingly, a clear pattern emerges when comparing development density with LST. The study found that higher density areas consistently reflected higher LST while lower density areas recorded lower LSTs. For instance, Ohanku had the highest density rate of 32.06du/ha (within the dataset) and also recorded a corresponding highest LST of 31.41°C, followed by Osusu (26.90du/ha density and 31.37°C LST), and finally Asaokpuaja (26.80du/ha density with 31.36°C LST). These areas have more built-up surfaces, less vegetation and thus greater heat absorption

and retention. On the contrary, low-density neighbourhoods like Umuogele which had the least density of 3.67du/ha also had the least LST of 30.15°C; followed by Umumba/Umuebeke/Nnentu with 5.46du/ha density and 30.27°C LST, and then Ohabiam (5.05du/ha density with an LST of 30.64°C). These areas benefit from more open spaces, vegetation cover, better airflow and cooling.

While this general trend holds, there are slight deviations. For instance, Industrial neighbourhood with a low density of 15.67du/ha recorded a relatively high LST of 31.22°C. This suggests the influence of land use (industrial activities, heat emissions, etc) on LST. Also, it was observed that Old GRA having a 18.57du/ha density also recorded a relatively high LST of 31.34°C. This confirms that despite being a low-density area, high LST may result from massive paved surfaces and reduced vegetation indicating that density alone does not fully explain LST, land use and surface materials also matter.

The simple linear regression analysis performed to examine the relationship between development density and LST revealed a statistically significant positive relationship between development density and LST:

Table 4: Regression Statistics

<i>Regression Statistics</i>	
<i>Multiple R</i>	0.889866
<i>R Square</i>	0.791862
<i>Adjusted R Square</i>	0.780299
<i>Standard Error</i>	0.167991
<i>Observations</i>	20

Table 5:
ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
<i>Regression</i>	1	1.932603	1.932603	68.48109	1.51E-07
<i>Residual</i>	18	0.507977	0.028221		
<i>Total</i>	19	2.44058			

Table 6:

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
<i>Intercept</i>	30.26748	0.104111	290.7236	1.67E-34	30.04875	30.48621
<i>Dev. Density</i>	0.043883	0.005303	8.27533	1.51E-07	0.032742	0.055024

The estimated regression line equation is $y = 30.267 + 0.0439x$

That is, $LST = 30.267 + 0.0439(Dev. Density)$

For the linear regression equation: $LST = 30.267 + 0.0439(Dev. Density)$. This means that for every one-unit increase in Development Density (X), the predicted value of LST (Y) increases by 0.0439 units. This indicates a positive relationship between Development Density (X) and LST (Y), meaning that as Development Density increases, LST also tends to increase.

Key Results:

- **R²:** 0.792 → About 79.2% of the variation in LST is explained by development density.
- **Intercept (const):** 30.2675°C → Estimated LST when Dev. Density = 0.
- **Slope (Dev. Density):** 0.0439 → For each unit increase in development density, LST increases by ~0.044°C.
- **p-value (slope):** < 0.001 → Relationship is statistically significant.
- **F-statistic:** 68.48, $p < 0.000001$ → Model is significant overall.
- **Durbin-Watson:** 2.264 → No strong evidence of autocorrelation.

This indicates a strong, positive, and significant relationship between development density and LST in the dataset. Figure 4 below further illustrates the scatter plot of observed data points with the fitted regression line, showing a clear upward trend between development density and LST.

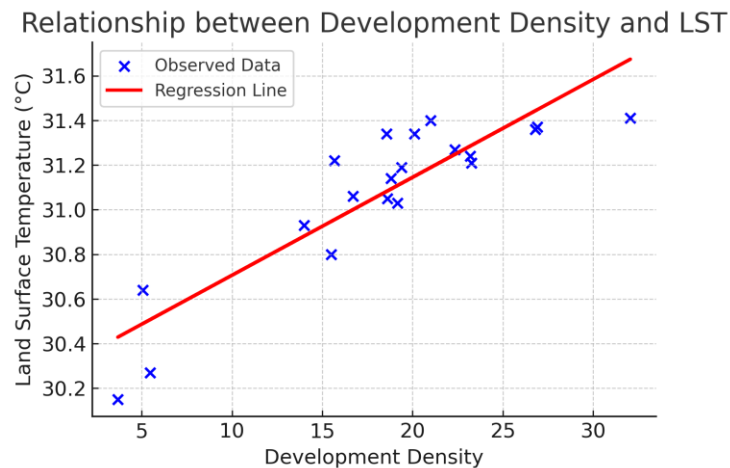


Figure 4: Scatter Plot Showing the Relationship between Development Density and LST with Regression Line

Overall, evidences demonstrate that increasing development density tends to elevate LST, reinforcing the concept of urban heat island effects at the neighbourhood scale. However, the presence of exceptions suggests that other factors, beyond density could play a crucial role in shaping thermal environments, the reason only about 79.2% of the variation in LST is explained by development density. Generally, the study corroborates findings from other studies, demonstrating that densely developed neighborhoods in Aba exhibited higher LST values, while less developed or non-urban areas experienced lower LST values (Obiefuna *et al.*, 2018; Adeleke and Moshood, 2023; Olatunde and Martins, 2023). Specifically, neighborhoods like Umuogele, Umumba, Iheorji, and Ohabiam consistently recorded lower LST due to minimal development density and a higher prevalence of vegetation. These areas, with less urbanization and more green spaces, were better insulated against heat accumulation.

In contrast, areas such as Aba Crown Land (the core inner city), Ohanku, Osusu, and Asaokpuaja showed a consistent higher LST values and thus constituted the Urban Heat Island (UHI) hotspot zones in the study area. Notably, these same locations experienced substantial and widespread urban development and the dominance of paved surfaces like tarred roads and buildings. The absence or paucity of green cover in these zones due to their replacement with developmental projects contributed significantly to the higher LST, as impervious surfaces trap and retain heat, creating the UHI Pattern of Aba. This contrast between densely developed and less urbanized areas explains the critical role of urbanization in creating UHI effects in Aba.

4.2 Temporal Variations in LST Across Neighbourhoods: Temporal variations in LST across neighbourhoods between the two epochs (1986 and 2025) were examined to further elucidate the influence of development density on surface temperature patterns. Although, due to technical constraints, the development density of 1986 could not be determined, it is evident that density levels changed over time as a result of sustained development activities by both residents and government. Table 7 therefore presents a longitudinal (time-series) profile of LST across the twenty (20) neighbourhoods, enabling a detailed assessment of the magnitude and spatial pattern of thermal change over four decades. A close analysis reveals a clear and consistent upward shift in LST across all neighbourhoods between 1986 and 2025, accompanied by a narrowing of temperature differences and intensification of urban heat conditions. This pattern reflects the effects of increasing development pressure, providing strong empirical evidence of evolving urban thermal environments at the neighbourhood scale.

Table 7: LST Values of Aba Neighbourhoods in 1986 and 2025

<i>S/No</i>	<i>Neighbourhoods</i>	<i>LST 1986 (°C)</i>	<i>LST 2025 (°C)</i>
1	Umumba / Umuebeke	25.5216	30.27

2	Crown Land	28.6102	31.24
3	Ohabiam / Asa Nnetu	26.7359	30.93
4	Ariaria	27.9356	31.34
5	Eziukwu 1/2	27.8052	31.21
6	Uratta	27.7044	31.14
7	Iheorji	26.3377	30.8
8	Obohia	27.5291	31.27
9	Umuogor / Asaokpulo	26.8482	31.06
10	Osusu	28.6091	31.37
11	Ogbor 1	27.2667	31.05
12	Asaokpuaja	28.5469	31.36
13	Ogbor 2	27.282	31.03
14	Eziama Ward	27.6783	31.19
15	Umuogele	25.3117	30.15
16	Old GRA	28.3716	31.34
15	Industrial	27.9218	31.22
18	Crown Land	29.1304	31.4
19	Ohanku	28.79	31.41
20	Ohabiam	26.1862	30.64

H₀: There's no significant difference in the LST of Aba neighbourhoods between 1986 and 2025

A striking feature of the dataset is the observation that higher density areas (like Ohanku, Osusu and Asaokpuaja) though with consistent higher LSTs had comparable minimal increases of LST about +2.6°C, +2.76°C and +2.81°C respectively, while low-density areas (like Umuogele, Umumba/umuebeke and Ohabiam) though with consistent lower LSTs recorded higher LST increases of +4.8°C, +4.75°C and +4.45°C. In fact, the understanding of intra-urban thermal dynamics as well as the comparative review of LST changes across all neighborhoods in Aba over the study epochs provided important insights. At least it revealed distinct trends in the transitional-urban and suburban neighborhoods using Umuogele, (a suburban/low/rural periphery), and the Crown Land, the city's most urbanized zone (transitional-urban neighbourhood) as examples to highlight the contrast in thermal responses to urbanization over time.

Generally, net LST rise between 1986 and 2025 was widest in the rural and peri-urban zones (low density neighbourhoods) and smallest in the transitional-urban sections (medium density neighbourhoods), underscoring the thermal vulnerability of peri-urban landscapes, where land use transitions are often more abrupt and unregulated. This corresponds to documented evidences in land use transformations in many peri-urban environments, where vegetative and agricultural lands are progressively converted for developmental projects, often without accompanying green infrastructure (Hajer *et al.*, 2023; Bethel *et al.*, 2020; Adeaga, *et al.*, 2019). Recent literatures reinforce this observation; studies such as Melese *et al.*, (2025) and Zhu *et al.*, (2025) noted that it is normal for rural zones undergoing rapid densification to experience LST increases, largely driven by loss of vegetative cover and proliferation of impervious materials. Moreover, Chen, *et al.*, (2022) emphasize that peri-urban areas in sub-Saharan Africa are particularly susceptible to heat stress escalation due to their exposure to uncoordinated development and infrastructural lag. While on the contrary, the thermal behaviour of urban cores often displays slower yet persistent increases, due to saturation of impervious surfaces, high building density, and limited capacity for further structural change (Hajer *et al.*, 2023, Bethel *et al.*, 2020).

For instance, the Umuogele neighborhood, categorized as a low density / rural zone, recorded the lowest baseline LST of 25.31°C in 1986. This relatively low temperature aligns with Umuogele's rural status at the time, which likely featured high proportions of vegetated land cover and low development density. The net LST rise from 1986 to 2025 was 4.84°C or 19.11%. Conversely, the Crown Land neighborhood, representing the urban core (medium-density neighbourhood) of Aba, exhibited the highest LST values in both epochs. In 1986, the LST was 29.13°C. But the cumulative LST rise between 1986 and 2025 was 2.27°C or 7.80%, indicating a

stabilized yet consistently elevated thermal environment. Recent empirical studies show similar patterns in dense city centers. According to Goward (2013), urban hotspots demonstrate thermal inertia, where despite greening or planning efforts, legacy heat effects persist due to structural constraints and deep entrenchment of anthropogenic heat sources.

This comparative LST differentia analysis in peri-urban (rural) and core urban neighbourhoods where for instance Umuogele and Crown Land neighbourhoods have been used as representative illustration for all the neighbourhoods in the study provides critical insights into the spatial disparities in LST trends within the same urban system. While Crown Land remains a chronic heat zone with modest fluctuations, Umuogele's experience reflects acute thermal escalation due to developmental transition and insufficient planning frameworks to address the emerging challenges. These findings align with the observations of LST amplification in formerly rural or peri-urban regions (Zhou *et al.*, 2011). Furthermore, the differential rates of LST increase (19.11% in Umuogele versus 7.80% in Crown Land) underscore the asymmetric impacts of urbanization, where thermal exposure risks shift outward from the core to the periphery as cities expand. Such shifts demand targeted thermal governance strategies that account for land-use-specific vulnerabilities and prioritize green infrastructure integration in new development zones.

These LST dynamics as observed in the neighbourhoods, 1986 and 2025, reveal a dual narrative: persistent heat accumulation in the urban core and rapid thermal transformation in the peri-urban fringe. These findings illustrate the non-uniform nature of urban warming, with critical implications for climate-sensitive planning in fast-growing African cities. This also suggest that mitigation actions and policy interventions need to be tailored according to the situation observed in each scenario or neighbourhood.

Furthermore, the student's t-test (paired two-sample for means) performed at 0.05 significant level to examine temporal variations in LST across neighbourhoods between the two epochs revealed a statistically significant difference in the LST of Aba neighbourhoods between 1986 and 2025 further confirming a significant change in the development density:

Table 8: t-Test: Paired Two Sample for Means

	1986	2025
Mean	27.50613	31.071
Variance	1.161341709	0.128452
Observations	20	20
Pearson Correlation	0.940749797	
Hypothesized Mean Difference	0	
Df	19	
t Stat	21.24553557	
P(T<=t) one-tail	5.29501E-15	
t Critical one-tail	1.729132812	
P(T<=t) two-tail	1.059E-14	
t Critical two-tail	2.093024054	

Above reveals that the mean LST in 1986 is 27.51 while 2025 has a mean of 31.07. The result showed a strong positive correlation (0.94). A t-statistic (21.2422) greater than the t-critical (2.0930) indicates that there is a significant difference in the LST of Aba neighbourhoods between 1986 and 2025. Thus, H_0 was rejected.

5.0 Conclusion:

Overall, the integration of descriptive and inferential analyses demonstrates that the observed spatial variations in the LST of Aba urban are not only evident across the identified twenty (20) neighbourhoods, but are also statistically significant over time and strongly influenced

by development density, thereby confirming the role of urbanization in intensifying neighbourhood-scale thermal conditions. The study found the prevalence of persistent heat accumulation in the urban core and rapid thermal transformation in the peri-urban fringe. These findings illustrate the non-uniform nature of urban warming, with critical implications for climate-sensitive planning in fast-growing African cities. In fact, the results from this study indicate that the increase in LST across the study area is both temporally significant and spatially structured, with development density emerging as a key explanatory factor. While all neighbourhoods have warmed significantly over time, medium-density areas consistently exhibit higher LST values, confirming the role of urban development in intensifying neighbourhood-scale heat conditions.

Recommendations:

Based on the study findings, the following recommendations are made to address the challenges of intra-urban land surface temperature variability in Aba, South-east, Nigeria:

1. Promotion of Sustainable Urban Planning and Effective Development Control:

Greater Aba Development Authority (GADA) and its affiliate town planning authorities should promote of sound urban planning interventions that will help guide the urban growth of Aba in a sustainable manner. They should design and implementation of urban layouts plans that favour the incorporation of green spaces to reduce UHI effects. Particularly, the observed thermal variability between the core-urban and the peri-urban neighbourhoods of Aba calls for sustained urban heat management policies, underpinned by spatially explicit

data and equitable planning approaches to ensure climate resilience across all neighborhoods.

2. **Monitoring and Evaluation:** There is the need to continuously monitor LST variations using remote sensing and GIS technologies to assess the effectiveness of implemented environmental measures in the study area. By implementing a continuous monitoring program that helps to gain real-time insights, it is possible to evaluate the impact of any implemented environmental mitigative action.
3. **Public Awareness and Participation:** Public enlightenment on the dangers of urban heat escalation and benefits of green spaces and sustainable urban practices is crucial. This will help in gaining their support and active participation in environmental initiatives. The Abia State Orientation Agency is to specifically lead this aspect while collaborating with GADA.
4. **Award of Incentives:** Government through GADA needs to start awarding incentives to developers who integrate green infrastructure or urban heat reduction strategies into their projects as this is vital for advancing sustainable urban development.

This study believes that Aba can successfully manage its urban development, mitigate LST variability and create a more sustainable and livable urban space by implementing the above recommendations.

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EFFECT OF CLIMATE VARIABILITY ON CEREALS YIELD: ADAPTATION STRATEGIES IN NIGER STATE, NIGERIA

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ABSTRACT

Globally, climate variability is one of the greatest socioeconomic and biophysical challenges confronting the world in the 21st century. Climate variability is increasingly affecting the livelihoods of people as they experience negative impacts of climate variability given their lack of capacity to prepare for and cope with its effects. One of the major limitations to cereals yields in Nigeria can be attributed to climate variability. Hence, this study assessed adaptation strategies to curb the effect of climate variability on cereals yield in Niger State and determine adaptation strategies employed by farmers to mitigate the impact of climate variability on cereals yield in Niger State. The study adopted survey research design. Purposive sampling technique was employed to select Badeggi from Katcha LGA in Zone A, Paiko was selected in Paikoro LGA in Zone B and Wushishi from Wushishi LGA in Zone C based on the predominance of maize and rice production and concentration of smallholder farmers. Primary data were used in this study. The primary data were obtained by the researcher through the administration of structured questionnaire and conducting of interview. The study further revealed that across the 12 items, the average percentage of Strongly Agree (30.1%) and Agree (53.1%) shows that more than four-fifths of the farmers positively perceive the existence and negative impacts of climate variability on cereal yields. The study concluded that, a large percentage of the respondents used adaptation strategies. The study further revealed that majority of the respondents generally experience significant constraints in adopting climate adaptation strategies. It thereby recommends that government and agricultural agencies should increase the number of trained extension workers in farming communities and federal and state governments should expand low-interest credit schemes to cereal farmers.

Keywords: Adaptation Strategies, Cereals Yield, Climate Variability, Rainfall, Temperature,

1. Introduction

The implications of climate variability on agricultural productivity have become a critical area of interest as a large proportion of the population depends on agriculture for livelihood and food security. This study aligns with both national and global objectives to combat the adverse effects of climate variability on agriculture. Since, this study contributes to the global discourse on climate variability and agricultural adaptation, this research study aligns with Sustainable Development Goal 13 (Climate Action) and Goal 2 (Zero Hunger), as well as Nigeria's National Adaptation

Strategy and Plan of Action for Climate variability (NASPA-CC). By identifying adaptation measures to combat effect of climate variability on cereal yields, farmers, researchers and policymakers can work towards ensuring sustainable food production, improving livelihoods, and safeguarding food security in Nigeria (Yahaya *et al.*, 2025). Climate variability, which poses a serious threat to crop production, especially in tropical regions like Nigeria. The effect of climate variability are at a scale that need efforts to prevent additional rise and ability to adopt strategies to cope with the climate change. While poor people, especially in Africa, are contributing less to the climate variability with their simple living they are most vulnerable especially to problems of increasing temperature, water scarcity, and food security among others (Komolafe *et al.*, 2023). Maize and rice are major staple crops in Nigeria and a vital component of food security in Niger State, is highly sensitive to temperature fluctuations, particularly during critical stages of growth such as pollination and grain filling. Knowledge of this study will provide empirical evidence on strategies for mitigating against the menace of climate variability on cereals yields in Niger State. This might enable maize farmers in Niger State and invariable in Nigeria to understand the strategies to adopt to limit the effect of temperature rise on maize yields which will lead to greater maize yields, safeguard food security and prevent potential food crises in the region.

Adaptation to temperature rise is modifications by nature or human systems in reaction to either actual or expected increase in temperature which reduces harm or exploits beneficial opportunities (Komolafe *et al.*, 2023) Adaptations to climate variability are actions taken to help communities and ecosystems moderate, cope with, or take advantage of actual or expected changes in climatic conditions (Samuel and Ikpe, 2024). Climate variability adaptation refers to adjustments in management strategies to actual or expected temperature rise or their effects, in order to reduce risks or realise opportunities. Yahaya *et al.* (2025) added that with the use of drip irrigation or precision agriculture, farmers can ensure that crops receive the right amount of water at the right time, reducing water waste and ensuring optimal growth. There are many adaptation strategies in the agricultural sector for maximum yield. These include the use of improved crop varieties, capacity building and training, building of strong partnerships between farmers, researchers, government agencies, and other stakeholders, adjusting the timing of planting and changing planting date can make farmers optimise the growing conditions for their crops and minimise the risks of temperature rise. Adaptation is the adjustment of natural or human systems in response to current or expected climate variability and its effects, to moderate negative consequences and take advantage of any opportunities (Samuel and Ikpe, 2024). Climate variability adaptation is the process of adjusting to the effects of climate variability. More so, Ankrah *et al.* (2023) established that delayed sowing time improves crop yield, and supplementary irrigation, increased fertilizer application, soil and moisture conservation practices. Didiso and Hunegnaw (2022) noted that using improved crop varieties, mixed crop livestock farming, construction of soil and water conservation, adjusting planting date (early and late planting) and enhancing irrigation schemes (including water harvesting) were also adoption strategies. Leaving temperature rise, without mitigation is generally hazardous to the agriculture sector; but with adequate adaptation methods in place, vulnerability can be adequately checked.

Adaptation strategies might also include planting cover crops, drought resistant varieties, mulching, green manuring, crop rotation, organic manure, mixed cropping, shifting cultivation, minimum tillage, alley cropping. This was buttressed by Adeagbo *et al.* (2021) who asserted that adaptation strategies of maize to temperature rise at the farm level includes changes in crop

management practices such as planting dates, planting densities, crop varieties, livestock management practices and land use and management such as fallowing, tree planting or protection, irrigation and water harvesting, soil and water conservation measures, tillage practices, soil fertility management. Adaptation aims to moderate or avoid harm for people, and is usually done alongside climate variability mitigation. There are many adaptation strategies which are expected to be adopted in the agricultural sector for maximum yield. Ankrah *et al.* (2023) noted that effective climate variability strategies are crucial in the fight against climate variability in reducing the adverse effects. Hence, the goal of adaptation is to reduce the risks from the harmful effects of climate variability. Without adaptation, climate variability will generally be detrimental to the agricultural sector, but with adaptation, vulnerability can be largely reduced and effective agricultural outputs can be guaranteed.

Despite the need to adopt adaptation strategies to help farmers mitigate against effect of temperature rise. Maize farmers might encounter challenges in adopting the strategies. Yahaya *et al.* (2025) asserted that understanding the specific impacts of temperature rise on maize yield in Nigeria is crucial for developing effective adaptation strategies that can help mitigate challenges and build resilience in the agricultural sector. However, the effectiveness of these measures can be constrained by factors such as inadequate access to water for irrigation, knowledge gaps, financial limitations, inadequate institutional support and lack of access to resources are critical for sustaining maize farming. Social and cultural limits to adaptation can be related to the different ways in which people and groups experience, interpret and respond to rise in temperature. This is because individuals and groups may have different risk tolerances as well as different preferences about adaptation measures, depending on their worldviews, values and beliefs. Komolafe *et al.* (2023) also asserted that inadequate training, lack of awareness, credit constraint, low extension agent contact, low farms' income, farmers' education and non-availability of organic manure are the challenges farmers' encounter. This study also intends to assess the challenges Maize farmers might encounter in adopting their adaptation strategies in Niger State.

Niger State is recognised as one of the leading maize-producing states in Nigeria, benefiting from relatively fertile land and a sizeable farming population. However, the increasing temperature rise, frequency of heat stress, unpredictable rainfall patterns, and prolonged dry spells are undermining maize productivity, with significant implications for household food security and income generation. By identifying the challenges faced by farmers and assessing the adaptation strategies in use, the study will generate actionable insights that can inform targeted interventions by policymakers, extension services, and development agencies.

The study will also revealed the challenges maize farmers encounter in adopting adaptation strategies in Niger State in maximising the maize yields. This will lead to proffering recommendations which will help to remediate the situations to maximise the maize yields and outputs. By identifying the challenges faced by farmers and exploring effective adaptation strategies, this study will contribute to the development of sustainable agricultural practices. Although the study focuses on Niger State, it is believed that the result generated from this study might be relevant to other states of the country as well as other countries with similar climate and socio-economic structures. Although some farmers in Niger State have begun adopting adaptation strategies to cope with the changing climate, these efforts remain largely undocumented and unstructured. This study bridge the gap by identifying and analysing existing adaptation strategies.

Despite the economic importance of maize and rice, they have not been produced in such quantity that could meet food and industrial needs of Nigeria (Samuel and Ikpe, 2024). This is because major maize and rice production areas have been experiencing crop yield reduction. One of the major limitations of cereals yields in Nigeria can be attributed to climate variability. Niger State, known for its agricultural economy has witnessed noticeable changes in its climatic conditions, including increased average temperatures and prolonged dry spells. These shifts have begun to disrupt traditional farming calendars, reduce soil moisture availability, and increase the incidence of pest and disease outbreaks all of which negatively impact maize production. Climate variability is increasingly affecting the livelihoods of people as they experience negative impacts of climate variability given their lack of capacity to prepare for and cope with its effects. The demand for maize and rice are increasing daily, because they are major staple food for human and animals. In view of the demand for maize, Nigeria and international bodies such as Food and Agriculture Organization (FAO) have developed interest in promoting maize production for households food security and poverty alleviation. However, despite the great potential of Nigeria in maize and rice production, in northern part of Nigeria where most of the maize are produced experienced frequent occurrence of drought occasioned by cessation of rain and rise in temperature during the growing season. In order to curb this menace associated with the effect of climate variability on cereals yields, adaptation strategies were expected to be adopted. Also, studies on the adaptation strategies farmers adopt and the challenges they face in adopting adaptation strategies are scarce. Hence, this study filled in the gap. The main aim of the study was to investigate the effect of climate variability on cereals yields considering the adaptation strategies in Niger State, Nigeria.

2. Theoretical Framework

Niger State have witnessed tremendous increase in temperature due to climate variability. This could probably be due to ceasation of rainfall during raining season. Assessing the effects of temperature rise on maize yields, adaptation strategies of farmers and the challenges that usually arise in the farmers' implementation of the strategies. Hence, this theory underpinning this study is the resilience theory. Resilience theory explores the capacity of social-ecological systems to absorb disturbances and maintain function in the face of change. Crawford S. Holling was the first to integrate the already available primary elements of the ecosystem resilience theory in several phases to obtain a closed system in 1965/66 (Gößling-Reisemann *et al.*, 2018). According to him, resilience entails the evolutionary adaptation of organisms and animal populations to changes in the environment and to human interventions. Resilience means the skills, abilities, knowledge, and insight that accumulate over time as people struggle to surmount adversity and meet challenges (Hersberger, 2011). Ledesma (2014) also defined resilience as the ability to bounce back from unfavourable conditions, adversity, frustration and misfortune. Resilience is not a stable, permanent characteristic which should be maintain as it depends on the setting, the moment and definitely the interaction between individual and the surrounding environment (Bertsia and Poulou, 2023).

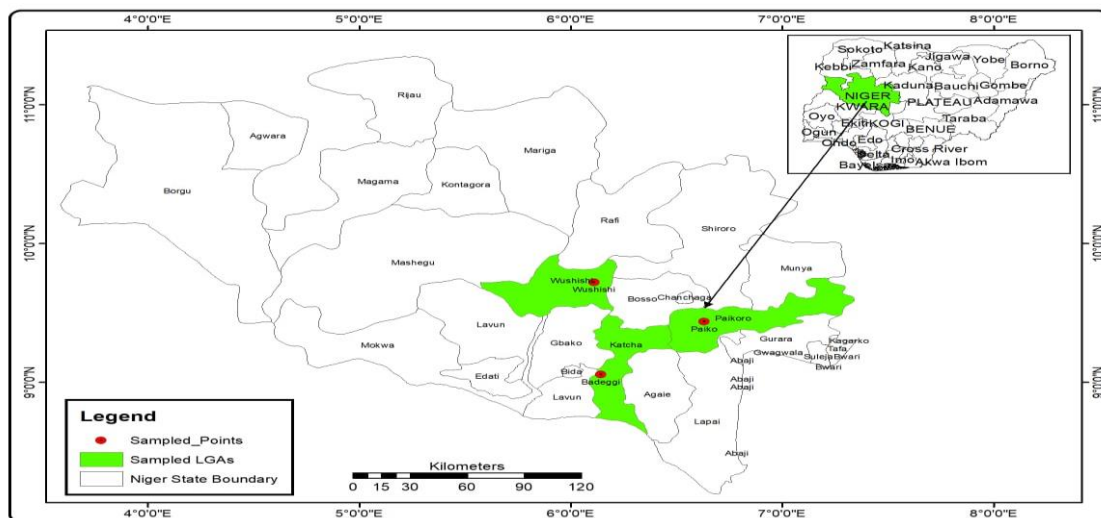
The theory describes one's ability to recover from negative life experiences and become stronger while overcoming them. Resilience theory entails a socio-technical system's ability to maintain its stability under dynamic changes in system structure and environment, irregular conditions and limited predictability. Hence, resilience theory open the floor for introducing complementary approaches to dealing with dynamic changes in the environment and irregular weather conditions.

It also involves the use of adaptive habits which in turn help to beat the odds of dynamic changes in the environment and irregular weather conditions.

Applying resilience theory to this study, in this 21st century, farmers are confronted with a large number of different and complicated weather conditions and they need to adjust to this constantly changing environment. The theory emphasises the need to build resilience within Nigeria's agricultural systems to withstand and adapt to the impacts of climate variability. This involves enhancing the adaptive capacity of farmers, promoting diversification of crops and income sources, and improving the resilience of agricultural infrastructure to climate-related risks. Farmers are faced with the threats of temperature rise due to climate variability provoking negative productivity implications for farm yields. Farmers are at risk since there is no guarantee for good yields of growing crops when there is any rise in temperature as the crops might dry up. As the farmers adjust and take up measure to overcome this menace of rise in temperature, they become stronger. Hence, resilience reduce the negative effect of temperature rise and strengthen adaption strategies that could be used to mitigate the negative effects. This will also involve the need to take actions and implement holistic programmes in order to enhance farmers' ability to enhance greater crops yields.

3. The Study Area

Niger State, located at North Central geo-political zone of Nigeria is one of the 36 states of Nigeria created on 3rd February 1976 out of the defunct North Western state. Administratively, the State comprises of 25 Local Government Areas with Minna as the capital. The LGAs are grouped into three Administrative Zones: A, B and C with 8, 9 and 8 Local Government Areas respectively. Each LGA is subdivided into districts and the districts are further subdivided into 274 wards and villages. Geographically, Niger State lies between latitude $8^{\circ}20' - 11^{\circ}30' \text{ N}$ and Longitude $3^{\circ}30' - 7^{\circ}20' \text{ E}$. It shares boundaries borders with republic of Benin (West), Zamfara State (North), Kebbi (North-West), Kogi (South), Kwara (South West), Kaduna (North-East) and the FCT (South-East). The state is one of the largest states in Nigeria covering about $86,000 \text{ km}^2$ (or about 8.6million hectares) representing about 9.3% of the total land area of the Country. The state's major rivers are: Niger, Kaduna, Gbako, Eko, Gurara, Ebba, Ega, Mariga and their tributaries. The State is the largest in the country in terms of landmass (about 10% of the country's total) with a total land area of $76,363 \text{ km}^2$ (over 7.8 million hectares). Niger State has a typical Middle Belt tropical savanna climate characterised by distinct dry and wet seasons with annual rain fall varying from 1,100mm in the



northern parts to 1,600mm in the southern parts. The maximum temperature (usually not more than 30°C) is recorded between March and June, while the minimum (22°C) is usually between December and January. The rainy seasons last for about 150 days in the northern parts to about 120 days in the southern parts of the state. Generally, the fertile soil and hydrology of the state permits the cultivation of most of Nigeria's staple crops and still allows sufficient opportunities for grazing, fresh water fishing and forestry development. Niger's State geology is characterised by both basement complex rocks and Cretaceous sedimentary rocks. About half of the state is underlain by the basement complex which include granitic rocks like leucocratic and biotite granites. The remaining half is covered by Cretaceous sedimentary rocks. Map of Niger State showing the study area is presented in figure 1.

Figure 1: Map of Niger State showing the study area (Geography Department, Federal University of Technology Minna, Niger State)

4. MATERIALS AND METHODS

The study adopted a survey research design. Primary data were obtained by the researcher through the administration of structured questionnaire and conducting of interview. The questionnaire were administered to the literate framers who can read and write. While, interview were conducted for the illiterate who cannot read and write. Data for the study were collected from the three zones in Niger State. Purposive sampling technique was employed in the study. Firstly, one Local Government Area (LGA) was selected from each zone purposefully based on the predominance of maize and rice production and concentration of smallholder farmers in the area. The selected LGAs are Katcha, Paikoro and Wushishi. Purposive sampling technique was used to select Badeggi from Katcha LGA in Zone A, Paiko were selected in Paikoro LGA in Zone B and Wushishi from Wushishi LGA in Zone C. Also, purposive sampling technique was used to select 100 maize and rice farmers from each of the selected study area totalling to 300. The respondents comprised of male and female maize and rice farmers above twenty (20) years of age and who must have lived in the study area for at least ten (10) years and who were identified through the "Sarkin Noma" (Head of the Farmers) and the village Heads. This is because maize and rice farmers above twenty years old are used to farming system and will be well knowledge on the information needed about the effect of climate variability on cereals yield in the area. Therefore, the sample size of the study were 300 respondents selected using simple random sampling technique. The structured questionnaire were administered to literate famers. While, illiterate farmers were interviewed and then the questionnaire were ticked based on their responses by the researcher. Three hundred questionnaires were administered but only two hundred and seventy-two questionnaires were retrieved after eight weeks of administering the questionnaires. During data entry, responses from twenty-nine of the questionnaires were invalid and not used for data analysis. Hence, two and forty-three questionnaires were retrieved with valid responses. The data obtained were analysed using frequency and percentage using Statistical Package for Social Science (SPSS) and presented in tables and clustered bar chart.

5. RESULTS AND DISCUSSION

The analysis of demographic data of the respondents is presented in Table 1

Table 1: Demographic Data of the Respondents

	Attributes	Frequency	Percent
Gender	Male	201	82.72
	Female	42	17.28
Age	21-30	21	8.64
	31-40	39	16.05

	41-50	72	29.63
	50-60	83	34.16
	61 and above	28	11.52
Length of years as a farmer	0-10	28	11.52
	11-20	52	21.40
	21-30	78	32.10
	30-40	62	25.51
	41 and above	23	9.47
Educational status	No Formal Education	32	13.17
	Primary School	40	16.46
	Secondary School	73	30.04
	Tertiary	98	40.33
Membership to a farmers' association	Yes	58	23.87
	No	185	76.13
Type of farming	Subsistence	41	16.87
	Commercial	202	83.13

(Authors, Fieldwork 2025)

Table 1 shows the demographic data of the respondents. The table shows that majority of the respondents are male, 201 accounting for 82.72% of the respondents, while only 42 accounting for 17.28% of the respondents are female, suggesting that farming activities in the study area are predominantly male-dominated. The table also revealed that, the respondents are mostly within the 50–60 years age group (34.16%), followed by those aged 41–50 years (29.63%), those aged 31–40 years are 16.05% and those aged 61 and above account for 11.52 of the respondents. Only 8.64% are between 21–30 years, indicating that younger individuals are less involved in cereals farming in the study area. Based on farming experience, most respondents have been engaged in farming for a considerable period. The largest group has 21–30 years of farming experience (32.10%), followed by 30–40 years (25.51%), then those with 11–20 years of experience with only 9.47% having 41 years and above farming experience. Only 11.52% have 0–10 years of experience. This indicates that majority of the farmers are experienced farmers.

Furthermore, the table shows that a significant percentage of the respondents have higher educational attainment. While 13.17% have no formal education and 16.46% completed primary school, 30.04% have secondary education and 40.33% have tertiary education. This indicates a relatively well-educated respondents which may positively affect their responses effectively. Membership in farmers' associations appears low, with only 23.87% being a registered member of a family association, compared to 76.13% who are not members. Also, most respondents are engaged in commercial farming (83.13%), while only 16.87% practice subsistence farming. This indicates that the majority of the farmers are oriented toward market-driven production rather than farming solely for household consumption.

Perception of Farmers on the Effect of Climate Variability on Cereals Yield in Niger State

Frequency and percentages were used to ascertain the perception of farmers on the effect of climate variability on cereals yield in Niger State as shown in Table 2.

Table 2: Frequency and Percentages on Perception of Farmers on the Effect of Climate Variability on Cereals Yield in the Study Area

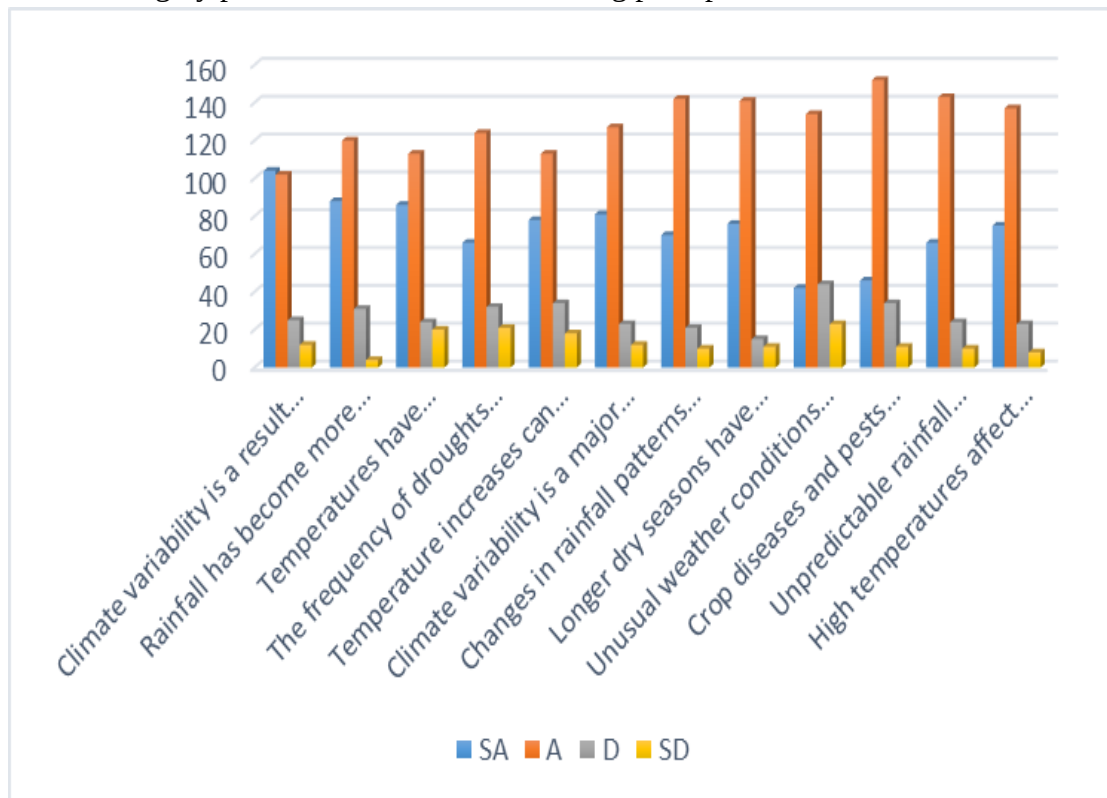
S/N	Items	SA	A	D	SD
1	Climate variability is a result of natural and human-induced factors.	104 (42.8%)	102 (42.0%)	25 (10.3%)	12 (4.9%)
2	Rainfall has become more unpredictable in recent years	88 (36.2%)	120 (49.4%)	31 (12.8%)	4 (1.6%)
3	Temperatures have increased in my area over time.	86 (35.4%)	113 (46.5%)	24 (9.9%)	20 (8.2%)
4	The frequency of droughts and dry spells has increased in recent years	66 (27.2%)	124 (51.0%)	32 (13.2%)	21 (8.6%)
5	Temperature increases can affect farming activities.	78 (32.1%)	113 (46.5%)	34 (14.0)	18 (7.4%)
6	Climate variability is a major challenge affecting crop yields	81 (33.3%)	127 (52.3%)	23 (9.5%)	12 (4.9%)
7	Changes in rainfall patterns have led to lower crop yields in my farm	70 (28.8%)	142 (58.4%)	21 (8.6%)	10 (4.1%)
8	Longer dry seasons have reduce crop yields	76 (31.3%)	141 (58.0%)	15 (6.2%)	11 (4.5%)
9	Unusual weather conditions have damaged my crops.	42 (17.3%)	134 (55.1%)	44 (18.1%)	23 (9.5%)
10	Crop diseases and pests have increased due to changing weather patterns	46 (18.9%)	152 (62.6%)	34 (14.0%)	11 (4.5%)
11	Unpredictable rainfall causes poor germination of seeds	66 (27.2%)	143 (58.8%)	24 (9.9%)	10 (4.1%)
12	High temperatures affect crop growth, flowering and maturity.	75 (30.9%)	137 (56.4%)	23 (9.5%)	8 (3.3%)
Average Percentage		30.1%	53.1%	11.3%	5.5%

(Authors, Fieldwork 2025)

Keys: Strongly Agree (SA), Agree (A), Disagree (D), Strongly Disagree (SD)

Table 2 shows the frequency and percentages on the perception of farmers on the effect of climate variability on cereals yield in the study area. The table revealed that a majority of respondents (84.8%) agree that climate variability arises from both natural and human-induced factors. Similarly, a high proportion (85.6%) believe that rainfall has become increasingly unpredictable in recent years. Also, farmers strongly believe that extreme weather events are becoming more frequent. About 78.2% agree that droughts and dry spells have increased, which aligns with their perception that rising temperatures affect farming activities with 78.6% agreement. The table also shows that a total of 85.6% of farmers agree that climate variability is a major challenge impacting crop yields. Likewise, 87.2% of respondents indicate that changes in rainfall patterns have reduced crop yields on their farms. The perception that longer dry seasons reduce crop productivity is also strongly supported by 89.3% of farmers. Farmers further attribute crop losses to unusual weather conditions, with 72.4% reporting that such conditions have damaged their crops. In addition, 81.5% believe that pests and diseases have increased due to changing weather patterns. Poor seed germination caused by unpredictable rainfall is identified by 86% of respondents, while 87.3% agree that high temperatures negatively affect crop growth, flowering, and maturity. The table further revealed that across the 12 items, the average percentage of Strongly Agree (30.1%) and Agree (53.1%) shows that more than four-fifths of the farmers positively perceive the existence

and negative impacts of climate variability on cereal yields. This implies that farmers in the study area have a highly positive awareness and a strong perception of the effects of climate variability on



cereals yield as farmers perceive climate variability as a major threat to agricultural productivity which adversely affect crop performance and yield outcomes. The perception of farmers on the effect of climate variability on cereals yield in the study area is further illustrated using clustered bar chart in Figure 2.

Figure 2: Clustered bar chart on perception of farmers on the effect of climate variability on cereals yield in the study area (Authors, Fieldwork 2025)

Adaptation Strategies Employed by Farmers to Mitigate the Impact of Climate Variability on Cereals Yield in Niger State

Frequency and percentages were used to ascertain adaptation strategies employed by farmers to mitigate the impact of climate variability on cereals yield in Niger State in Table 3.

Table 3: Frequency and Percentages on Adaptation Strategies Employed by Farmers to Mitigate the Impact of Climate Variability on Cereals Yield in the Study Area

S/N	Items	OU	U	RU	NU
1	Early cultivation/planting	12 (4.9%)	47 (19.3%)	111 (45.7%)	73 (30.0%)
2	Adjusting the timing of planting	59 (23.5%)	145 (59.7%)	39 (15.2%)	10 (1.6%)

3	Use of early maturing varieties of crops	63 (25.9%)	129 (53.1%)	38 (15.6%)	13 (5.3%)
4	Irrigation farming	47 (19.3%)	102 (42.0%)	63 (25.9%)	31 (12.8%)
5	Use of soil conservation techniques like bush fallowing, shifting cultivation, crop rotation, alley cropping	41 (16.9%)	56 (23.0%)	112 (46.1%)	34 (14.0%)
6	Purchase of water from vendors	76 (31.3%)	123 (50.6%)	34 (14.0%)	10 (4.1%)
7	Use of fertilizers	92 (37.9%)	108 (44.4%)	25 (10.3%)	18 (7.4%)
8	Migrate to neighbouring town	20 (8.2%)	65 (26.7%)	104 (42.8%)	54 (22.2%)
9	Planting of economic trees	73 (30.0%)	110 (45.3%)	42 (17.3%)	18 (7.4%)
10	Diverging from crops production to livestock rearing	15 (6.2%)	23 (9.5%)	153 (63.0%)	52 (21.4%)
11	Use of mixed farming	23 (9.5%)	96 (39.5%)	92 (37.9%)	32 (13.2%)
12	Use of mixed cropping	74 (30.5%)	152 (62.6%)	14 (5.8%)	3 (1.2%)
13	Enhancing irrigation schemes	14 (5.8%)	98 (40.3%)	121 (49.8%)	10 (4.1%)
14	Planting of drought resistant varieties of crops	34 (14.0%)	104 (42.8%)	93 (38.3%)	12 (4.9%)
15	Use of organic farming strategies such as mulching, green manuring, organic manure	72 (29.6%)	141 (58.0%)	21 (8.6%)	9 (3.7%)
Average Percentage		20.5%	42.9%	28.0%	8.6%

(Authors, Fieldwork 2025)

Often Used (OU) Used (U) Rarely Used (RU) Never Used (NU)

Table 3 shows the frequency and percentages on adaptation strategies employed by farmers to mitigate the impact of climate variability on cereals yield in the study area. The table shows that majority of the farmers employ a variety of adaptation strategies, though the degree of usage varies widely across practices. The most frequently adopted strategies include: mixed cropping which is often used by 30.5% and used by 62.6% of the respondents. Also, organic farming strategies (mulching, green manuring and organic manure) were often used by 29.6% and used by 58% of the respondents. Planting of economic trees is often used by 30% and used by 45.3% of the respondents. Use of early maturing varieties of crops was often used by 25.9% and used by 53.1% of the respondents. Adjusting the timing of planting is often used by 23.5% and used by 59.7% of the respondents. Purchasing of water from vendors was often used by 31.3% and used by 50.6% of the respondents. The high usage indicates growing water stress and limited availability of natural water sources. The use of fertilisers was often used by 37.9% and used by 44.4% of the respondents. The table revealed that moderately used strategies were irrigation, planting drought-resistant crop varieties, use of soil conservation techniques and mixed farming and the least used or rarely adopted strategies are diverging to livestock rearing which is often used by 6.2%, used by 9.5%, rarely and never used by 84.4%, migration to neighbouring towns which is often used by 8.2% and rarely/never used by 65%, early cultivation which is often used by 4.9% and rarely/never

used by 75.7% and enhancing irrigation schemes which is often used by 5.8% and rarely used by 49.8% of the respondents.

The average percentage showed that 20.5% of the respondents often used adaptation strategies, 42.9% used adaptation strategies, 28.0% rarely used adaptation strategies and only 8.6% of the respondents never used adaptation strategies. Also, the table also revealed a large percentage of the respondents used adaptation strategies. Hence, a large percentage of the respondents used adaptation strategies. Adaptation strategies employed by farmers to mitigate the impact of climate variability on cereals yield in the study area is presented in Figure 3.

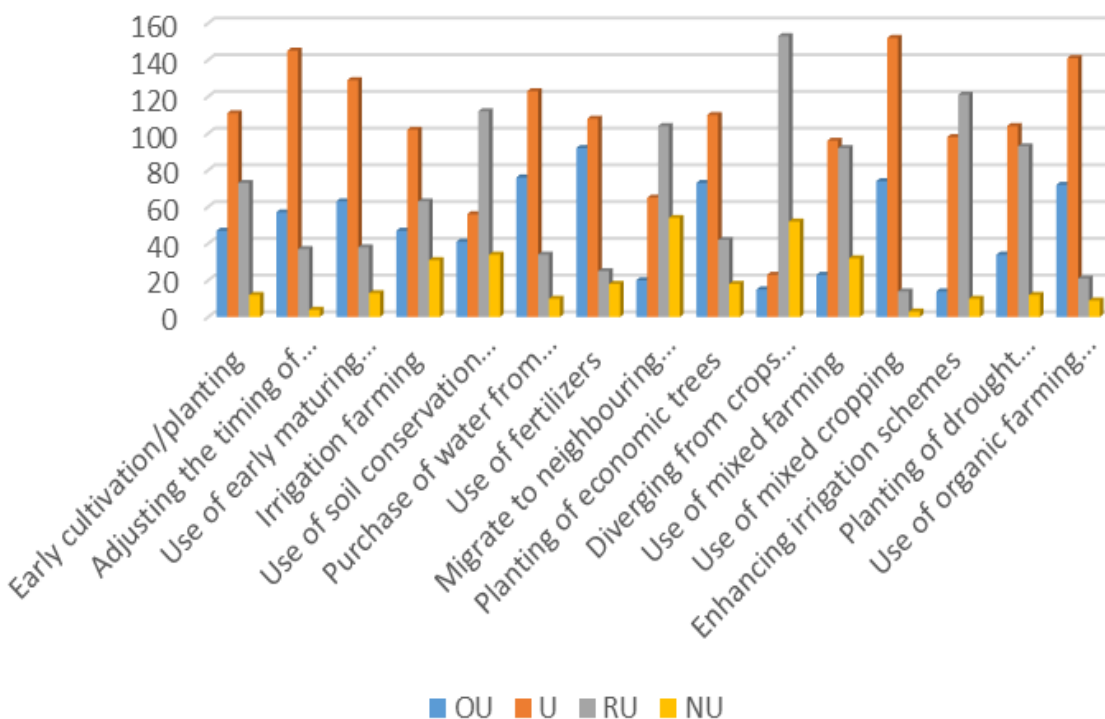


Figure 3:

Clustered Bar Chart on Adaptation Strategies Employed by Farmers to Mitigate the Impact of Climate Variability on Cereals Yield in the Study Area
(Authors, Fieldwork 2025)

Challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability

Frequency and percentages on the challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability is presented in Table 4.

Table 4: Frequency and Percentages on the Challenges Farmers Encounter in their Use of Adaptation Strategies to Curb Impact of Climate Variability

S/N	Items	SA	A	D	SD
1	Inadequate awareness/knowledge on temperature rise adaptation strategies	64 (26.3%)	121 (49.8%)	32 (13.2%)	26 (10.7%)
2	None availability of credit	18 (7.4%)	112 (46.1%)	72 (29.6%)	41 (16.9%)
3	Inadequate capital	75 (30.9%)	108 (44.4%)	47 (19.3%)	13 (5.3%)
4	Inadequate access to water for irrigation	23 (9.5%)	78 (32.1%)	99 (40.7%)	43 (17.7%)
5	Poor government attention to temperature rise	64 (26.3%)	127 (52.3%)	34 (14.0%)	18 (7.4%)
6	Ineffectiveness of indigenous methods/organic farming strategies	71 (29.2%)	110 (45.3%)	42 (17.3%)	20 (8.2%)
7	Inadequate access to improved seed varieties	65 (26.7%)	83 (34.2%)	64 (26.3%)	31 (12.8%)
8	Irregularities of extension services	34 (14.0%)	132 (54.3%)	62 (25.5%)	15 (6.2%)
9	Inadequate access to fertile land	47 (19.3%)	108 (44.4%)	72 (29.6%)	16 (6.6%)
10	Low agricultural outputs and farms' income	56 (23.0%)	127 (52.3%)	37 (15.2%)	23 (9.5%)
11	Non-availability of organic manure	76 (31.3%)	123 (50.6%)	34 (14.0%)	10 (4.1%)
Average Percentage		22.20%	46.0%	22.2%	9.6%

(Authors, Fieldwork 2025)

Strongly Agree (SA), Agree (A), Disagree (D), Strongly Disagree (SD)

Table 4 shows the frequency and percentages on the challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability. The table shows that a high percentage of respondents agreed that poor government attention (78.6%), inadequate awareness and knowledge on adaptation strategies (76.1%), inadequate capital (75.3%), perceived ineffectiveness of indigenous/organic methods (74.5%), low farm output and income (75.3%), and non-availability of organic manure (81.9%), irregularities in extension services (68.3%), inadequate access to fertile land (63.7%), and inadequate access to improved seed varieties (60.9%) and none availability of credit (53.5%) are the challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability. The table further revealed that the average percentages indicated that 22.2% strongly agreed and 46.0% agreed with the listed challenge items. This shows that 68.2% of the respondents generally experience significant constraints in adopting climate adaptation strategies. Also, 22.2% disagreed and 9.6% strongly disagreed, suggesting that opposition to these challenges is minimal. The respondents also agreed that they experienced inadequate access to water for irrigation (41.6%). The table further revealed that the average

percentages indicated that 22.2% strongly agreed and 46.0% agreed with the listed challenge items. This shows that 68.2% of the respondents generally experience significant constraints in adopting climate adaptation strategies. Also, 22.2% disagreed and 9.6% strongly disagreed, suggesting that opposition to these challenges is minimal. Also, Samuel and Ikpe (2024) result showed that adaptation strategies are constrained by inadequate access to water resources for irrigation farming, inadequate knowledge on climate variability adaptation strategies and financial constraint. This study shows that challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability are poor government attention, inadequate awareness and knowledge on adaptation strategies, inadequate capital, perceived ineffectiveness of indigenous/organic methods, low farm output and income, non-availability of organic manure, irregularities in extension services, inadequate access to fertile land, and inadequate access to improved seed varieties, none availability of credit, inadequate access to water for irrigation. The challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability is further illustrated using clustered bar chart in Figure 4.

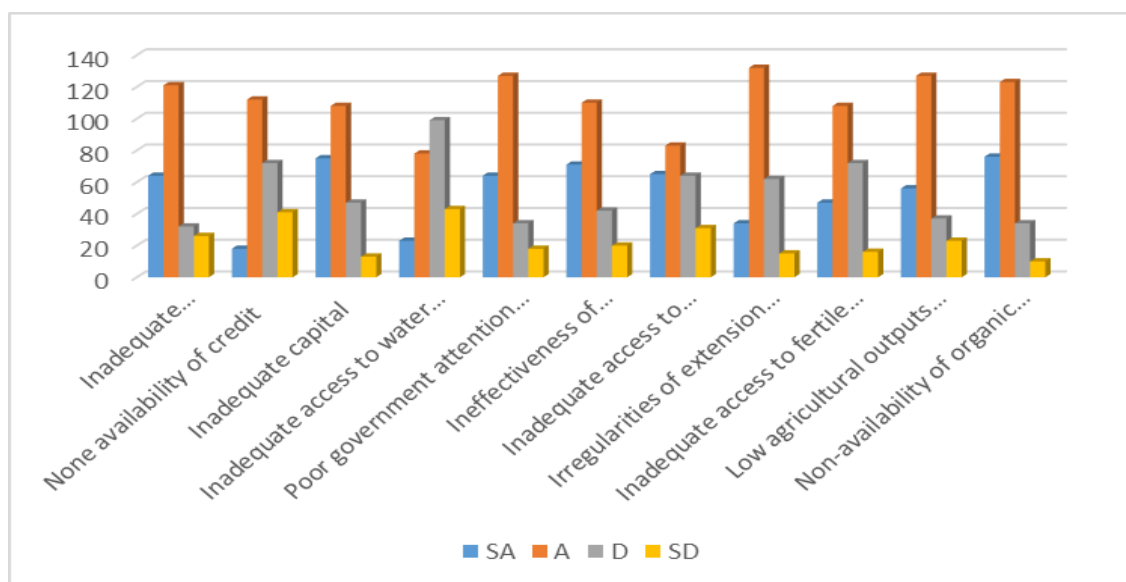


Figure 4:

Challenges Farmers Encounter in their Use of Adaptation Strategies to Curb Impact of Climate Variability (Authors, Fieldwork 2025)

6. Summary of Findings

The result from table 1 shows that 73.7% of farmers perceive an increase in temperature over time. It also shows that about 78.2% agree that droughts and dry spells have increased, which aligns with their perception that rising temperatures affect farming activities with 78.6% agreement. The table also shows that a total of 85.6% of farmers agree that climate variability is a major challenge impacting crop yields. As also revealed from the study, 87.2% of respondents indicated that changes in rainfall patterns have reduced crop yields on their farms. Table 4.6 revealed that the average percentage of Strongly Agree (30.1%) and Agree (53.1%) shows that more than four-fifths of the farmers positively perceive the existence and negative impacts of climate variability on their farming activities. The study revealed a highly positive awareness and a strong perception of the effects of climate variability on cereals yield as farmers perceive climate variability as a major threat to agricultural productivity which adversely affect crop performance and yield outcomes.

Table 2 shows the frequency and percentages on adaptation strategies employed by farmers to mitigate the impact of climate variability on cereals yield in the study area. The table shows that majority of the farmers employ a variety of adaptation strategies, though the degree of usage varies widely across practices. It is revealed from the table that the most frequently adopted strategies include: mixed cropping, organic farming strategies (mulching, green manuring and organic manure), planting of economic trees, and use of early maturing varieties of crops. The result in table 3 shows that challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability are poor government attention, inadequate awareness and knowledge on adaptation strategies, inadequate capital, perceived ineffectiveness of indigenous/organic methods, low farm output and income, non-availability of organic manure, irregularities in extension services, inadequate access to fertile land, and inadequate access to improved seed varieties, none availability of credit, inadequate access to water for irrigation.

7. DISCUSSION

The study revealed that a majority of respondents (84.8%) agree that climate variability arises from both natural and human-induced factors. Similarly, a high proportion (85.6%) believe that rainfall has become increasingly unpredictable in recent years. This unpredictability is further supported by the finding that 73.7% of farmers perceive an increase in temperature over time. Also, Komolafe *et al.* (2023) result showed perceived high temperature. Farmers also strongly believe that extreme weather events are becoming more frequent. In the same vein, Didiso and Hunegnaw, (2022) survey results about 81% of the respondents stated that, the amount of rainfall in the study area is decreasing. Farmers also strongly believe that extreme weather events are becoming more frequent. About 78.2% agree that droughts and dry spells have increased, which aligns with their perception that rising temperatures affect farming activities with 78.6% agreement. Similarly, Oparinde and Okogbue. (2018) results revealed that farmers face climate-related risk as temperature increased the production risk of maize farmers. The study also shows that a total of 85.6% of farmers agree that climate variability is a major challenge impacting crop yields which corresponds with that of Ogunjobi (2018) finding whose study revealed a significant negative relationship between increases in temperature and maize yields. Likewise, 87.2% of respondents indicate that changes in rainfall patterns have reduced crop yields on their farms. Also, Tajudeen *et al.* (2022) survey results indicate that rain-fed and climate variability negatively impacts crop productivity by decreasing crop yield and soil fertility, limiting the availability of soil water, increasing soil erosion, and contributing to the spread of pests. The perception that longer dry seasons reduce crop productivity is also strongly supported by 89.3% of farmers. Farmers further attribute crop losses to unusual weather conditions, with 72.4% reporting that such conditions have damaged their crops. In addition, 81.5% believe that pests and diseases have increased due to changing weather patterns. Poor seed germination caused by unpredictable rainfall is identified by 86% of respondents, while 87.3% agree that high temperatures negatively affect crop growth, flowering, and maturity. The study further revealed that across the 12 items, the average percentage of Strongly Agree (30.1%) and Agree (53.1%) shows that more than four-fifths of the farmers positively perceive the existence and negative impacts of climate variability on cereal yields. In similar vein, Akintonde *et al.* (2019) result revealed that maize farmers adopted different adaptation strategies against the effects of climate variability and have different perceptions about the effects of climate variability on maize production. The implies that farmers in the study area

have a highly positive awareness and a strong perception of the effects of climate variability on cereals yield as farmers perceive climate variability as a major threat to agricultural productivity which adversely affect crop performance and yield outcomes.

The study revealed that majority of the farmers employ a variety of adaptation strategies, though the degree of usage varies widely across practices. This agrees with the finding of Akintonde *et al.* (2019) whose result revealed that maize farmers adopted different adaptation strategies against the effects of climate variability. Also, Tajudeen *et al.* (2022) survey results indicated that farmers in this area are currently implementing techniques to adapt to changes in climate based on the type of crop grown. Similarly, Ankrah *et al.* (2023) revealed that adaptation strategies correlate with maize yields. The most frequently adopted strategies include: mixed cropping which is often used by 30.5% and used by 62.6% of the respondents. Also, organic farming strategies (mulching, green manuring and organic manure) were often used by 29.6% and used by 58% of the respondents. Planting of economic trees is often used by 30% and used by 45.3% of the respondents. Use of early maturing varieties of crops was often used by 25.9% and used by 53.1% of the respondents. Adjusting the timing of planting is often used by 23.5% and used by 59.7% of the respondents. Purchasing of water from vendors was often used by 31.3% and used by 50.6% of the respondents. The high usage indicates growing water stress and limited availability of natural water sources. The use of fertilisers was often used by 37.9% and used by 44.4% of the respondents. The study revealed that moderately used strategies were irrigation, planting drought-resistant crop varieties, use of soil conservation techniques and mixed farming and the least used or rarely adopted strategies are diverging to livestock rearing which is often used by 6.2%, used by 9.5%, rarely and never used by 84.4%, migration to neighbouring towns which is often used by 8.2% and rarely/never used by 65%, early cultivation which is often used by 4.9% and rarely/never used by 75.7% and enhancing irrigation schemes which is often used by 5.8% and rarely used by 49.8% of the respondents.

The average percentage showed that 20.5% of the respondents often used adaptation strategies, 42.9% used adaptation strategies, 28.0% rarely used adaptation strategies and only 8.6% of the respondents never used adaptation strategies. Similarly, Komolafe *et al.* (2023) result showed that majority mitigated climate variability with the adoption of organic manure, cover cropping, planting resistant varieties and mixed cropping. Also, Didiso and Hunegnaw (2022) study also identified that, the main adaptation measures being practiced by the farmers include using; improved crop varieties, crop-livestock mixed system, micro irrigation, soil and water conservation, adjusting planting date and income diversification activities. Kamuzora (2023) findings indicate that smallholder farmers adopted climate variability adaptation tactics such as drought-resistant maize varieties, intercropping, minimal tillage, adjusted planting dates, fertilizers, irrigation and short-duration maize varieties. Soom *et al.* (2024) result on the climate variability adaptation strategies used by the maize farming households revealed that most of the farmers adopted improved/multiple varieties, multiple planting dates and fertilizer application as climate variability adaptation strategies in the study area. Samuel and Ikpe (2024) result showed that the farmers used mixed cropping which was ranked, use of chemical fertilizers, and early planting. Also, the study revealed a large percentage of the respondents used adaptation strategies. This correlates with the finding of Komolafe *et al.* (2023) whose result showed that 95.0% of the farmers mitigated against weather variability. Hence, a large percentage of the respondents used adaptation strategies.

The study showed that a high percentage of respondents agreed that poor government attention (78.6%), inadequate awareness and knowledge on adaptation strategies (76.1%), inadequate capital (75.3%), perceived ineffectiveness of indigenous/organic methods (74.5%), low farm output and income (75.3%), and non-availability of organic manure (81.9%), irregularities in extension services (68.3%), inadequate access to fertile land (63.7%), and inadequate access to improved seed varieties (60.9%) and none availability of credit (53.5%) are the challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability. The study further revealed that the average percentages indicated that 22.2% strongly agreed and 46.0% agreed with the listed challenge items. This shows that 68.2% of the respondents generally experience significant constraints in adopting climate adaptation strategies. Also, 22.2% disagreed and 9.6% strongly disagreed, suggesting that opposition to these challenges is minimal. The respondents also agreed that they experienced inadequate access to water for irrigation (41.6%). The study further revealed that the average percentages indicated that 22.2% strongly agreed and 46.0% agreed with the listed challenge items. This shows that 68.2% of the respondents generally experience significant constraints in adopting climate adaptation strategies. Also, 22.2% disagreed and 9.6% strongly disagreed, suggesting that opposition to these challenges is minimal. Also, Samuel and Ikpe (2024) result showed that adaptation strategies are constrained by inadequate access to water resources for irrigation farming, inadequate knowledge on climate variability adaptation strategies and financial constraint. This study shows that challenges farmers encounter in their use of adaptation strategies to curb impact of climate variability are poor government attention, inadequate awareness and knowledge on adaptation strategies, inadequate capital, perceived ineffectiveness of indigenous/organic methods, low farm output and income, non-availability of organic manure, irregularities in extension services, inadequate access to fertile land, and inadequate access to improved seed varieties, none availability of credit, inadequate access to water for irrigation.

8. Conclusion

The study also settled that farmers possess a good awareness and understanding of climate variability. A large majority reported noticeable increases in temperature, more erratic rainfall patterns, prolonged dry spells, and more frequent extreme weather events. Many farmers attributed reduced yields, increased pest incidences, poor germination, and general crop stress to changing climatic conditions. Overall, farmers demonstrated high awareness and a strong perception of the negative impacts of climate variability on cereal production. It is also affirmed from the study that farmers in the area adopt a variety of strategies to mitigate climate risks.

The most widely used adaptation practices include mixed cropping, organic farming methods (mulching, green manuring, and organic manure), adjusting planting dates, planting economic trees, using fertilizers, and introducing early-maturing crop varieties. These practices indicate a strong willingness among farmers to adapt, despite limited access to resources. Less commonly adopted strategies include migration, diversification into livestock rearing, early planting, and enhanced irrigation systems, largely due to high cost, inadequate facilities, or limited knowledge. It is clear from the study area, that challenges farmers encounter are inadequate government support, insufficient knowledge of adaptation methods, limited capital, poor access to improved seed varieties, irregular extension services, inadequate availability of organic manure, lack of credit, water scarcity for irrigation, and limited fertile land further hinder their ability to cope

effectively with climate variability. These constraints collectively undermine farmers' resilience and reduce the effectiveness of their adaptation practices.

Recommendations

Based on the findings of the study, the following were recommended:

1. Since farmers reported good awareness of adaptation strategies but irregular extension support, government and agricultural agencies should increase the number of trained extension workers in farming communities.
2. Given the constraints of inadequate capital and lack of credit, it is essential that Federal and State governments should expand low-interest credit schemes to cereal farmers.
3. Since farmers reported non-availability of organic manure and low soil fertility; Government and NGOs should support the production and distribution of compost and organic manure.

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**Integrating Formal and Informal Waste Sectors for Improved Urban Service Delivery:
Evidence from Bauchi Metropolis, Nigeria**

Nabiha Auwal Aliyu & A.B. Shuaibu

Abstract

This study examines the inefficiencies of solid waste collection in Bauchi Metropolis, Nigeria, and identifies the legal, social, and economic requirements for integrating formal and informal/private waste sectors into a unified management system. A mixed-methods approach was adopted, involving 356 household surveys and supporting qualitative insights. Data were analysed using descriptive statistics and logistic regression. Findings reveal significant inefficiencies, including inadequate service coverage, irregular collection, low user satisfaction, and widespread illegal dumping. Institutional weaknesses such as poor enforcement of regulations, weak inter-agency coordination, and limited collaboration with private operators were also identified. Despite these challenges, there is strong public support for integration, indicating high reform potential. The study concludes that an integrated waste management system is essential for improving urban service delivery in Bauchi Metropolis. Policy recommendations emphasize strengthening enforcement mechanisms, formalizing public-private partnerships, expanding service coverage, and enhancing community participation.

Keywords: Environmental sustainability, Integrated waste management, Public-private partnership, Service delivery inefficiency.

1.0 Introduction

Rapid urbanization in developing countries has intensified challenges associated with solid waste management, particularly in rapidly growing cities where infrastructure development has not kept pace with population growth. In Nigeria, urban centres such as Bauchi Metropolis face significant difficulties in ensuring efficient waste collection, leading to environmental degradation and public health risks (World Bank, 2022). Inefficient waste management systems are often characterized by irregular collection, inadequate coverage, and reliance on informal disposal practices such as open dumping and burning (Kaza *et al.*, 2021; UNEP, 2023).

Contemporary studies emphasize that sustainable waste management requires an integrated approach that incorporates both formal (government-led) and informal/private sector actors

(Wilson *et al.*, 2020; Guerrero *et al.*, 2021). However, in many developing cities, these actors operate in fragmented systems with weak coordination, resulting in inefficiencies and service delivery gaps (Abarca-Guerrero *et al.*, 2021). Bauchi Metropolis exemplifies such a fragmented system, where government agencies, private collectors, and informal operators function with limited integration.

This study addresses two key objectives: first, to assess the current state and systematic inefficiencies of the solid waste collection system; and second, to identify the legal, social, and economic requirements necessary for integrating formal and private waste sectors into a unified system. By providing empirical evidence, the study contributes to the growing body of knowledge on Integrated Solid Waste Management (ISWM) and offers policy-relevant insights for improving urban environmental governance.

2.0 Literature Review

Integrated Waste Management (IWM) has emerged as a widely accepted framework for addressing the increasing complexity of urban solid waste systems. It promotes a holistic approach that covers the entire waste value chain generation, segregation, collection, transportation, treatment, recycling, and final disposal with the aim of minimising environmental impacts while maximising resource recovery. Rather than focusing solely on disposal, IWM emphasizes waste reduction, recycling, and sustainability through coordinated stakeholder involvement, including government agencies, private operators, and communities (UNEP, 2015; World Bank, 2018). Despite its global recognition, implementation in developing countries remains weak due to institutional fragmentation, inadequate infrastructure, and limited financial capacity.

Urban waste management in developing countries is increasingly challenged by rapid urbanisation, population growth, and changing consumption patterns. These pressures have outpaced the capacity of municipal authorities to provide efficient waste services. As a result, many cities experience irregular collection, insufficient coverage, and widespread environmental degradation caused by indiscriminate dumping and open burning of waste. Studies consistently show that these inefficiencies are linked to weak governance structures, poor planning systems, and inadequate funding mechanisms (UN-Habitat, 2010; World Bank, 2018). In Nigeria, these challenges are particularly pronounced in rapidly growing urban centres, where waste systems struggle to meet increasing demand.

A significant dimension of urban waste systems in developing contexts is the role of the informal waste sector. Informal actors, including waste pickers, itinerant buyers, and small-scale recyclers, contribute substantially to material recovery and recycling. In many cities, they form an essential part of the waste value chain by diverting recyclable materials from disposal sites, thereby reducing environmental burdens and operational costs for municipalities (Wilson *et al.*, 2006; Gutberlet, 2015). However, despite their importance, informal waste workers often operate under precarious conditions, lacking legal recognition, social protection, and institutional support. This exclusion limits their efficiency and prevents full integration into formal waste management systems. Recent literature increasingly advocates for inclusive models that integrate informal actors into formal structures to enhance system efficiency and social equity.

Public–Private Partnerships (PPPs) have been widely promoted as a strategy for improving waste management service delivery in urban areas. PPPs allow governments to leverage private sector efficiency, innovation, and investment capacity while maintaining regulatory oversight. When

properly structured, PPP arrangements can improve service coverage, enhance operational efficiency, and reduce public sector financial burdens (Cointreau, 2014). However, their effectiveness is often constrained by weak contract enforcement, unclear institutional roles, and inadequate cost-recovery mechanisms, particularly in developing countries where regulatory capacity is limited.

Environmental sustainability remains a central objective of modern waste management systems. Poor waste governance contributes to severe environmental challenges, including land and water pollution, greenhouse gas emissions, and public health risks. Sustainable waste systems are therefore grounded in the principles of reduce, reuse, and recycle (3Rs), combined with environmentally sound disposal practices. Achieving sustainability requires strong institutional coordination, effective regulatory frameworks, adequate financing, and active stakeholder participation. Literature suggests that cities with integrated governance systems are more likely to achieve sustainable waste outcomes compared to those with fragmented institutional arrangements.

In Nigeria, solid waste management remains a critical urban challenge. Municipal systems are often characterised by inadequate infrastructure, weak enforcement of regulations, and inefficient service delivery mechanisms. Waste collection coverage is typically uneven, with peri-urban and informal settlements experiencing the greatest service deficits. In addition, poor route planning, insufficient disposal facilities, and weak monitoring systems further undermine efficiency. Although informal recycling activities play a significant role in waste diversion, they remain largely unregulated and disconnected from formal systems. Attempts to introduce PPPs and

integrated frameworks have yielded mixed results due to institutional weaknesses and coordination challenges.

Service delivery inefficiency in urban waste management systems is a recurring issue across developing countries. It is typically manifested through irregular collection schedules, low coverage rates, inefficient resource allocation, and poor disposal practices. These inefficiencies are often driven by weak institutional capacity, inadequate funding, and lack of data-driven planning tools. Recent studies highlight the importance of Geographic Information Systems (GIS) and digital monitoring technologies in improving operational efficiency through route optimisation, performance tracking, and spatial planning of waste services.

Despite growing research on urban waste management, a key gap remains in understanding how formal and informal waste sectors can be effectively integrated within a unified system that enhances service delivery efficiency and environmental sustainability. This gap is particularly evident in medium-sized Nigerian cities, where empirical evidence on integrated governance models remains limited. Furthermore, there is insufficient understanding of how PPP frameworks, institutional coordination, and technological tools collectively influence waste service performance.

This study therefore contributes to existing literature by examining the integration of formal and informal waste sectors within an urban waste management system, with a focus on improving service delivery efficiency and environmental sustainability in Nigerian urban contexts.

3.0 Methodology

The study was conducted in Bauchi Metropolis, the administrative and commercial centre of Bauchi State, Nigeria. The metropolis comprises a of core, intermediate, and peri-urban settlements which are the Core City, Modern and Suburban Zones which are characterized by varying levels of infrastructure development and service accessibility. Rapid urban expansion, population growth, and increasing commercial activities have contributed to rising solid waste generation, making the area suitable for investigating integrated waste management and service delivery challenges.

The study adopted a cross-sectional descriptive research design. This design was considered appropriate because it allows for the collection of data at a single point in time to examine existing conditions and relationships between formal and informal waste management systems, service delivery efficiency, and environmental sustainability.

The population of the study comprised households, waste management operators (both formal and informal), and relevant institutional stakeholders involved in waste governance within Bauchi Metropolis. This includes personnel from environmental agencies, private waste contractors, and informal waste collectors.

A multi-stage sampling technique was employed to ensure representativeness across different residential zones.

- **Stage 1:** Stratification of the metropolis into core, intermediate, and peri-urban areas.
- **Stage 2:** Proportionate sampling of wards within each stratum.
- **Stage 3:** Systematic random sampling of households within selected wards.

Key informants from government agencies and private waste firms were selected using purposive sampling, based on their involvement and experience in waste management operations.

Primary data were collected using structured questionnaires, key informant interviews, and field observations. The questionnaire captured household waste generation behaviour, service satisfaction, and perceptions of waste management efficiency. Key informant interviews were conducted with officials from environmental agencies and private waste operators to obtain institutional perspectives. Field observations were used to assess waste collection practices, disposal sites, and service coverage.

Secondary data were obtained from relevant government reports, academic literature, and policy documents on urban waste management.

Quantitative data from questionnaires were analysed using descriptive statistics such as frequencies, percentages, and mean scores to summarize respondents' perceptions and service delivery patterns. Inferential statistics were applied where necessary to examine relationships between variables such as service efficiency and institutional arrangements. Qualitative data from interviews were analysed thematically; focusing on recurring patterns related to governance challenges, informal sector participation, and PPP arrangements.

Conceptual Focus of Analysis

The analysis was guided by three key thematic areas: Integration of formal and informal waste sectors, Service delivery efficiency in waste collection and disposal, Environmental sustainability outcomes of existing waste management practices

Ethical approval was observed through informed consent of respondents, confidentiality of information, and voluntary participation. Respondents were assured that data collected would be used strictly for academic purposes.

4.0 Results

1. Household Waste Disposal Practices and Service Gaps

The findings show that household waste disposal in Bauchi Metropolis is dominated by informal and environmentally unsafe methods. As presented in Table 1, open dumping (34.3%) is the most common disposal method, followed by government collection (27.8%), private waste collectors (24.7%), and burning (13.2%).

Table 1: Method of Waste Disposal

Method of Disposal	Frequency	Percentage (%)
Private Waste Collectors	88	24.7
Government Collection	99	27.8
Burning	47	13.2
Open Dumping	122	34.3
Total	356	100.0

Field Survey (2025)

This distribution indicates significant gaps in formal waste service provision, forcing households to rely on unsafe disposal alternatives.

2. Service Reliability and User Satisfaction

Results on service reliability (Table 2) reveal widespread dissatisfaction among residents. A combined 55.3% of respondents disagreed that waste collection services are reliable, indicating irregular and inconsistent service delivery.

Table 2: Reliability of Waste Collection Services

Response Category	Frequency	Percentage (%)
Strongly Disagree	92	25.8
Disagree	105	29.5
Neutral	33	9.3
Agree	51	14.3
Strongly Agree	75	21.1
Total	356	100.0

Field Survey (2025)

Similarly, overall satisfaction levels show that 53.1% of respondents report negative experiences, with a mean score of 2.83, confirming general dissatisfaction with waste management services.

3. Adequacy of Service Coverage

As shown in Table 3, a majority of respondents (73.6%) disagreed that waste collection services adequately cover their areas. This highlights a major structural gap in service provision, particularly in peri-urban and underserved communities.

Table 3: Adequacy of Waste Collection Coverage

Response Category	Frequency	Percentage (%)
Strongly Disagree	106	29.8
Disagree	156	43.8
Neutral	15	4.2
Agree	52	14.6
Strongly Agree	27	7.6
Total	356	100.0

Field Survey (2025)

4. Prevalence of Illegal Dumping

Findings in Table 4 indicate that 70.8% of respondents agree that illegal dumping is common in the metropolis. This reinforces the presence of uncontrolled waste disposal practices across the city.

Table 5: Illegal Dumping is Common

Response Category	Frequency	Percentage (%)
Strongly Disagree	51	14.3
Disagree	46	12.9
Neutral	7	2.0
Agree	151	42.4
Strongly Agree	101	28.4
Total	356	100.0

Field Survey (2025)

5. Institutional and Governance Factors

Perceptions of institutional performance reveal significant weaknesses. Table 5 shows that 78.1% of respondents believe waste management laws are poorly enforced, indicating weak regulatory implementation.

Table 5: Enforcement of Waste Management Laws

Response Category	Frequency	Percentage (%)
Strongly Disagree	101	28.4
Disagree	177	49.7
Neutral	23	6.5
Agree	34	9.6
Strongly Agree	21	5.9
Total	356	100.0

Field Survey (2025)

Additionally, while private waste collectors are strongly recognized (Mean = 3.84), collaboration between government and private operators remains low (Mean = 2.45), suggesting fragmented institutional coordination.

6. Integration and Reform Readiness

Despite institutional weaknesses, respondents show strong support for system reform, with a high acceptance of integration strategies (Mean = 4.10). This suggests readiness for a more coordinated waste management system involving both formal and informal actors.

5.0 Major Discussion

1. Service Delivery Deficits and Informal Disposal Practices

The dominance of open dumping and burning reflects severe deficiencies in formal waste collection systems. The findings suggest that households adopt informal disposal methods not by choice, but due to limited access to reliable services. This supports UNEP (2023), which argues that weak service coverage in developing cities directly drives environmental dumping behaviours.

Similarly, Kaza *et al.*, (2021) note that inadequate municipal infrastructure in low- and middle-income countries often leads to household reliance on unsafe disposal practices.

2. Inefficiency of Waste Collection Services

The high level of dissatisfaction and perceived unreliability of services indicates systemic inefficiency in operational waste management. Irregular collection schedules and inconsistent service delivery reduce public confidence and encourage non-compliant disposal behaviours.

This finding aligns with Abarca-Guerrero *et al.*, (2021), who emphasize that unreliable waste services in developing urban areas lead to accumulation of waste and increased environmental risk.

3. Coverage Inequality and Environmental Consequences

The inadequate service coverage identified in the study highlights spatial inequality in waste management provision. Peri-urban and informal settlements are disproportionately affected, reinforcing environmental injustice within urban service delivery systems.

UNEP (2023) similarly reports that underserved urban areas are more likely to experience open dumping and burning due to lack of formal collection services.

4. Illegal Dumping as a Structural Outcome

The high prevalence of illegal dumping is not merely behavioural but structural. It reflects the failure of institutional systems to provide accessible and reliable waste services. As Wilson *et al.*, (2020) argue, illegal dumping in developing cities is primarily driven by infrastructural and governance deficits rather than individual negligence.

5. Institutional Weakness and Fragmented Governance

The findings reveal weak enforcement of waste regulations and poor coordination between public and private actors. This fragmentation reduces system efficiency, creates service gaps, and weakens accountability.

World Bank (2023) similarly notes that weak institutional enforcement is a major barrier to effective waste governance in developing countries.

6. Role of Integration in Waste System Reform

Despite challenges, strong public support for integration indicates a viable pathway for reform. The results suggest that improving legal frameworks, strengthening enforcement, and enhancing public–private collaboration could significantly improve system performance.

This aligns with integrated waste management theory, which emphasizes coordinated governance across institutional, economic, and social dimensions (Wilson *et al.*, 2020; UNEP, 2023).

7. Overall Synthesis of Findings

Overall, the study demonstrates that waste management challenges in Bauchi Metropolis are driven by three interconnected issues:

- Service delivery gaps, leading to reliance on informal disposal methods
- Institutional fragmentation, limiting coordination and efficiency
- Weak regulatory enforcement, allowing illegal dumping to persist

These findings reflect broader patterns in developing urban systems where infrastructure deficits and governance weaknesses jointly constrain effective waste management.

6.0 Conclusion

The study concludes that the solid waste collection system in Bauchi Metropolis is inefficient, fragmented, and unable to meet the growing demands of urban waste management. Key challenges

include inadequate coverage, unreliable service delivery, weak regulatory enforcement, and widespread illegal dumping.

However, the findings also highlight strong potential for improvement through the integration of formal and private waste sectors. The significant role of private waste collectors, combined with public support for integration, provides a strong foundation for developing a unified and efficient waste management system.

7.0 Policy Recommendations

1. Strengthen enforcement of environmental regulations through monitoring and penalties

This recommendation emphasizes the need to move beyond the existence of environmental laws to effective implementation. In many urban settings, waste management regulations exist but are weakly enforced due to limited institutional capacity, corruption, or lack of monitoring tools. Strengthening enforcement means increasing the presence and effectiveness of regulatory agencies through routine inspections, real-time monitoring of waste activities, and strict application of sanctions for illegal dumping, improper disposal, and non-compliance by waste operators. Penalties should be sufficiently deterrent (fines, license suspension, or prosecution) to change behaviour. This also requires training environmental officers and ensuring transparency in enforcement processes.

2. Develop formal public–private partnership (PPP) frameworks for waste collection

This recommendation highlights the need to institutionalise collaboration between government and private waste operators. In many cities, private participation exists but is often informal, uncoordinated, or poorly regulated. A structured PPP framework would clearly define roles,

responsibilities, service standards, pricing structures, and accountability mechanisms for both public and private actors. Government can focus on regulation, planning, and oversight, while private firms handle collection, transport, or recycling services. A well-designed PPP improves efficiency, reduces service gaps, and encourages investment in waste infrastructure.

3. Provide financial incentives and cost-recovery mechanisms for private operators

Private waste operators often face financial constraints such as high fuel costs, inadequate user payments, and delayed government subsidies. Financial incentives such as tax reductions, subsidies, access to soft loans, or performance-based payments can improve service delivery and attract more private investment into the sector. Cost-recovery mechanisms, such as standardized user fees or pay-as-you-throw systems, ensure that service provision is financially sustainable. This reduces over-reliance on government funding and helps private operators maintain equipment and expand services.

4. Expand waste collection coverage to underserved and peri-urban areas

Many cities experience unequal waste service delivery, where central urban areas are well-served while peri-urban and informal settlements are neglected. This recommendation calls for inclusive waste management planning that ensures equitable access to waste collection services. Expansion can involve deploying additional collection points, increasing route coverage, and introducing community-based waste collection systems in hard-to-reach areas. This reduces illegal dumping, flooding risks from blocked drains, and public health hazards associated with unmanaged waste in low-income neighbourhoods.

5. Promote public awareness campaigns on proper waste disposal practices

Effective waste management depends not only on service provision but also on public behaviour. Awareness campaigns aim to educate residents on proper waste segregation, disposal methods, recycling practices, and the environmental and health consequences of indiscriminate dumping. These campaigns can be delivered through radio, schools, community associations, religious institutions, and social media platforms. Behavioural change initiatives encourage households and businesses to take responsibility for their waste, thereby reducing pressure on collection systems and improving overall urban cleanliness.

6. Introduce GIS-based and data-driven waste management monitoring systems

This recommendation focuses on modernizing waste management through technology. Geographic Information Systems (GIS) and data analytics can be used to map waste generation hotspots, optimize collection routes, monitor service coverage, and track the performance of waste operators. Real-time data improves decision-making by identifying underserved areas and inefficiencies in the system. For example, route optimization reduces fuel costs and improves collection frequency. A digital monitoring system also enhances accountability by allowing authorities to verify whether contracted services are being properly delivered.

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**Urban Sustainability and Solid Waste Collection Governance in Bauchi Metropolis:
Implications for Inclusive Service Delivery**

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Abstract

Rapid urbanisation in medium-sized cities across Sub-Saharan Africa has intensified pressure on municipal solid waste collection systems, raising concerns about service equity, governance capacity, and environmental sustainability. This study examines solid waste collection governance in Bauchi Metropolis, Nigeria, and develops an integrated framework for inclusive and sustainable service delivery. Using a mixed-methods design combining household surveys (n = 356), institutional interviews, and spatial analysis of waste generation and service coverage, the study identifies significant intra-urban disparities in collection efficiency, institutional coordination gaps, and conditional willingness among residents to support improved services. Findings reveal that modern and suburban areas receive relatively higher service coverage compared to core residential zones, reflecting spatial inequalities in urban service provision. The results are interpreted through socio-technical systems theory and urban sustainability transition frameworks, highlighting the interdependence of infrastructure, governance, financial sustainability, and community participation. The study proposes a spatially differentiated and institutionally coordinated waste collection model aligned with SDG 11 and SDG 12. The research contributes new empirical evidence from an under-researched medium-sized Nigerian city and advances inclusive service delivery discourse within sustainable urban governance scholarship.

Keywords: Bauchi Metropolis; governance; inclusive service delivery; solid waste management; spatial inequality; urban sustainability.

1.0 Introduction

Urban sustainability has become a central concern in developing countries, particularly in rapidly growing cities where population expansion is not matched with adequate infrastructure and service delivery systems. One of the most critical urban challenges in this context is solid waste management, which directly affects environmental quality, public health, and the overall liveability of cities. In many Nigerian urban centres, including Bauchi Metropolis, solid waste

collection systems are often characterized by inefficiencies such as irregular service delivery, inadequate coverage, and weak institutional coordination, all of which undermine sustainable urban development goals (Ojikutu & Ibikunle, 2025; Onicha *et al.*, 2024).

Recent studies have shown that urban waste governance in Nigeria is constrained by fragmented institutional frameworks, weak enforcement of environmental regulations, and limited integration between public and private sector actors (Batagarawa *et al.*, 2024; Ojikutu & Ibikunle, 2025). These governance gaps frequently result in widespread environmental challenges such as open dumping, illegal waste disposal, and blocked drainage systems, and increased exposure to vector-borne diseases. In addition, rapid urbanization and population growth continue to intensify waste generation rates, further straining already weak municipal capacities (Onicha *et al.*, 2024).

In Bauchi Metropolis, solid waste management remains a persistent urban sustainability challenge despite the presence of both formal government agencies and private waste operators. Empirical evidence suggests that service delivery is often inconsistent, with significant spatial inequalities in waste collection coverage and varying levels of household satisfaction (Abdu *et al.*, 2020; Kamaruddin & Muhammed, 2022). Furthermore, the in-formalisation of waste services, combined with weak regulatory enforcement, has contributed to inefficient governance structures that limit the effectiveness of existing waste management systems (Batagarawa *et al.*, 2024).

From a governance perspective, inclusive service delivery has been recognised as a key strategy for improving urban sustainability outcomes. This approach emphasizes collaboration between government institutions, private sector operators, and community stakeholders in order to enhance efficiency, accountability, and service accessibility (Ojikutu & Ibikunle, 2025). In the context of solid waste management, inclusive governance is particularly important because it enables the

integration of formal and informal actors who collectively play significant roles in waste collection and disposal processes.

Despite growing recognition of these issues, there remains a limited understanding of how governance structures, service delivery inefficiencies, and stakeholder interactions collectively influence urban sustainability outcomes in Bauchi Metropolis. This study therefore seeks to fill this gap by examining the state of solid waste collection governance and its implications for inclusive service delivery. By doing so, it contributes to on-going academic and policy debates on sustainable urban management in developing cities.

This study therefore examines the governance structure of solid waste collection in Bauchi Metropolis and analyses its implications for inclusive and sustainable urban service delivery. The study contributes to the growing body of literature on urban sustainability by providing empirical evidence from a medium-sized Nigerian city that remains underrepresented in waste governance research.

2.0 Literature Review

Contemporary literature on solid waste governance emphasizes the importance of institutional coordination, spatial equity, and stakeholder participation in achieving sustainable urban development. Urban political ecology theory argues that environmental services are unevenly distributed across cities due to socio-economic and political inequalities. Consequently, low-income and densely populated neighbourhoods often experience inadequate waste collection services compared to affluent urban districts.

Studies conducted in Nigeria and other developing countries reveal that privatization of waste collection services has improved operational efficiency in some urban areas; however, service delivery remains selective because private operators concentrate on locations with better infrastructure and higher payment capacity. Research by the World Bank and UN-Habitat further indicates that fragmented governance systems reduce accountability and limit environmental sustainability outcomes.

Socio-technical transition theory also explains that sustainable urban waste management requires interaction between institutions, technology, policy frameworks, and community participation. Geels (2020) argues that sustainable transitions occur when innovative systems are integrated into existing institutional structures through coordinated governance mechanisms. In many African cities, however, weak integration between public and private actors continues to undermine sustainability transitions.

Empirical studies in Bauchi and other Nigerian cities identify major challenges such as irregular collection schedules, inadequate disposal facilities, open dumping practices, insufficient waste transportation infrastructure, and weak environmental monitoring. Despite these challenges, there is limited research examining how spatial inequalities and governance fragmentation jointly affect inclusive waste service delivery in medium-sized cities such as Bauchi Metropolis.

3.0 Methodology

A mixed-methods research design was adopted for this study. Quantitative data were collected through structured household questionnaires administered across selected residential wards in Bauchi Metropolis, while qualitative data were obtained through interviews with officials of the

Bauchi State Environmental Protection Agency (BASEPA) and Private Waste Collection Companies (PWCCs).

The sample size of 400 households was derived using the Taro Yamane sampling formula:

$$n = N / (1 + N(e^2))$$

Where:

n = sample size

N = population size (178,943 households)

e = level of precision (0.05)

The residential zones were classified into two broad categories based on urban morphology, settlement characteristics, and infrastructure conditions:

1. Core city zones located within the traditional city wall.
2. Suburban/modern residential zones located outside the city wall.

GIS spatial analysis techniques were used to map waste collection centres, service coverage patterns, and residential distribution. Descriptive statistics, comparative zonal analysis, and thematic interpretation were used to analyse the findings.

Table 1: Residential Wards and Distribution of Sample Size

S/N	RESIDENTIAL WARDS	H/H POPULATION	FREQUENCY	PERCENTAGE OF FRQ	LOCATI ON
1	Makama A & B	22,659	51	13	WITHIN THE CITY WALL
2	Dan Kade	7,673	17	4	
3	Dawaki	22,051	49	12	
4	Dan Amar A & B	27,713	62	15	
6	Hardo	3,769	8	2	
	Total	83,865	187	46	
7	Dan Iya	29,738	67	17	OUSIDE THE CITY WALL
8	Miri	19,078	43	11	
9	Tirwun	46,262	103	26	
	Total	95,078	213	54	
	TOTAL	178,943	400	100	

Source: National Population Commission Bauchi State Chapter and Field Survey (2026)

4.0 Results

1. Structure and Operational Characteristics of PWCCs

The findings reveal that Private Waste Collection Companies (PWCCs) operate predominantly within suburban and planned residential areas such as Dan Iya, Miri, and Tirwun. These neighbourhoods are characterised by better road accessibility, organized housing layouts, and relatively higher household income levels. In contrast, only a limited proportion of households within the traditional core city receive services from private operators.

The study further shows that PWCCs operate on a subscription-based system in which households pay monthly service charges ranging between ₦1,500 and ₦2,000. Operationally, most companies

employ between two and six staff members and undertake one to two waste collection trips daily using mini-trucks and motorcycles.

2. Quantity and Spatial Distribution of Waste Collected

The analysis of waste generation patterns indicates significant spatial disparities between suburban and core urban areas. Suburban areas recorded substantially higher volumes of collected waste compared to the traditional core city.

Table 2: Weekly Waste Generation by Residential Zone

Zone	Average Waste (kg/household/week)	Total Waste (kg/week)
Suburban/Modern Areas	51.45	118,437.9
Core Urban Area	3.50	423.5

Field Survey (2026)

The study also found that lower quantities of waste were recorded in the core urban area compared to suburban locations.

3. Operational Structure of BASEPA

BASEPA operates a centralized waste evacuation system based primarily on communal waste collection points rather than direct household collection. The agency utilizes approximately three trucks with a combined daily evacuation capacity of about 240 tons.

The findings further indicate that waste disposal is mainly carried out through open dumping and borrow pits.

Table 3: Operational Characteristics of PWCCs

Variable	Description
Workforce size	2–6 staff per company
Collection frequency	Weekly
Trips per day	1–2
Service fee	₦1,500 – ₦2,000/month
Vehicle type	Mini trucks & motorcycles
Capacity range	500–1,500 kg

Field Survey (2026)

4. Spatial Representation of Waste Collection

The spatial maps presented in Figures 1 and 2 illustrate the unequal distribution of waste collection services across Bauchi Metropolis. Figure 1 shows that waste collection activities are concentrated mainly in suburban and modern residential zones where accessibility and infrastructure conditions are relatively better. Figure 2 identifies the major waste collection centres and disposal locations managed by BASEPA.

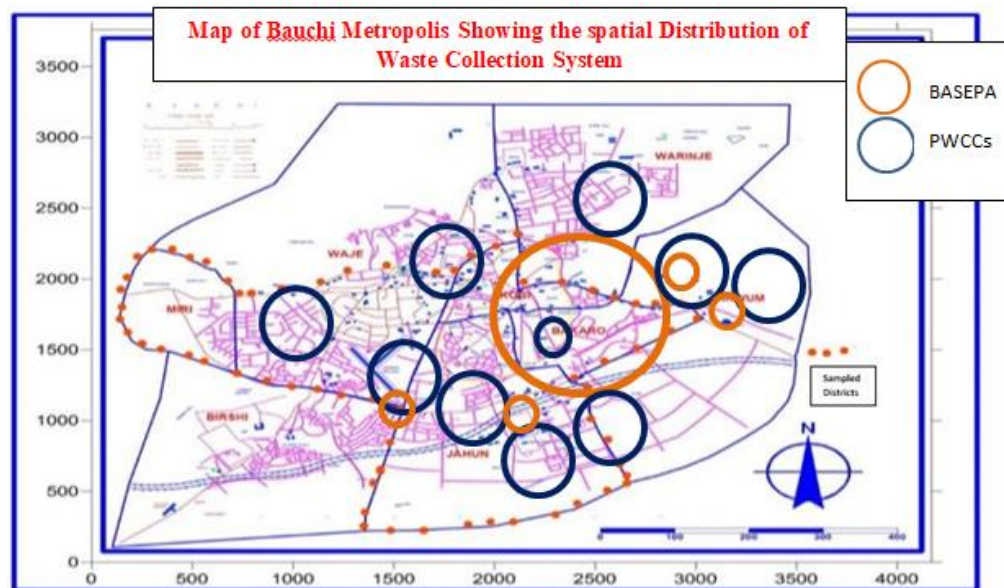


Figure 1: Spatial Distribution of Waste Collection in Bauchi Metropolis

Source: Author, 2026

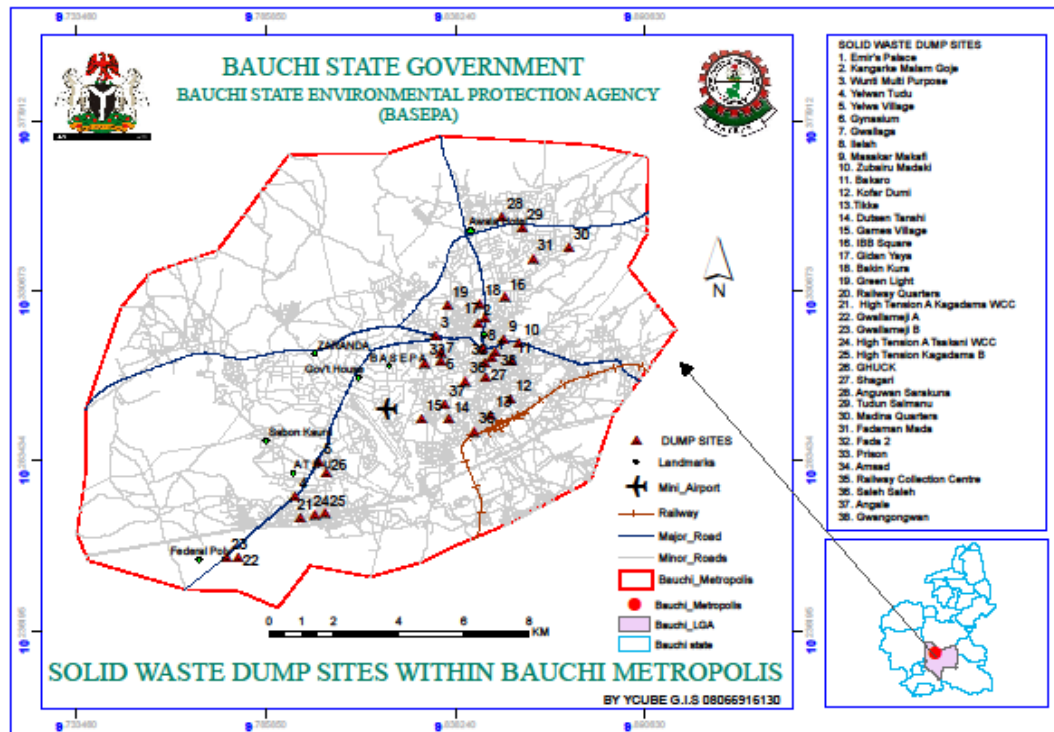


Figure 2: Solid Waste Collection Centres in Bauchi Metropolis

Source: BASEPA, January 2026

The maps further reveal that several traditional settlements experience limited access to organized waste collection services.

5.0 Discussion

The concentration of PWCC operations within suburban and planned residential neighbourhoods suggests that private waste operators prefer areas with better infrastructure, easier accessibility, and higher household payment capacity. This reflects market-driven patterns of service delivery commonly reported in developing cities.

The use of small-capacity vehicles such as mini-trucks and motorcycles demonstrates adaptive operational strategies adopted by PWCCs to overcome poor road conditions and limited

accessibility in densely populated areas. However, the limited service coverage within the traditional city core indicates persistent spatial inequality in waste collection services.

The higher volume of waste collected in suburban areas may be associated with higher income levels, increased consumption patterns, and improved service accessibility. Conversely, the lower quantity of waste recorded within the core city is likely a reflection of under-collection, informal disposal practices, and exclusion from formal waste management systems rather than genuinely low waste generation.

Although BASEPA demonstrates substantial institutional capacity for large-scale waste evacuation, its reliance on communal collection systems instead of direct household collection reduces operational effectiveness and service integration. Furthermore, the continued use of open dumping and borrow pits raises serious environmental sustainability and public health concerns.

The spatial distribution maps further confirm that waste collection services are unevenly distributed across Bauchi Metropolis. Residents within traditional settlements remain underserved, increasing the likelihood of indiscriminate dumping, environmental degradation, and poor sanitary conditions. Overall, the findings indicate that waste governance in Bauchi Metropolis is characterized by institutional fragmentation, unequal service accessibility, and weak integration between public and private waste management systems.

Comparative Governance Analysis: PWCCs vs. BASEPA

Bauchi's waste collection governance is characterized by structural fragmentation and spatial inequities. PWCCs provide decentralized, household-oriented services in suburban zones, whereas BASEPA offers centralized evacuation services within the core city. This dualistic system reflects

fragmented governance, limiting operational efficiency, data integration, and accountability (World Bank, 2023).

From a socio-technical transition perspective, Bauchi represents a hybrid regime in which emerging private niches coexist with legacy public systems. Without formal integration through public–private partnerships, these parallel systems impede systemic sustainability transitions, including environmental protection, service equity, and operational efficiency (Geels, 2020).

Environmental implications are significant, as both systems rely predominantly on open dumping, undermining climate mitigation and circular economy objectives (Klemeš *et al.*, 2020).

Implications for Inclusive Urban Sustainability

The study reveals that waste collection governance in Bauchi is shaped by spatial inequality, institutional fragmentation, and partial cost-recovery mechanisms. PWCCs improve efficiency in planned areas but exclude core city residents, whereas BASEPA ensures volumetric evacuation without household integration.

Three key sustainability concerns emerge:

1. **Equity Gap:** Service provision is spatially uneven, reinforcing socio-economic disparities.
2. **Institutional Fragmentation:** Parallel operational systems reduce efficiency and accountability.
3. **Environmental Vulnerability:** Continued reliance on open dumping undermines sustainability.

Effective waste governance requires integrated, data-driven strategies that reconcile financial sustainability with social inclusion (UN-Habitat, 2022; World Bank, 2023). Urban political

ecology emphasizes socio-spatial power dynamics, while transition theory advocates coordinated multi-actor interventions to achieve systemic change (Heynen **et al.**, 2019; Geels, 2020).

Concluding Analytical Insight

Bauchi's waste collection system is functionally active but structurally fragmented. Private operators deliver targeted efficiency, and public agencies provide large-scale evacuation capacity. However, neither system independently achieves inclusivity, environmental control, or systemic integration.

These insights underscore the need for an Integrated and Sustainable Solid Waste Collection Framework that: - Harmonizes public and private roles, - Incorporates spatial planning and GIS-based tools, - Strengthens environmental controls, - Aligns cost recovery with social equity, - Integrates community participation into operational design.

Such a framework is essential to align Bauchi Metropolis with global sustainable urban transition pathways, enhancing resilience, inclusivity, and environmental sustainability.

6.0 Conclusion

This study examined the governance structure of solid waste collection in Bauchi Metropolis and assessed its implications for inclusive urban sustainability. The findings reveal that waste collection services are spatially uneven, institutionally fragmented, and environmentally unsustainable in several respects. Private Waste Collection Companies provide relatively efficient household-level services within suburban and planned neighbourhoods, while residents within the traditional city core remain underserved.

The study also established that weak coordination between public and private institutions has reduced operational efficiency and limited the development of an integrated waste management system. Furthermore, the continued reliance on open dumping practices undermines environmental protection and public health objectives.

To achieve inclusive and sustainable waste governance in Bauchi Metropolis, there is a need for stronger public–private partnerships, GIS-based planning systems, improved environmental monitoring, equitable service expansion, and active community participation. Integrated institutional frameworks that combine financial sustainability with social inclusion are essential for improving urban environmental management and aligning the city with global sustainability targets such as SDG 11 and SDG 12.

The study therefore recommends the development of an integrated solid waste collection framework that harmonizes institutional responsibilities, improves spatial service coverage, and promotes environmentally sustainable waste disposal practices. Such measures will enhance urban resilience, environmental sustainability, and inclusive service delivery in Bauchi Metropolis and similar medium-sized cities in Nigeria.

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CRIME PREVALENCE IN NIGERIAN URBAN SLUM AREAS: THE WAY FORWARD**Osuji, Sabina Chiaka**Department of Urban and Regional Planning, Imo State University, Owerri, Imo State
+2348037360784, chiakanne@yahoo.com**Abstract**

One of the ugliest phenomena in Nigerian Urban Centres is crime prevalence and slums. Slums are the home the urban poor of people in search of a better life or without a better places to go. Half of the world has become urbanized and number of people living in cities is only projected to grow. The most rapid growth is expected in developing countries and will contribute to more slums. Slums are described as centres of violence and crime and these informal communities are a veritable breeding grounds for criminal activities accompanied by an increased rate of crime, violence and lawlessness. The phenomenon of crime knows no boundary and does not distinguish between developed and developing countries. Crime prevalence is the proportion of people or targets for example households, properties or cars in an area who are victimized and is used to identify the risk of being a victim(s). The number of potential victims commonly equates to an area's population. Consequently, the paper investigates the present causes and effects of the urban slums and examines the crime prevalence in Nigerian urban slum areas. However, the study relied on secondary data. Data were basically obtained from literature in journals, textbooks, official records, private papers, and the internet. The study identifies poverty, bad governance, unemployment, lack of planning for the lower-income classes of the society, improper use of land, poor infrastructure and social exclusion; health hazards, prone to natural and man-made hazards, and their inhabitants are often in danger of violence and crime such as burglary and housebreaking, drug abuse, armed robbery, kidnapping. The study suggests the implementation of poverty eradication projects, effective planning, good governance, slum upgrading programme, monitoring system and data management, and increasing the presence of police.

Keywords: Causes, Crime Prevalence, Effects, Planning, Urban Slum,**1.0 Introduction**

One of the most enduring physical manifestations of social exclusion in African cities is the proliferation of slums and informal settlements. People living in these settlements experience the most deplorable living and environmental conditions, which are characterized by inadequate water supply, squalid conditions of environmental sanitation, breakdown of the non-existence of waste disposal arrangements, overcrowded and dilapidated habitation, hazardous location, insecurity of tenure, and vulnerability to serious health risks. (Arimah, 2001). These are areas in which little government attention in terms of provision or maintenance of public facilities and infrastructure is being felt. These are high-density squalid central city tenements to spontaneous squatter settlements without legal recognition which sprawl at the edge of cities (Orewere, Oguoyewa and Owonubi, 2019).

Slum arise from poor people's need to find affordable and accessible housing. They are created by the market or by the people themselves when increasing numbers of people in poverty meet inadequate housing and planning responses. Slum conditions are worsened by economic decline, increasing inequality, loss of formal – sect jobs, rapid immigration, poor governance and exclusionary actions (The Challenge of Slum: Global Report on Human Settlements, 2003).

The global assessment of slums undertaken by UN-HABITAT (2010) shows that 828 million or 33% of the urban population of developing countries resides in slums. In Sub-Saharan Africa, 62% of the urban population residents in such settlements. Such large concentrations of slums in which inhabitants live in inequitable and life-threatening conditions impose enormous burden on city authorities that are often cash-strapped and lack the institutional and technical capacity to provide even the most basic of urban services.

In Nigerian cities, slum dwellers have limited access to formal health, education and other social services, and live in environments characterized by poor housing sanitation and infrastructure, alcohol abuse, stigma, rape, discrimination, high unemployment rates, high crime rates, low quality of life and high rates of violence. Despite these challenging conditions, cheap housing and close proximity to urban amenities continue to attract large number of in-migrants leading to the rapid growth of slum settlement (Ekpenyong & Mathias, 2019; and Nubi, 2015).

Slums are areas of deprivation of basic needs such as adequate shelter, food, clothes, sanitation and security (and this is consistent across different slums). Based on these similarities, it is expected that the level of crime would be similar across the different slums as well. However, available literature and research indicates divergent views (Ekpenyong and Mathias, 2019). Available literature have shown that Slums are breeding grounds for criminal activities, accompanied by increased rates of crime, violence and lawlessness. Hence, reducing the population of urban slums by 100 million was a critical point of the Millennium Development Goals (MDGs) (Ekpenyong, and Mathias, 2019).

Crime is deviance that violates a law. Crime represents an expression of how a society frames or constructs what is appropriate and what is inappropriate behaviour (Coomber, Donnermeyer, McElrath, and Scott, 2014). Crime is one of the human security problems confronting humanity across the world. Nations have grappled to contain the rising incidence of homicide, armed robbery, kidnapping, drug trafficking, sex trafficking, illegal gun-running, and a host of others (Ukoji, and Okolie 2016).

Crime is an inevitable reality in human society. It is inherent in human nature; hence no society or human settlement is completely free from the shackles of crime. The phenomenon (crime) knows no boundary and does not distinguish between developed and developing world. It is social contact, relative to time and place (Olusegun, 2015).

Africa has been on the forefront on global statistics on crime. South Africa and Nigeria have recorded high incidents of violent and non-violent. Nigeria is currently caught in the web of crime dilemma, manifesting in the convulsive upsurge of both violent and non-violent crimes. Notable in this regard are the rising incidents of armed robbery, assassination, and ransom-driven kidnapping, which are now ravaging the polity like a tsunami and spreading a climate of fears and anxieties about public safety. The upsurge of crime has been ongoing as Nigeria has been on the global crime map since 1980 (Oruwari, 2006).

Crime prevalence refers to the proportion of people (or targets e.g. households, properties, or cars) in an area who are victimized and is used to identify the risk of being a victim(s). The number of potential victims commonly equates to an area's population. However, in many cases, potential targets are more narrowly defined. For example, the potential victims of vehicle crime should be restricted to the number of individuals who own or have access to a vehicle. The crime prevalence of different crime types is burglary, other theft, assault, threats, vandalism, and racial abuse and theft from the person (Rogerson, 2004).

According to Africa Check, incidents of murder increased from 15,609 murders in 2011/12 to 16,259 murders in 2012/13 in South Africa, with increase of 650 murder cases or a 4.2% increase

when comparing the total numbers with the previous year. According to the same report, murders and attempted murders that take place during an aggravated robbery or inter-group conflict (such as gang or taxi violence) and vigilantism make up between 35% and 45% of all murders and attempted murders.

National Bureau of Statistics report-crime statistics on reported offenses reflected that a total of 125,790 cases were reported in 2016 in Nigeria. Offence against property has the highest number of cases reported with 65,397 as such cases reported while offence against persons recorded 45,554 cases (Aduloju, Adeniran, and Ageh, 2020).

Therefore, the paper investigates the present causes, and effects of urban Slums examines the crime prevalence in Nigerian urban slum areas.

Objectives

The objectives of the study is to provide a safe, pleasant, healthy, socially functional living and working environment, find lasting solutions to the formation and proliferation of slums and informal settlements and to find crime prevention strategies.

2.0 Slum

Slum is a universal phenomenon spreading its tentacles in virtually every urban settlement. Slum is an informal, criminalized illegal space both in the occupation of land and the formation of substandard structures and is often marginalized by the local and national governments. Consequently, slum dwellers – many who are poor in the first place - are made poorer by the various forms of exclusion that they face (Arimah, 2001).

Slum is a major phenomenon accompanying Nigerian cities, characterized by overcrowded dwellings, unemployment, poor environmental conditions, limited water supply, poor sanitation, inadequate electricity supply and access to health facilities. Slums are generally marked by a distinctiveness of poverty, lack, and frustration (Ekpenyong, and Mathias, 2019).

A slum is a heavily populated urban informal settlement characterized by substandard housing and squatter (poverty). Slums punctuate almost every city in the world, a trend that has become a universal phenomenon accompanying urban growth. Late in 2003, the United Nations reported that one billion people, approximately one-third of the world's urban dwellers and a sixth of all humanity live in slums. Similarly, UN-HABITAT stated that around 33% of the urban population of the developing world in 2012, or about 863 million people lived in slums. The proportion of urban population living in slums was highest in Asia and Africa especially Sub-Saharan Africa with a staggering 61.7% (UN-HABITAT, 2007).

Slum is any specific place, whether a whole city or a neighbourhood, more than half of all households lack improved water, improved sanitation, sufficient living area, durable housing, secure tenure, or a combination of two (UN-HABITAT, 2012). The houses inhabited by slum dwellers are mostly decrepit, and overcrowded, in neighbourhoods that are prone to flooding and beset with poor sanitation and shortage of portage water (Emma-Ochu and Onwuka, 2016). These are areas which little government attention terms of provision or maintenance of public facilities

and infrastructure is being felt. These are high-density squalid central city tenements to spontaneous squatter settlement without legal recognition which sprawl at the edge of cities (Orewere, Ogurayewa and Owonubi, 2019).

According to Nubi (2015) slums are decried as centres of violence and crime and that these informal communities are a veritable breeding grounds for criminals. Slums are known for high crime rates, unemployment, low self-esteem alcohol abuse, stigma, discrimination, and low quality of life.

Majority of the people in slums mostly the youth lack occupation, are redundant and end up in crimes for survival or under the influence of drugs. (Munana, 2019). Slums create conditions that expose and stimulate youth criminal tendencies. Living in deprived slum neighbourhoods had a levelling effect on young people's occupational and educational aspirations. Limited opportunities in slums lead many to make early transitions out of school and into crime. Hence, living in slums invariably result in youths' susceptibility to crime as victims. For example, exposure to high rates of violence and crime, which is typical in many resource-poor urban slums, can have negative impacts on youth development (Furlong and Cartmel, 1997). These include depression, poor academic performance, post-traumatic stress symptoms, delinquency, and aggression (Kabiru, Mojolam, Beguy and Okigbo, 2013)

The increase of shanty dwellings, squatter settlements are slums in most of our cities in Nigeria and other less developed nations of the world is attributed to a chain of factors. Of course, such factors are closely associated with the low level of socio-economic and cultural lifestyles of the inhabitants (Omole, 2010). Slums are areas that concentrate low-income earners, low-cost houses, possibly mud houses, with no layout and poor inhabitants.

Slums range from high-density, squalid central city tenements to spontaneous squatter settlements without legal recognition or rights, sprawling at the edge of cities. Slums have various namely; Favelas, Kampung, bidonvilles, tugurios, yet share the same miserable living conditions. Slums are not static; there are ongoing dynamics that, over a period of years, may turn an established urban area into a slum or that may lead to the redevelopment of an existing slum (The Challenge of Slums: Global Report on Human Settlements, 2003).

In Nigerian cities, slum dwellers have limited access to formal health, education, and other social services, and live in environments characterized by poor housing, sanitation and infrastructure, high unemployment rates and high rate of violence. Despite these challenging conditions, cheap housing and close proximity to urban amenities continue to attract a large number of in-migrants leading to the rapid growth of slum settlements (Ekpenyong and Mathias, 2019 and Nubi, 2015).

2.1 Types of Slums

- i. **Slum of Hope/Notified Slums:** This slum of hope is characterized by attitude of the residents, whether or not they expect to improve their situation and whether or not there are opportunities for advancing out of slum. Slum of hope have generally been the home for recent immigrants to the community. The type of people here are respectable poor, the

trapped, beginners, climbers and entrepreneurs who are utilizing vital slum economic opportunities. They are temporary necessitation who are never adjusted to slum living nor reconciled to it (Shagufta, 2010). Notified slum dwellers can usually afford to invest in education and skill training (Krishna, Sriram and Prakash, 2014).

- ii. **Slum of Despair/Non-Notified Slums:** Slum of despair is populated by groups of longer residence. They are indolent, the adjusted poor, social outcasts, fugitives, unfindable, sporting crowds. They consist of people living in slum because of opportunity offered them. They are also permanent necessitation. Their values and identifications if any, remain within the slum area. They are no longer new immigrants who have potential of moving up the social economic scale. The urban economics have not favoured them hence they remain (Shagufta, 2020). Non-notified slums are where residents are mostly unconnected to basic services and formal livelihood opportunities. (Krishna, Sriram and Prakash, 2014).

Table 1: Slum Growth in Developing Countries

Country	Slum Annual Growth Rate (%)	Slum Population (Thousands)	Scenario 2020 with no Change
Angola	5.28	3,918	10,677
Kenya	5.88	7,605	23,223
Nigeria	4.96	41,595	76,749
South Africa	0.19	8,376	8,677
Uganda	5.32	3,241	8,904
Tanzania	6.16	11,031	35,561
Brazil	0.34	51,676	55,074
Elsalvador	1.89	1,386	1,986

Source: UN-HABITAT, Urban Observation, 2007, as cited in Orewere, Ogunrayewa and Owonubi, 2019.

2.2 The Characteristics of Slums (Challenge of Slums: Global Report on Human Settlement, 2003; Hiraskar & Hiraskar, 2010; and Rangwala & Rangwala, 2011)

1. **Appearance:** This is rather the universal mark of the slum and its unpleasant appearance offends the eyes, nose and conscience. The structures appear to have deteriorated and to be of over-age.
2. **Lack of Basic Services/Inadequate Infrastructural Facility:** Lack of access to sanitation facilities and safe water sources is the most important feature, sometimes supplemented by the absence of waste collection systems, electricity supply, surfaced roads and footpaths, street lighting and rainwater drainage.
3. **Overcrowding and High Density:** The slum is overcrowded with buildings or the buildings are overcrowded with people or in the worst condition, both conditions prevail in the slum. Overcrowding is associated with a low space per person, high occupancy rates, cohabitation by different families and a high number of single-room units. Many slum dwelling units are overcrowded with five and more persons sharing a one-room unit used for cooking, sleeping and living. Bangkok requires at least 15 dwelling units per rai (1,600 square metres).
4. **Substandard Housing or Illegal and Inadequate Building Structure:** Many cities have building standards that set minimum requirements for residential buildings. Slum areas are

associated with a high number of substandard housing structures, often built with non-permanent materials unsuitable for housing given local conditions of climate and location. The slum is often exposed to fire accidents and consequent damages. One stick of matches may prove to be sufficient to reduce the whole slum to ashes in no time. Factors contributing to a structure being considered substandard are for example, earthen floors, mud – and – wattle walls or straw roofs. Various space and dwelling placement bylaws may also be extensively violated.

5. **Unhealthy Living Conditions and Hazardous Locations:** The slum is characterized by low standards of sanitation and is often reflected most by the public services for sanitation. It also refers an area of high sickness and death rates. Unhealthy living conditions are the result of a lack of basic services, with visible open sewers, lack of pathways, uncontrolled dumping of waste, polluted environments, etc. House may be built on hazardous locations or land unsuitable for settlement, such as floodplains, in proximity to industrial plants with toxic emissions or waste disposal sites, and on areas subject to landslip. The layout of the settlement may be hazardous because of a lack of access way densities of dilapidated structures.
6. **Poverty and Exclusion/Income Criteria:** The slum is a poverty area and it is occupied by people of the lowest income group of the society. Income or capability poverty is considered with some exceptions, as a central characteristic of slum areas. It is not seen as an inherent characteristic of slums, but as a cause (and, to a large extent, a consequence) of slum conditions. Slum conditions are physical and statutory manifestations that create barriers to human and social development. Furthermore, slums are areas of social exclusion that are often perceived to have high levels of crime and other measures of social dislocation. In some definitions, such areas are associated with certain vulnerable groups of the population, such as recent immigrants, internally displaced persons, or ethnic minorities. The slum area is of the lowest social status and it is usually linked up with the rest of the community through its labour force. In a democratic society, the slum dwellers can identify themselves with certain political groups because of their quality of voting and other legal rights with the rest of the community.
7. **Population:** If the slum population is racial or cultural, it grants a degree of social organization even though the area looks poverty-stricken slum area. For a heterogeneous occupancy, the inhabitants are of different categories who are not welcome in other localities or they cannot afford to live elsewhere.
8. **Insecure Tenure; Irregular or informal settlements:** A number of definitions consider lack of security as a central characteristic of slums and regard lack of any formal document entitling the occupant to occupy the land or structure as prima facie evidence of illegality and slum occupation. Informal or unplanned settlements are often regarded as synonymous with slums. Many definitions emphasize both informality of occupation and the non-compliance of settlements with land-use plans. The main factors contributing to non-

compliance are settlements built on land reserved for non-residential purposes, or which are invasions of non-urban land.

9. **Minimum Settlement Size:** Many slum definitions also require some minimum settlement size for an area to be considered a slum, so that the slum constitutes a distinct precinct and is not a single dwelling.
10. **Way of Life/Morals:** Depending upon the manner in which the slum has come up, the way of life of the inhabitants may be such that they are strangers to one another or they form a family slum with a thick acquaintance with one another. The socially disorganized slum may prove to be an area of delinquency crime and vice.

2.3 Causes of Slums

1. **Economic Conditions/Poverty:** The unemployment and growth of the population may force the affected persons to stay even in unhealthy atmosphere. Poverty encourages the formation and demand for slums. With rapid shift from rural to urban areas for the purpose of employment and income, poverty migrates to urban areas.
2. **Urbanization:** The formation of slums is closely linked to urbanization. Urbanization creates slums because governments are unable to manage urbanization, and migrant workers without an affordable place to live in, dwell in slums. Rapid urbanization drives economic growth and causes people to seek working and investment opportunities in urban areas.
3. **Politics:** Governments have for political interest subverted efforts to remove, reduce or upgrade slums into better housing options for the poor. Vote politics also support the slums. Removal of slums brings conflicts of interest of politician. Slum population forms a good amount of easy vote bank and politicians want them to remain as they are, because their upliftment and education will hurt their vote bank (Social Window India, 2013).
4. **Decentralization:** When decentralization takes place, the rich and middle-class people move to the extended portions of the town and thus, the poor people are left unattended in the overcrowded central area of the town.
5. **Industrialization:** The slums may be said to be the direct evil result of industrialization which in the early stages never took care of planning houses for labourers. Those that were built near factories were cheap structures with rent as the only motive. Through the industrial revolution, more people have been attracted to move from rural to urban areas on account of improved employment opportunities (Hiraska and Hiraska, 2010 and CONSERVE ENERGY FUTURE – Be Green, Stay Green. conserve-energy-future.com. Hence, whenever, they find land, public or private, they start living there in temporary hutments, as the time progress, more people join them and the area soon develops into slums. (Social Window of India, 2013).
6. **Bad Governance:** Slums develop due to bad governance. Government often fails to recognize the rights of the urban poor and incorporate them into urban planning, thereby contributing to the growth of slums. People are coming to cities far faster than the planning process can incorporate them. Often, they find their own land and build a shack before the government has a chance to learn of their existence.

The attitude of a government towards urbanization is also an important component. Some governments take a hostile approach to urbanization. They believe that if they provide urban services to the poor, it will attract urbanization and cause the slums to grow. The problem with this view is that very few people come to the city for water or services. They come looking for work. In other cases, governments take more of a passive approach to urbanization. They either do not have the planning tools to deal with the rapid urbanization that is happening, or the tools in place are not sufficiently responsive to the reality on the ground.

7. **Poor Housing Planning/Lack of Planning for the Lower Income Classes of the Society:** Lack of affordable low-cost housing and poor planning by the government encourages the supply side of slums (Deng, 2017 and Paknezhad, 2017). Insufficient financial resources and lack of coordination in government bureaucracy are two main causes of poor housing planning (Social Window of India, 2013).
8. **Poor Infrastructure and Social Exclusion:** It forces people to adapt the conditions beyond his/her control.
9. **Improper Use of Land/Lack of Zoning:** If lands fit for residence are used for industries or vice versa, the slum will be formed. If the town is not divided into suitable zones and development is allowed to take place at random, the slums may be created.
10. **Migrants:** The persons migrating from the surrounding areas may occupy, usually illegally, the vacant or empty places in or outside the city. The term squatter is used to mean a person who is occupying the land without title. The colonies of squatters may result in slums. The flow of migrants per day increases in metropolitan cities. About one-third of the urban population lives in ramshackle huts with no civic amenities.
11. **Physical Planning:** If the authority concerned does not possess adequate powers to control the development of towns, the slums may be formed, if preventive measures are not taken in time, the decent localities of the town will be the slums of tomorrow. The neglecting of basic principles of urban planning leads to widespread slums.

2.4 Effects of Slums

1. **Health Hazards:** The poor living condition in slums affect the health of people mentally and physically. The people residing in slums are easily attacked by various types of diseases. The climate of slums is such that it easily leads to unhealthy conditions of living (Rangwala, and Rangwala, 2011). Water contamination cause diseases like blood dysentery, diarrhoea, malaria, typhoid, jaundice, etc. Children with bloated bellies or famished skeletons, many suffering from polio, are a common sight. People are not aware of health problems.
2. **Undesirable Spots:** The slums as such on a city plan forms undesirable spots and, in a sense, disturbs the appearance of good features of a city plan.
3. **Working Conditions:** It is not possible to work peacefully in slums because the whole area is full of congested houses, traffic congestion, street trading, dusk and darkness. Living

in deprived slum neighbourhoods had a leveling effect on young people's occupational and educational aspirations. Limited opportunities in the slums lead many to make early transitions out of school and into crime. When faced with significant real or perceived barriers, many youths may adjust their aspirations to the reality of constraints within their environment. Hence, living in slums invariably result to youth's susceptibility to crime as well as being victims. For example, exposure to high rates of violence and crime which is typical in many resource-poor urban slums can have negative impacts on youth development (Furlong and Cartmal, 1997).

4. **Absence of Amenities:** The surrounding area of slums is lacking in essential amenities in required proportions because of overcrowding. Slums have invariably extreme unhygienic conditions. There are no toilets and defecate in open places. Slums have practically no drainage.
5. **Surrounding Locality:** The working of institutions like libraries, schools, hospitals, and clinics located nearby slums are seriously affected.
6. **Prone to Natural and Man-Made Hazards:** In slums, houses are crammed in a little space, they are often prone to dangerous hazards like floods, water logging, fire, etc. Extent of hazard is increased because of high population density.
7. **Social Problems:** Socially, slums remain isolated from the rest of the urban society and exhibit pathological social symptoms like drug abuse alcoholism, crime, vandalism, violence, stigma, low self-esteem, discrimination and low quality of life.

Table 2: Slum Prevalence in Nigeria Cities.

S/N	Nigerian Cities	Slum Areas
1.	Lagos	Agege, Ajegunle, Amukoko, Badia, Bariga, Bodija, Ijeshatedo/Itire, Ilaje, Iwaya, Makoko, Mushin, Oke-Offa Babasale, Somolu, Ikorodu.
2.	Kano	Kurna, Asabe, Sabon Gari, Nasarawa.
3.	Ibadan	Beere, Oje, Inalende, Mapi, Oke Padi, Yemetu, Oniyanrin, Agbokojo, Akobo-Ojuirin, Bodija, Ojoo.
4.	Akure	Erekesan, Obarila, Isolo, Idiagba/Ijemikin.
5.	Kaduna	Angwan Kurmin Gwari, Television, Nasarawa, Angwan Shanur, Malali, Ungwan Rimi, Barnawa.
6.	Jos	Angwan Rogo, Gangare, Katako, Angwan Rukuba, Hwolshe, Tudun Wada.
7.	Enugu	Akwuke, Ugwuaji, Abakpa, Emene, Akegbeugwu
8.	Port Harcourt	Njemanze, Igbo-Etche, Bundu, Water side, Mile 1, Eleme.
9.	Ado-Ekiti	Oke-Isa, Irona, Oke-Ila.
10.	Abuja	Dutsen Alhaji, Karimu Gwagwa, Kabusa, Kuchi, Gishiri, Bena, Jabi Daki Biyu, Utako Village.
11.	Minna	Tudun Fulani, Kpakungu, Angwan Biri, Dutsen, Kura.
12.	Makudi	Wadata, Angwan Jukun, Idye, Logo.
13.	Zaria	Parts of Samaru, Hagin Dogo.
14.	Owerri	Amaigbo, Oparanozie, Umezurike, Amadi (Umuodu), Old Ogboshishi, Egbu.
15.	Lokoja	Kabawa, Adankolo, Gadumo, Angwan Kura, Karaworo, Kpakungu, Madabo, Rimi, Galilee and Shabayagi.

Source: Adapted from Sunday A. B & Alexander A. F., 2011 Field and DAILY TRUST 2022.

Findings by our correspondent show that Ajegunle is one of many chaotic slums in Lagos, where people from all tribes in Nigeria live. Meaning of Ajegunle in Yoruba is, “This is where I have found my wealth” but ironically, poverty is the second name of the busy slum called Ajegunle (DAILY TRUST) dailytrust.com.

Slum is a heaven for criminals who attack residents during the day and at night

3.0 Crime

Crime is an inevitable reality in human society. It is inherent in human nature; hence no society or human settlement is completely free from the shackles of crime. The phenomenon (crime) knows no boundary and does not distinguish between the developed or developing world (Olusegun, 2015). Crime is deviance which violates a law. Crime represents expressions of how a society frames or constructs what is appropriate behaviour (Coomber, DonnerMeyer, McElrath and Scott, 2014).

Nigeria is currently caught in the web of crime dilemma, manifesting in the convulsive upsurge of both violent and non-violent crimes. Notable in this regard are the rising incidents of armed robbery, assassination and ransom driven kidnapping, which are now ravaging the polity like a tsunami, and spreading a climate of fears and anxieties about public safety. The upsurge of crime has been ongoing as Nigeria has been on the global crime maps since 1980. These theories of crime for decades are traceable to poverty, poor parental upbringing, and greed amongst the youth; get rich quick mentality, inadequate crime control model of national security among others (Oruwari, 2006). The issue of crime is associated with slums because of factors such as lack of adequate employment and also finally environment of nurturing a sense of helplessness and hopelessness and mostly neighbouring leafy suburbs makes crime an attractive venture for the jobless youths. Frequent ejection of the slum dwellers from their residence push them into criminal activities which are high and noted to be increasing yearly (Masese, 2007 and Kubende, 2018).

A report by UN-Habitat 2006 indicated that the presence of lack of semi-public areas which are protected and have inadequate public security infrastructure lead to the spread of lawlessness areas around the world. Urban centres are affected by both unplanned and planned crime activities and Nigeria is no exception.

Crime institutes a difficult situation when the frequency is extensive in the society as to entail a menace to the safety of the persons and possessions (Adebayo, 2013).

Poverty and urbanization mix may encourage youths to enlist into crime activities to enable them “to protect themselves and their neighbourhoods but also engage in criminal activities in the absence of steady sources of employment and in the absence of effective social support mechanisms” (Beall and Fox, 2007). Stravrou (2002) argued that existing forces found in destitute and dehumanizing living standards of the poor in communities could drive majority of these individuals into criminal activities which results in an increase in crime rates (Kubende, 2018).

3.1 Social Factors Influencing Crime in the Urban Slum Areas**1. Poverty and Crime**

The Oxford Dictionary or Sociology revealed that poverty refers to a deficiency of basic resources, especially of social needs. Scott and Marshal (2009) defines poverty as a condition where a person lacks important basics for sustenance. Poverty entails various dimensions. It involves low level of earnings and lack of ability to afford the most basic of goods and necessary survival services for dignity. It also entails inadequate education and health, inadequate security, lack of access for sanitation and clean water, no voice and lack of opportunity for betterment of lives (Silver, 1994). Poverty enhances development of anti-social behaviours of people. When people are extremely lacking, most often they resolve to crime to address lack of means for livelihood. As a result, they may be involved in crime to meet the needs of living, those which are basic in life (Bowlby, 1988).

2. Unemployment and Crime

Unemployment imposes negative effects on people and their dependents while anxiety, hostility and depression are features of such people (Clark, 1978). Staying out of work for long periods of time results in reduced self-respect and leads to frustration and perceptions of uselessness. These feelings may result in criminal activities in effort to regain sense of purpose and status. Children are particularly severely affected by unemployment as they suffer from poor diet, housing conditions, health and clothing. When the head of the family is unemployed, then such families mostly live in overcrowded housing (Clark, 1978).

It will be problematic for little educated immigrants from rural areas to procure a well repaying job due to deficiency in skills and knowledge in the jobs that are competitive on the market (Obeng – Odoom, 2011). The increasing group of seekers of employment becomes part of the urban underprivileged. Stability of society is destabilised by anti-social delinquency exhibited by the idle young people who are not employed but are readily for proscribed behaviours. The high rate of unemployed young people has adversely affected the efficacy and capability of police in combating criminal activities (Dambazau, 2007).

3. Housing and Crime

The housing in slums are mainly single room units made of inferior materials leaving occupants exposed to the elements of weather. The houses are often occupied by over 8 individuals mostly sleeping on the floor due to the limited space. The structures lack basics such as sanitation, water, safety and fire protection. The tenants pay more than what is expected as rents given the poor quality of housing. A major feature of these houses is existence of organized groups which collaborate with the local administration to obtain illegal payments.

In his book *Creating Defensible Space* (Newman, 1996) indicated that houses with a large number of families per entry, they are also susceptible to various types of deviance behaviours. Some of the deviance behaviours experienced by single family households is burglary, that is committed when members of the household are sleeping or far from home. These areas are where delinquents await to ambush their targets or victims and threaten them back into their residences with intention of robbing them.

4. Family Structure and Crime

It has been noted that the family influences maintenance of free and stable society. The size of the family, poor and ineffectual skills used for parenting, kid's ill-treatment, antisocial and disorderly parents and family dissonance may lead to delinquency in juveniles (Wasserman and Seracini, 2001). In his study involving 250 boys, McCord's (1979) concluded that parental conflict, aggression, poor parental supervision and harsh punishment while disciplining children led to adult convictions for violent offences. McCord, Wisdom and Crowell, (2001), identified children raised in single-parent family as likely to be involved in future delinquency. Similarly, results were obtained by Wringht and Wringht (1994) in their study on single parent families especially mother-only family. The study found that these families are likely to have children who easily fall into delinquency than families with two parents. Muehlemberg (2002) particularly found that lack of an intact family may drive youth into joining gangs.

Kids or children that come from collapsed families are most possibly likely to involve in deviance conducts than ones from steady backdrops. Out of 10, about 7 of these deviances are likely to belong to broken homes (Adebayo, 2013).

Poor families and homes are susceptible to numerous fundamental personality traits and child development, poor family organization practices surfacing due to uncontrollable situations such as staying in localities with very high deviance activities, lack of schooling and poverty (Patterson, DeBaryshe, and Ramsey, 1989).

5. Low Levels of Education and Crime

According to Chege (2015), majority of the youth living in slums have low education levels. Inability to access centres for education is an important issue that children in slums face. Local institutions in most cases intentionally fail to register the children which leads to reliance on external donations or organizations. Over a period of time, the quantity of uneducated and jobless youths drawn towards crime for survival increases, as they find the crime attractive. In addition, children attending school have no guaranteed security. Young girls have to be escorted to school due to idle youths who may attack them. Informal settlement school kids sometimes opt for unskilled employment (like house girls or boys) and drop out of schools even when performing well in academic field. Children in informal settlement usually work to survive, survival for the fittest is key in these slums, so most of the time school going children will not care about the laws that require them to go to school but look for any job that will put food in their household.

3.2 Causes of Crime in the Urban Slum Areas

The causes of crime in the urban slum areas are traceable to poverty, poor parental upbringing and greed amongst the youth; get rich quick mentality, inadequate crime control model of national security among others (Oruwari, 2006).

According to Neto (2002), the causes of crime are manifold but may be placed in three major categories: social, institutional and situational.

- 1. Social Causes:** Social causes include marginalization and social exclusion, lack of social control, lack of socialization in the family and school, crises in local traditions and values and lack of integration into society.

2. **Institutional Causes:** Institutional causes include deliberate government policies to disenfranchise certain sections of society as well as weak law enforcement and criminal justice systems.
3. **Situational Causes:** Situational causes of crime which are directly related to the urban environment include failure to master the urbanization process, lack of urban services, absence of the conception of security in urban policies and planning, degradation of urban neighbourhoods as well as overcrowding and proliferation of zoning abuses and squatter settlement.

4.0 Crime Prevalence

Crime prevalence refers to the proportion of people (or targets e.g. households, properties, or cars) in an area who are victimized and it is used to identify the risk of being a victim(s). The number of potential victims commonly equates to an area's population. However, in many cases potential target is more narrowly defined. For example, the potential victims of vehicle crime should be restricted to the number of individuals who own or have access to a vehicle. (Rogerson, 2004).

The prevalence of different crime types is burglary, other theft, assault, threats and vandalism and between racial abuse and theft from the person (Rogerson, 2004).

Police recorded crime is as known, not equivalent to "all" crime. A well-known fact is that a large proportion of "all" crime remains unrecorded.

Kidnapping is a more serious crime that violates severely the personal integrity of the victim. Assault remains the most common type of crime reported based on its mean value followed by burglary. The least among the crime types is manslaughter.

Table 3: Crime Statistics: Reported Offences by Type and State 2016 in Nigeria

State	Offence Against Persons	Offence Against Property	Offence Against Lawful Authority	Offence Against Local Acts	Total No of Cases 2016	% Share or Total Cases
FCT	2,984	9,350	843	4	13,181	10.48
Abia	230	113	21	0	364	0.29
Adamawa	779	1,417	56	7	2,259	1.80
Akwa Ibom	840	333	232	6	1,411	1.12
Anambra	898	1,413	142	81	2,534	2.01
Bauchi	812	1,713	118	14	2,657	2.11
Bayelsa	612	837	91	1	1,541	1.23
Benue	463	497	0	129	1,089	0.87
Borno	423	479	3	269	1,174	0.93
Cross River	1, 134	1,154	100	35	2,423	1.93
Delta	3,911	2,502	1,202	252	7,867	6.25
Ebonyi	572	595	44	0	1,211	0.96
Edo	697	1,307	0	0	1,004	0.80
Ekiti	718	1,008	103	0	1,829	1.45
Enugu	886	1,094	124	0	2,104	1.67
Gombe	513	1,350	19	356	2,238	1.78
Imo	954	873	103	0	1,930	1.53
Jigawa	321	214	37	74	646	0.51
Kaduna	338	502	129	37	1,006	0.80

Kano	1,981	2,375	318	243	4,917	3.91
Katsina	51	65	4	0	120	0.10
Kebbi	656	370	21	108	1,555	0.92
Kogi	294	480	17	7	798	0.63
Kwara	327	614	21	22	984	0.78
Lagos	15,426	22,885	6,768	306	45,385	36.08
Nasarawa	489	725	14	92	1,320	1.05
Niger	528	1,083	53	105	1,769	1.41
Ogun	1,122	1,112	145	0	2,379	1.89
Ondo	1,037	1,934	521	1	3,493	2.78
Osun	258	540	57	333	1,188	0.94
Oyo	1,377	1,752	314	0	3,443	2.74
Plateau	470	1,938	145	0	2,553	2.03
Rivers	1,683	897	271	143	2,994	2.38
Sokoto	496	1,055	29	0	1,580	1.26
Taraba	719	998	55	45	1,817	1.44
Yobe	398	520	18	8	944	0.75
Zamfara	157	303	6	17	483	0.38
National	45,554	65,397	12,144	2,695	125,790	100.00

Source: National Bureau of Statistics Nigeria, 2016

According to National Bureau of Statistics Nigeria (2016), Crime statistics on reported offences reflected that a total of 125,790 cases were reported in 2016. Offences against property has the highest number of cases reported with 65,397 of such cases reported. Offences against persons recorded 45,554 cases reported while offence against lawful authority and local acts recorded the least with 12,144 and 2,695 cases reported respectively. Lagos State has the highest percentage share of total cases reported with 36.08% and 45,385 cases recorded. FCT Abuja and Delta State followed closely with 10.48% and 13,181 and 6.25% and 7,867 cases recorded respectively. Katsina State has the lowest percentage share of total cases reported with 0.10% and 120 cases recorded. Abia and Zamfara States followed closely with 0.29% and 364 and 0.38% and 483 cases recorded respectively.

1. Offence against persons are those offences against human beings – eg. murder, kidnapping, manslaughter, infanticide concealment of birth, rape and other physical abuse etc.
2. Offence against properties are those offences against human belonging. Properties of any kind – e.g. stealing, receiving stolen properties, obtaining property by false pretence, armed robbery, burglary and house breaking.
3. Offence against lawful authority is any offence committed against any establishment of the law. e.g. The law says pay your tax (FIRS), failure to do this amounts to an offence against lawful authority.
4. Offence against local acts are those laws that we cannot enforce outside Nigeria – e.g. Liquor Act or Firearms Act. Here in Nigeria, you cannot go selling arms/ammunitions without a license but in the Republic of Benin, they are freely sold.

Crime Statistics: Reported Offences by Type and State (2017)

According to National Bureau of Statistics Nigeria (2017), Crime statistics on reported offences reflected that a total of 134,663 cases were reported in 2017. Offence against property has the

highest number of cases reported with 68,579 of such cases reported. Offence against persons recorded 53,641 cases reported while offence against lawful authority recorded at least with 12,443 cases recorded respectively.

Lagos State has the highest percentage share of total cases reported with 50,975 (37.9%) cases recorded. Abia and Delta States followed closely with 12,408 (9.2%) and 7,150 (5.3%) cases recorded respectively. Kebbi State has the lowest percent share of total cases reported with 205 (0.2%) cases recorded. Kogi and Bauchi States followed closely with 282 (0.20%) and 386 (0.30%) cases recorded respectively.

5.0 Methodology

The study covers Crime Prevalence in Nigerian Urban Slum Areas: The Way Forward. The paper investigates the present causes and effects of the urban slums and examines the crime prevalence in Nigerian Urban Slum Areas. The research objectives were achieved through extensive document review. However, the study relied on secondary data. Data were basically obtained from literature in journals, textbooks, academic articles, official records, private papers, and the internet. Ministry of Environment, Agriculture and Natural Resources, Lands, Survey and Physical Planning, Owerri Capital Development Authority (OCDA), Environmental Transformation Commission (ENTRACO), Police Stations and Tertiary Institutions were visited on the case of slums and crime.

6.0 Findings

Slum development has become a major urban planning and management problem due to the challenges they pose to the larger urban environment. Activities of slum dwellers are known to undermine the social, economic and environmental sustainability efforts of the city.

Most of the settlements in Nigeria were built more than 50 years ago and reduced to slums. Most slums are caused due to rapid population growth, decentralization, industrialization, poor infrastructure and social exclusion, migrants, uncontrolled urban development/lack of planning for lower income classes of the society which also resulted in overdependence on facilities. Crime institutes a difficult situation when the frequency is extensive in the society as to entail a menace to the safety of the persons and the possessions.

- **Poverty** is one of the main reasons for crime countries with high rates of economic deprivation tend to witness higher crime rates than other countries. Since people do not have the means to secure a living in the right ways, they invest their time in criminal activities. Poverty encourages the formation and demand for slums.
- **Unemployment** is an issue faced by developing and developed countries especially in Nigeria. A huge portion of the youth of today are unemployed. The unemployment rate in our country is ever increasing. Naturally, this leaves the youth frustrated as despite spending a lot of time and money on their education they still find it tough to get a good job. This leads to a feeling of resentment towards the system in the minds of many youngsters who then rebel and resort to crime early on in their lives. Unemployment may force the affected persons to stay even in

unhealthy atmosphere. Unemployment is a driving force of youth criminality in slum areas of Nigeria. The slum areas serve as hideouts of criminals since accessibility to these areas is difficult.

- **Politics:** The interrelation between politics and crime is overlooked many times. This is problematic as many people have engaged in criminal activities while dealing with political issues. Additionally, there have been quite a few politicians in developing countries who have also been associated with violent crimes and murders. So many youth members of parties are often given weapons and instructed to handle matters violently during conflicts. This does not only expose youth to criminal activities but also puts the lives of various citizens at risk. So, an unstable political situation in a country leads to an exponential increase in the crimes that take place there.

Governments have for political interest subverted efforts to remove, reduce or upgrade slums into better housing option for the poor. Slum population forms a good amount of easy vote bank and politicians want them to remain as they are.

- **Bad Governance:** Slums develop due to bad governance. Government often fails to recognize the rights of the urban poor and incorporate them into urban planning thereby contributing to the growth of slums.
- **Health Hazards:** The poor living conditions in slums affect the health of people mentally and physically. The people residing in slums are easily attacked by various types of diseases like malaria, typhoid, diaorrhea, decency etc.
- **Working Condition:** It is not possible to work peacefully in slums because the whole area is full of congested houses, traffic congestion, street trading, pollution etc. which affect young people's occupational and educational aspirations.
- **Undesirable Spots:** The slums are such on a city plan form undesirable spots and in a sense, disturbs the appearance of good features of a city plan.
- **Absence of Amenities:** The surrounding area of slums is lacking in essential amenities in required proportions because of overcrowding.
- **Surrounding Locality:** The working of institutions like schools, hospitals, libraries, clinics located nearby slums are seriously affected.
- **Prone to Natural and Man-Made Hazards:** In slums houses are crammed in a little space, they are often prone to dangerous hazards like water logging, floods, fire etc.
- **Social Problems:** Socially, slums remain isolated from rest of the urban society and exhibit pathological social symptoms like drug abuse, crime, alcoholism, violence etc.
- **Peer Pressure** plays a significant role in the lives of all teenagers and young adults. That is a phase of life where people tend to look up to their friends and believe what they do is the or rather 'hip and happening' thing to do. The lack of wisdom and experience these people have just added fuel to the fire. As a result, many individuals in their youth subconsciously get drawn to vices like alcohol consumption and smoking just by looking at peers.
- **Unfair Justice System:** The flawed justice system is another major contributor to crimes. When people believe that they are not given their due and are unfairly treated by the system

itself, they harbour feelings of resentment towards it and start to rebel. This involves them engaging in criminal activities and doing the opposite of what is expected of them. People try to get just for themselves when they feel like the state is not going to do the same and tend to commit various acts of crime in their journey to avenge themselves and get what they believe they deserve. Many innocent people resort to crimes when they are wrongly proven to be guilty in the Court of law owing to a lack of trust in the system.

- **Background:** Often times the background and family conditions of a criminal can be attributed to the reason behind their crimes. When people believe that they are responsible to provide for their family and they are unable to do so owing to lack of opportunities, lack of education or other such issues that handicap them, they resort to crime. This issue does not lead to crimes such as theft alone but also motivates people to commit gruesome acts that put their freedom and lives at risk just so they can make a good amount of money through bribes or ransoms that can be used for their family's sustenance.
- **Unequal Rights:** Deprivation is another significant contributor to the increasing crime rates. People resort to notorious activities when they are deprived of their basic rights since that impedes their means to obtain a livelihood in a conventional and honest way. They have limited options and are already at a disadvantaged position in society that they choose to make money and sustain themselves through hook or crook. This usually involves them engaging in criminal activities.
- **Religion:** Even today, unfortunately, various divides and issues of society can be attributed to religion. Despite it being a basic human right, many people are deprived of practicing their own religion. This leads to a feeling of resentment in the minds of believers. Moreover, there have been an awful lot of cases involving crimes over different schools of thought too.

Innocent lives have been lost in this war over ideological concepts that have existed since time immemorial. This is an extremely sad state of affairs considering that it is already the 21st Century and human beings have progressed so much in other areas. There are a huge number of crimes committed by religious fanatics while they try to further their cause by propagating their religion or at times try to establish their religious superiority over other faiths by resorting to destruction and vandalism.

- **Drugs:** Crime and drug abuse are closely related. A person under the influence of drugs tends to indulge in criminal activities that they may have not indulged in otherwise. The main problem arises when they get addicted to the drugs and believe they require it to sustain themselves. In such a situation, drug addicts are ready to go to any extent to procure these illegal substances. Under the influence of drugs, people feel the urge to do things that are not only illegal but also have the potential to ruin and at times even end their lives.
- **Society:** In today's times, money is one of the most important aspects of everyone's life. The meaning of money is not restricted to the amount of wealth in a person's bank account but is instead also attributed to their societal status, worth, and even values. As a result of this, people value money more than their relationships and happiness. What other people think of a person is more important to them than how they feel. Even schools and universities do not teach

children how to be happy and satisfied in life but instead teach them how to make more money, which indirectly attributes wealth to worth. (IPleadersblog.ipleadersin>causes-of-crime).

The crime prevalence in Nigerian Urban slum areas are murder, manslaughter, infanticide, concernment of birth, rape, assault, prostitution, kidnapping, assassination, political motivated killings, religious clashes, drug abuse, armed robbery, burglary and house breaking, stealing, pick pocketing, motor vehicle/automobile theft, counterfeited currency, fraud, bribery and corruption.

7.0 The Way Forward

- Slum is a universal phenomenon spreading its tentacles in virtually every urban settlement. It is a breeding ground for criminal activities accompanied by increased rates of crime, violence and lawlessness. These are areas when little government attention in terms of provision or maintenance of public facilities and infrastructure is being felt. If cities are to play their role as drivers of economic and social development, these challenges have to be addressed through effective planning and good governance at Federal, State and Local Government levels. These planning programmes can include removal of high fences that provide cover to criminals and the rehabilitation and re-appropriation of community public space, slum clearance programmes, forced eviction and demolition, resettlement or relocation. Slum upgrading programmes by constructing high rise blocks of flats to replace slums by government.\
- Implementation of poverty eradication projects that improve living standards and give support to the poor and needy through supporting the youths in attaining more education, introduction of vocational training which can help the youths in self-employment hence limiting unemployment, idleness and joblessness.
- Structural efficiency through provision of employment opportunities by government in partnership with private organizations to improve the quality of life of the people.
- Encourage community participation and involvement in the security management especially at policy formulating, planning, implementation and monitoring among other issues.
- There should be combined efforts of the police and vigilante to check criminality in the urban areas.
- Neighbourhood Watch is most often employed on our area basis but has been found to be more successful when activity is clustered in small cocoons' surrounding victims' addresses.
- Education and Public Awareness Campaigns are most commonly used as an area wide strategy including posters, newsletters, leaflets, door to door, jingles, radio programme, play lets, T.V. programmes, and Town hall meetings will be activated to enlighten the citizenry on living standards and be free from crime.
- Increasing patrols of security officers and community policing initiatives declines the number of crime activities.
- Increasing the presence of police personnel, vehicles/patrol cars or the wider policing family is a common area based strategy that will assist in containing crime. Policy and Warden teams can also be mobilized to target specific problem areas and this may be identified either as areas with crime prevalence or concentration. It is desirable to adopt a response to repeat

victimization that involves some form of detection activity. This is particularly appropriate since around 80% of repeat burglary, kidnapping etc. victims are likely to have been revictimized by the same offender.

- Police data is the most frequently used source of information used to identify repeats. This has its limitations. Chronic victims are less likely to report crimes. They may have had previous negative experience with criminal justice agencies and may be resigned to experiencing victimization. They may also fear reprisals associated with assisting the police. Initiatives to encourage the reporting of crime and to increase the avenues through which crimes can be reported will have additional benefits in the identification of repeat victimization.
- Searching for repeat victims amongst recorded incidents is not an easy task. Many police systems have limited searching facilities. Incomplete, incorrect and inconsistent recording of information further hinders attempts to match incidents to victims. Efforts to improve the accuracy and availability of crime data should be in delivery plans. A Crime Tracking Data and Analysis System should provide a computer system to receive data both from the police and other partner agencies. The system is designed to improve the ability to sort, link and analyse data.

The use of standard Geographical Information Systems, searching geographically referenced crime locations can dramatically improve the time and accuracy of identifying repeats, they can identify geographic areas of concentration in which to target crime reduction interventions. They can also be used to identify areas in which to further investigate crime concentration at the level of the individual victim.

- Nigerian cities should be planned, built, and managed, so as to ensure transformability towards sustainable and harmonious development.

8.0 Conclusion

Most cities in Nigeria today are confronted with slum development and crime. Poverty, uncontrolled and unplanned settlements as well as the absence of urban physical landscape in Nigeria remained the challenges affecting urban development in most states.

Making cities a safe and healthy living environment depends on the capacity of the planning, design and policy models employed to cope with the forces that are shaping the cities and causing the threats (Salau and Lawanson, 2009). In this regard, government should focus more on providing adequate health facilities in the area as well as good roads, adequate electricity supply, portable water and good drainage system to ensure a safe, healthy and working environment. Create more opportunities to reduce rural poverty and promote sustainable development. Therefore, education and public awareness, CCTV and surveillance, physical design, physical presence of security outfit, community participation and involvement in the security management, land use planning, infrastructure development, monitoring system and effective data management are ways of reduction of slums, violence and crime.

Good governance is a key to achieving safety and healthy living environment because it will ensure that the right response is given when the occasion arises (Achi, 2009). Physical planning remains

a veritable tool, a special purpose vehicle for among others things, actualizing sustainable settlement in Nigeria. This will generate multiple benefits in all sectors which are necessary to improve basic development needs of citizens.

There is a need to carry out a study to establish the law enforcement readiness and strategies to combat the rising cases of slums and criminal activities in the slums. The findings from such a study will add knowledge on the government readiness in combating these behaviours.

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Relationship between the Spatial Distributions of Existing Primary Health Care Facilities and the Socio-Economic Features of Enugu Urban, Nigeria.

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Abstract

This study examined the relationship between the spatial distribution of primary health care facilities (PHCF) and socio-economic characteristics in Enugu Urban, Nigeria. The study adopted an exploratory research design using a case study approach to assess accessibility to PHC services across selected neighbourhoods in Enugu Urban. A multi-stage random sampling technique was employed, and data were collected using both primary and secondary sources. A total of 1,300 questionnaires were distributed, out of which 1,219 were valid for analysis. Spatial and statistical techniques, including multiple linear regression analysis, were used to examine the relationship between PHCF distribution and selected socio-economic variables. Findings revealed a very strong relationship (97.2%) between the spatial distribution of PHCF and key socio-economic factors such as population density, household size, household income, travel distance, travel time, age, and political or economic influences on facility location. The results show that variables such as number of facilities, population density, and urbanization significantly improve accessibility, while factors such as distance, income, and political influence tend to reduce it. The model indicates that health facility location in Enugu Urban is strongly influenced not only by population distribution but also by planning decisions and socio-economic conditions. Overall, the study concludes that access to primary health care in Enugu Urban is shaped by a combination of demographic, economic, and spatial factors, with significant implications for equity in health service delivery.

Keywords: *Accessibility; Enugu Urban; GIS and Spatial Analysis; Health Facilities; Health Service Delivery; Nigeria; Primary Health Care; Socio-economic Factors; Spatial Distribution; Urban Health*

1 Introduction

Access to primary health care (PHC) is widely accepted as one of the most important foundations of a functional and fair health system across the world. Since the Alma-Ata Declaration of 1978, PHC has been seen as key to achieving universal health coverage and improving people's overall

health (World Health Organization, 2018). However, despite these global efforts and commitments, access to health facilities is still uneven, especially in low- and middle-income countries. In many places, where health facilities are located often reflects existing socio-economic inequalities, patterns of urban growth, and levels of infrastructure development. This situation leads to unequal access to essential health services (Peters et al., 2008; WHO, 2020).

Globally, cities are growing very rapidly, and this growth is changing how health services are distributed. Although urban areas generally have more health facilities than rural areas, not everyone living in the city benefits equally. Factors such as income, education, type of job, and housing conditions play a major role in determining both where health facilities are located and whether people can actually use them (Guagliardo, 2004). As a result, even when facilities are physically close, poorer or marginalized groups may still face serious challenges in accessing primary health care.

In Africa, this problem is even more noticeable. Many cities are expanding quickly, often without proper planning, which makes it difficult to provide infrastructure and services evenly (UN-Habitat, 2016). Research across different African countries shows that health facilities tend to be located in wealthier or more developed parts of cities, leaving poorer and peri-urban communities with limited access (Noor et al., 2006). At the same time, issues like poverty, unemployment, and low levels of education further reduce people's ability to seek and receive care, leading to poorer health outcomes (Oluwole et al., 2019).

Nigeria also reflects many of these challenges, but the situation is made more complex by weaknesses within the health system itself. The country operates a three-tier health care system primary, secondary, and tertiary with primary health care designed to be the first point of contact for individuals and communities (Federal Ministry of Health, 2016). Even though PHC is emphasized in policy, its actual distribution is often uneven, especially in fast-growing urban areas where infrastructure has not kept pace with population increase. Studies have shown that some neighborhoods have better access to health facilities than others, while areas such as informal settlements are often neglected (Onokerhoraye, 2010). Socio-economic conditions, population pressure, and poor urban planning all contribute to this imbalance.

At the local level, Enugu State particularly Enugu Urban clearly reflects these issues. As a growing urban center in southeastern Nigeria, Enugu Urban has experienced rapid population growth and social change in recent years. However, the development of health facilities has not kept up with this growth. This has created noticeable differences in how primary health care services are distributed across the city. Some areas have relatively good access to facilities, while others, especially those with lower-income populations, have limited or inadequate access to basic health services. The socio-economic structure of Enugu Urban is quite varied, with clear differences in income, employment, education, and living conditions across neighborhoods. These differences influence not only where health facilities are located but also how easily people can use them. For example, people living in low-income or densely populated areas may have to travel longer distances or spend more money to access care. On the other hand, wealthier areas tend to attract more health facilities due to better infrastructure and higher financial returns.

Given these realities, it is important to understand how the location of primary health care facilities relates to the socio-economic characteristics of the population in Enugu Urban. Studying this relationship can help reveal areas that are underserved and highlight existing inequalities. Such information is crucial for better planning and decision-making in the health sector. This study therefore aims to examine the relationship between the spatial distribution of existing primary health care facilities and the socio-economic features of Enugu Urban. By combining spatial analysis with socio-economic data, the study seeks to provide practical insights that can support more fair and effective distribution of health care services.

2 Review of Literature

Relationship between the Spatial Distribution of Primary Health Care Facilities and the Socio-Economic Features

Studies have shown that there is a strong relationship between the social and economic characteristics of urban populations and the level at which public services, such as health care facilities, are used (Olawuni, 2008; Riman & Akpan, 2012; Owoseni et al., 2014; Olugbamila, 2016). In particular, Owoseni et al. (2014) noted that the socio-economic status of a country or community largely influences its overall health condition.

The importance of socio-economic characteristics cannot be overlooked, as several studies have consistently found that factors such as income, level of education, ethnicity, age, number of children (parity), and decision-making power all affect how people use health care services (Babalola & Fatusi, 2009; Owoseni et al., 2014; Adeyinka & Olugbamila, 2016). These factors shape not only people's ability to access health facilities but also their willingness and frequency of use.

Overall, these findings suggest that socio-economic variables play a key role in determining how available health care facilities are utilized. The following socio-economic factors, among others, have been identified as important in influencing the use of health care services.

Education

Education plays an important role in how people understand and use modern health care services. Owoseni et al. (2014) explain that education helps individuals gain better knowledge of health care, improves how they communicate with health providers, and makes them place more value on maintaining good health. Because of this, people who are more educated are generally more likely to seek out and use modern health services.

This pattern is also seen in many developing countries. For example, studies carried out in Bangladesh show that formal education is strongly linked to higher use of health care facilities (Chakraborty et al., 2003; Kamal, 2009). In particular, the more educated a woman is, the more likely she is to seek medical care when needed.

Education is also very important when it comes to maternal health. Women with higher levels of education tend to better understand the importance of prenatal care and are more likely to know where to access such services (Raghupathy, 1996). This means that education not only increases awareness but also helps women make better decisions about their health and the health of their children.

In general, it can be said that educated women are more informed about health issues, more aware of available health services, and better able to use this knowledge to maintain or improve their overall health.

Employment and Access to Healthcare

The kind of work people do and the conditions under which they work can greatly influence their access to primary health care services. According to Adamu (2011), it is often assumed that women who are employed and earn an income are more likely to have financial independence and, therefore, a better ability to pay for health care services.

However, this is not always straightforward. Miles-Doan and Brewster (1998) point out that it is not just about earning money, but also about the nature of the job. Some jobs may not provide enough stability, time, or income to support regular use of health services. For example, women engaged in less secure or physically demanding jobs, such as farming, are often less likely to use health care facilities (Addai, 2000). This shows that both the type of job and the level of income matter when it comes to accessing health care.

Income

Income plays a major role in determining how people use health care services. It reflects a person's or household's economic situation and influences the kind of health care they can afford. In many cases, income determines not only whether people seek medical help but also where they go, how often they go, and what actions they take when they are sick.

Research has shown that as people's income increases, they are more likely to make use of health care services (Chakraborty et al., 2003). This is because seeking health care often comes with several costs, such as transportation, consultation fees, drugs, and other related expenses. For people with low income, these costs can be difficult to afford, which may discourage them from visiting health facilities even when they need care (Adamu, 2011).

Several studies have also confirmed that household income strongly affects the ability to pay for and use available health care services (Olawuni, 2008; Adeyinka, 2013; Owoseni et al., 2014). This makes income a very important factor in understanding access to and use of primary health care.

Migration and Urbanization

Migration and urbanization have a strong impact on the availability and use of primary health care facilities. As more people move into urban areas, the demand for health services increases, often putting pressure on the existing facilities (Bello, 2022).

Cities tend to grow because they offer more economic opportunities, better infrastructure, and access to markets. For example, Bello (2022) explained how cities like Aba and Umuahia grew rapidly due to trade, railway development, and industrial activities. These developments attracted people from different places, leading to population growth through both natural increase and migration. As the population increases, so does the need for essential services like healthcare.

Migration simply refers to the movement of people from one place to another. When people move into a place, it is called immigration, and this can be measured by the number of people entering a region over time. Urbanization, on the other hand, refers to the increasing number of people living in cities, usually expressed as a percentage of the total population (Oyesiku, 2010; Population Reference Bureau, 2011).

According to the United Nations Population Fund (UNFPA, 2007), many young people move from rural areas to cities every year in search of better job opportunities. While international migration can be risky and challenging, movement within a country (especially from rural to urban areas) is more common and has a greater impact on cities.

In Nigeria, migration also affects the health sector in another way through the movement of skilled health workers to other countries. Darlene et al. (2006) noted that many Nigerian doctors and health professionals leave the country for better opportunities abroad. This “brain drain” has contributed to shortages of health workers and has made it more difficult for the health system to meet the needs of the population.

Although migration is sometimes seen as a result of poverty and lack of jobs (Dang, 2003), it can also be beneficial. According to the Department for International Development, migration can help improve people’s livelihoods and contribute to economic growth. Laczko (2005) also noted

that migration allows households to earn more income, diversify their sources of livelihood, and improve their standard of living.

Despite these benefits, rapid migration and urban growth often place heavy pressure on existing health care facilities. This can lead to overcrowding, uneven distribution of services, and difficulties in accessing care, especially for low-income populations.

Nigeria National Health Policy

The Nigeria National Health Policy (2016) is designed to strengthen the country's overall health system, with particular emphasis on primary health care (PHC). Its main goal is to move Nigeria closer to universal health coverage by improving the quality, accessibility, and affordability of health services for all citizens.

This policy did not emerge in isolation. Nigeria had earlier versions of national health policies in 1988 and 2004, each aimed at improving health system performance. The 2016 version, however, builds on these earlier efforts while also responding to new and emerging challenges such as disease outbreaks, climate change, and the effects of globalization on health systems.

At its core, the policy focuses on strengthening primary health care, expanding universal health coverage, improving health data systems, and promoting collaboration among key stakeholders. It also emphasizes long-term planning through structured frameworks such as the National Strategic Health Development Plan.

Importantly, the 2016 policy aligns with the National Health Act (2014), which provides the legal and institutional framework for regulating and managing the health sector in Nigeria. In simple terms, while the National Health Policy serves as a guiding vision for the health system, the National Health Act provides the legal structure that supports its implementation. Together, they aim to promote a health system that is more equitable, efficient, accessible, and of better quality for all Nigerians.

Minimum Standards for Primary Health Care in Nigeria

Nigeria operates a three-tier system of government federal, state, and local and the health system follows the same structure. Within this arrangement, primary health care is delivered mainly at the local government level, secondary care at the state level, and tertiary care at the federal level. Among these, PHC serves as the foundation of the entire health system and is usually the first point of contact for most people seeking medical attention.

Because PHC plays such a critical role, it is important to establish clear standards that guide its planning and delivery. According to the World Health Organization, health standards are essential tools for improving service management and ensuring that the best possible quality of care is achieved within available resources.

To this end, the Minimum Standards for Primary Health Care in Nigeria was developed by the National Primary Health Care Development Agency (NPHCDA) in collaboration with key stakeholders. These include the Federal Ministry of Health, academic institutions, public health experts, and international development partners such as WHO, UNICEF, UNFPA, the World Bank, PATHS2, and FHI.

The development of these standards was driven by the need to improve equity and access to health care services. A major milestone in this process was the introduction of the Ward Minimum Health Care Package in 2007, which highlighted the need for clearly defined standards in infrastructure, staffing, funding, and essential medical supplies for PHC facilities across the country.

The overall goal of the Minimum Standards document is to clearly define what is expected at each level of PHC delivery in Nigeria. This includes standards for health infrastructure, human resources, and service provision at the local government level. By doing so, it aims to improve access to health services, ensure quality of care, and support effective planning, monitoring, and evaluation of PHC delivery.

Specifically, the document outlines minimum requirements in three key areas:

- Health infrastructure: This includes the types and levels of PHC facilities, as well as basic requirements for buildings, equipment, and furniture.
- Human resources for health: This specifies the minimum number and categories of health workers required at each level of care.
- Service delivery: This defines the essential health services to be provided, along with the minimum equipment and essential medicines needed to deliver those services effectively.

These standards are intended to serve as a baseline. In other words, while they set the minimum acceptable requirements, additional improvements can be made depending on available resources and local needs.

The National Primary Health Care Development Agency (NPHCDA) plays a central role in implementing the National Health Policy as it relates to primary health care. One of its key responsibilities is to develop systems for supervision, monitoring, and evaluation of PHC services based on national guidelines and standards.

In practice, primary health care remains the foundation of Nigeria's health system. For most people, it is the first place they go when they need medical attention. It is expected to handle basic and uncomplicated health conditions, promote health education, and serve as a gateway for referring patients to higher levels of care when necessary.

To strengthen PHC delivery in Nigeria, four key approaches are emphasized:

1. Promoting community participation in planning, management, monitoring, and evaluation of health services.
2. Strengthening collaboration between different sectors that influence health outcomes.
3. Improving coordination and integration across all levels of the health system.
4. Enhancing management systems to support effective health development at all levels.

3 Materials and Methods

For this study, both primary and secondary data were collected. Given the nature and objectives of the research, an exploratory research design was adopted to better understand access to primary

health care services. Within this framework, the case study approach was used to examine the spatial distribution and accessibility of health care facilities in residential areas of Enugu Urban. This approach made it possible to gain a deeper and more detailed understanding of how people in different neighbourhoods access primary health care. The choice of this design is appropriate because it allows for a thorough and context-based analysis of health care accessibility (Creswell, 2014).

Cochran's formula was used as the base for the sample-size calculation, adjusted for multi-stage clustering by a design effect (DEFF) and inflated for anticipated non-response ($Z=1.96$, $p=0.5$, $e=0.05$, $DEFF=2.0$, planned $r=0.40$); this pathway yields the field target of 1,300 distributed questionnaires to residents through face-to-face administration across various neighbourhoods in the study area. Out of these, 1,219 were properly completed and retained for analysis, giving an achieved valid response rate of 93.8% of distributed instruments (non-response/invalid rate $\approx$ 6.2%).

The study employed a multi-stage random sampling technique for data collection. In the first stage, the three Local Government Areas (LGAs) that make up Enugu Urban Enugu East, Enugu South, and Enugu North were selected. In the second stage, neighbourhoods with clear urban characteristics were identified within each LGA. Based on predefined criteria, three neighbourhoods were selected from Enugu East – Abakpa Nike, Emene, and Trans Ekulu; five from Enugu South – Achara Layout, Uwani, Maryland, Garki, and Awkunanaw; seven from Enugu North – New Haven, GRA, Asata, Iva Valley, Independence Layout, Coal Camp, and Ogui.

In the subsequent stage, streets within the chosen neighbourhoods were selected using a simple random sampling technique. The names of all streets in each selected neighbourhood were placed into separate containers and specific streets were drawn without replacement. Finally, buildings and households within these selected streets were chosen, and questionnaires were administered to residents. This multi-stage approach ensured that different parts of Enugu Urban were adequately represented and that the data collected reflected the diversity of the study area.

The study combined exploratory spatial statistics (global and local autocorrelation), hotspot analysis, and multivariate spatial regression. Key tests included ArcGIS 10.8 Global Moran's I,

Local Indicators of Spatial Association (LISA) / Getis-Ord Gi*, and a multiple linear regression framework checked for spatial dependence and multicollinearity; where, spatial regression or geographically weighted regression (GWR) was used to account for spatial non-stationarity.

4 Results and Discussion

The hotspot analysis (Global Moran's I, Local Indicators of Spatial Association (LISA) / Getis-Ord Gi*) for the spatial pattern of primary health care facilities in the study area indicated an irregular clustered pattern of distribution of these facilities in Enugu while the multiple linear regression analysis of the research shows a very strong relationship (97.2%) between the spatial distribution of primary health care facilities (PHCF) and the ten socio-economic variables examined in this study (adjusted model $R^2 \approx 0.972$). These variables include the number of PHCF in an area, population density, household size, household income, travel cost, travel time, travel distance, age of respondents, and the factors influencing the location of PHCF (whether political or economic). Most of these variables were obtained from secondary data sources rather than respondents' opinions. Overall, the results indicate that about 97% of the variation in the spatial distribution of PHCF can be explained by these socio-economic factors. The multiple linear regression model developed from the analysis reflects how each of these variables contributes to spatial accessibility.

Looking at individual variables, the number of PHCF in an area has a strong and significant positive effect on spatial accessibility. This simply means that as the number of health facilities increases, access to health care also improves. This is expected, as more facilities generally lead to better coverage and reduced pressure on existing ones.

Similarly, population density shows a significant positive relationship with spatial accessibility. This suggests that areas with higher population density tend to have better access to health facilities. Although this may seem surprising since higher population could increase demand and strain services it may also indicate that more facilities are located in densely populated areas to meet demand.

On the other hand, household size does not show a significant effect on spatial accessibility. However, the relationship is negative, meaning that as household size increases, access slightly decreases. In practical terms, larger households may place greater demand on available facilities,

which could reduce accessibility. The fact that this relationship is not statistically significant suggests that household size alone may not strongly determine access in the study area.

In the same way, household income is found to have an insignificant relationship with spatial accessibility. The result shows a negative relationship, implying that as income increases, spatial accessibility slightly decreases. This may reflect the reality that higher-income households may prefer private health facilities, thereby reducing their reliance on primary health care centres. At the same time, it is important to note that low income can still limit people's ability to seek care due to associated costs such as transport and medication (Adamu, 2011; Fernandez, 2000).

Distance to health facilities shows a significant relationship with spatial accessibility. Generally, distance is an important factor in determining access, as longer distances can discourage the use of health services. This highlights the importance of locating facilities closer to where people live.

The age of respondents does not have a significant effect on spatial accessibility. Although the results show a slight negative relationship, age mainly plays a supporting role by influencing how people respond to other factors rather than directly affecting access to health facilities.

The decision to locate PHCF (whether influenced by political or economic factors) is found to be significant. The results suggest that when political or economic considerations play a stronger role in deciding where facilities are located, spatial accessibility tends to decrease. This implies that facility location may not always be based on need or fairness, but sometimes on political interests. In this study, this variable was measured as a categorical one, indicating whether community input was considered in the siting of facilities. The findings support earlier observations that political influence can affect the distribution of public services, including health facilities (Tanser, 2006).

Finally, urbanization also shows a significant relationship with spatial accessibility. As urban areas expand, access to health facilities tends to improve. This is likely because urban areas attract more infrastructure development, including health services, to meet growing demand.

Overall, the findings show that while several socio-economic factors significantly influence the spatial distribution and accessibility of primary health care facilities, others play a less direct role. Importantly, the results highlight that access to health care in the study area is shaped not only by

population and infrastructure but also by planning decisions and broader socio-economic conditions.

5 Conclusion

The findings of this study show that there is a strong and significant relationship between these socio-economic factors and the spatial accessibility of primary health care facilities. This means that future decisions about where to locate new facilities should take these variables into account in order to ensure a more balanced and equitable distribution of health services.

In addition, the study has clearly identified these variables as major determinants of how PHCF are distributed across the study area. Because of their strong influence, they can serve as a practical guide for planners and policymakers, not only in Enugu Urban but also in other similar urban settings. Using these factors as a benchmark will help ensure that health facilities are located in areas where they are most needed and can be easily accessed by the population.

To further support decision-making, a mathematical model was developed (using the major determinants of PHCF distribution) in this study to explain the relationship between spatial accessibility and the identified variable coefficients from the MLR analysis:

Spatial accessibility = 10982.9 + 40404.3 (number of PHCF in the area) – 15.77 (distance from residence to PHCF) + 0.151 (population density) – 15809 (household size) – 42.5 (household income) – 3487.0 (travel time) – 2563.21 (age of respondents) – 2168.81 (political/economic factor) + 118005871 (population) – 420.16 (urbanization) – 0.15809 (household size) – 17707 (error term).

One of the key contributions of this study is that it provides a practical and evidence-based tool that can support both health planners and urban planners in making better and faster decisions. Compared to more complex approaches, this model offers a relatively cost-effective way of guiding the location of health facilities. It also improves the reliability of health care data and makes it easier to store, retrieve, and analyze information when needed.

6 Recommendation

Improving health care provision in Enugu Urban requires a more structured and well-regulated approach to the siting of primary health care facilities (PHCF). One important step is to establish clear and standardized guidelines for locating these facilities. Such guidelines should be based on the key factors identified in this study as influencing their spatial distribution. These include the number of existing PHCF in an area, population density, household size, household income, travel cost, age of residents, and whether location decisions are influenced by political or economic considerations.

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Slope as a criterion for land suitability assessment for urban development in Kwara South District, Kwara State – Nigeria

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Abstract

Urbanization has led to the degradation of natural landscapes and land resources, which are critical for preserving biodiversity and natural benefits. Land suitability assessment aim to balance urban development with preserving and protecting land and natural resources to achieve greater sustainability. This study evaluated slope as a criterion for land suitability assessment for urban development in Kwara South District, Nigeria, using a combination of the analytical hierarchy process and geographic information system. Slope regimes in the study area were discovered to basically ranged between 0° - 54° , it was revealed that more than 70% of the study area fall within 0° - 3° which is ranked highly suitable; 3° - 8° (25%) moderately suitable, while 3% (8° - 16°) and 1% (16° - 25°) are ranked marginally and less suitable respectively. The Unsuitable class has the least coverage with less than 1%. The study also created a land suitability map for urban development using the slope criterion; this can hugely contribute to urban planning and environmental management to promoting sustainable urban development and protecting the environment.

Keywords: AHP; GIS, land suitability, urban development.

1.0 Introduction

Urbanization is a worldwide phenomena that has been transforming the world's population geography for centuries. It is a process of transforming natural landscape to urban set up in terms of dense and high-rise built-up area, resemblance with increasing population and economic importance. As more people move from rural areas to cities, the dynamics of population distribution, density, and composition undergoes significant changes, with a complex set of socio-economic, demographic, and physical development in urban settlements (Adedeji, 2023). The United Nations Economic Commission for Africa Department of Economic and Social Affairs

(2024), listed Gabon, Nigeria, Egypt, and Democratic Republic of Congo to be in the forefront of the ongoing increase in population and spatial extent of urban areas in African continent.

In Nigeria, urban development is associated with population increase, and characterized by haphazardly pattern of growth and driven by a multitude of processes, resulting in inefficient land resources utilization (Umar *et al.*, 2023). Goel and Vishno (2022) associated the urban development with rational land resource utilization, environmental protection, and infrastructure development to ensure sustainable physical development. Therefore, effective land use planning, control and management are needed to tackle these problems and ensure sustainable urban development, which will coexist harmoniously with other land uses to ensure development, sustainable use of land resources, and overcome the problems arising from haphazard urban development (Shafiu and Ashiru, 2023).

Land suitability assessment is a powerful and effective tool which combine several criteria in favourable measures and weights for locating suitable sites for urban development employing physical, socioeconomic and ecological factors and geospatial applications. Land suitability assessment for urban development requires consideration of a comprehensive set of factors (criteria) and balancing of multiple objectives in determining the suitability of a particular area for a defined land use (Al-Shalabi et al., 2006). According to Blaschke and Merschdorf (2014), these criteria are derived from multi-disciplinary scientific theories related to physical and socio-economical attributes; they fall within two categories, namely the opportunities and limitations/constraints of the environment. Specific factors can be chosen for specific kinds of development. However, most physical and socioeconomic factors have both permissive and restrictive features for urban development, which are determined by spatial location (Daniel and Chornor, 2018). For instance, the factor slope; a high gradient location is restrictive and a low

gradient location is permissive for urban development. The cumulative effect of these factors will determine the degree of suitability and also helps in further categorizing of the land into different orders of urban development; each factor will also play a different role in determining the degree of opportunity in site selection for urban development (Alani, 2016).

Slope, a fundamental topographic component of land suitability assessment has been acknowledged to be better suited for topographic description. It is frequently used as quantitative terrain gradient factor to explore the limiting effect of natural conditions on physical and socioeconomic development (Barnabas,2020). According to Alquraish and Kumar (2016) gentle slopes are recognized to facilitate urban development and various human activities such as transportation, agriculture and different types or models of constructions. Thus, it is mostly considered in land suitability assessment in various urban models and studies (Mohammed, 2021).

Slope is an important criterion for the urban development that has economic implications especially during the establishment of any urban infrastructure. Several studies, (Ontumbi 2012; Hussaini, 2017; Al-Ghorayeb et al., 2023) have reiterate the importance of lower to medium slope areas as highly suitable for urban development due to their balance and ease of constructability, cost-effectiveness, and environmental considerations to urban development and related activities. It is widely agreed that the lower the slope, the suitable the site for urban development, thus a flat and gentler ground (between 0° - 16°) is adequately suitable and preferable for urban development than the steeper slopes. Steep slopes are disadvantageous for construction, increase construction costs limits and contribute to erosion during construction and subsequent uses. (Chandrasekar *et al.*, 2017).

Several studies have been carried out on land suitability for urban development; for instance, Sharma and Kumar (2025), analyzed site suitability for urban development in Hisar City, India using the Analytical Hierarchy Process (AHP) with a mix of both physical and socioeconomic criteria (land use / land cover, proximity to road network and soil salinity). Al-Ghorayeb et al., (2024) also analyzed land suitability for sustainable urban development in Nabatiyeh region of Lebanon employing a combination of multi-criteria decision analysis technique and GIS. The criteria used were elevations, slopes, proximity to urban agglomerations, industrial areas, accessibility and land cover types.

Ibrahim and Mohammed (2024) assessed land suitability for urban development in Katsina Metropolis, Nigeria. The study employed Multi-Criteria Evaluation (MCE) using pair wise comparison in Analytical Hierarchy Process (AHP) to weigh the criteria influencing site suitability for urban development (slope, land cover, drainage density, road proximity and aspects). A detailed examination of the previous studies revealed that these studies used slope as a criterion in combination with either other physical or socioeconomic factors. This study however aim to examine Slope as a criterion for land suitability assessment to define the most suitable sites for future sustainable urban growth in the study area. This will underscore the relevance of slope in physical urban expansion, site selection and suitability for urban development. It will also give a direction to property developers and relevant policy makers to prioritize suitable sites in developmental strides.

2.0 Materials and Methods

2.1. Study Area

Kwara South Senatorial District is located between Latitudes $8^{\circ} 05^1 \text{ N} - 9^{\circ} 10^1 \text{ N}$ and Longitudes $4^{\circ} 20^1 \text{ E} - 5^{\circ} 50^1 \text{ E}$ of Greenwich Meridian with an area extent of about 6084.25 km^2 . It is a

prominent and fairly homogenous senatorial district in Kwara State comprising seven Local Government Areas sharing boundaries with Kogi and Ekiti States to the east; Osun and Oyo States to the south; Niger State and international boundary with Benin Republic in the north and west respectively. Figure 1 depict the map of the study area.

The recent rapid, extensive, and unplanned urbanization was behind the study area selection. Moreover, few studies examined the urban development in the country of the study area, but none of them exclusively consider slope as a criterion of land suitability assessment for sustainable urban development. For instance, Olabode (2019) and Oladuntoye (2021) in their studies, dwelled on socioeconomic factors like proximity to roads, infrastructures and rivers for sustainable urban planning and development in parts of the study area (precisely Omun-Aran and Offa).

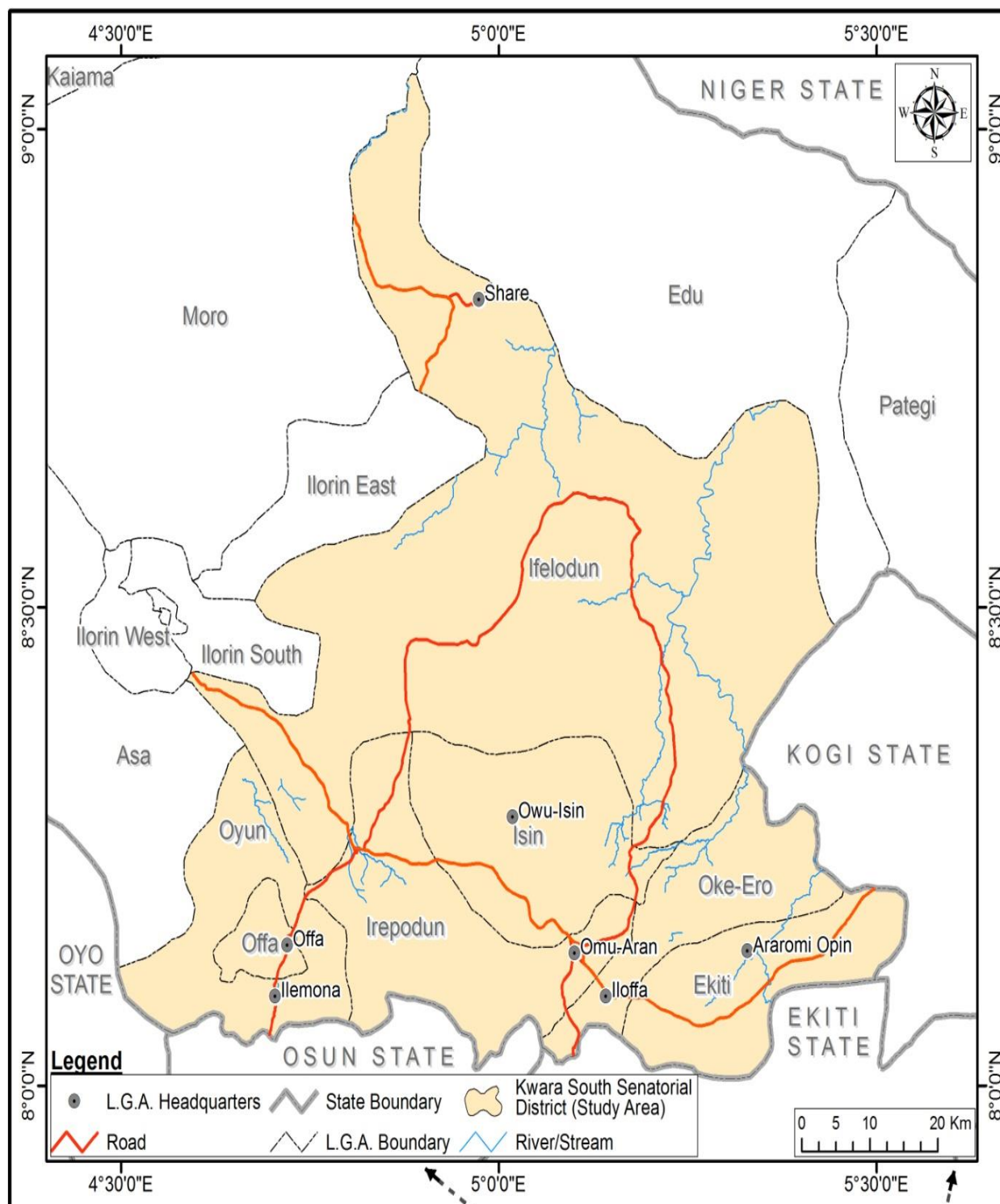


Figure 1.: Kwara South Senatorial District

Source: Modified from the Administrative Map of Kwara State (2022)

2.2. Methodology

The study adopted technical approach consisting of (a) defining the Slope criterion as the driving factors for sustainable urban development, (b) applying the AHP to weight criterion (c) rank the suitability to different classes such as highly, moderately, marginally, low and unsuitable and finally (d) using both the weights and classes of these criteria to generate a summary weighted overlay map (WOL) showing the overall land suitability.

2.2.1 Types and Sources of Data

Table 1 depicts the types and source of data employed in this study

Table 1: Data Types, Sources and Purposes

S/N	Types of Data	Sources	Purpose
1	Landsat – 8 (OLI) imagery (21 th September, 2023) with 30m resolution	United State Geological Survey (USGS). (http://glovis.usgs.gov)	For creation of land use land cover map, proximity to road, drainage, infrastructure
2	Shuttle Radar Topographic Map (SRTM) with 90m resolution	United State Geological Survey (USGS). (http://glovis.usgs.gov)	Slope and elevation and drainage
3	Administrative map of Kwara Sstate.	Kwara State Ministry of Land and Survey	Base map and delineation of boundaries.

Source: Author's analysis, 2026

2.2.2 Data Processing*2.2.2.1 Image pre-processing*

The images were obtained in different layers and the layer were stacked together using ERDAS imagine 16.8 software; A subset of the study area were obtained, and georeferenced using the ERDAS imagine software subset tool. Certain pre-processing operations are still required before the classifications are image geo-referencing and sub-setting.

a. Image Geo-referencing

Image Geo-referencing entails the registering of images to the real world by importing the satellite images into the ERDAS environment where they were rectified to a common projection; Universal Traverse Mercator (UTM) Zone 32 to conform its coordinates to the real world.

b. Image sub-setting

The different layers of imageries acquired from LandSat 8 (Operational Land Imager) and SRTM was stacked together and a sub-set of image of Kwara South Senatorial District was obtained from full scene of the imageries using ERDAS Imagine 16.8 subset tool.

2.2.2.2 Digitizing

The geo-referenced image was digitized with their unique feature characteristics (polygon, polyline and point) in ArcGIS 10.8, and independent thematic shapefile for each feature was created. These features include Local Government Area boundaries, built up areas, major and minor roads, rail line, and rivers.

2.2.2.3 Image Classification

The intent of the Image classification is to categorize all pixels in a digital image into one of several land cover classes, or "themes" (Reddy, 2008). This categorized data may then be used to produce thematic maps of the land cover present in an image. In this study, Image classification was made using supervised classification technique (Maximum Likelihood) in ERDAS Imagine 2023 (v16.8.0) environment. This technique is preferred due to its highly level of accuracy and reliability in handling spatial data; and allows natural spectral clusters to be distinct with high degree of objectivity (Ahmed, 2011).

A criterion map was generated for slope criterion in ArcGIS 10.6 environment and assigned weight using pairwise comparison method in Saaty's Analytic Hierarchy Process (AHP), a form of Multi Criteria Evaluation technique. Separate field were created for each layer in ArcGIS environment. Classes associated with criterion were given a rank and stored as separate field in geo-database. The criteria (data layers) were measured in a variety of scales and units, and the attributes of the variables were ranked based on their relative impact on land suitability for urban development using a common measurement scale. Reclassifying tool in ArcGIS 10.6 was used to categorize the criteria into a common scale of 1 – 5; 1 denoting highly suitable, 2 denoting moderately suitable, 3 denoting marginally suitable, while 4 and 5 denotes less suitable and unsuitable classes. Based on their theoretical applicability, the criteria for the AHP-based assessment were chosen and adapted from Ebre *et al.*, (2022) and Al-Ghorayeb *et al.*, (2023). The measurement scale ranges and classes (according to distances, heights, and buffers) was modified from Al-Ghorayeb *et al.*, (2023) and presented in the Table 2

Table 2: Standardization of criteria for urban development

Criterion	Measurement indicator	Scale	Range	Classification
Topography	Slope	0% - 37%	00 – 05	Very suitable
			06 – 15	Suitable
			16 – 25	Lowly suitable
			>25	Unsuitable

Source: Modified from Al-Ghorayeb *et al.*, (2023).

3.0 Results and Discussion

The slope map was derived from the Digital Elevation Model (DEM) of the study area using spatial analyst toolbox in ArcGIS 10.8. Slopes less than 10° are considered gentle slope and are highly suitable for urban development (Al-Ghorayeb et al., 2023). Table 3 shows the slope regimes of the study area in km sq and percentages with degree of suitability

Table 3: Slope regimes for urban suitability

Category	Description	Area (Km ²)	%
0 - 3	Highly Suitable	4264.71	70.09
3-8	Moderately Suitable	1548.03	25.44
8-16	Marginally Suitable	194.76	3.20
16 - 25	Less Suitable	64.37	1.06
25 - 53.16	Unsuitable	12.38	0.20
Total		6084.25	100

Source: Author's Analysis, 2025

According to Table 4.6, about 70% of the study area ranged between $0 - 3^{\circ}$ slope regime are highly suitable for urban development, and are highly concentrated in Ifelodun, Irepodun, Offa and Ogun LGAs. While the $3 - 8^{\circ}$ slope regime ranked moderately suitable class occupies 25% (1515km²) of the total land coverage; are majorly noticed in Ekiti, Irepodun, and Isin. Ifelodun LGAs, with few patches observed in Oke – Ero LGA. The marginally suitable, less suitable and unsuitable with 3.20%, 1.06% and 0.20% coverage respectively are the least slope regimes accordingly. These results implied that more than 95% of the study area is adequately suitable for almost all

forms of physical developments, constructions and human activities. Figures 2 and 3 present the slope map and the reclassified slope map of the study area displaying the suitability classes.

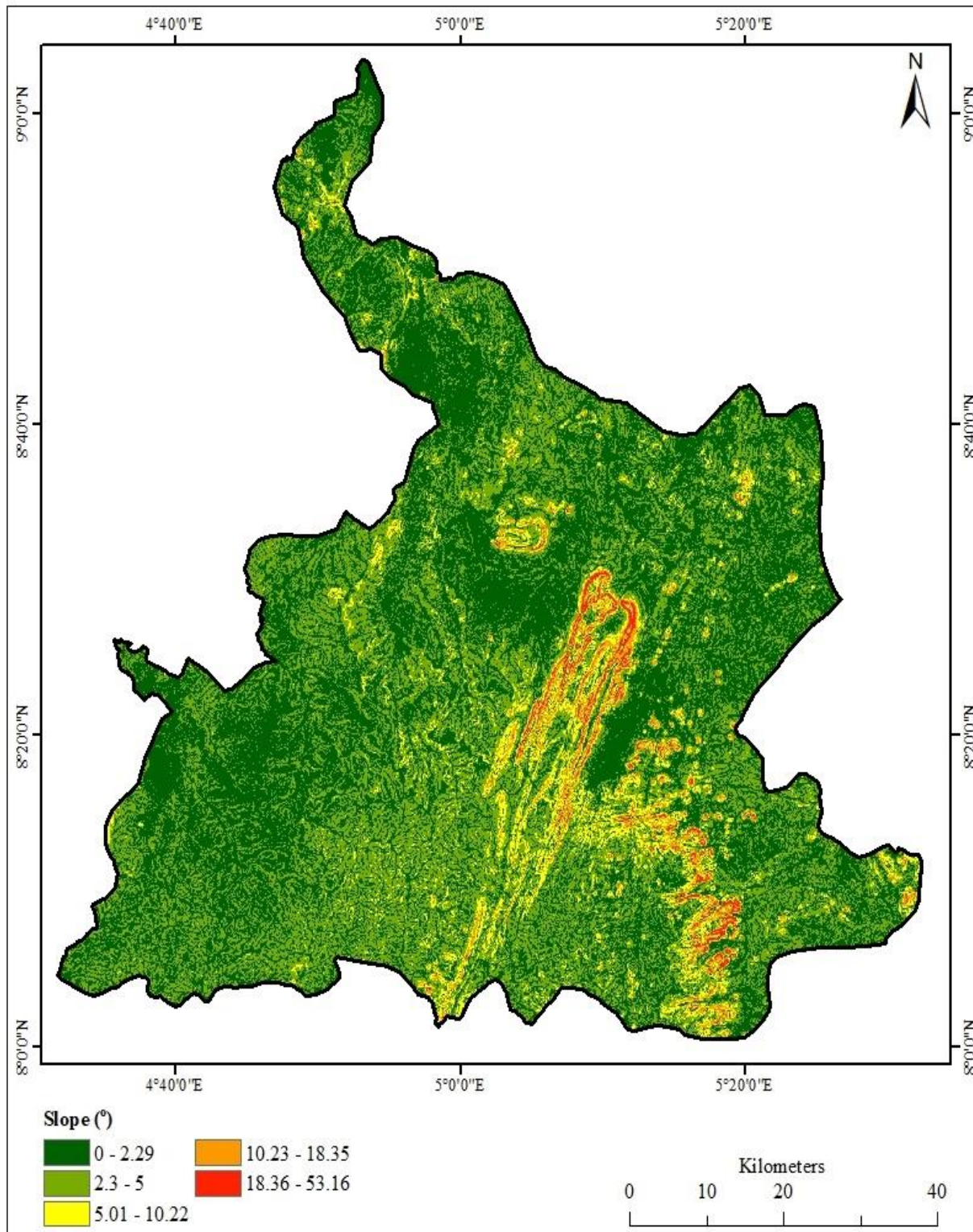


Figure 2: Slope regime of the study area

Source: Author's analysis 2025

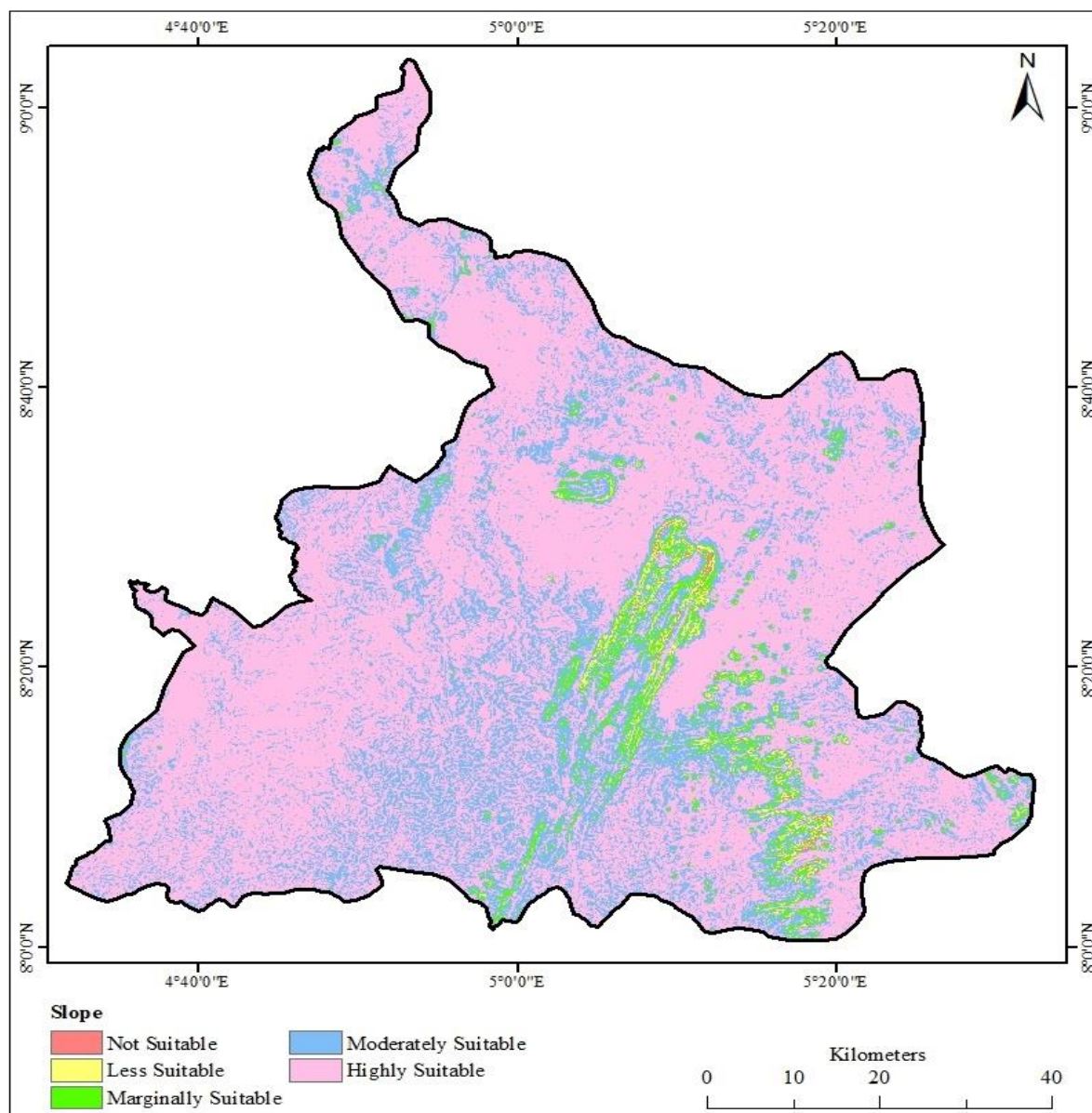


Figure 3: Reclassified Slope of the Study Area.

Source: Author's analysis, 2025

Discussion

The slope regime in the study area clearly display a spatial pattern of low to medium slopes ($0 - 8.2^0$) which favourably fall between highly suitable to medium suitable classes for urban development. About 96% and 3% of the total area is precisely between $0 - 2^0$ and $2.1 - 4.1^0$ respectively. These classes are termed as highly suitable for urban development; it is characterized by low plain expanse of that that is suitable for almost all forms of human constructions and activities. The slope regime of $0 - 2^0$ (93.3%) cut across the all the local governments but are highly concentrated in Ifelodun, Offa and Oyun LGAs. while the slope regime $2.1 - 4.1^0$ covers 3.3% of the study area which are majorly noticed in noticed in Ekiti, Irepodun, and Isin. Ifelodun and Oke Ero also have few patches of this class. It is deduced from the finding are that the sizes of the highly and moderately suitable areas are significantly larger (more than 98%) and there are some little variations in slope steepness in the study area, meaning that the study area is primarily a plain.

Population distribution and density, urban development, social facilities and accessibilities in these areas such as Offa, (Offa LGA); Share, Babaloma, Igbaja, Oke Ode, Oro Ago and Omupo (Ifelodun LGA); Omun Aran, Ajashe Ipo and Otun Oro(Irepodun LGA); Erin-Ile and Ijagbo (Oyun LGA) are observed to be higher and easier than other settlements in Kwara South Senatorial District. This is in accordance with the works of Alquraish and Kumar(2016); Zhao et al.,(2017), which argued that Gentle slopes facilitate and promotes several human activities including urban development by providing an easily accessible and stable terrain for various constructions, agriculture, and transportation among others. These areas also command significant political presence; Offa, Omun –Aran and Share are headquarters of Offa, Irepodun and Ifelodun LGAs respectively. Commercial activities, agricultural produce aggregation centers

and significant number of tertiary institutions (both public and private), government agencies/Institutions are also linked to the areas.

The growing urban development noticeably cutting cross Offa, Omun Aran, Share, Iludun Oro, Ajasse Ipo, Igbaja, and Idofian (in Offa Ifelodun and Irepodun LGAs) are indications of favourable slope regimes among other factors, which facilitates significant conversion of old buildings and development of new ones (through cost reductions, safety and environmental stability) compared to higher slopes) to accommodate the growing urban population and easier accessibility to urban facilities and services deliveries.

The remaining area (less than 1%) falls within the area with moderate suitability for urban development. The Least suitable areas for urban development consist of areas with more than 25° slopes. These are areas around Owu waterfall in Owu Kajola; Oreke Hill in Oreke, Alasaru hill, Ikotun hill and Oke Igbana, in Idofin Igbana (Ifelodun, Oke Ero and Oyun LGAs) which constitute less than 3.4% of the study area. These hilly areas are sources of employment and wealth creation as they serves as tourist centers (Owu fall) and some mineral resources deposits such Kaolin, marble, silica, and quartz among others. from an economic perspective, gentle, fairly gentle slopes or flat terrain are more suitable for urban development; steep slope areas can results in increase in the construction cost, property damage, instability and increased potentials for erosion and water pollution; they can also sources of revenue generation like the ones in the study area.

4.0 Conclusion

The slope map identified the slope regimes of the study area ranged between 0 – 53°, with about 70% of the study area ranging between 0 – 3° constituted the highly suitable class for urban

development. The moderately suitable class ranged between 3 – 8° has about 25% coverage, while less than 1% of the study area are unsuitable with 25 – 53. The slope factor exhibits varying influences on determining suitability of the study area for urban development as revealed by the resultant weights from AHP analysis and the generated criterion based suitability map.

The high and highest suitability areas identified in the land suitability map offer a promising opportunity for sustainable urban development, especially since they take into consideration the region's topography, urban agglomeration, and existing infrastructure. This identification assists urban planners and policymakers in making informed decisions regarding the development of urban areas, ensuring that they are sustainable, efficient, and meet the needs of the population.

These findings illustrate the efficiency of combining multi-criteria decision analysis with geospatial techniques for urban planning and environmental management in promoting sustainable development and protecting the environment. This study offers vital information and insights for decision-makers on sustainable urban development using a multi-criteria decision analysis combined with geographic information systems and remote sensing, and it represents a necessary step toward sustainable growth and mitigation measures against natural degradation.

With regard to future research, it is recommended in this context to study the possibility of integrating insecurity issues and administrative reforms to promote the studies and implementation of sustainable urban development. These studies could be based on some practices of administrative reforms, security measures including improved governance, consolidating, and enhancing the efficiency of governmental agencies and local authorities that are responsible for urban development, building more scientific capacities for the aforementioned entities, and increasing security stability. Moreover, the existing land use and zoning master plan could be

updated according to the land suitability map to provide more guidance toward sustainable development.

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**RESIDENTS' PERCEPTION ON IMPACT OF MINING ACTIVITIES ON SURFACE
WATER QUALITY IN MINNA ENVIRONS**

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ABSTRACT

Mining activities have become increasingly prominent in Minna environs, Niger State, Nigeria, with growing concerns about their implications for environmental sustainability, particularly surface water quality. Hence, this study investigated the perception of residents on the impact of mining activities on surface water quality in Minna environs. A descriptive survey research design was adopted. Structured questionnaires were administered to residents to assess their perception on the impact of mining activities on surface water quality. Taro Yamane's formula was used to determine the sample size of the study area. The sample size of the study was 400 respondents and selected using simple random sampling technique. However, only 382 questionnaires were retrieved back and used for the data analysis. The study revealed that water vendors constitute the most dominant source of domestic water supply, followed by hand-dug wells, boreholes, pipe-borne water and rivers as their primary source of domestic water supply. It also revealed a positive disposition toward all the proposed measures, as evidenced by the very high average percentages of Strongly Agree (53.75%) and Agree (44.82%), with minimal levels of disagreement (Disagree = 1.17%, Strongly Disagree = 0.26%). The study concluded that water vendors constitute the most dominant source of domestic water supply, followed by hand-dug wells, boreholes, pipe-borne water and rivers respectively. It is therefore recommended that Government agencies responsible for water supply should improve the provision of surface water in Minna by ensuring the proper distribution of pipe borne water and establishing properly protected boreholes to reduce residents' use of contaminated surface water.

Keywords: Minna Environs, Mining Activities, Surface Water Quality, Residents perception,

Introduction

Nigeria has been marked as one of the countries that have been blessed with abundant solid minerals on the continent. It constitutes some of the largest known deposits of different categories made up of precious metals, stones and industrial minerals like coal, tin, gold. The presence of these minerals is a major attraction for informal and conventional mining activities. Mining of

solid minerals has been identified as a major source of heavy metals in the environment because such minerals generally contain both heavy and essential metals as component (Ishaya *et al.*, 2018). Molua *et al.* (2024) asserted that the mining sector is an area of significant importance in the economic and development framework of Nigeria and contributes immensely to the nation's GDP through the exploitation of various resources such as oil and minerals metals, among others. Solid minerals can be a source of raising the national income and earning foreign exchange, can provide employment and is an economic driver for other industries which increase sources of revenue (Senouci, 2020). According to Abraham *et al.* (2023) negative environmental impacts seem to outweigh positive effects in mining especially pollution. Mining activities involve scraping away earth and rocks surfaces to get to the deposits buried under or near the surface and literal blasting apart of mountains to reach mineral deposits (Ali *et al.*, 2018). Bello *et al.* (2024) added that mining refers to the process of extracting metals and minerals from the earth.

Water is essential for the sustenance of life, it occupies 71% of the entire earth's surface and biologically makes up a large percentage of the total body fluids of all living things (Ukwuije *et al.*, 2023). Water is indispensable to the continued existence of biological organisms and ecosystems, viable development and especially food security (Bello *et al.*, 2024). However, pure water is required for good quality consumption. Water quality is key parameters that defines the quality of a given water and such parameters include chemical, metabolic activities, growth, feeding and reproduction, physical and biological contents of water. Also, Ayiwouo *et al.* (2022) asserted that water's quality is determined by its physio-chemical and biological qualities. Also, Gbedzi *et al.* (2022) added that as water flows on the land surface, its quality and purity are influenced by environmental and surface conditions from source to destination. In Nigeria, poverty coupled with poor policy frameworks to address mining activities has made the mining industry a

major threat to environmental sustainability (Ishaya *et al.*, 2018). Ogungbile *et al.* (2023) also noted that rapid growth in population and industrial activities are negatively impacting water quality which has become a serious environmental problem in Niger State.

Contaminants and toxic compounds from mining activities jeopardizes quality of surface and underground water by making it unsafe for drinking and industrial usage, disturbing the hydrology of the area (Ishaya *et al.*, 2018). This was buttressed by Bello *et al.* (2024) who noted that the activities of mining as a source of pollution for human communities or natural ecosystems deteriorate water quality and quantity daily. According to Ugya *et al.* (2018), mining could impact water through acid mine drainages and heavy metal contamination and leaching. Abraham *et al.* (2023) added that the effects of mining include its impacts on aquatic biodiversity, water turbidity, water table levels and chemical constituents of water. Mining activities could pollute the surrounding environment through a range of pathways, including physical disturbance of the landscape, spilling of mine tailings, emissions of dusts contain heavy metals into atmosphere, and generation of large quantity of acidic drainage that contains heavy metals (Akankali *et al.*, 2017; Bello *et al.*, 2024). In addition, Bajrović *et al.* (2025) noted that mining has an impact on local water resources, surface waters which are contaminated by the discharge of mine water, which is also called mine drainage and the extraction of mineral creates produced water (wastewater) that, if not treated appropriately, will contaminate surface and groundwater systems.

Water quality assessment provides information on the concentration of solutes, physiochemical characteristics and health of aquatic ecosystems (Batagarawa and Lawal, 2019; Sadiq *et al.*, 2022). Quality of water generally refers to the component of water, which is to be present at the optimum level for suitable growth of plants and animals. Water quality is a measure of the suitability of water for particular use based on selected physical, chemical and biological characteristics (Kur *et*

al., 2019). To ensure good water quality, measures of pollution prevention should be emphasised. Pollution prevention entails reducing industrial and agricultural waste, this is because pollution. Abubakar *et al.* (2020) asserted that industrial waste, agricultural runoffs, municipal waste and accidental spills are the four primary causes of water pollution. Odunze and Chinonso (2020) added that the major source of pollution in streams, rivers and underground water arise from anthropogenic activities largely caused by the poor and uncultured living habit of people as well as the unhealthy practices of factories, industries and corporate bodies; resulting in the discharge of untreated effluents and waste. Industries can minimise waste by adopting cleaner production processes, and developing products with reduced environmental impact.

Adequate safe water supply, hygienic and sanitized freshwater is a crucial factor in man's economic development quest. Good and safe drinking quality water is important for the physical wellbeing of all people. In the rural areas of Niger State, rivers are used for artisanal fishing, bathing, cooking, drinking and other domestic purposes. Hence, residents run the risk of ingesting any harmful materials that may be present in the water due to water pollution because they only rely on untreated shallow (rivers) and groundwater (shallow wells and boreholes). Despite the relevance of good and safe quality water, water supplies have become contaminated in many regions of Niger State and this declining quality of surface water and groundwater is becoming a serious problem in the state. Also, Ogungbile *et al.* (2023) asserted that the rapid growth in population and industrial activities in Niger State are negatively impacting water quality in the state. Hence, this study intends to investigate residents' perception on the impact of mining activities on surface water quality in Minna environs.

Furthermore, Ohwo and Abel (2014) assessed access of residents to the supply of potable water in Yenagoa Metropolis. The study concluded that the access of residents to the supply of potable

water in the study area in quality and quantity dimensions wise was insufficient and inadequate as revealed by the result. Ibrahim *et al.* (2014) assessed alternative water supply sources for domestic uses in Minna Environs, Niger State, Nigeria. The study opined that population growth occasioned by the trooping of people from different regions to seek better life in Minna, has compounded water supply challenge to the populace by conventional means. These challenges have triggered individual efforts to meet their daily water demand. Meride and Ayenew (2016) analysed drinking water quality and its effect on community's residents of Wondo Genet. However, none of the study considered residents' perception. Hence, this study filled in this literature gap by assessing resident perception on the impact of mining activities on surface water quality in Minna environs

Objectives of the Study

The research aimed to investigate the resident perception on the impact of mining activities on surface water quality in Minna environs. The specific objectives are to:

- i. Examine the level of residents access to quality water supply in Minna environs
- ii. Establish acceptable measures for good water quality provision in Minna environs.

Research Questions

The following research questions were raised and answered in this study:

- i. What is the level of residents' access to quality water supply in Minna environs?
- ii. What could be the acceptable measures for good water quality provision in Minna environs?

MATERIALS AND METHODS

Descriptive survey research design was adopted for the study. Rahi (2017) defined descriptive survey design as a research design associated with a deductive research approach where strategic

information are collected using a pre-designed questionnaire. Primary data was collected through the administration of structured questionnaire and interview of residents. Taro Yamane's formula was used to determine the sample size of the study area. The population of Minna is now estimated at 532,497 at 2025 (World Population Review, 2025). Taro Yamane's formula was used to calculate the sample size of the study area as presented:

$$\text{Formula: } n = \frac{N}{1+N(e)^2}$$

Where N = study population and e = level of significance = 0.05.

$$n = \frac{532,497}{1+532,497(0.05)^2}$$

$$n = \frac{532,497}{1+532,497(0.0025)}$$

$$n = \frac{532,497}{1+1331}$$

$$n = \frac{532,497}{1332}$$

$$n = 400$$

Therefore, the sample size of the study was 400 respondents selected using simple random sampling technique. However, only 382 questionnaires were retrieved back and used for the data analysis. Data obtained were analysed using frequency and percentage.

RESULTS AND DISCUSSION

Examining the level of residents' access to water supply in Minna Environs

Source of domestic water supply

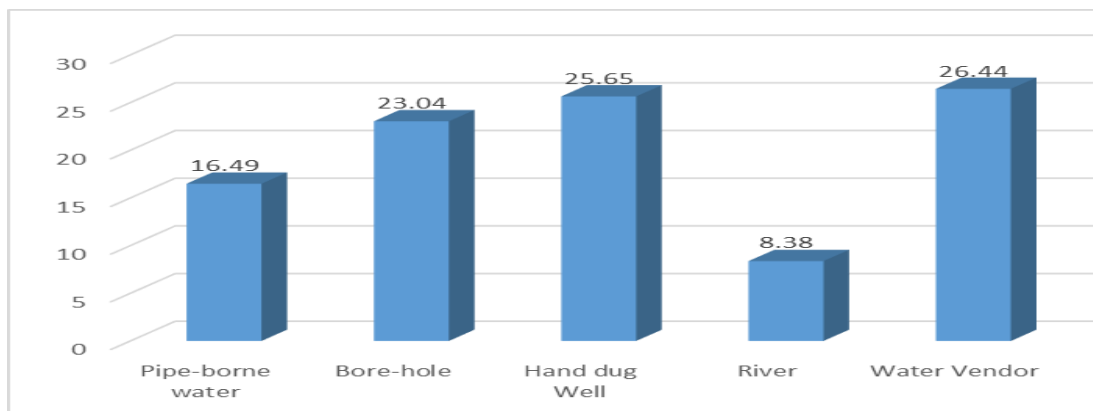
Responses on respondents' source of domestic water supply is presented in Table 1.

Table 1: Source of domestic water supply to your household

Sources	Frequency	Percentage
Pipe-borne water	63	16.49
Bore-hole	88	23.04
Hand dug Well	98	25.65
River	32	8.38
Water Vendor	101	26.44
Total	382	100.00

(Authors, Fieldwork 2025)

Table 1 shows the source of domestic water supply to your respondents in Minna environs. The result in the table revealed that water vendors constitute the most dominant source of domestic water supply, accounting for 26.44% of the water sources. Followed by hand-dug wells which supplied water to 98 respondents accounting for 25.65% of the respondents and boreholes as a source of water for 88 respondents accounting for 23.04% of the respondents. However, pipe-borne water is a source of water to 63 respondents accounting for only 16.49% of the total



responses.

A smaller proportion of respondents

32

accounting for 8.38% of the respondents depend on rivers as their primary source of domestic water supply. The table revealed that domestic water supply to households in the study area is predominantly sourced from non-pipe-borne alternatives, with water vendors, hand-dug wells, and boreholes serving as the major sources. The sources of domestic water supply is further illustrated using bar chart as shown in figure 1.

**Figure 1: Bar chart on Source of domestic water supply
(Authors, Fieldwork 2025)**

Factors influencing the selected source of water

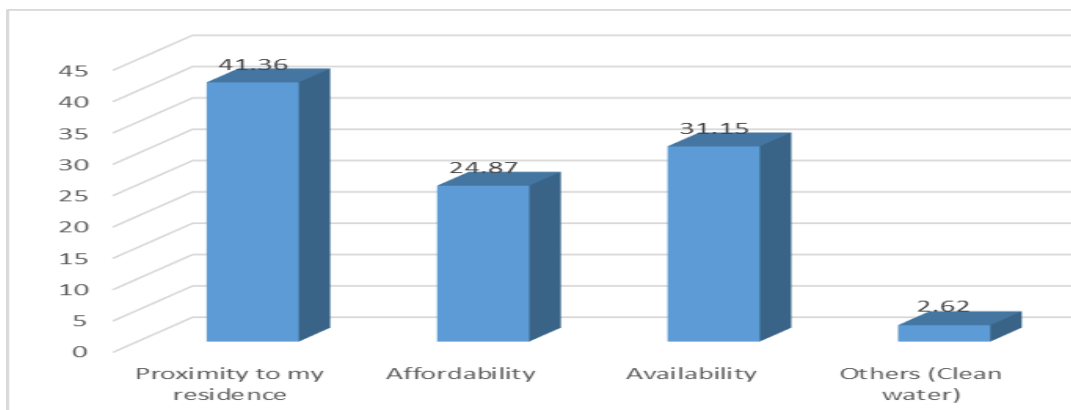
Responses on the factors influencing the selected source of water is presented in Table 2.

Table 2: Factors influencing the selected source of water

Factors	Frequency	Percentage	(Authors, Fieldwork 2025)
Proximity to my residence	158	41.36	Table 2
Affordability	95	24.87	
Availability	119	31.15	
Others (Clean water)	10	2.62	
Total	382	100.00	

shows the

factors influencing the selected source of water. From the table, proximity to residence is the most influential factor determining 158 respondents' choice of water source, accounting for 41.36% of responses, implying that respondents prioritise convenience and time efficiency, which is particularly important in contexts where daily water collection is labour-intensive and may compete with other domestic or economic responsibilities. The second most influential factor is availability of water, reported by 119 respondents accounting for 31.15% of the respondents. Affordability was chosen by 95 respondents accounting for 24.87% of the responses. Only 10 respondents accounting for 2.62% of the total responses identified water cleanliness as the primary factor influencing their choice. The study concluded that the selection of water sources among the respondents is determined by proximity to residence and availability emerge as the dominant



determinants,

while

affordability

also plays a

significant role rather than water quality.

Factors influencing the selected source of water is further illustrated using bar chart as shown in figure 2.

Figure 2: Bar chart on factors influencing the selected source of water
(Authors, Fieldwork 2025)

Bodies responsible to provide residents with good quality water

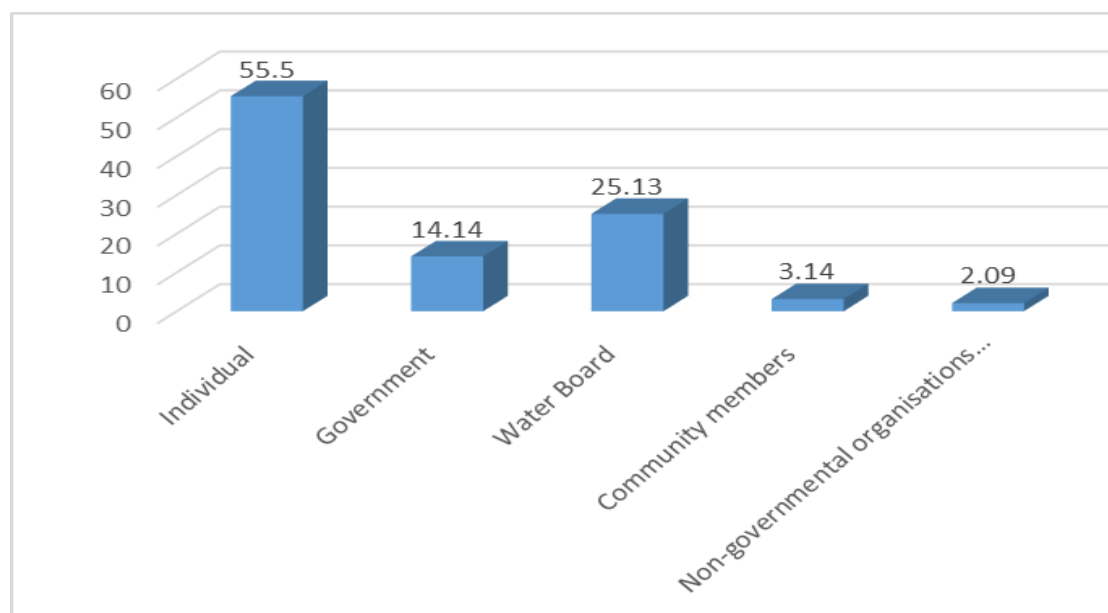
Responses on bodies responsible to provide residents with good quality water is presented in Table 3.

Table 3: Bodies responsible to provide residents with good quality water

Bodies responsible	Frequency	Percentage
Individual	212	55.50
Government	54	14.14
Water Board	96	25.13
Community members	12	3.14
Non-governmental organisations (NGOs)	8	2.09
Total	382	100.00

(Authors, Fieldwork 2025)

Table 3 presents responses on bodies responsible to provide residents with good quality water. The results from the study indicate that a majority of the respondents 212 accounting for 55.50% of the



responses identified individuals as the primary providers of good quality water. Only 54 respondents accounting for 14.14% of the responses attributed responsibility to the government, while 96 respondents accounting for 25.13% identified the Water Board as responsible for providing good quality water. Furthermore, 12 respondents accounting for 3.14% of the total respondents attributed responsibility to community members and non-governmental organisations (NGOs) was selected by eight respondents accounting for 2.09% of the responses. Responses on bodies responsible to provide residents with good quality water is further illustrated using bar chart as shown in figure 3.

Figure 3: Bar chart on Bodies Responsible to Provide Residents with Good Quality Water (Authors, Fieldwork 2025)

Access to sufficient water for your daily use

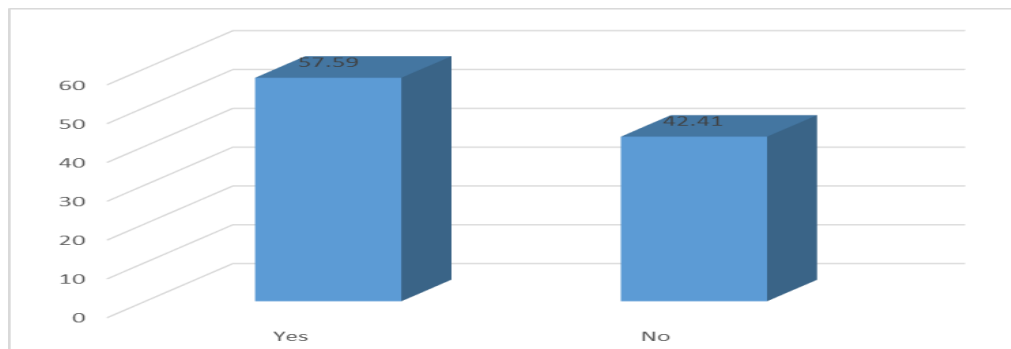
Respondents' responses on access to sufficient water for daily use is presented in Table 4.

Table 4: Access to Sufficient Water for Daily Use

Responses	Frequency	Percentage	(Authors, Fieldwork 2025)
Yes	220	57.59	
No	162	42.41	
Total	382	100.00	

Table 4

shows the respondents' access to sufficient water for daily use in the study area. The result revealed that 220 respondents accounting for 57.59% of the total responses reported they have access to sufficient water for their daily use, while, 162 respondents accounting for 42.41% of the total responses reported not having access to sufficient water for their daily use. From the table, more



than half of the respondents in the study area

can meet their daily water needs, the proportion of

respondents without sufficient access remains considerably high. It can be concluded that access to sufficient water for daily use among the respondents is moderately available but far from satisfactory. While, a majority of respondents reported adequate access, a significant minority still experience water insufficiency. This is similar to the finding of Ohwo and Abel (2014) who reported that the access of residents to the supply of potable water was insufficient and inadequate. Responses on access to sufficient water for daily use is further illustrated using bar chart as shown in figure 4.4.

Figure 4: Bar chart on Access to Sufficient Water for Daily Use
(Authors, Fieldwork 2025)
Quantity of water for use daily

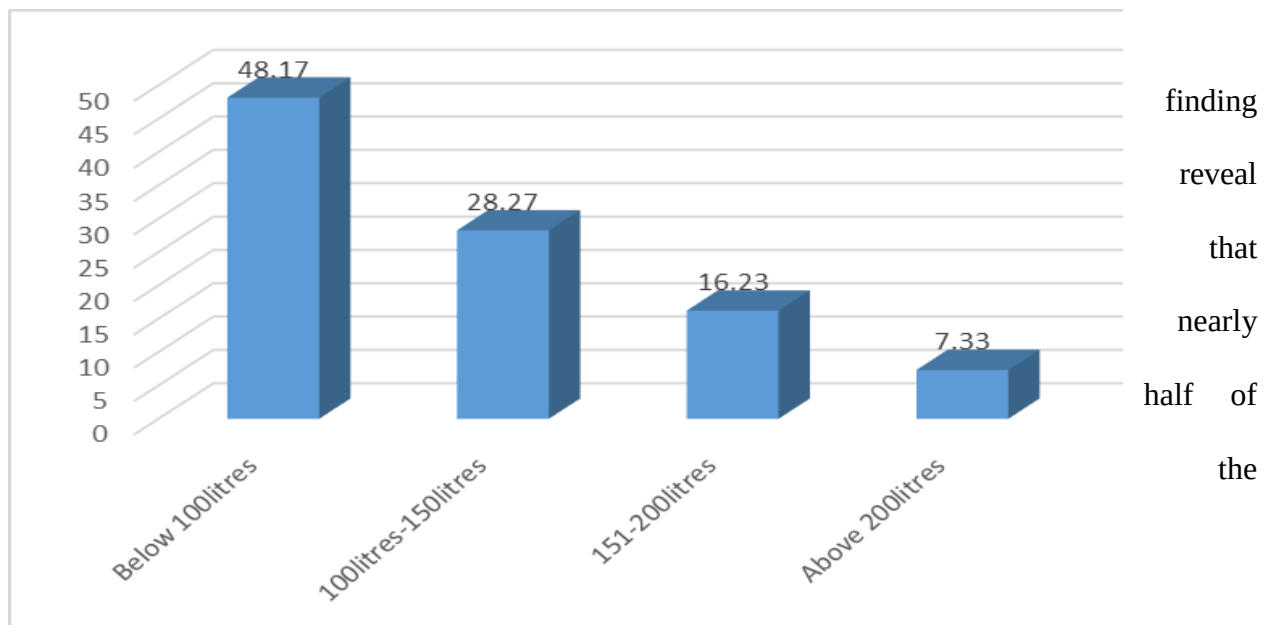
The quantity of water for use daily by the respondents is presented in Table 5.

Table 5: Quantity of water for use daily

Quantity of water	Frequency	Percentage
Below 100litres	184	48.17
100litres-150litres	108	28.27
151-200litres	62	16.23
Above 200litres	28	7.33
Total	382	100.00

(Authors, Fieldwork 2025)

Table 5 presents the distribution of respondents based on the quantity of water used daily. The



respondents, 184 (48.17%), used below 100 litres of water per day, while 108 respondents (28.27%) used between 100 and 150 litres. A smaller proportion, 62 respondents (16.23%), reported using 151–200 litres, and only 28 respondents (7.33%) used above 200 litres of water daily in the study area. Hence, majority of respondents relies on relatively low quantities of water for daily activities in the study area. Responses on the quantity of water used daily is further illustrated using bar chart as shown in figure 5.

Figure 5: Bar chart on the Quantity of Water Used Daily

(Authors, Fieldwork 2025)

Factors responsible for the shortage of water in the selected period

On the factors responsible for the shortage of water in the selected period. The respondents identified inconsistent power supply as a cause of water shortage which highlights the use of electricity for pumping and distribution of water. Frequent power outages disrupt pumping operations which reduce water supply, and limit the ability of the water board to supply potable water consistently. Leakage of pipes was also reported as a significant factor responsible for water shortage. This indicates the prevalence of aging, poorly maintained, or damaged distribution infrastructure, which leads to substantial water losses before reaching end users. Respondents also reported that bad water from the water board contributes to water shortage which reflects challenges related to water quality management. Respondents also identified shortage of water in hand-dug wells, suggesting declining groundwater availability. This might be attributed to seasonal variability, over-extraction, reduced recharge, or environmental degradation. Other respondents identified the factor of more people with limited water sources highlighting the role of rapid population growth and increased urbanisation in intensifying water demand. This agrees with the finding of Ibrahim *et al.* (2014) who reported that population growth occasioned by the trooping of people from different regions to seek better life in Minna, has compounded water supply challenge to the populace by conventional means.

Providing acceptable measures for good water quality provision in Minna Environs

Acceptable measures for good water quality provision in Minna Environs is presented in Table 6.

Table 6: Acceptable measures for good water quality provision in Minna Environs

S/N	Items	SA	A	D	SD
1	Water supply should be protected from animals and pollution.	193 (50.52%)	182 (47.65%)	5 (1.31%)	2 (0.52%)
2	Broken pipes and leakages should quickly be repaired by water board authorities	211 (55.24%)	166 (43.45%)	4 (1.05%)	1 (0.26%)
3	Water sources should be located at a safe distance from toilets and septic tanks	191 (50.00%)	183 (47.91%)	6 (1.57%)	2 (0.52%)
4	There should be regular checks and monitoring of water quality and infrastructure by water board officials and relevant agencies	155 (40.58%)	221 (57.85%)	5 (1.31%)	1 (0.26%)
5	Disposal of industrial wastes should be regulated to prevent water pollution	224 (58.64%)	148 (38.74%)	8 (2.1%)	2 (0.52%)
6	Agricultural products (like use of fertilizer and pesticides) should be controlled to ensure good water quality	201 (52.62%)	173 (45.29%)	7 (1.83%)	1 (0.26%)
7	Laws and policies should be enacted and enforced by government to prevent illegal dumping of refuse in water bodies	223 (58.38%)	157 (41.10%)	2 (0.52%)	
8	Members of the community should participate in environmental sanitation	241 (63.09%)	141 (36.91%)		
9	Awareness campaigns and training should regularly be organised to enlighten the public on measures to ensure good water quality	209 (54.71%)	170 (44.50%)	3 (0.79%)	
	Average Percentage	53.75%	44.82%	1.17%	0.26%

(Authors, Fieldwork 2025)

Keys: Strongly Agree (SA), Agree (A), Disagree (D), Strongly Disagree (SD)

Table 6 presents the acceptable measures for good water quality provision in Minna Environs. The results reveal that the protection of water supply sources from animals and pollution recorded very high agreement (98.17%), underscoring widespread awareness of contamination risks associated with open and poorly protected water sources. Similarly, prompt repair of broken pipes and leakages by water board authorities attracted near-unanimous agreement (98.69%), highlighting public concern about infrastructural failures as major contributors to water contamination and wastage. The finding that a large majority of respondents agreed that water sources should be located at safe distances from toilets and septic tanks (97.91%) reflects a strong understanding of the dangers of faecal contamination and groundwater pollution. Regular monitoring of water quality and infrastructure by water board officials and relevant agencies also received strong

support (98.43%), indicating public trust in institutional oversight as a key mechanism for maintaining safe water standards.

Furthermore, regulation of industrial waste disposal (97.38%) and control of agricultural inputs such as fertilizers and pesticides (97.91%) were strongly endorsed, suggesting heightened awareness of chemical pollution and its implications for public health. The call for stronger laws and enforcement to prevent illegal dumping into water bodies (99.48%) recorded one of the highest levels of agreement, emphasising the perceived need for effective governance and regulatory frameworks. Community participation in environmental sanitation achieved the highest level of strong agreement (63.09%), reinforcing the view that water quality protection is a shared responsibility between government and community members. Likewise, the strong support for regular awareness campaigns and training (99.21%) indicates recognition of education and sensitization as essential tools for sustaining safe water practices. The results reveal an overwhelmingly positive disposition toward all the proposed measures, as evidenced by the very high average percentages of Strongly Agree (53.75%) and Agree (44.82%), with minimal levels of disagreement (Disagree = 1.17%, Strongly Disagree = 0.26%). The very low level of disagreement across all items demonstrates uniformity in respondents' views and reflects a collective understanding of both preventive and corrective measures necessary for good water quality provision in Minna Environs. Responses on acceptable measures for good water quality provision in Minna Environs is further illustrated using bar chart as shown in figure 7.

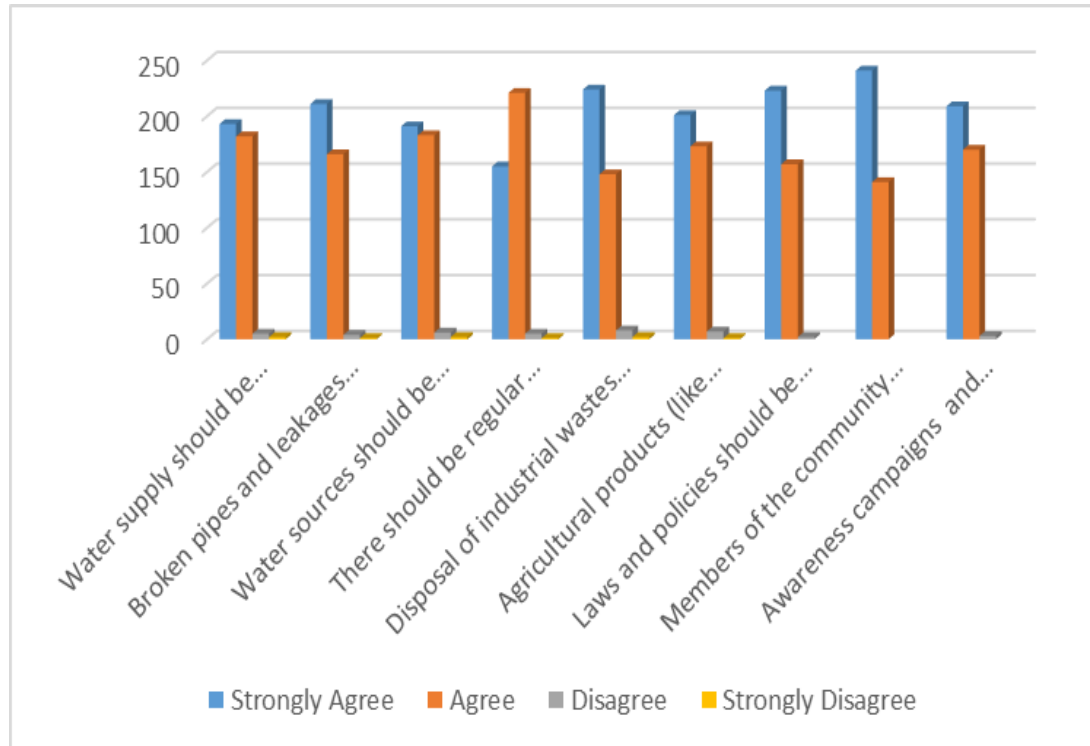


Figure 7:
Bar chart
on

Acceptable Measures for Good Water Quality Provision in Minna Environs (Authors, Fieldwork 2025)

Summary of Findings

Table 1 revealed that water vendors constitute the most dominant source of domestic water supply, accounting for 26.44% of the water sources, followed by hand-dug wells which supplied water to 98 respondents accounting for 25.65% of the respondents and boreholes as a source of water for 88 respondents accounting for 23.04% of the respondents, pipe-borne water to 63 respondents accounting for only 16.49% of the total responses and 32 respondents accounting for 8.38% of the respondents depend on rivers as their primary source of domestic water supply. Table 2 revealed that proximity to residence and availability emerge as the dominant determinants, while affordability also plays a significant role rather than water quality. Table 3 revealed that a majority of the respondents identified individuals, followed by government, Water Board, community

members and non-governmental organisations (NGOs) as the primary providers of good quality water,

Result from Table 4 revealed that 220 respondents accounting for 57.59% of the total responses reported they have access to sufficient water for their daily use, while, 162 respondents accounting for 42.41% of the total responses reported not having access to sufficient water for their daily use. Table 5 result revealed that majority of respondents relies on relatively low quantities of water for daily activities in the study area. Table 6 result revealed that respondents reported the period between January and March as the time of the year when water shortage is most severe, followed by April and June, October to November with no responses between July to September. Result from Table 7 revealed an overwhelmingly positive disposition toward all the proposed measures, as evidenced by the very high average percentages of Strongly Agree (53.75%) and Agree (44.82%), with minimal levels of disagreement (Disagree = 1.17%, Strongly Disagree = 0.26%).

Conclusion

The study concluded that water vendors constitute the most dominant source of domestic water supply, followed by hand-dug wells, boreholes, pipe-borne water and rivers respectively. It is also clear from the study that proximity to residence and availability emerge as the dominant determinants, while affordability also plays a significant role rather than water quality. The study further settled that individuals, government, Water Board, community members and non-governmental organisations (NGOs) respectively are the primary providers of good quality water. The study also discovered that more than half of the respondents have access to sufficient water for their daily use, although a significant number do not have access to sufficient water for their daily use. Also, majority of respondents relies on relatively low quantities of water for daily activities in the study area. It is also established from the study that January to March is the time

of the year when water shortage is most severe, followed by April and June, October to November with no responses between July to September. It is also discovered from the study that the respondents have positive disposition toward all the proposed measures. The study identified acceptable measures for improving water quality provision in Minna environs which include strict enforcement of mining and environmental regulations, proper management and treatment of mining waste, regular monitoring of surface water quality, and improvement of public water supply systems, community awareness on the health risks associated with contaminated water was also identified as a key strategy.

Recommendations

Based on the findings of the study, the following were recommended:

- i. Government agencies responsible for water supply should improve the provision of surface water in Minna environs by ensuring the proper distribution of pipe borne water and establishing properly protected boreholes to reduce residents' use of contaminated surface water;
- ii. Mining operators should adopt environmentally sustainable mining techniques and environmental friendly techniques, such as controlled excavation and proper waste containment, to minimise adverse effects on surface water quality;
- iii. Community sensitisation programmes should be organised to promote basic household water treatment methods such as boiling and filtration.

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ASSESSING THE SUSTAINABLE HOUSING OUTCOMES OF URBAN ENVIRONMENTAL MANAGEMENT IN A CIRCULAR ECONOMY: A MIXED-METHODS HOUSEHOLD STUDY IN LAPAI, NIGERIA

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ABSTRACT

Rapid urbanisation in secondary cities of developing countries is intensifying challenges related to housing quality, environmental degradation, and inefficient resource use. This study assessed the sustainable housing outcomes of urban environmental management within a circular economy framework, focusing on households in Lapai, Niger State, Nigeria. Anchored on SDG 11 (sustainable cities and communities) and SDG 12 (responsible consumption and production), the study adopted a mixed-methods research design. Quantitative data were collected through a structured household survey administered to approximately 300 residential units. Qualitative insights were obtained from key informant interviews with urban planners, environmental health officers, and community representatives. Descriptive statistics and multivariate regression analysis were employed to examine the influence of urban environmental management practices such as waste management, water and sanitation services, and neighbourhood environmental maintenance on sustainable housing indicators including habitability, environmental quality, and resource efficiency. Qualitative data were analysed thematically to provide deeper understanding of household experiences and institutional practices. The findings revealed that waste management, access to improved water and sanitation, and regular neighbourhood environmental maintenance have a significant positive effect on sustainable housing outcomes in Lapai. However, there is low public awareness and adoption of circular economy practices at the household level, particularly in material reuse, waste management, and energy conservation, due to weak institutional capacity and inadequate enforcement of environmental regulations. The study concludes that strengthening urban environmental governance and mainstreaming circular economy principles into household practices are essential to enhance sustainable housing outcomes. These findings provide policy-relevant evidence for implementing SDGs 11 and 12, while contributing to SDG 13 (climate action) through improved urban resource efficiency and environmental management.

Keywords: Environmental management, Circular economy, Housing, Sustainable, Urban

1.0 INTRODUCTION

Rapid urbanization is increasingly shaping the development trajectory of many cities in the Global South, particularly in Sub-Saharan Africa. While urban growth can stimulate economic opportunities and infrastructure development, it also creates significant challenges related to housing quality, environmental degradation, and inefficient resource utilization (Bryan et al., 2020; Kuddus et al., 2020). These challenges are particularly pronounced in secondary cities where rapid population growth often occurs without adequate urban planning, environmental management systems, or infrastructure provision (Korah and Wimberly, 2024). Consequently, many emerging urban centres experience problems such as poor waste management, inadequate water and sanitation services, and deteriorating neighbourhood environments, all of which directly affect housing habitability and environmental sustainability.

In Nigeria, improving the sustainability of housing environments has become increasingly important in the context of the global development agenda, particularly the United Nations Sustainable Development Goals. Of particular relevance are Sustainable Development Goal 11, which promotes inclusive and resilient cities, and Sustainable Development Goal 12, which emphasizes efficient resource use and waste reduction. Achieving these goals requires effective urban environmental management practices such as improved waste management, reliable water and sanitation services, and regular neighbourhood environmental maintenance.

More recently, the Circular Economy has emerged as a strategic framework for promoting sustainable urban development (Marinov, 2025). The circular economy emphasizes resource efficiency through waste reduction, material reuse, and energy conservation, offering a pathway for improving housing sustainability while minimizing environmental impacts (Adebakin and

Mohammed, 2026; Grace et al., 2024). Integrating circular economy principles into urban environmental management can therefore enhance housing conditions and contribute to broader urban sustainability objectives.

Despite the increasing relevance of these concepts, empirical studies examining the relationship between urban environmental management practices and sustainable housing outcomes within a circular economy framework remain limited in developing-country secondary cities (Suleman et al., 2023). In Nigeria, existing research has largely focused on sustainable building design, urban growth patterns, or environmental governance, with relatively little attention given to how everyday environmental management practices at the household level influence housing sustainability outcomes. This gap is particularly evident in rapidly growing secondary cities such as Lapai in Niger State, where environmental management challenges increasingly shape residential living conditions.

Against this background, this study assesses the sustainable housing outcomes of urban environmental management within a circular economy framework in Lapai, Nigeria. Specifically, the study aims to assess the level of urban environmental management practices among households in Lapai, examine the influence of these practices on sustainable housing outcomes, including habitability, environmental quality, and resource efficiency, and explore household awareness and institutional perspectives regarding circular economy practices in the study area. Using a mixed-methods approach that combines household survey data with key informant interviews, the study provides empirical evidence on how environmental management practices influence sustainable housing conditions in a rapidly urbanizing secondary city. The study contributes to the literature by linking urban environmental management practices with housing sustainability outcomes within a circular economy perspective, while generating policy-relevant insights to support the

implementation of Sustainable Development Goal 11, Sustainable Development Goal 12, and Sustainable Development Goal 13 in Nigerian urban contexts.

2.0 LITERATURE REVIEW

Rapid urbanization in developing countries has led to significant transformations in secondary cities, often resulting in unplanned growth, infrastructure deficits, and environmental pressures. In Sub-Saharan Africa, for instance, secondary cities like those in Ghana and Nigeria experience accelerated peri-urban expansion, driven by population influx and economic activities, which exacerbate land use conflicts and housing shortages (Abdulai et al., 2022; Korah et al., 2025). This pattern is echoed in other developing regions, such as Indonesia and China, where secondary urban centres face diseconomies including congestion, inadequate services, and vulnerability to climate risks, underscoring the need for integrated urban planning (Katherina and Indraprahasta, 2019; Du et al., 2024). In Nigeria, these challenges are particularly acute in secondary cities like Lapai, where economic volatility and institutional barriers hinder sustainable development, aligning with broader calls for resilient urban governance (Yahaya and Shaibu, 2020; Iduseri et al., 2024).

The intersection of urbanization and environmental degradation has amplified demands for sustainable housing solutions, particularly within the framework of the United Nations Sustainable Development Goals (SDGs). SDG 11 emphasizes inclusive, safe, and resilient cities, while SDG 12 focuses on responsible consumption and production, both critical for addressing urban inefficiencies in resource use and waste management (Mustapic et al., 2025). In Nigerian contexts, studies highlight the role of urban environmental management in achieving these goals, with evidence from cities like Abuja and Lagos showing that poor governance leads to vegetation loss, pollution, and inadequate housing, necessitating policy interventions for sustainable land use

(Iduseri et al., 2024). Furthermore, integrating SDG 13 (climate action) through enhanced resource efficiency is vital, as urban sprawl in Nigeria contributes to environmental vulnerabilities that indirectly affect housing quality.

The Circular Economy (CE) emerges as a promising framework for mitigating these challenges by promoting resource reuse, waste reduction, and closed-loop systems in urban settings. In developing countries, CE practices at the household level such as material recycling and energy conservation are often necessity-driven, yet constrained by infrastructure gaps, low awareness, and regulatory weaknesses (Ahmed et al., 2022; Korsunova et al., 2022). Specific to Nigeria, adopting CE in the built environment faces barriers including limited institutional capacity, financial constraints, and sociocultural resistance, particularly in housing design and waste management (Suleman et al., 2023; Ayanrinde and Mahachi, 2025). Research on sustainable architecture in Nigeria underscores the potential of CE principles, such as low-carbon materials and modular construction, to enhance housing affordability and environmental quality, though implementation is hindered by weak enforcement and skills shortages (Moral et al., 2026).

Household-level adoption of CE practices in developing contexts reveals persistent constraints, including economic disparities, inadequate infrastructure for waste collection, and limited policy support, which perpetuate linear consumption patterns (Shollo et al., 2025). In Nigeria, these issues are compounded by low public awareness and institutional inefficiencies, limiting the integration of practices like reuse and conservation into daily urban life (Adams, 2024; Suleman et al., 2024). Studies from similar low-income settings, such as Bangladesh, indicate that while informal sectors drive value retention, formal policy alignment is essential to overcome barriers and achieve SDG-linked outcomes (Ahmed et al., 2022).

Despite these challenges, evidence suggests that strengthening urban environmental governance through CE mainstreaming can yield positive housing outcomes (Adesua-Lincoln, 2025). In African contexts, integrating CE into life cycle assessments for buildings promotes sustainability, with recommendations for localized strategies to address regulatory and funding gaps. For Nigeria, policy-relevant interventions, such as enhanced regulations and community education, are proposed to foster habitability, resource efficiency, and environmental quality in secondary cities like Lapai, contributing to SDGs 11, 12, and 13. However, empirical evidence linking urban environmental management practices with sustainable housing outcomes within a circular economy framework at the household level in Nigerian secondary cities remains limited and this is what this research seeks to address using the following conceptual framework.

Conceptual Framework

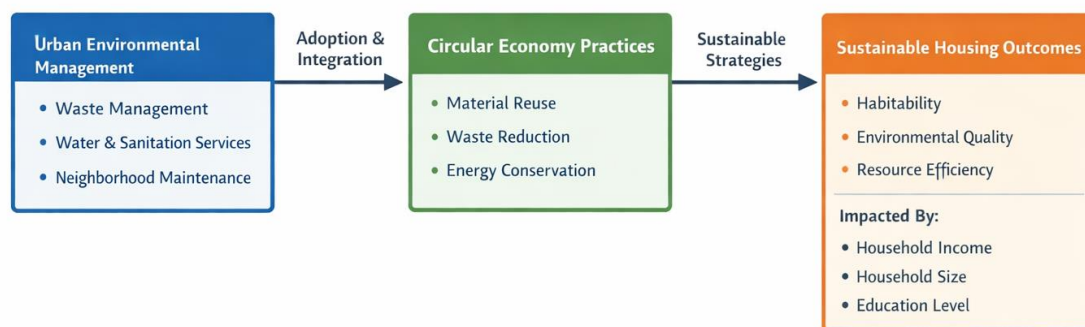


Figure 2.1: the relationships between Urban Environmental Management → Circular Economy Practices → Sustainable Housing Outcomes

Source: Computer Generated, 2026

3.0 METHODOLOGY

3.1 Research Design

This study adopted a mixed-methods research design to comprehensively assess the sustainable housing outcomes of urban environmental management within a circular economy framework in

Lapai, Niger State, Nigeria. The design integrated quantitative and qualitative approaches, allowing for triangulation of data to enhance the validity and depth of findings (Takona, 2024). Anchored on Sustainable Development Goals (SDGs) 11 (sustainable cities and communities) and 12 (responsible consumption and production), the mixed-methods approach facilitated the examination of both measurable impacts and contextual insights into household and institutional practices.

3.2 Study Area

The research was conducted in Lapai, a secondary city in Niger State, Nigeria, characterized by rapid urbanization and associated challenges such as housing shortages and environmental degradation. Lapai Local Government Area has a population of approximately 164,400, with significant urban expansion influencing land use and resource management (Yahaya and Shaibu, 2020). The selection of Lapai as the study site was informed by its representation of typical secondary urban centres in developing countries facing diseconomies of scale and infrastructure deficits (Yahaya and Shaibu, 2020).

3.3 Population and Sampling

The target population for this study comprised households residing in residential units within Lapai Local Government Area of Niger State, Nigeria. According to available demographic records, Lapai has an estimated population of approximately 164,400 residents (National Population Commission of Nigeria, 2022 projection). Using the national average household size of about five persons per household in Nigeria (National Bureau of Statistics, 2024), the estimated number of residential households in Lapai is approximately 32,880 households (National Population

Commission of Nigeria, 2022 projection). This population provided the sampling frame for the quantitative component of the study.

To determine an appropriate sample size for the household survey, the study employed the widely used Yamane sample size formula, which is suitable for large populations and commonly applied in social science research to obtain representative samples. The formula is expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = required sample size

N = population size

e = level of precision (sampling error), typically set at 0.05 for a 95% confidence level

Substituting the estimated number of households in Lapai (32,880) into the formula:

$$n = \frac{32,880}{1 + 32,880(0.05)^2}$$

$$n = \frac{32,880}{1 + 32,880(0.0025)}$$

$$n = \frac{32,880}{1 + 82.2}$$

$$n = \frac{32,880}{83.2} \approx 395$$

The statistical calculation indicates that a sample size of approximately 395 households would be required for full representation at a 95% confidence level. However, due to field constraints typical of household surveys in developing urban settings such as time limitations, accessibility challenges, and non-response risks a sample size of 300 households was adopted. Sample sizes

between 200 and 500 households are widely considered adequate for multivariate statistical analysis, particularly when regression techniques are employed in urban and housing studies.

For the quantitative survey, a multi-stage sampling technique was adopted to ensure representativeness across the study area. In the first stage, Lapai was stratified into identifiable neighbourhood clusters to account for spatial variation in housing and environmental conditions. In the second stage, residential streets within each neighbourhood were randomly selected. Finally, individual residential units were selected through systematic random sampling. This approach ensured that households from different socio-economic and environmental contexts within Lapai were proportionately represented in the survey.

For the qualitative component, purposive sampling was used to identify key informants with relevant expertise and institutional knowledge related to urban environmental management. Participants included urban planners, environmental health officers, and community representatives. A total of 12 key informants were interviewed, which is consistent with qualitative research guidelines that emphasize depth of insight rather than large sample sizes. The interviews provided contextual understanding of governance structures, institutional constraints, and community-level practices related to circular economy adoption and sustainable housing outcomes.

3.4 Data Collection

Quantitative data were collected via a structured questionnaire focusing on urban environmental management practices (e.g., waste management, water and sanitation services, and neighbourhood maintenance) and sustainable housing indicators (e.g., habitability, environmental quality, and resource efficiency). The instrument was pre-tested for reliability and validity. Qualitative data

were gathered through semi-structured key informant interviews, which explored experiences with circular economy adoption, constraints, and governance issues. All data collection adhered to ethical standards, including informed consent and confidentiality.

3.5 Data Analysis

Quantitative data were analysed using descriptive statistics to summarize patterns and multivariate regression analysis to examine the influence of independent variables (urban environmental management practices) on dependent variables (sustainable housing indicators). Regression models assessed significance at a 95% confidence level, controlling for potential confounders such as household size and income. Qualitative data were analysed thematically (Braun and Clarke, 2006), involving coding, theme identification, and interpretation to enrich quantitative findings. Integration of results occurred at the interpretation stage to provide a holistic understanding of the study's objectives.

3.6 Model Specification and Operationalisation of Variables

To examine the influence of urban environmental management practices on sustainable housing outcomes in Lapai, a multiple linear regression model was employed. The model estimates the extent to which selected environmental management practices predict variations in sustainable housing indicators while controlling for relevant household socio-economic characteristics.

The general functional form of the regression model is expressed as:

$$SHO = \beta_0 + \beta_1 WM + \beta_2 WS + \beta_3 NEM + \beta_4 INC + \beta_5 HHS + \beta_6 EDU + \varepsilon$$

Where:

SHO = Sustainable Housing Outcomes (composite index derived from habitability, environmental quality, and resource efficiency indicators)

β_0 = Intercept (constant term)

β_1 – β_6 = Regression coefficients measuring the influence of each independent variable

WM = Waste management practices

WS = Access to improved water and sanitation services

NEM = Neighbourhood environmental maintenance

INC = Household income (control variable)

HHS = Household size (control variable)

EDU = Education level of household head (control variable)

ε = Error term capturing unexplained variation in the dependent variable

The dependent variable, sustainable housing outcomes, was constructed as a composite index derived from multiple survey indicators measured on a five-point Likert scale ranging from 1 (very poor) to 5 (very good). These indicators captured three dimensions of housing sustainability: Habitability – adequacy of housing conditions, ventilation, and structural safety; Environmental quality – cleanliness of surroundings, sanitation conditions, and exposure to environmental hazards; Resource efficiency – household practices related to water conservation, energy use, and waste reduction.

Independent variables representing urban environmental management practices were also measured using Likert-scale responses based on household perceptions and reported practices. Waste management practices included indicators such as waste segregation, regular waste collection, and proper disposal methods. Access to water and sanitation services captured the availability and reliability of improved water sources and sanitation facilities. Neighbourhood environmental maintenance reflected the regularity of street cleaning, drainage maintenance, and community sanitation activities.

Control variables were included in the regression model to account for socio-economic differences among households that could influence housing conditions. Household income was measured in income brackets reported by respondents, household size represented the number of occupants in each dwelling, and education level referred to the highest educational attainment of the household head.

Prior to regression analysis, composite indices were constructed by averaging relevant Likert-scale items for each variable category. Diagnostic checks were conducted to ensure the suitability of the regression model, including tests for multicollinearity among predictor variables and examination of residual distributions. Statistical significance was evaluated at the 95% confidence level ($p \leq 0.05$).

This modelling approach enabled the study to quantify the relationship between environmental management practices and sustainable housing outcomes while integrating household socio-economic characteristics that may influence housing conditions in rapidly urbanising secondary cities.

4.0 RESULTS AND DISCUSSION

4.1 Quantitative Results

Descriptive statistics from the household survey ($N = 300$) revealed varying levels of urban environmental management practices and sustainable housing outcomes in Lapai. Approximately 62% of respondents reported adequate access to improved water and sanitation services, while 54% indicated regular neighbourhood environmental maintenance. Waste management practices were less optimal, with only 48% of households engaging in proper segregation and disposal. On sustainable housing indicators, mean scores (on a 5-point Likert scale) were 3.2 for habitability,

2.9 for environmental quality, and 3.0 for resource efficiency, suggesting moderate performance but room for improvement.

Multivariate regression analysis examined the influence of urban environmental management practices on sustainable housing indicators, controlling for covariates such as household income, size, and education level. The model explained 42% of the variance in sustainable housing outcomes (adjusted $R^2 = 0.42$, $p < .001$). As shown in Table 1, waste management ($\beta = 0.28$, $p < .01$), access to improved water and sanitation ($\beta = 0.35$, $p < .001$), and neighbourhood environmental maintenance ($\beta = 0.24$, $p < .01$) had significant positive effects on overall sustainable housing indicators. These findings align with the hypothesis that effective environmental practices enhance habitability, environmental quality, and resource efficiency.

Table 4.1: Regression Coefficients for Urban Environmental Management Practices on Sustainable Housing Indicators

Predictor Variable	β	SE	t	p-value
Waste Management	0.28	0.09	3.11	<.01
Water and Sanitation Services	0.35	0.08	4.38	<.001
Neighborhood Environmental Maintenance	0.24	0.10	2.40	<.01
Household Income (Control)	0.12	0.07	1.71	.09
Household Size (Control)	-0.05	0.06	-0.83	.41
Education Level (Control)	0.15	0.08	1.88	.06

Note. N = 300. Dependent variable: Composite sustainable housing score. SE = standard error.
Source: Analysis, 2026

4.3 Qualitative Results

Thematic analysis of key informant interviews (n = 12) identified three main themes: low public awareness of circular economy (CE) practices, institutional constraints, and opportunities for governance strengthening. Participants highlighted limited household adoption of CE principles, such as material reuse (mentioned by 8 informants) and energy conservation (mentioned by 7), attributing this to inadequate education and cultural norms favoring linear consumption. Weak

institutional capacity emerged as a barrier, with urban planners noting insufficient funding and staffing for enforcement (theme frequency: 10/12). Community representatives emphasized poor regulatory frameworks, leading to inconsistent waste management and sanitation services. However, informants suggested potential for mainstreaming CE through community-led initiatives and policy reforms.

4.4 Discussion

The quantitative findings demonstrate that urban environmental management practices significantly positively influence sustainable housing outcomes in Lapai, consistent with prior research on secondary cities in developing contexts. For instance, effective waste management and water/sanitation access align with studies in Nigeria showing their role in reducing environmental degradation and improving habitability. Neighbourhood maintenance's positive effect echoes literature on urban governance in Sub-Saharan Africa, where regular upkeep mitigates diseconomies of scale and enhances resource efficiency. These results support SDG 11 by promoting resilient communities and SDG 12 through responsible resource use, while indirectly advancing SDG 13 via reduced urban vulnerabilities to climate impacts.

Qualitative insights enrich these findings by revealing low CE awareness at the household level, driven by institutional weaknesses and enforcement gaps, corroborating barriers identified in Nigerian built environment studies. This low adoption of practices like reuse and conservation mirrors necessity-driven but constrained CE in low-income settings, highlighting the need for targeted education and policy alignment. The interplay of quantitative and qualitative data underscores a gap in mainstreaming CE, as noted in broader African urban sustainability literature.

These results have policy implications for local SDG implementation in secondary cities like Lapai. Strengthening urban environmental governance through enhanced regulations, capacity building, and community awareness programs could amplify sustainable housing outcomes. Limitations include the cross-sectional design, which limits causality inference, and reliance on self-reported data, potentially subject to bias. Future research could employ longitudinal methods to track CE adoption over time. Overall, this study provides evidence-based recommendations for integrating CE into household practices, fostering sustainable urban development in Nigeria.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has demonstrated that urban environmental management practices significantly contribute to sustainable housing outcomes in Lapai, a secondary city in Niger State, Nigeria. Quantitative findings from the household survey and multivariate regression analysis confirmed that effective waste management, improved access to water and sanitation services, and regular neighbourhood environmental maintenance positively influence key indicators of habitability, environmental quality, and resource efficiency. These results align with broader evidence from Nigerian and Sub-Saharan African contexts, where such practices mitigate the adverse effects of rapid urbanization on housing quality and resource use.

Qualitative insights from key informant interviews further illuminated persistent challenges, particularly the low level of public awareness and adoption of circular economy (CE) principles at the household level. Constraints including weak institutional capacity, inadequate enforcement of environmental regulations, and limited community education perpetuate linear consumption patterns, hindering the mainstreaming of practices such as material reuse, waste reduction, and

energy conservation. These barriers resonate with documented issues in the Nigerian built environment and developing-country secondary cities, where economic volatility, infrastructure gaps, and regulatory weaknesses impede CE transitions.

The study underscores the interconnectedness of SDG 11 (sustainable cities and communities) and SDG 12 (responsible consumption and production), while contributing to SDG 13 (climate action) through enhanced urban resource efficiency and reduced environmental degradation. In Lapai, strengthening these linkages offers a pathway to more resilient and inclusive urban development, addressing housing deprivation and environmental pressures characteristic of secondary cities in developing regions.

5.2 Recommendations

To advance sustainable housing outcomes and accelerate CE adoption in Lapai and similar secondary cities, the following policy-relevant recommendations are proposed:

1. Strengthen urban environmental governance: Local authorities in Lapai should prioritize institutional capacity building, including increased funding, staffing, and training for urban planners and environmental health officers. Enhanced enforcement mechanisms for existing environmental regulations are essential to ensure consistent implementation of waste management, sanitation, and neighbourhood maintenance practices.
2. Mainstream circular economy principles into household practices: Targeted awareness campaigns and community education programs should be developed and implemented to raise public knowledge of CE benefits, focusing on practical actions such as material reuse, waste segregation, and energy conservation. Collaboration with community representatives can facilitate culturally appropriate interventions to overcome sociocultural resistance.

3. Promote integrated policy frameworks for SDGs localization: Niger State and federal agencies should integrate CE strategies into local urban planning and housing policies, aligning with national SDG implementation plans. This includes developing incentives for households and small enterprises to adopt sustainable practices, such as subsidies for improved sanitation infrastructure and waste recycling initiatives.
4. Foster multi-stakeholder partnerships: Engage public-private partnerships and community-based organizations to support infrastructure improvements and monitoring. Drawing from successful models in other Nigerian contexts, such partnerships can enhance resource mobilization and ensure inclusive participation in environmental management.
5. Support further research and monitoring: Longitudinal studies in Lapai and comparative analyses across other secondary cities are recommended to track CE adoption trends and evaluate the long-term impacts of governance interventions. Regular data collection on sustainable housing indicators will enable evidence-based policy adjustments.

By implementing these recommendations, Lapai can serve as a model for advancing sustainable urban development in Nigeria's secondary cities, contributing meaningfully to national and global SDG targets while improving living conditions for residents.

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SPATIAL ASSESSMENT OF LAND-USE TYPOLOGIES IN SELECTED INFORMAL SETTLEMENTS OF ABUJA, NIGERIA: IMPLICATIONS FOR URBAN REGULARIZATION

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Abstract

Rapid urbanization in developing countries has intensified the growth of informal settlements, particularly in rapidly expanding cities such as Abuja, Nigeria. These settlements are often characterized by unregulated spatial development and complex land-use structures, which pose significant challenges for urban planning and integration. This study examines the spatial distribution and land-use typologies of selected informal settlements in Abuja, with a view to understanding their implications for urban regularization. A quantitative geospatial research design was adopted, integrating Geographic Information Systems (GIS) analysis with field survey data collected from 1,568 households across eight selected settlements within Phases I–IV of the Abuja Master Plan. High-resolution satellite imagery was used for land-use mapping and classification, while descriptive statistics were employed to analyze socio-economic characteristics. The findings reveal that informal settlements in Abuja exhibit predominantly high-density and mixed-use land-use patterns, with significant variations across locations. Residential use dominates, often coexisting with commercial and small-scale economic activities within limited space, reflecting adaptive spatial organization. However, these patterns are associated with inadequate infrastructure, inefficient land utilization, and environmental challenges. The study concludes that informal settlements possess inherent spatial logic that can be harnessed for planning purposes rather than disregarded. It recommends a shift from demolition-based approaches toward data-driven urban regularization strategies that integrate existing land-use structures into the formal urban system.

Keywords: Informal settlements, land-use typologies, spatial analysis, urban regularization

1.0 Introduction

Urbanization in developing countries has accelerated significantly over the last two centuries, with average annual growth rates estimated at about 2% compared to 0.5% in more developed regions (Kuddus *et al.*, 2020; Dijkstra *et al.*, 2021; Wang *et al.*, 2021). This rapid expansion has raised concerns about the ability of cities to effectively accommodate increasing populations, particularly in relation to land-use organization, infrastructure provision, environmental sustainability, and social inclusion. As cities expand, the spatial structure of urban areas becomes increasingly

complex, often resulting in fragmented and unregulated land-use patterns (Kookana *et al.*, 2020; Tay & Ocansey, 2022).

In Africa, the urban population currently stands at approximately 48.2% and is projected to exceed 60% by 2025. Nigeria, the most populous country on the continent, is experiencing one of the fastest urban growth rates, averaging about 5.8% annually (Aliyu & Amadu, 2017; Kuddus *et al.*, 2020). With an estimated urban population of 400 million by 2050, the pressure on land resources and urban space will intensify significantly (Abubakar & Aina, 2019; Jiboye *et al.*, 2020). Abuja, Nigeria's capital city, exemplifies this trend, with rapid population growth rates of 5.15% in 2022 and 4.84% in 2023. However, this expansion has outpaced formal planning mechanisms, leading to uncoordinated spatial development and increasing demand for land beyond planned layouts.

One of the most visible consequences of this imbalance is the proliferation of informal settlements. Globally, about 1.1 billion people reside in slums or slum-like conditions, with projections suggesting this could rise to 2 billion within the next three decades (United Nations, 2023). These settlements are typically characterized by inadequate access to basic services, insecure land tenure, and poor housing conditions (UN-Habitat, 2015). However, beyond these deficiencies, informal settlements exhibit distinct land-use typologies shaped by necessity, proximity to economic opportunities, and adaptive spatial practices.

In Nigeria, informal settlements are widespread across major cities, including Lagos, Ibadan, and Abuja. In Abuja, areas such as Mpape, Durumi, Gwagwalada, and Kuchi Bena have developed outside formal planning frameworks, resulting in irregular land-use patterns, mixed-use developments, and high-density spatial configurations (Ayuba, 2019; Eneh, 2021; Eze, 2023). These settlements often combine residential, commercial, and small-scale industrial activities within limited space, reflecting a functional but largely unregulated land-use structure. Such typologies, while often perceived as chaotic, reveal underlying spatial logic driven by accessibility, livelihood needs, and social networks.

Despite their informal nature, these settlements play a critical role in the urban system. They provide affordable housing close to employment centers, support informal economic activities, and contribute to the overall functioning of the city. However, the absence of formal planning control results in inefficient land utilization, environmental degradation, poor accessibility, and limited infrastructure integration. These challenges are fundamentally spatial in nature and require a detailed understanding of land-use patterns and typologies within informal settlements.

Urban policy responses in Nigeria have traditionally focused on demolition and eviction, often classifying informal settlements as illegal developments (Abubakar *et al.*, 2019). Such approaches fail to recognize the spatial complexity and socio-economic significance of these areas. More importantly, they overlook the need for data-driven planning interventions that can guide the regularization and integration of these settlements into the formal urban system.

Contemporary planning approaches emphasize urban regularization, which involves the systematic integration of informal settlements into the formal city structure through land-use reorganization, infrastructure provision, and tenure security. Central to this process is a clear understanding of existing land-use typologies and spatial arrangements within these areas. By examining how land is utilized and organized, planners can identify patterns, inefficiencies, and opportunities for restructuring and upgrading.

In the context of Abuja, there is a growing need to move beyond generalized perceptions of informal settlements toward detailed spatial analysis. Understanding the distribution, intensity, and interaction of land-use typologies within these settlements is essential for developing effective urban regularization strategies. Such analysis provides a basis for informed decision-making, enabling planners to design interventions that are both context-sensitive and sustainable.

Therefore, this study focuses on the spatial assessment of land-use typologies in selected informal settlements in Abuja, Nigeria, with a view to generating insights that can inform urban regularization efforts.

2.0 Study Area

Geographically, the study is delimited to selected slum communities within Phases 1, 2, 3, and 4 of the Abuja Master Plan areas identified as having significant informal settlement challenges and spatial inequalities (Obiadi *et al.*, 2019). In phase 1, has Asokoro which is an urban settlement that has within it the informal settlement as original occupants. Phase 2 communities such as Dutse originally planned for formal development, have evolved into informal settlements characterized by substandard housing, overcrowding, and inadequate infrastructure. Phase 3 comprises Mpape which have expanded along the peri-urban fringes due to rapid rural–urban migration and unregulated development, while Phase 4 such as karmo includes emerging informal communities relevant for evaluating policy and integration frameworks. These areas collectively provide the empirical basis for analyzing the physical structure, socio-economic dynamics, environmental

conditions, and spatial patterns of slum settlements in Abuja, as well as their relationship with the broader urban system. By linking these thematic and spatial components, the study seeks to provide an in-depth understanding of slum dynamics and develop strategies for sustainable integration into Abuja's physical, economic, environmental, and social systems.

3.0 Methodology

This study adopts a quantitative geospatial research design to examine the land-use typologies within selected informal settlements in Abuja, Nigeria, and to assess their implications for urban regularization. The choice of this design is informed by the need to systematically analyze both spatial and non-spatial characteristics of informal settlements in a measurable and objective manner. The study integrates Geographic Information Systems (GIS) techniques with statistical analysis to enable the mapping, classification, and interpretation of land-use patterns, as well as the evaluation of settlement structure and functionality. While quantitative methods provide measurable indicators such as housing conditions, density, and access to infrastructure, spatial analysis facilitates an understanding of the distribution and organization of land uses within the urban fabric. This integrated approach ensures a comprehensive and evidence-based assessment of informal settlement dynamics.

Data for the study were obtained from both primary and secondary sources. Primary data were collected through field surveys and direct observation within selected informal settlements. These data included information on housing characteristics, land-use activities, environmental conditions, and infrastructure availability. Secondary data comprised spatial datasets such as high-resolution satellite imagery, land-use maps, and administrative boundary data. Specifically, WorldView-4 satellite imagery with a spatial resolution of 0.5 meters was sourced from Google Earth, while land-use maps were obtained from the Abuja Geographic Information System (AGIS). Additional spatial data, including geographic coordinates, were acquired from the National Space Research and Development Agency (NASRDA). These datasets provided the foundation for spatial mapping and land-use classification.

The household survey population was drawn from eight settlements selected to represent the full spatial gradient from inner-city enclaves to peri-urban settlements. These eight settlements were purposively selected on the basis of spatial location (covering inner, middle-ring, and outer settlement types), settlement size, and density typology (representing High-Compact, Moderate, and Low-Dispersed classifications from the building density analysis). This study investigated the

urban poor communities (slums) in phases 1 to 4 and they have a total population of 114738 in 2019 with each phase population as 10830, 21700, 16714 and 65494 respectively. The sample size for the household questionnaire survey was determined using Yamane's (1973) simplified formula for finite populations:

$$\text{Sample Size } (n) = \frac{N}{1+N(e)^2}$$

Where n is the sample size, N is the estimated total population of households across the eight study communities, and e is the acceptable margin of error, set at 0.05 (5%) for a 95% confidence level.

The study arrived at a sample size of 1568 households across the eight selected slums. The sample size of 1568 households was then distributed across the eight communities in proportion to their estimated household populations.

A spatially clustered random sampling technique was employed to select respondents for the household questionnaire survey. The eight study communities constituted the sampling cluster, with the number of respondents allocated to each community in proportion to its estimated household population. Within each cluster, a systematic random sampling approach was applied: the total number of structures in each community was estimated from the GIS building density analysis, and a sampling interval was computed by dividing the total estimated structures by the number of respondents allocated to that community. The starting structure was selected randomly within the first interval, and thereafter every n th structure was approached for an interview. Where a sampled structure was vacant, inaccessible, or where the household head declined to participate, the immediately adjacent structure was substituted.

Data collection was carried out using a structured questionnaire and field observation. The questionnaire was designed to elicit information across areas corresponding to the study's objectives. Data on the socio-economic characteristics of respondents, including gender, age, marital status, educational attainment, occupation, monthly household income, household size, and length of residence. The housing condition data contain information on housing type, wall and roof construction materials, tenure status, water supply source, sanitation facilities, solid waste disposal method, and road access condition while residents' perceptions of their access to five urban system components, major roads, the CBD, commercial and market areas, employment centres, and social

service facilities was gotten and rated on a five-point Likert scale (1 = Very Poor to 5 = Very Good). This helped to validate and complement the data obtained from the questionnaires.

Spatial data processing and analysis were conducted using ArcGIS software. Satellite imagery was first georeferenced to the Universal Transverse Mercator (UTM) coordinate system using ground control points obtained through GPS surveys. Subsequently, key spatial features such as buildings, roads, infrastructure, and land-use categories were digitized into vector formats. A geodatabase was developed to store and manage both spatial and attribute data, including information on land-use type, building function, and infrastructure characteristics. Land-use typologies were then classified into categories such as residential, commercial, mixed-use, and public or institutional uses. Spatial analysis techniques, including overlay analysis, density mapping, and proximity analysis, were applied to examine the distribution, intensity, and relationships among different land uses. The analysis of non-spatial data was carried out using descriptive statistical techniques, including frequencies, percentages, and cross-tabulations. Spatial outputs in the form of maps and thematic layers were generated to illustrate the distribution of land-use typologies, patterns of informal development, infrastructure accessibility, and density of land-use activities. These analytical outputs provided insights into the spatial structure of informal settlements and highlighted areas of inefficiency and planning gaps.

4.0 Result and Discussion

4.1 Socio-economic characteristics

The gender classification of the respondents within the study area was examined. The results are as displayed in Table 1, showing that 65.6% of the respondents were male and 34.4% were female in the study area. This shows that the majority of the respondents in the study area were male. The study area is dominated by male household heads. Additionally, males are predominantly the heads of households in the study area.

Table 1 shows the age of respondents. The table shows that 30.8% were between 26 and 35 years, 22.9% were between 36 and 45 years, 14.1% were less than 18 years, 12.3% were between 36 and 45 years, 11.0% were between 18 and 25 years, and the remaining 8.8% were above 55 years. The cumulative percentage shows that the majority (54.9%) of the respondents were 26 years of age and older.

The marital status of the respondents, as shown in Table 1, shows that 53.8% of the respondents in the study area were married, 5.7% were separated, and 40.1% were single. This implies that the majority of the respondents in the study area were married, which might compel them to explore more sources of income including within the urban centre.

Table 1 shows the distribution of survey respondents' educational qualifications. 33.0% of respondents had secondary qualification, 25.1% had primary school qualification, 22.0% had BSC/HND qualification, 18.5% had ND/NCE qualification, and the remaining 1.3% had M.Sc., M.Tech, and above qualification. Therefore, the respondents are adequately knowledgeable.

The occupational structure of slum dwellers in the study area was made up of civil servants, business, private, artisans, students, apprentices, and retired. Table 1 shows that business people (petty traders and retail shops) constituted 49.3% of the respondents; individuals involved in the private sector were 18.9%; 14.1% were civil servants; 9.7% were artisans; 4.8% were students; 2.2% were retired; and 0.9% were apprentices.

The investigation into the average amount of money that respondents accrue at the end of every month was also considered relevant to the achievement of this study's objectives. The fact that people engage in different forms of business of different capacities to make ends meet made it necessary to investigate the average amount of money that accrues to a household head at the end of every month. As a result, the residents' estimated monthly income was considered in ranges to accommodate a degree of precision as well as flexibility. The results from the study area show that 24.2% of the respondents earned below 30,000 naira per month, 30.4% earned between 60,001 and 90,000 naira, 15.9% indicated their monthly income to be between 30,001 and 60, 000 naira, and 15.4% earn between 90,001 and 120,000 naira. The lowest percentage, 14.1%, represents residents who received more than 120,000 thousand naira monthly, as shown in Table 1. Based on the current situation in the Nigerian economy, where a dollar is equivalent to 1530 naira, the majority of the respondents can be grouped as low-income earners.

Table 1: Socio-economic characteristics

Profile		Frequency	Proportion (%)
Gender	Male	745	65.6
	Female	390	34.4
	Total	1135	100.0
Age of Respondents	Less than 18	160	14.1
	18-25	125	11.0

	26-35	350	30.8
	36-45	260	22.9
	46 - 55	140	12.3
	above 55	100	8.8
	Total	1135	100.0
Marital status	single	450	40.5
	separated	65	5.7
	married	610	53.8
	Total	1135	100.0
Education level of the Respondents	Primary	285	25.1
	secondary	375	33.0
	ND/NCE	210	18.5
	BSC/HND	250	22.0
	M.Sc / M.tech and Above	15	1.3
	Total	1135	100.0
Occupational structure of respondent	Civil servant	160	14.1
	Business	560	49.3
	Private	215	18.9
	Artisan	110	9.7
	Student	55	4.8
	Apprentice	10	9
	Retired	25	2.2
	Total	1135	100.0
Monthly income of respondents	Less than ₦ 30,000	275	24.2
	₦30,001-60,000	180	15.9
	₦60,001- 90,000	345	30.4
	₦ 90,001- 120,000	175	15.4
	Above ₦ 120,000	160	14.1
	Total	1135	100.0

4.2 Land-use Pattern in the Slums of Abuja

The discernible land use patterns in the slums of Abuja reveal varying degrees of residential density, mixed-use development, and the presence of community facilities. While Asokoro is predominantly a low-density residential area, Dutse, Gwarinpa, and Karmo exhibit higher residential densities with significant mixed-use developments. Mabushi and Wumba provide a balance of residential, educational, and recreational land uses. Each slum area is analysed below:

i. Asokoro village (Kpaduma)

The percentage of land use in Asokoro (Kpaduma) is predominantly characterised by low-density residential areas, which occupy 74.51% of the total land area. Medium-density residential areas cover 9.01% of the total land area as presented in Figure 2. High-density residential zones are significantly smaller, comprising 5.99%. Educational facilities, specifically schools, account for

3.01% of the land use. Health centres occupy a minimal portion, accounting for 0.04% of the total area.

Table 2: Percentage of land use in Asokoro village (Kpaduma)

Landuse	Area (square metres)	Percentages (%)
Medium Density	720444.39	9.01
Low Density	5956821.34	74.51
High Density	478782.65	5.99
Schools	240945.08	3.01
Health Centre	3533.90	0.04
Hotel	25923.58	0.32
Police Station	103864.39	1.30
Community and Public Institution	464740.88	5.81
Total	7995056.25	100.00

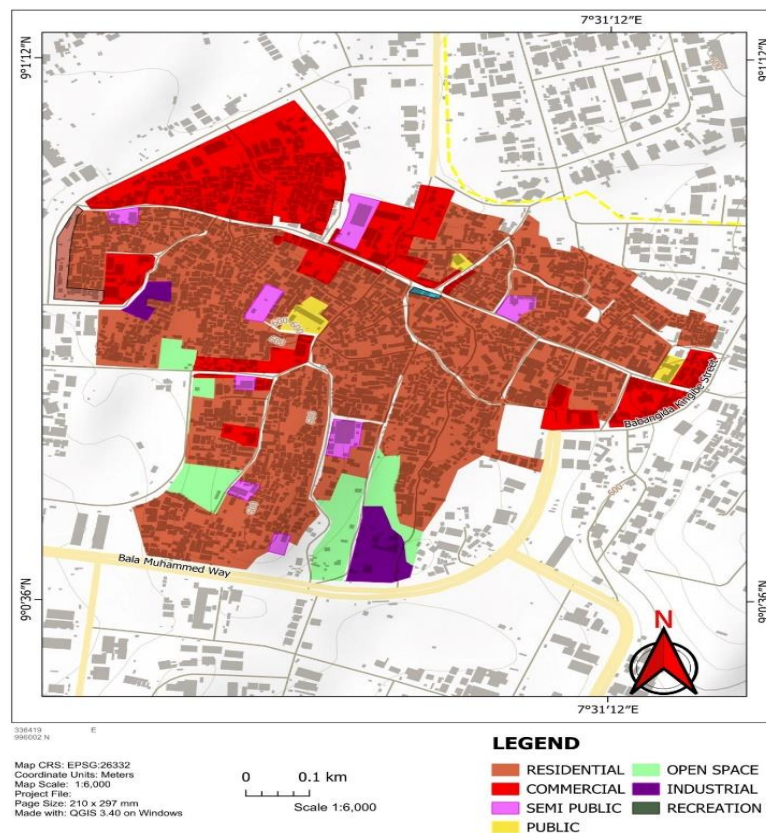


Figure 1. Land use in Asokoro Village (Kpaduma)

ii. Dutse Apo

The land use in Dutse Apo is diverse, with high-density residential areas being dominant, covering 38.05% of the total land. Comprehensive development occupies 26.13%. Medium-density

residential areas represent 11.35%. Mixed development areas constitute 2.41% of the land use. Low-density residential areas are the least extensive, covering 1.15% of the total area. Table 2 shows the percentage of land use in Dutse Apo. Figure 2 shows the map depicts the diverse land use patterns in Dutse.

Table 2: Percentage of land use in Dutse Apo

Landuse	Area (square metres)	Percentages (%)
High Density	761425.25	45.68
Low Density	43417.65	2.61
Medium Density	287850.13	17.27
School	9936.62	0.60
Comprehensive development	333505.10	20.01
Health Centre	5508.08	0.33
Hotel	27496.82	1.65
Religious Ins	5421.50	0.33
Commercial	192222.39	11.53
Total	1666783.57	100.00

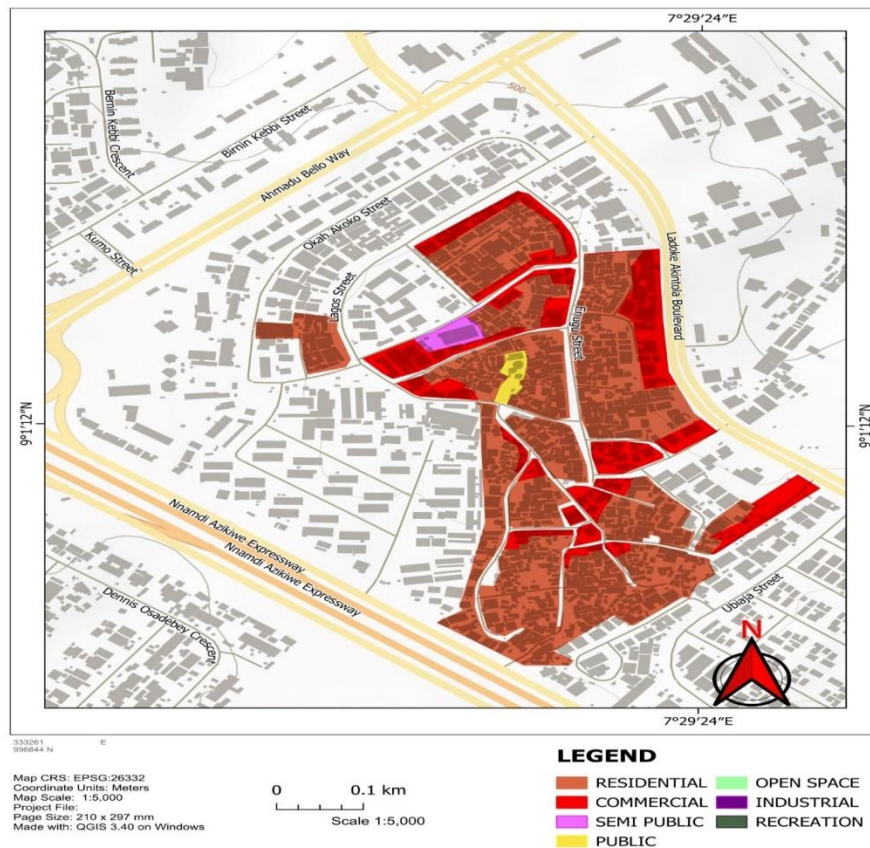


Figure 2. Land use in Dutse Apo

iii. Gwarimpa village (Kado Bimko)

In Gwarimpa village (Kado Bimko), high-density residential areas dominate, occupying 45.68% of the total land area. Medium-density residential areas represent 17.27% of the land use. Comprehensive development account for 20.01%. Low-density residential zones are significantly smaller, comprising 2.60%. Schools make up 0.60% of the land use. Table 3 shows the percentage of land use in Gwarimpa village (Kado Bimko). Figure 3 shows the map depicts the diverse land use patterns in Gwarimpa village (Kado Bimko).

Table 3: Percentage of land use in Gwarimpa village (Kado Bimko)

Landuse	Area (square metres)	Percentage (%)
Medium Density	733002.91	20.20
High Density	102229.72	28.17
Low Density	317592.56	8.75
Comprehensive Development	245252.37	6.76
Schools	212752.71	5.86
Employment Area	114849.32	3.16
Police Station	64123.51	1.77
Fire Station	9872.80	0.27
Health Centre	36877.99	1.02
Financial Ins	2985.18	0.08
Undeveloped Land	543245.84	14.97
Mixed Dev	130296.51	3.59
Active Recreation	139909.90	3.86
Commercial	56468.38	1.5
Total	3629527.43	100.00%

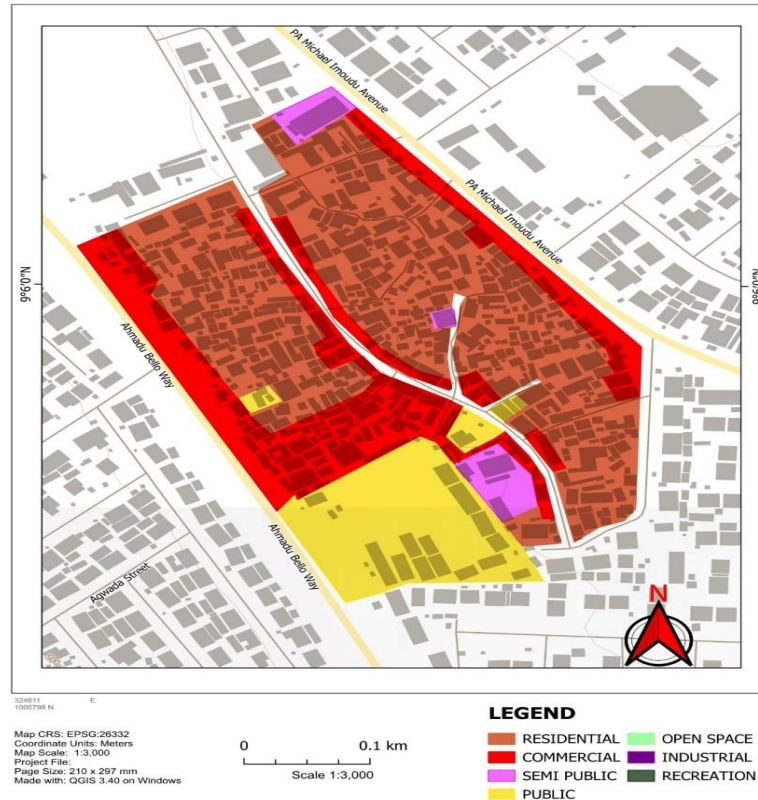


Figure 3. Land use in Gwarimpa village (Kado Bimko)

iv. Karmo

In Karmo, the land use is primarily high-density residential area, which occupies 28.17% of the total area. Medium-density residential areas represent 20.20%. Low-density residential zones comprise 8.75% of the land use. Comprehensive development projects account for 6.76%. Schools make up 5.86% of the total area. Table 4 shows the percentage of land use in Gwarimpa. Figure 4 shows the map depicts the diverse land use patterns in Gwarimpa.

Table 4: Percentage of land use in Karmo

Landuse	Area (square metres)	Percentage (%)
Undevelopable land, Flood Area and Steep Ground	438818.52	20.56
Low Density	401868.37	18.83
High Density	589215.24	27.61
Medium Density	248838.88	11.66
Employment Area	122814.64	5.75
Nursery and Primary School	17537.10	0.82
Open Space, Recreation and Undeveloped Land	36132.93	1.69
Commercial	34515.07	1.62
Passive Recreation	6871.43	0.32
Health Centre	4643.41	0.22

Market	7078.20	0.33
Hotels	19024.09	0.89
Mixed Development	206949.02	9.70
Total	2134306.95	100.00

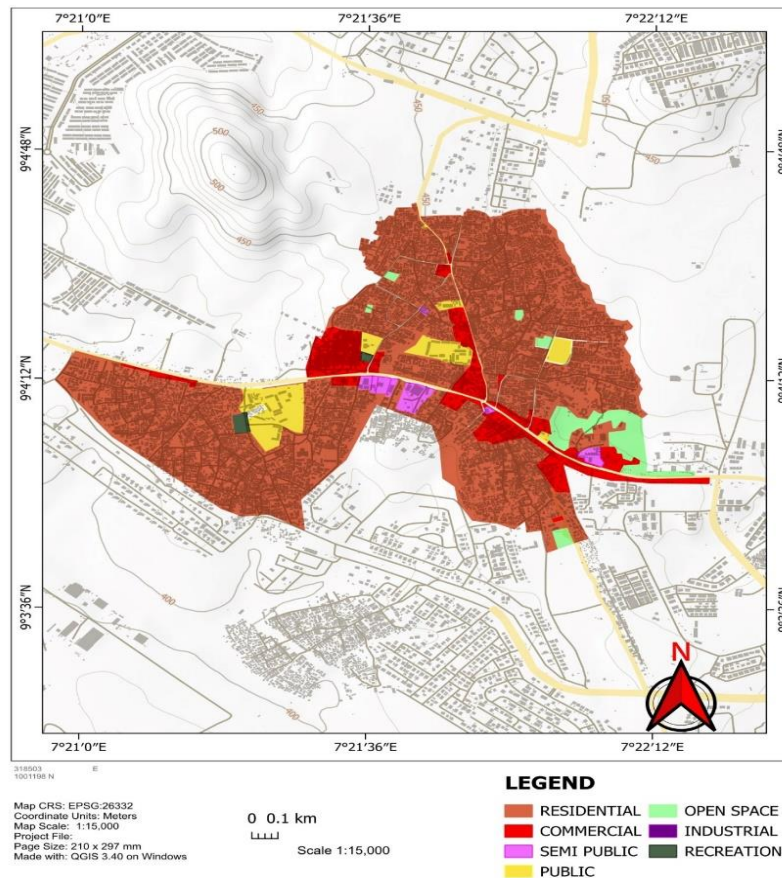


Figure 4. Land use in Karmo

4.3. Discussion

- i. The findings identify several key locations where informal settlements are concentrated. The eight identified slums were often in proximity to notable landmarks and infrastructure. The discernible land use patterns in the slums of Abuja reveal varying degrees of residential density, mixed-use development, and the presence of community facilities. While Asokoro (Kpaduma) is predominantly a low-density residential area, Dutse, Gwarinpa Village, and Karmo exhibit higher residential densities with significant mixed-use developments. Mabushi and Wumba provide a balance of residential, educational, and recreational land uses. This finding is consistent with Ayuba's (2019) findings, which reveal that the primary

land use in Abuja's slums is residential, characterized by densely packed informal housing units. These settlements often lack proper planning and infrastructure, leading to overcrowding and substandard living conditions. Informal settlements in Abuja frequently exhibit mixed land uses, where residential spaces coexist with small-scale commercial activities, informal markets, and sometimes industrial activities. This mixed-use pattern reflects the adaptive strategies of slum residents to generate income and meet daily needs within their immediate environment (Wahab, 2017).

- ii. The spatial distribution of slums in Abuja reflects socio-economic disparities around the area where they are located. The findings reveal that the slum at Mpape with area coverage of 2,624,605.45m² cover the largest landmass, while the slum located in Idu, is the next in line with a landmass of 2,222,631.69m². Abuja has experienced rapid urban growth driven by administrative and political functions. This growth has outpaced urban planning and infrastructure development, leading to the proliferation of informal settlements and slums. Studies highlight the expansion of slums into peri-urban areas and marginal lands due to rural-urban migration, population increase, and inadequate affordable housing options (Badaru *et al.*, 2014; Okimiji *et al.*, 2021). These settlements often cluster in peripheral and underserved areas of the city. GIS tools have been used to map out where the slums are located and they show that most of them are in districts where land is cheap and there isn't much government oversight (Adepoju *et al.*, 2020).

5.0 Conclusion

This study set out to examine the spatial characteristics and land-use typologies of selected informal settlements in Abuja and to explore their implications for urban regularization. The findings demonstrate that informal settlements are not random or entirely chaotic; rather, they exhibit identifiable spatial patterns shaped by socio-economic needs, accessibility, and proximity to livelihood opportunities. Across the study areas, residential land use was found to dominate, often integrated with commercial, institutional, and mixed-use activities within limited and densely occupied spaces. The analysis further revealed significant variations in land-use composition among the selected settlements, reflecting differences in development intensity, location, and historical growth patterns. High-density residential development was particularly prominent in peri-urban and rapidly expanding areas, while some inner-city settlements retained elements of

low- and medium-density structures. Despite their functional adaptability, these settlements are constrained by inadequate infrastructure, poor environmental conditions, and inefficient spatial organization. Importantly, the study highlights that the challenges associated with informal settlements are fundamentally spatial and planning-related. The lack of formal land-use control and infrastructure provision has resulted in fragmented urban forms that limit accessibility, service delivery, and environmental sustainability. However, the presence of mixed-use development and localized economic activities also underscores the resilience and functionality of these settlements within the broader urban system. The study establishes that effective urban regularization in Abuja must be grounded in a clear understanding of existing land-use typologies and spatial arrangements. Rather than viewing informal settlements solely as areas of deficiency, they should be recognized as dynamic urban spaces with inherent structure and potential for integration into the formal planning framework.

5.1 Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Planning authorities should shift from demolition-oriented approaches to inclusive regularization strategies that recognize and integrate existing land-use patterns within informal settlements into the formal urban system.
2. Government agencies should invest in geospatial data infrastructure and GIS-based planning tools to support continuous monitoring, mapping, and analysis of informal settlements for informed decision-making.
3. Given the prevalence of mixed land-use in informal settlements, planning policies should accommodate and formalize compatible mixed-use developments rather than enforcing rigid zoning systems.
4. Targeted interventions should be implemented to improve access to roads, drainage, water supply, sanitation, and waste management, particularly in high-density areas.

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**Analysis of Flood Trend Activities Across Selected Settlements In Minna, Niger State.
Nigeria**

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Abstracts

Flooding has become an increasingly frequent and destructive environmental hazard in many urban centers across Nigeria, particularly in rapidly expanding cities such as Minna metropolis, Niger State of Nigeria. This study focuses on the analysis of flood trend activity differentials across selected areas within Minna, with a view of identifying temporal variations in flood occurrence in these areas. The research utilizes historical hydrological records elicited from the Niger State Emergency Management Agency (NSEMA) from 2014 to 2024. The study adopts a comparative approach to highlight disparities in flood experiences among three different settlements in Mina, namely, Fadikpe, Barkin- Sale and Lapai Gwari. Bar charts, tables and percentages were used to analyse the data. The result of the study shows that the main triggers of flooding in the study areas were heavy downpours, the Niger River overflowing its banks, and a host of harmful human habits. The study further showed that was a significant difference in flood occurrence rates among the three selected settlements with Lapai Gwari, have the highest occurrence in the study period. In other words, findings revealed significant variations in flood trends across the selected areas, driven by both natural and anthropogenic factors. The outcome of this research contributes to improved flood risk management strategies, inform urban planning policies, and support sustainable development initiatives in Minna metropolis and similar urban environments.

Keywords: Hydrological, Metropolis, Disparities

Introduction

Floods are intense natural weather events where massive volumes of water spill over onto land that's typically dry (Agbonkhese et al., 2014). They happen often when rivers, oceans, or seas overflow their banks. Human actions like deforestation, poor land use, and clogged drains or

waterways frequently trigger these floods. Climate change worsens the problem by raising sea levels (Oladokun, 2016). Happening across much of the world's land areas, floods cause massive yearly losses, damaging economies, businesses, infrastructure, services, and public health (Adekola and Lamond, 2020). Urban flooding is often sparked by intense rainfall events, like flash floods. It strikes various cities to varying degrees, endangering farmland, vegetation, human lives, and property (Eldho et al., 2018). Cities tend to have vast expanses of impervious surfaces—think concrete and asphalt—that block rainwater from soaking into the soil. This leads to massive runoff, elevated floodwaters, widespread inundation, and hefty damages (Eldho et al., 2018). In densely packed urban zones brimming with economic activity, such floods can trigger disasters that stall city growth for years.

Urban flooding often stems from intense downpours, rivers overflowing their banks, or coastal surges driven by high tides and storms. For instance, the UK faced around £1 billion in flood-related damages during the 2015–2016 winter, while China's August 2020 floods claimed at least 219 lives, prompted emergency calls from 0.82 million people, wrecked about 0.4 million homes, ruined 5 million hectares of farmland, and caused direct economic losses exceeding US\$25 billion (Miller & Hutchins, 2017; Guo et al., 2020). Experts have long valued how flood-impacted communities perceive risks a recognition dating back to Gilbert White's groundbreaking 1945 book, *Human Adjustment to Flooding*. Today, in flood risk management, people's subjective views of danger play a key role in assessing threats. Grasping these perceptions among residents in vulnerable areas is crucial for shaping policies, guiding decisions, and building effective mitigation strategies. Yet, the growing toll of floods on lives and property has not gotten the focus it deserves.

This study aims to examine flood patterns and types in the study area over the past 12 years (2013–2024). It will explore the coping strategies communities have used to mitigate flood risks, evaluate

the impacts across all levels, and analyze Vulnerability Community Assessments (VCA) for selected communities in the Minna metropolis.

Methodology

Description of the Study Area

Minna in Niger State is geographically located between latitude $9^{\circ}36'22''\text{N}$ and longitude $6^{\circ}33'15''\text{E}$. It covers a total area of about 76,363 square kilometers. Minna has a population of 463,000 in 2021 (Ouma, 2014). The villages surrounding Minna metropolis consists of Bejo, Beji, Bosso, Garatu, Kampala, Kodo, Maikunkele, Maitumbi and Shata. It is home to the campuses of the Federal University of Technology Minna. It is bounded by Katcha, Shiroro, Wushishi and Paikoro local government areas. (Ouma, 2014). The town is drained by many drainage channels, with the main course taking its source from the north central highlands and thereafter, flowing towards the western lowlands. The study area is located in a tropical climate region which is characterized by two seasons in a year, the wet seasons and dry seasons.

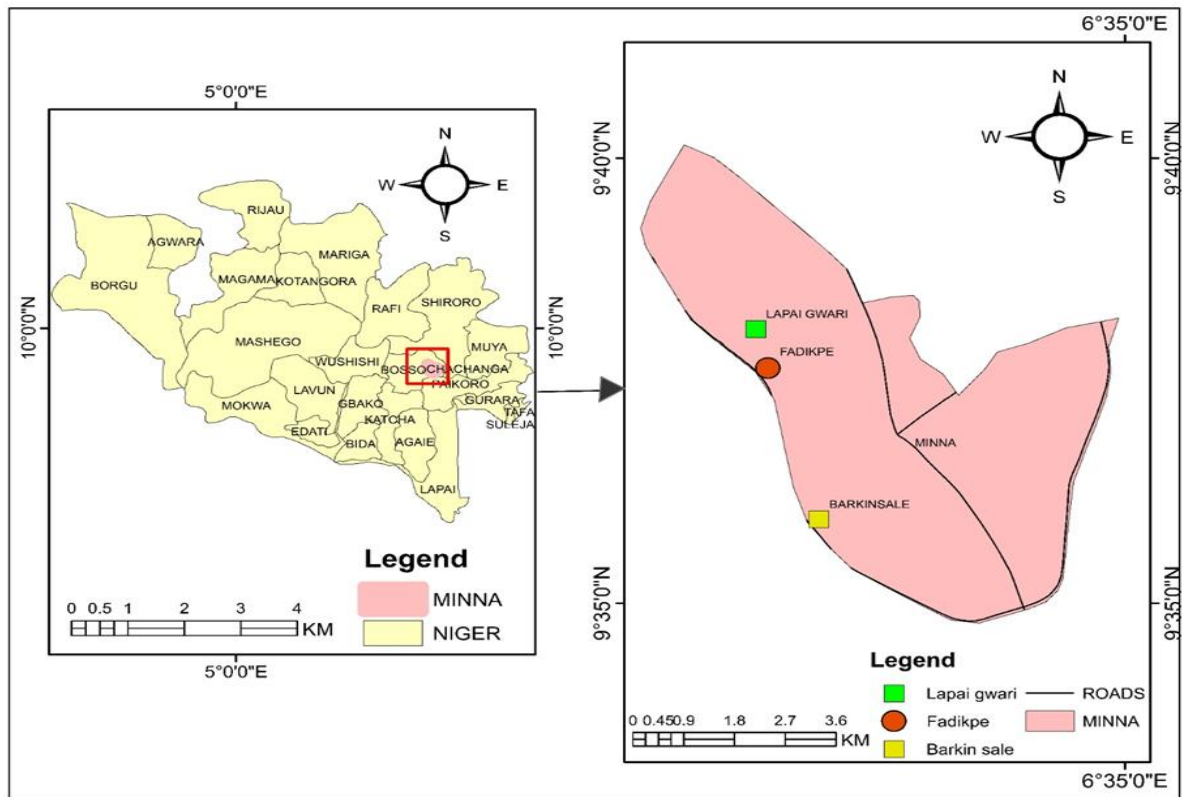


Figure 1. Map of Minna Showing the Study areas

Source: Department of Geography FUT Minna (2025)

Data Requirements

Simple random sampling technique were used in which each member of the respondents has an equal chance of being selected. To determine the appropriate sample size for this study, a preliminary survey of one hundred and twenty (120) household as well as the institutions responsible for records keeping on floods events were conducted. This is for the purpose of sampling techniques to the selection. This method was employed to observe on-the-spot flood relevant areas, this is to authenticate their existence and assess their activities. About three

settlements were selected for the study through the use of questionnaires; the reason for picking these areas is due to the fact that the floods at one point or the other occurred in these vicinities

Trend analysis of flood activities and types in the study area from 2014-2024 in the study area was examined, the Mann-Kendall test (Mann, 1945; Kendall, 1975) model modified by Yue (2004), was used in conducting trends in time- series data to determine trend analysis. According to Yue (2004) test, the trend line shows the basic long- term underlying pattern.

Let $x_1, x_2 \dots x_n$ represent n data points where x_j represents the data point at time j . Then the Mann-Kendall statistic (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sign}(x_j - x_k)$$

$$VAS(S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^m t_i(t_i-1)(2t_i+5)]}{18}$$

Where:

n = the number of data points

t_i = the number of ties for the i value

m = the number of tied values (a tied group is a set of sample data having the same value)

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} = \text{if } S > 0 \\ 0 = \text{if } S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} = \text{if } S < 0 \end{cases}$$

The test statistic Z was also used to measure the significance of the trend. This test statistic was used to test the null hypothesis, H_0 . If $|Z|$ is greater than $Z_{\alpha/2}$, where α represents the chosen significance level (example: 5% with $Z_{0.025} = 1.96$) then the null hypothesis is invalid the trend is significant.

The trend decreases if Z is negative and the computed probability is greater than the significance level. The trend is increasing if the Z is positive and the computed probability is greater than the significance level. If the computed probability is less than the level of significance, there is no trend.

Result and Discussion

Assessment of flood trend activities and types in the study areas from 2014-2024

Figure 4.1 shows trend of flood disaster in some selected areas in Minna Metropolis, the result indicates that there is a consensus that flood incidents in Minna, Niger State have become more frequent in recent years. Majority of the peoples believed that in the past eleven (11) years, flood incidents have become very common. This view is more popular with residents in Lapai Gwari and Barkin Sale. This indicates that the subsequent years are likely to experience flooding as indicated from the year 2020-2024 if preventive measures are not put in place.

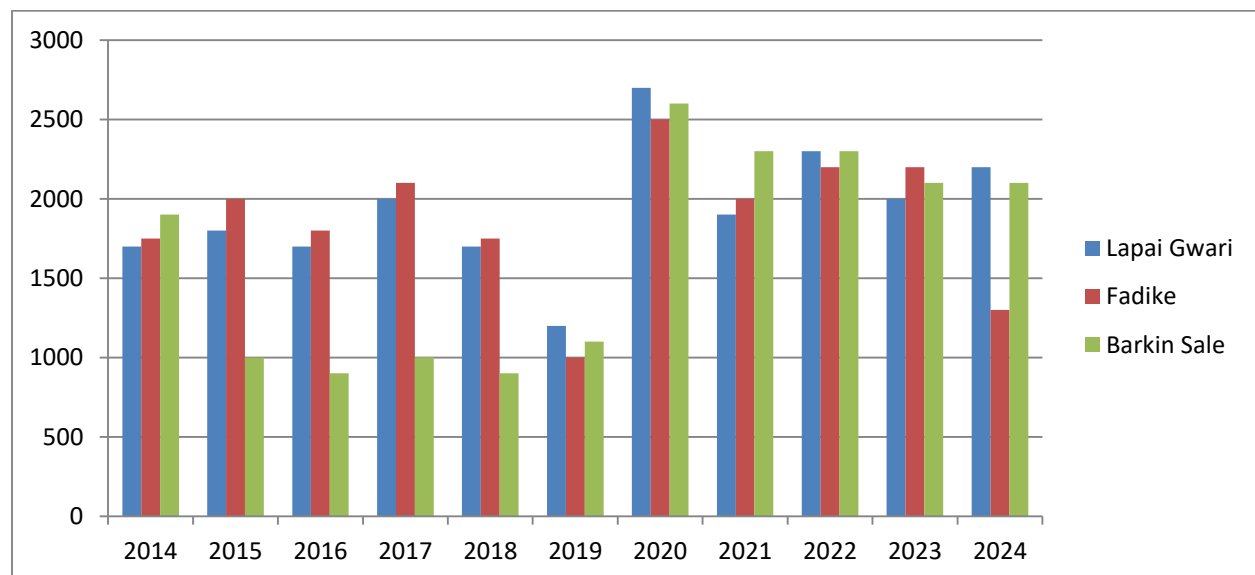


Figure 2: Trend of flood disaster in some selected areas in Minna Metropolis

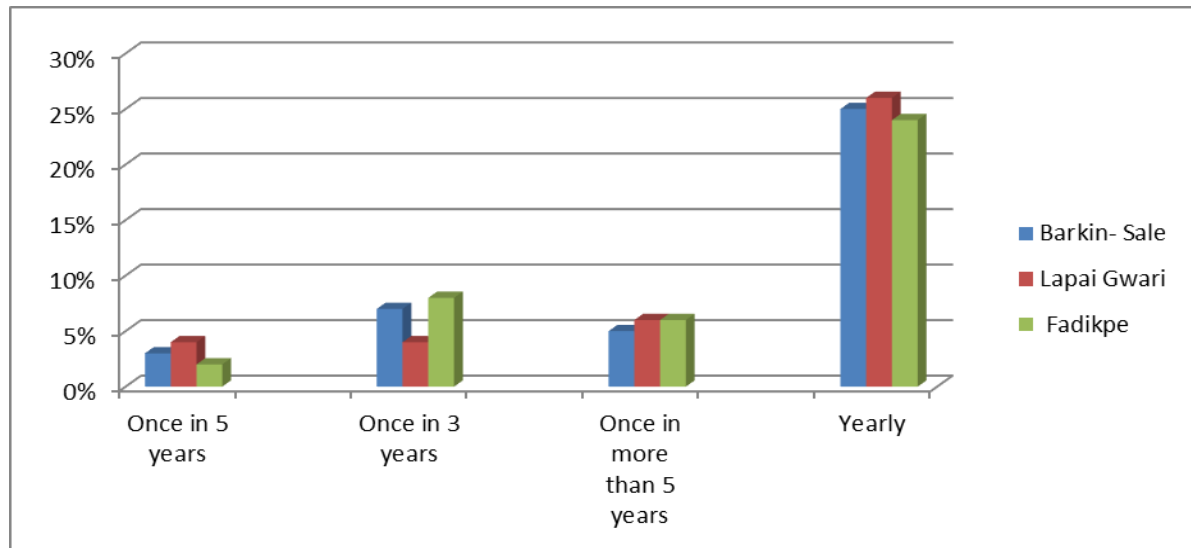


Figure 3: Frequency of flood occurrence

Figure 4.8 shows that about 75% of the respondents across the three areas are of the opinion that flood occurrence is a yearly phenomenon. Another 23% of the respondents agree that flood incidents occur once in 5 years. Overall, the consensus (98%) is that flood incidents occur yearly. Again, this calls for concerted efforts by flood managers and all stake holders to be more proactive in mitigating this hazard. A once- in- five years devastating flood can erode all the social and economic achievements of ten years.

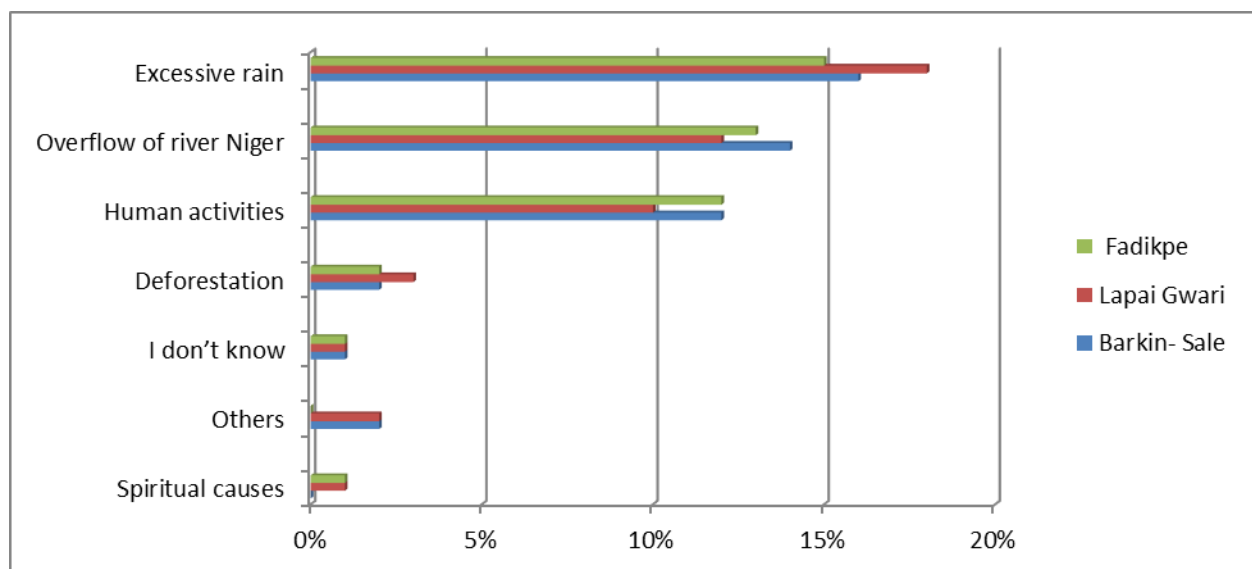


Figure 4: Causes of flood

Figure 4.9 shows that responders believe that flooding is caused by a wide range of factors. However, majority of them are of the opinion that flooding in the communities is mainly caused by excessive rainfall, human activities and overflow of river Niger. Respondents in Lapai Gwari are more affirmative in this regard. These observations are in conformity with theoretical and empirical principles of flood occurrence by (Gordon and David, 2014). This fact should inform preventive and mitigation measures.

Conclusion

Flooding has turned into a yearly nightmare in Minna, hitting hardest from August through October and leaving widespread devastation in its wake. This pattern has held steady over the past decade, and climate change is likely making it even worse. The main triggers include heavy downpours, the Niger River overflowing its banks, and a host of harmful human habits. Our survey revealed a glaring gap: Niger State lacks any Early Warning System (EWS) for floods. This leaves Niger SEMA powerless to act effectively—their emergency responses are weak, and proactive risk prevention is almost nonexistent. Communities we visited seem to be sitting back, expecting the state government to handle everything. To turn things around, we strongly recommend setting up a robust EWS for real-time flood monitoring and alerts—this could drastically cut down on damage and lives lost. Ramp up public awareness campaigns to shift outdated cultural practices that worsen flooding. And hold regular simulation drills in these areas so residents know exactly how to prepare for and respond during floods.

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AFFORDABILITY AND ACCESSIBILITY OF PRIVATE SECTOR LOW-INCOME HOUSING IN ABUJA, NIGERIA: EVIDENCE FROM CIVIL SERVANTS IN THE FEDERAL CAPITAL TERRITORY

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ABSTRACT

Access to affordable housing remains among the most persistent challenges facing low-income workers in rapidly urbanising cities of Sub-Saharan Africa. This paper examines the affordability and accessibility of private sector low-income housing delivery in Nigeria's Federal Capital Territory (FCT), Abuja, using evidence drawn from 373 civil servants across Grade Levels 1–9. The study computed the House Price-to-Income Ratio (HPIR) and Housing Expenditure-to-Income Ratio (HEIR) to quantify cost burdens across five income bands. Accessibility was assessed through a structured survey of awareness, application outcomes, and perceived barriers. Inferential analysis employed Spearman's rank correlation and Chi-square tests to determine the relationship between income and housing access. Results show that 87.4% of respondents cannot afford the cheapest available unit priced at ₦9.5 million, yielding an HPIR of 10.29 for the dominant income group, which is more than three times the internationally accepted affordability threshold. The HEIR for the same group stands at 61.8%, more than double the 30% benchmark. Accessibility analysis reveals that only 17% of applicants secured housing, with income ineligibility (81%), deposit failure (73.8%), and mortgage inaccessibility (69%) as the leading causes of rejection. A statistically significant relationship between income level and housing access was confirmed ($\rho = 0.504$, $p < 0.001$). All 24 developers concentrated their projects exclusively in peripheral locations, resulting in a location diversity score of 0. The study concludes that the prevailing private sector model systematically excludes its intended beneficiaries. Targeted policy reforms in mortgage subsidisation, regulatory pricing, and spatial planning are recommended to close the documented affordability and accessibility gaps.

Keywords: *housing accessibility; housing affordability; Federal Capital Territory; low-income housing; private sector housing; price-to-income ratio*

1. Background and Rationale for the Study

The provision of affordable housing for low-income workers ranks among the most pressing challenges in urban governance in Nigeria. Despite decades of policy intervention, formal housing production in the country meets less than 15% of annual demand (Lawanson et al., 2022), thereby leaving the vast majority of urban residents without adequate, affordable shelter. In the Federal Capital Territory (FCT), Abuja, where over 300,000 civil servants form the backbone of the federal workforce, this deficit is particularly acute. The FCT was established as a planned capital city, yet its housing trajectory has diverged sharply from its original mandate of accommodating residents across all economic strata.

The 2006 National Housing Policy formally repositioned the government from a direct provider to an enabler, placing responsibility for the production of affordable housing largely on private

developers through public-private partnerships and mass housing schemes (Nubi and Oyalowo, 2022). Under this arrangement, the Federal Capital Territory Administration (FCTA) allocates land and provides primary infrastructure, while developers are expected to produce housing at price points accessible to low- and middle-income earners. In practice, however, studies have consistently documented that private developers gravitate towards higher-income market segments where commercial returns are more predictable (Ndubueze, 2009; Ukoje and Kanu, 2014). This commercial orientation generates a fundamental mismatch between housing production and the needs of Grade Level 1–9 civil servants, which are workers who earn between ₦70,000 and ₦200,000 monthly and represent the primary intended beneficiaries of low-income housing programmes. The scale of this mismatch is documented but rarely disaggregated to the beneficiary level.

Some studies have examined dimensions of housing affordability and access in Nigerian cities (Adabre and Chan 2019; Daniel and Hunt; 2014; Ajayi et al. 2023) but none applied combined HPIR and HEIR metrics to quantify affordability burdens by specific income bands within the FCT civil service, nor has any study systematically assessed the accessibility of formally delivered housing for this population.

This study addresses that gap by examining the affordability and accessibility of private-sector low-income housing delivery in the FCT. The study quantifies cost burdens across five income categories, assesses barriers to engagement with formal housing programmes, and tests whether income level is a significant predictor of housing access. The findings directly inform policy interventions needed to align private-sector housing production with the financial realities of its stated target population.

2. Literature Review

2.1 Housing Affordability: Concepts and Metrics

Housing affordability is conventionally defined as the relationship between housing expenditure and household income, with the standard international benchmark treating housing costs exceeding 30% of gross income as a cost burden (Whitehead, 2007). Stone (2006) refined this through the "shelter poverty" framework, recognising that affordability cannot be assessed by fixed ratios alone but must also consider the adequacy of residual income for non-housing necessities. Hulchanski (2010) extends this critique, arguing that conventional affordability metrics fail to

account for variations in household composition, life-cycle stage, and geographical context, a shortcoming that is particularly relevant in heterogeneous urban populations like those in Abuja.

Two operational metrics are widely used in international housing research. The House Price-to-Income Ratio (HPIR) measures the ratio of median housing price to median annual household income, with Demographia International (2024) classifying markets as affordable (HPIR < 3.0), moderately unaffordable (3.0–3.9), seriously unaffordable (4.0–5.0), and severely unaffordable (> 5.1). The Housing Expenditure-to-Income Ratio (HEIR) measures the share of gross income consumed by housing costs, with values below 30% considered affordable and values above 50% indicating severe cost burden. Ndubueze (2009) documented that conventional mortgage instruments in Nigeria are inaccessible to over 70% of the population, positioning the HEIR as particularly relevant for capturing the depth of housing cost burdens in the Nigerian context.

Empirically, the scale of Nigeria's affordability challenge is well-established at the national level. Olotuah and Bobadoye (2009) estimate a housing deficit of more than 17 million units, with acute shortages concentrated among lower-income segments. Within the FCT, Alufohai (2013) identifies a deficit of approximately 600,000 units that expands alongside rapid urbanisation. The structural drivers of unaffordability in Nigeria operate through multiple channels: limited mortgage market development, high interest rates, restrictive lending criteria, excessive land costs, and inflation-driven escalation of construction costs (Adegun and Taiwo, 2011; Adegboye *et al.*, 2022). These factors collectively widen the gap between what workers earn and what housing costs, creating an affordability barrier that policy has thus far failed to bridge.

2.2 Housing Accessibility in Sub-Saharan Urban Contexts

Housing accessibility encompasses both physical and procedural dimensions of access, the ability of intended beneficiaries to navigate formal housing systems and secure allocation. Leckie (2003) positions housing access within a rights-based framework, emphasising state obligations to ensure that formally produced housing reaches vulnerable populations rather than being captured by higher-income groups through administrative or market mechanisms. In practice, studies across Sub-Saharan Africa document persistent access gaps that reflect institutional failure alongside affordability constraints.

Spatial accessibility is a critical dimension often overlooked in affordability studies. The World Bank (2019) Stocktaking Report on Sub-Saharan Africa identifies a systematic spatial mismatch in the delivery of affordable housing, where lower land costs draw developers to urban peripheries while employment remains concentrated in city centres. Beier (2023), examining post-apartheid housing in South Africa, found that peripheral location was among the primary reasons low-income households vacated state-provided housing; residents traded formal tenure for informal proximity to livelihoods. Adabre and Chan (2019) link accessibility deficits in the FCT directly to developer location preferences driven by land-cost minimisation rather than by beneficiary proximity to services and employment.

Procedural barriers constitute a second major dimension of accessibility. Studies across Nigeria document that complex application processes, long waiting periods, limited information dissemination, and corruption in allocation procedures create filters that systematically exclude the most economically vulnerable applicants even from programmes ostensibly designed for them (Ibem *et al.*, 2015; Efobi *et al.*, 2020). Oluwaseyi *et al.* (2023) find that finance, land availability, and administrative complexity are the primary factors constraining access to PPP housing in Lagos, with qualitative analysis revealing that informal networks and political connections disproportionately shape allocation outcomes. These findings suggest that accessibility failures in Nigerian housing are not incidental but structurally embedded in programme design and institutional practice.

2.3 Private Sector Housing Delivery and the Low-Income Gap

Private sector housing delivery in developing countries predominantly serves middle- and upper-income market segments, with limited voluntary engagement in affordable housing (Keivani and Werna, 2001). Ndubueze (2009) documents how commercial developers in Nigeria target high-value market segments, creating substantial misalignment between housing production and population needs. This pattern is reinforced by financing constraints: high construction costs, limited developer finance at accessible rates, and the absence of a functional secondary mortgage market collectively make lower-priced housing financially unviable for profit-oriented developers without subsidy or cross-subsidisation mechanisms (Olofa and Nwosu, 2015).

Nigeria's public-private partnership approach to housing, formalised in the 2006 National Housing Policy, has generated mixed outcomes. Formal housing production increased by approximately

35% during the policy period but still met less than 20% of new housing demand (Lawanson et al., 2022). More critically, affordability outcomes remained poor, with Olugbenga and Adekemi (2023) documenting that formal mortgage penetration remained below 5% of the population despite multiple policy initiatives. Within the FCT, Ibimilua and Ibitoye (2015) found that the mass housing scheme introduced in 2000 largely failed to deliver units at price points accessible to the intended beneficiary population, with developer commercial pressures progressively shifting outputs toward higher-income segments. The literature thus consistently identifies a gap between stated affordability intentions in Nigerian housing policy and the actual cost of delivered units, a gap this paper seeks to quantify at the disaggregated beneficiary level.

3. Study Area and Methodology

3.1 Study Area

The Federal Capital Territory (FCT), located in the geographic centre of Nigeria between latitudes 9°3'N and longitudes 7°29'E, serves as the country's seat of government (FCTA, 2011). The territory covers approximately 8,000 square kilometres and is administered across six area councils: Abuja Municipal Area Council (AMAC), Bwari, Gwagwalada, Kuje, Kwali, and Abaji. Abuja city, developed according to the International Planning Associates (IPA) master plan of 1979, was designed across four phases to accommodate residents across all income levels. As of 2024, the FCT houses over 300,000 federal civil servants alongside a metropolitan population exceeding three million, making it the fourth most populous urban area in Nigeria (Abubakar, 2020).

The study targeted the residential housing stock delivered by formal private developers across the FCT's residential districts and satellite towns between 2000 and 2024. These districts span all four development phases and include both high-density satellite towns such as Nyanya, Kubwa, and Karu, where low-income housing is predominantly concentrated, and the formal districts of Phase 1 and Phase 2, which serve higher-income groups. The spatial distribution of low-income housing across these areas is central to the accessibility analysis presented in this paper.

3.2 Research Design and Sampling

The study adopted a cross-sectional survey design, with quantitative questionnaires as the dominant instrument. A positivist research philosophy underpins the design, consistent with the study's objective of producing measurable, generalisable evidence on affordability and

accessibility patterns (Saunders *et al.*, 2019; Creswell and Creswell, 2018). The quantitative dominant design is appropriate here because affordability and accessibility are amenable to systematic measurement across a defined population and require both descriptive and inferential analysis to establish patterns and test hypothesised relationships.

The target population for affordability and accessibility analysis comprised civil servants on Grade Levels 1–9 employed in FCT-based federal ministries, departments, and agencies. This group constitutes the primary intended beneficiaries of low-income housing programmes in the FCT, earning monthly incomes between ₦70,000 and ₦200,000. A stratified random sample of 373 respondents was drawn across the five grade-level strata (GL 1–3, GL 4–6, GL 7–9, split proportionally), with sample size determined using the Taro Yamane (1967) formula at a 95% confidence level and 5% margin of error applied to a population of approximately 300,000 civil servants. Data were collected in 2024 using self-administered questionnaires, while structured interviews were conducted with twelve key informants drawn from the Federal Capital Territory Administration (FCTA), Federal Mortgage Bank of Nigeria (FMBN), and housing development agencies to provide institutional context for the study.

3.3 Analytical Framework

Affordability was assessed using two complementary metrics. The House Price-to-Income Ratio (HPIR) was calculated as the ratio of average unit price to annual household income, computed across five income categories and three unit types. Thresholds followed Demographia International (2024) classifications: HPIR < 3.0 (affordable), 3.0–3.9 (moderately unaffordable), 4.0–5.0 (seriously unaffordable), and > 5.1 (severely unaffordable). The Housing Expenditure-to-Income Ratio (HEIR) was computed as annual housing cost (estimated at 6% of unit price as a proxy rental yield) divided by annual household income, with thresholds of < 30% (affordable), 30–39% (moderately burdened), 40–49% (seriously burdened), and ≥ 50% (severely burdened). Housing price data were obtained from the developer survey component of the wider study.

Accessibility was assessed using a structured survey instrument that measured programme awareness, application status and outcomes, rejection reasons, current housing tenure, and preferred financing mechanisms. Civil servants also rated six affordability constraint factors and six accessibility barrier factors on five-point Likert scales, with means interpreted using the scale:

< 1.50 (not important), 1.50–2.49 (slightly important), 2.50–3.49 (moderately important), 3.50–4.49 (important), ≥ 4.50 (very important).

To test the hypothesis that there is no significant relationship between civil servants' income level and their level of housing accessibility, Spearman's rank correlation coefficient (ρ) was computed as the primary statistic, with a Chi-square test of independence on a collapsed four-category income grouping as a corroborating analysis. Spearman's ρ is appropriate for ordinal-by-ordinal relationships and is robust to small cell sizes that can affect the reliability of the chi-square. Both statistics were computed in SPSS Version 25.

4.0 Results and Discussion

4.1 Socio-Economic Profile of Respondents

The socio-economic characteristics of the 373 surveyed civil servants as shown in Table 1 reveal that sample is predominantly male (75.6%), reflecting FCT federal service gender distribution. The most common household size is 4–6 persons (50.7%), consistent with Nigerian household norms. Most respondents (55.9%) have lived in the FCT for more than six years, indicating a stable and long-term resident workforce.

The grade-level distribution shows 72.9% of respondents in GL 1–6—the true low-income target group for housing programmes. Monthly income data reveal that 87.4% earn between ₦70,000 and ₦150,000, with the single largest cohort (50.7%) in the ₦70,000–₦100,000 band. Only 12.6% earn above ₦150,000 per month. These findings position the sample not as the extreme poor but as the "lower-middle income" working population caught between income ceilings too high for social housing eligibility and too low for market-rate affordability.

Table 1: Socio-Economic Characteristics of Civil Servant Respondents

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	282	75.6
	Female	91	24.4
Monthly Income	₦70,000 – ₦100,000	189	50.7
	₦101,000 – ₦150,000	137	36.7
	₦151,000 – ₦200,000	37	9.9
	₦201,000 – ₦250,000	8	2.1
	Above ₦250,000	2	0.5
Grade Level	GL 1–3	124	33.2
	GL 4–6	148	39.7
	GL 7–9	101	27.1
Length of Residence	Less than 2 years	52	14.0
	2–5 years	112	30.0
	6–10 years	127	34.1
	Above 10 years	82	21.9
Total		373	100.0

Source: Field Survey, 2024.

4.2 Housing Affordability: House Price-to-Income Ratio

Average selling prices for developer-delivered low-income units in the FCT range from ₦10.5 million for one-bedroom flats to ₦20.5 million for three-bedroom flats (minimum: ₦9.5 million for one-bedroom). These figures exceed the government's own low-income housing price benchmarks of ₦8.5 million (one-bedroom) and ₦12.5 million (three-bedroom), indicating that even the formal private sector's "low-income" product is priced above what public programme designers consider affordable.

Table 2 presents HPIR calculations for each income category and unit type. For the dominant income group, which comprises civil servants earning ₦70,000–₦100,000 monthly (50.7% of respondents), the HPIR for the cheapest one-bedroom unit is 10.29. This means an average earner in this bracket would need more than 10 years of gross income, without spending on any other needs, to purchase the least expensive housing on offer. This is more than three times the severely

unaffordable threshold of 5.1 (Demographia International, 2024). The second-largest income group (₱101,000–₱150,000; 36.7%) records a one-bedroom HPIR of 6.97, still firmly in the seriously unaffordable zone.

Only civil servants earning above ₱201,000 monthly, representing 2.6% of the sample, achieve a one-bedroom HPIR below 5.0, and even this group falls in the moderately unaffordable band. No income group achieves an HPIR of 3.0 or lower for any unit type. For three-bedroom units, the HPIR reaches 20.10 for the lowest income group, an affordability gap that is practically insurmountable without a substantial subsidy. These findings confirm that only 12.6% of civil servants can afford even the cheapest unit at current prices.

Table 2: House Price-to-Income Ratio (HPIR) by Income Category and Unit Type

Income Category	Annual Income (₱)	Unit Type	Avg. Price (₱M)	Formula	HPIR	Classification
₱70,000–₱100,000	₱1,020,000	1-Bedroom	10.5M	$10.5M \div 1.02M$	10.29	Severely Unaffordable
₱101,000–₱150,000	₱1,506,000	1-Bedroom	10.5M	$10.5M \div 1.506M$	6.97	Seriously Unaffordable
₱151,000–₱200,000	₱2,106,000	1-Bedroom	10.5M	$10.5M \div 2.106M$	4.99	Moderately Unaffordable
Above ₱200,000	₱2,706,000	1-Bedroom	10.5M	$10.5M \div 2.706M$	3.88	Moderately Unaffordable
₱70,000–₱100,000	₱1,020,000	2-Bedroom	13.0M	$13.0M \div 1.02M$	12.75	Severely Unaffordable
₱101,000–₱150,000	₱1,506,000	2-Bedroom	13.0M	$13.0M \div 1.506M$	8.63	Seriously Unaffordable
₱151,000–₱200,000	₱2,106,000	2-Bedroom	13.0M	$13.0M \div 2.106M$	6.17	Seriously Unaffordable
₱70,000–₱100,000	₱1,020,000	3-Bedroom	20.5M	$20.5M \div 1.02M$	20.10	Severely Unaffordable
₱101,000–₱150,000	₱1,506,000	3-Bedroom	20.5M	$20.5M \div 1.506M$	13.61	Severely Unaffordable
₱151,000–₱200,000	₱2,106,000	3-Bedroom	20.5M	$20.5M \div 2.106M$	9.73	Seriously Unaffordable

Note: HPIR = Annual housing price $\div$ Annual household income. Classifications per Demographia International (2024): < 3.0 Affordable; 3.0–3.9 Moderately Unaffordable; 4.0–5.0 Seriously Unaffordable; > 5.1 Severely Unaffordable.

4.3 Housing Expenditure-to-Income Ratio (HEIR)

HEIR analysis extends the HPIR findings and confirms the depth of the cost burden faced by FCT civil servants. Table 3 presents HEIR values computed using an annual housing cost of 6% of the unit price as a proxy rental yield. For the lowest income group (₦70,000–₦100,000/month), renting a one-bedroom unit would consume 61.8% of gross annual income, which is more than double the 30% affordability benchmark. For a two-bedroom unit, the burden rises to 76.5%, and for a three-bedroom unit, it exceeds 100% (120.6%), meaning that rent alone would surpass total annual earnings.

Civil servants in the ₦101,000–₦150,000 bracket record HEIR values of 41.8% for one-bedroom units and 81.7% for three-bedroom units, placing them in the moderately and critically burdened categories, respectively. Only households earning above ₦151,000 monthly, approximately 12.5% of the sample, achieve an HEIR below 30% for a one-bedroom unit. No income group can afford a three-bedroom unit within the 30% HEIR threshold. The combined HPIR and HEIR evidence establishes that 87.4% of respondents are structurally excluded from the housing market, not by preference but by income-price incompatibility.

Table 3: Housing Expenditure-to-Income Ratio (HEIR) by Income Category and Unit Type

Income Category	Annual Income (₦)	Unit Type	Annual Housing Cost	Formula	HEIR	Classification
₦70,000– ₦100,000	₦1,020,000	1-Bedroom	₦630,000	$630K \div 1,020K$	61.8%	Severely Burdened
₦101,000– ₦150,000	₦1,506,000	1-Bedroom	₦630,000	$630K \div 1,506K$	41.8%	Moderately Burdened
₦151,000– ₦200,000	₦2,106,000	1-Bedroom	₦630,000	$630K \div 2,106K$	29.9%	Affordable
₦70,000– ₦100,000	₦1,020,000	2-Bedroom	₦780,000	$780K \div 1,020K$	76.5%	Severely Burdened
₦101,000– ₦150,000	₦1,506,000	2-Bedroom	₦780,000	$780K \div 1,506K$	51.8%	Severely Burdened
₦201,000– ₦250,000	₦2,706,000	2-Bedroom	₦780,000	$780K \div 2,706K$	28.8%	Affordable
₦70,000– ₦100,000	₦1,020,000	3-Bedroom	₦1,230,000	$1,230K \div 1,020K$	120.6%	Critically Burdened
₦101,000– ₦150,000	₦1,506,000	3-Bedroom	₦1,230,000	$1,230K \div 1,506K$	81.7%	Critically Burdened

₦151,000– ₦200,000	₦2,106,000	3-Bedroom	₦1,230,000	1,230K ÷ 2,106K	58.4%	Severely Burdened
Above ₦250,000	₦3,300,000	3-Bedroom	₦1,230,000	1,230K ÷ 3,300K	37.3%	Moderately Burdened

Note: Annual housing cost = 6% of unit price (rental yield proxy). HEIR < 30% = Affordable; 30–39% = Moderately Burdened; 40–49% = Seriously Burdened; ≥ 50% = Severely Burdened. Source: Author's computation, 2024.

4.4 Civil Servant Ratings of Affordability Constraint Factors

Table 4 presents civil servant mean ratings for five structural factors driving housing unaffordability. All five factors were rated Very Important (mean ≥ 4.50), confirming that the affordability crisis is multi-causal and perceived as systemic rather than episodic. The highest-rated factor is the cost of land and land registration (mean = 4.72), consistent with findings from the developer survey in which all 24 developers identified high land cost as the primary driver of peripheral estate location. The low supply of housing units (mean = 4.68) reflects a sophisticated recognition that the affordability problem is, at once, a supply problem, with demand vastly outstripping production. High interest rates on mortgages (mean = 4.59) and low-income levels (mean = 4.55) are rated almost equally, indicating that respondents understand the dual-sided nature of the crisis: incomes are insufficient, while borrowing costs prevent bridging that gap. Although rated slightly lower (mean = 4.47), the high cost of building materials remains an important factor, reflecting awareness of inflation-driven cost escalation. The aggregate mean of 4.60 across all factors confirms that housing unaffordability is not reducible to a single constraint but reflects a compounding system of structural barriers.

Table 4: Civil Servant Perceived Ratings of Affordability Constraint Factors

Factor	NI (1)	SI (2)	MI (3)	I (4)	VI (5)	Mean	Remark
Cost of land and land registration	2	3	4	80	284	4.72	Very Important
Low supply of housing units	3	3	5	87	275	4.68	Very Important
High interest rates on mortgages	3	5	12	101	252	4.59	Very Important
Low-income levels	5	8	9	106	245	4.55	Very Important
High cost of building materials	4	5	13	141	210	4.47	Important

Total / Average	17	24	43	515	1,266	4.60	Very Important

NI = Not Important; SI = Slightly Important; MI = Moderately Important; I = Important; VI = Very Important. Scale: < 1.50 (NI); 1.50–2.49 (SI); 2.50–3.49 (MI); 3.50–4.49 (I); ≥ 4.50 (VI). Source: Field Survey, 2024.

4.5 Housing Accessibility: Awareness, Application, and Outcomes

Table 5 presents civil servants' experiences of accessibility to formal low-income housing programmes in the FCT. While 69.2% of respondents were aware of the programmes, 70% had never applied, indicating that awareness alone is insufficient to translate knowledge into engagement. The primary barriers to application are economic and procedural: 83.9% of non-applicants cited high costs or unaffordability, 65.9% pointed to complex application processes, and 60.5% reported a lack of information. Poor location (51.7%) and lack of trust in the allocation process (49%) are also prominent deterrents, revealing systemic confidence failures alongside practical obstacles.

Among the 112 respondents who applied (30%), the success rate was 17% (19 individuals), with 75% (84) rejected and 8% still in process. The reasons for rejection reveal that the filtering mechanism systematically targets the very population the programmes are meant to serve: 81% were rejected due to income level, 73.8% could not meet deposit requirements, and 69% failed to secure mortgages. These findings demonstrate that the formal housing system applies financial eligibility criteria that, by design, exclude low-income civil servants, not by accident.

Current housing tenure data show that 76.4% of civil servants live in rented accommodation, 14.5% own their homes, and 9.1% live in inherited family housing. Preferred financing mechanisms are dominated by government-subsidised mortgages (83.7%) and cooperative housing finance (77.5%), followed by rent-to-own schemes (65.7%). The strong preference for state-backed instruments over commercial options signals both a recognition that market rates are unworkable and an expressed demand for structured, affordable financial pathways to ownership.

Table 5: Accessibility of Low-Income Housing as Perceived by Civil Servants

Accessibility Factor	Response	Frequency	Percent (%)
Awareness of Programmes	Yes	258	69.2
	No	115	30.8
Application Status	Applied	112	30.0
	Never Applied	261	70.0
Reasons for Not Applying (N=261)	High cost/unaffordable	219	83.9
	Complex application process	172	65.9
	Lack of information	158	60.5
	Poor location of housing units	135	51.7
Application Success Rate (N=112)	Successful	19	17.0
	Unsuccessful	84	75.0
Reasons for Unsuccessful Application (N=84)	Income level too low to qualify	68	81.0
	Could not meet deposit requirement	62	73.8
	Could not secure mortgage	58	69.0
	Administrative/bureaucratic issues	45	53.6
Current Housing Tenure	Rental	285	76.4
	Owned	54	14.5
Preferred Financing Mechanism	Government subsidised mortgage	312	83.7
	Cooperative housing finance	289	77.5
	Rent-to-own scheme	245	65.7

Source: Field Survey, 2024.

4.6 Civil Servant Ratings of Accessibility Barrier Factors

Table 6 presents civil servant ratings for six factors affecting housing accessibility. All six are rated Very Important (mean ≥ 4.45), confirming that accessibility failure is as pervasive as affordability failure. Complex application procedures (mean = 4.72) rank highest, identifying bureaucratic complexity as the most immediate experiential barrier. Long waiting periods (mean = 4.64) compound this, signalling a system too slow to respond to urgent needs. Poor location of housing projects (mean = 4.58) confirms what the spatial data show: the civil servants are acutely aware that formally delivered housing is built in the wrong places, far from their workplaces and daily service needs.

Corruption in the allocation process (mean = 4.52) is the third-highest-rated factor, and perhaps the most diagnostically significant. It reveals that for a majority of respondents, housing access is not believed to operate on merit. Instead, allocation is perceived as controlled by connections, bribes, or political leverage, creating a fundamental legitimacy deficit that depresses engagement even among those who might otherwise qualify. Lack of information (mean = 4.49) and limited unit supply (mean = 4.45) complete a portrait of an inaccessible system characterised by opacity, spatial mismatch, corruption, and scarcity. The aggregate mean of 4.57 confirms that accessibility barriers are experienced as structurally entrenched rather than incidental.

Table 6: Civil Servant Perceived Ratings of Accessibility Barrier Factors

Factor	NI (1)	SI (2)	MI (3)	I (4)	VI (5)	Mean	Remark
Complex application procedures	2	3	5	78	285	4.72	Very Important
Long waiting periods	2	4	9	96	262	4.64	Very Important
Poor location of housing projects	3	5	12	104	249	4.58	Very Important
Corruption in allocation process	4	7	14	114	234	4.52	Very Important
Lack of information about programmes	5	6	12	127	223	4.49	Important
Limited number of housing units	5	7	15	135	211	4.45	Important

Total / Average	21	32	67	654	1,464	4.57	Very Important

NI = Not Important; SI = Slightly Important; MI = Moderately Important; I = Important; VI = Very Important.
Source: Field Survey, 2024.

4.7 Hypothesis Test: Income Level and Housing Accessibility

The null hypothesis tested was: there is no significant relationship between civil servants' monthly income and their level of accessibility to low-income housing in the FCT. Income was operationalised across the five monthly income bands in Table 1. Accessibility was collapsed into three ordinal levels: Low, Moderate, and High, based on respondents' composite barrier ratings. Table 7 presents the income-by-accessibility cross-tabulation.

A clear and consistent gradient is visible: as income rises, the proportion reporting low accessibility falls sharply, while the proportion reporting high accessibility rises. Among respondents earning ₦70,001–₦100,000 ($n = 189$, the largest cohort), 59.3% reported low accessibility, and only 10.1% reported high accessibility. This pattern inverts progressively as income increases. Among respondents earning above ₦200,000 ($n = 10$), 60.0% reported high accessibility and only 10.0% reported low accessibility as an almost exact reversal.

Table 7: Cross-Tabulation of Monthly Income by Level of Housing Accessibility

Income Group	n	Low Accessibility f (%)	Moderate Accessibility f (%)	High Accessibility f (%)
₦70,001 – ₦100,000	189	112 (59.3%)	58 (30.7%)	19 (10.1%)
₦101,001 – ₦150,000	137	62 (45.3%)	51 (37.2%)	24 (17.5%)
₦151,001 – ₦200,000	37	9 (24.3%)	16 (43.2%)	12 (32.4%)
Above ₦200,000	10	1 (10.0%)	3 (30.0%)	6 (60.0%)
Total	373	184 (49.3%)	128 (34.3%)	61 (16.4%)

Source: Field Survey, 2024. Income groups ₦201,001–₦250,000 and > ₦250,000 collapsed into "Above ₦200,000" for chi-square analysis due to small cell sizes.

Table 8 presents the results of both inferential tests. Spearman's rank correlation coefficient $\rho = 0.504$ ($p < 0.001$) indicates a moderate-to-strong positive relationship between income level and housing accessibility: higher-income civil servants report substantially better access to formally delivered housing. The Chi-square test ($\chi^2(6) = 36.240$, $p < 0.001$, Cramér's $V = 0.220$) corroborates both the direction and significance of this association. The null hypothesis is rejected at the 0.001 significance level. The effect size is moderate (Cramér's $V = 0.220$; $\rho = 0.504$),

indicating that income stratification alone accounts for a substantial share of accessibility differentials, even within a group that, by any external standard, is uniformly low-to-middle income.

Table 8: Inferential Test Results: Income Level and Housing Accessibility

Statistical Test	Statistic	df / N	p-value	Effect Size
Chi-square (χ^2)	36.240	df = 6	< 0.001	Cramér's V = 0.220
Spearman's Rank Correlation (ρ)	0.504	N = 373	< 0.001	Moderate–Strong
Critical value (χ^2 , $\alpha = 0.05$)	12.592	df = 6	—	—
Decision	Reject H_0: $\chi^2 = 36.240 > 12.592$; $\rho = 0.504$, $p < 0.001$			

*Note: Chi-square computed on 4×3 contingency table. Spearman's ρ treated as primary statistic. ** Significant at $p < 0.01$.*

4.8 Spatial Accessibility: Location of Low-Income Housing Estates

Spatial accessibility analysis, drawn from the developer survey component of the wider study, reveals a categorical failure in location equity. All 48 low-income housing estates delivered by the 24 active developers were located in satellite towns, peri-urban areas, or outer suburbs of the FCT. Not one estate was sited in or near the city centre or the inner-city districts where employment is concentrated. Table 9 summarises the location distribution.

The drivers behind this spatial pattern are well-established: 100% of developers cited low land cost and government allocation as primary location determinants, while only 62.5% considered proximity to employment centres. The data show a consistent trade-off in which developer financial logic of minimising land and input costs systematically displaces housing away from areas where its residents need to live and work. From the civil servant side, 51.7% of non-applicants cited poor location as a reason for not engaging with formal housing programmes, and 4.58 mean rating for "poor location of housing projects" among applicants confirms that this spatial pattern is experienced as a direct accessibility barrier.

Table 9: Summary of Low-Income Housing Estate Location Characteristics

Location Category	Number of Estates	Number of Developers (%)	Remark
City centre / Core urban area	0	0 (0.0%)	No estates in central locations
Suburban area (< 10 km from CBD)	12	18 (75.0%)	Peri-central, limited transit

Satellite towns (> 10 km from CBD)	36	24 (100.0%)	Peripheral; poor connectivity
Total Estates	48	24 (100.0%)	All exclusively peripheral

Source: Developer Survey, 2025.

4.9 Discussion of Results

The HPIR of 10.29 recorded for the dominant income group places FCT low-income housing firmly in the severely unaffordable category by every international classification system in use. For comparative reference, Demographia International (2024) reports that the most severely unaffordable global housing markets like Hong Kong, Sydney, and Vancouver record HPIRs of 14–23 for their least affordable segments. The FCT's position in this range, for a population of civil servants earning well below even modest global income thresholds, signals a structural crisis rather than a market imperfection. The CAHF (2024) national estimate that the median public-sector salary falls below ₦1.2 million annually, while urban house prices start at ₦25 million, contextualises and corroborates this study's FCT-specific findings.

The spatial pattern in this study is the finding most likely to concern policymakers. Every one of the 48 estates was in a peripheral area, with no city-centre provision. The World Bank (2019) Stocktaking Report on Sub-Saharan Africa describes this pattern as systemic, that is, lower land costs attract developers outward while jobs remain in urban cores, effectively transferring the cost of poor location to residents through transport expenditure, lost working hours, and reduced access to services. Beier (2023), studying post-apartheid housing in South Africa, found that peripheral location was among the primary reasons low-income households vacated state-provided housing. The FCT data suggest a similar risk: even when housing is formally "delivered", its practical utility to the intended beneficiaries is undermined by its location.

The 17% application success rate documented in this study is consistent with Efobi *et al.* (2020), who found that housing delivery in Southeast Nigeria had not adequately addressed the needs of low-income earners despite formal programme commitments. The dominant reasons for rejection (income level, deposit failure, and mortgage inaccessibility) point to a system designed with eligibility criteria that systematically exclude the population it nominally targets. Ibimilua and Ibitoye (2015) documented the same paradox in the FCT's mass housing scheme. Low-income groups cannot compete with higher-income buyers in allocation processes that apply uniform

financial eligibility criteria regardless of stated targeting objectives. The statistically significant income-accessibility relationship ($p = 0.504$, $p < 0.001$) confirms that, even within a uniformly low-income population, small income differentials produce meaningful differences in housing access, indicating that the allocation mechanism amplifies rather than corrects existing socioeconomic inequalities.

Civil servant preference data add important dimensions to the supply-side narrative. The dominant preference for government-subsidised mortgages (83.7%) and cooperative housing finance (77.5%) indicates not a rejection of homeownership but a recognition that existing financial instruments are structurally misaligned with civil service income profiles. These preferences signal actionable demand for specific, implementable financial reforms rather than a generalised call for more housing. The strong preference for rent-to-own schemes (65.7%) further suggests that incremental pathways to ownership may be more effective than lump-sum purchase models for a population whose incomes are too low to qualify for standard mortgages.

5.0 Conclusion and Recommendations

5.1 Conclusion

This study has documented a severe, multidimensional crisis in housing affordability and accessibility among civil servants in Nigeria's Federal Capital Territory. Using disaggregated HPIR and HEIR analyses across five income bands, the study demonstrates that 87.4% of civil servants in Grades 1–9 cannot afford the cheapest available private-sector housing unit. For the largest income cohort, the HPIR of 10.29 and HEIR of 61.8% place FCT housing among the most unaffordable in Sub-Saharan Africa relative to the incomes of its intended beneficiaries.

Accessibility failures compound affordability constraints. Only 30% of civil servants have ever applied for formally delivered housing, and only 17% of applicants succeeded. The primary causes of rejection (income ineligibility, deposit failure, and mortgage inaccessibility) confirm that the eligibility mechanisms of formal housing programmes systematically exclude their stated target population. A statistically significant, moderately strong relationship between income level and housing access ($p = 0.504$, $p < 0.001$) indicates that, within an already disadvantaged population, smaller income differentials lead to meaningful access inequalities. Spatially, all 48 documented estates are located in peripheral zones, with no city-centre provision, leading to a zero location diversity score that reflects a developer-driven spatial logic prioritising land cost minimisation

over beneficiary proximity to livelihoods. Together, these findings established that the current private sector-led housing delivery model in the FCT is not failing at the margins. It is failing at the core: the population it is mandated to serve cannot afford, access, or reach what it produces.

5.2 Recommendations

The FMBN should restructure access to National Housing Fund mortgages to cover civil servants earning below ₦150,000 monthly, at subsidised interest rates not exceeding 6% per annum. In addition, the FCTA should introduce a regulatory price ceiling for designated low-income units, capped at three times the annual income of the target grade level ($\leq$ ₦3.06 million for GL 1–6 at 2024 income levels). Without a price floor anchored to beneficiary incomes, neither increased supply nor improved process access will resolve the affordability gap.

Furthermore, FCT land allocation policy should require a minimum of 20% of new low-income housing licences to be located in suburban zones within ten kilometres of the Central Business District. All new housing approvals above 200 units should also satisfy Transit-Oriented Development (TOD) criteria, confirming verified proximity to public transport within 500 metres. This spatial equity floor directly addresses the zero location diversity score documented in this study and aligns development incentives with beneficiary commuting and service access needs.

Finally, an independent Housing Delivery Evaluation Unit should be established under the FCTA to conduct annual performance audits using GAM-based metrics, with public reporting on affordability, delivery, location, and beneficiary targeting outcomes. Performance data should be tied directly to developer access to government land allocations, creating accountability linkages that the current regulatory environment lacks.

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ENVIRONMENTAL INFLUENCE OF WEATHER VARIABLES ON URBAN CRIME IN ETHIOPE EAST OF DELTA STATE, NIGERIA

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Abstract

This study focused on the environmental influence of weather variables (rainfall and temperature) on urban crime (assault, stealing, fraud, break and entry, burglary, character deformation and murder) for 22 year period (1992-2014) in the Ethiopia east with special reference to Abraka, Delta state. Secondary and primary data were employed, which include record of weather variables and crime, obtained from Delta State University's Metro-logical Station and Divisional Police Station archives for twenty two years archives and internet search engines. Using purposive and simple random sampling procedure, about 10 security agents were sampled through an interview, questionnaire and focus group discussion. Data were analyzed using Pearson's Product Moment Correlation Coefficient and graph, tables. Finding revealed that rainfall has a major negative influence on crime occurrence and control. The analytic results showed an $r^2 = 0.272$ for the combined contribution of temperature and rainfall to the occurrence of rape and stealing crimes, indicating that these factors explain 27.2% of the variance in these crimes. Temperature had a strong negative correlation with crime occurrence $r^2 = -0.93$, implying that higher temperatures are associated with fewer instances of these crimes. Conversely, rainfall had a positive adjusted r^2 of 0.791, indicating a strong positive association, where rainfall accounts for 79.1% of the variance in crime occurrence, suggesting a higher prevalence during the wet season. Consequently, targeted crime monitoring and control measures during wet periods may enhance public safety and sustainable development.

Key Words: Environmental Influence, weather variables, urban, crime, safety, sustainability...

Introduction

All over the globe, the losses of life and properties from organized crime have been increasing at a worrisome rate (Mistra, 2003). Consequently, the events of crime occurrences in the world clearly showed that all nations, irrespective of how politically powerful and endowed, are secured from the menace of crime (Townsend, Homel and Chaseling, 2000). Increasing crime rates are not exclusively domiciled in particular continent but a quantitatively common features of life and existence round the globe (Fajemirokun, Adewale, Idowu, Oyewusi and Maiyagun, 2006). By definitive explanation, crime is the commission of acts and the acts of omission that violates the community's norms and values or acceptable conduct as being distinguished from torts and bench of contracts (Usman, Yakubu and Bello, 2009, Eme, O. (2012), UN-Habitat (2007) Siegel, L.J.

(2016). The global increase in crime activities had continued to attract attentions by which security agents are intensifying strategies to curb crime casualties (Hasan, 2013). For instance, (Hasan, 2013), observed that from New Delhi to Los Angeles, “urban crimes statistics exposed that not only is the characteristics of those crimes turning out to be heinous and seasoned strong holds, the level of development in these cities also depends to a very large extent on its state of security. Therefore, societal progress requires less or absence of insecurity and a better understanding of environmental determinism (Hasan, 2013).

Over the years, crime occurrence within Nigeria has been on a geometric escalating progression with more sophisticated weapons and aptitudes despite the cohesive and responsive armaments of security agents to fight crime (Fajemirokun *et al*, 2006). Furthermore, a community with a high persistent rate of criminal activities is less attractive or unattractive to both local and foreign investors and this is the ugly situation that transverse Nigeria (Olomo, ojieh and Orakwe, 2012). Social vices such as terrorism, kidnapping, human trafficking, slavery, prostitution, drug cartel and robbery are on the increase (Odekunle, 2005). In the year 2017, the National Bureau of Statistics (NBS) reported crime in Nigeria, with Lagos State having the highest percentage share of total cases reported with 50,975 (37.9%) cases recorded, Abia and Delta State followed closely with 12,408(9.2%) and 7,150(5.3%) cases recorded respectively. Thus offence against property has the highest number of cases reported with 68,579 of such cases reported. Offence against persons recorded 53,641 cases reported while offence against lawful authority recorded the least with 12,443 cases recorded respectively NBS (2017).

Abraka, and other parts of Ethiopian east, Nigeria has been experiencing increasing social vices such as terrorism, kidnapping, pipeline vandalism, prostitution, drug cartel and robbery, rape among others which are critical matters that have continued to attract local and international mercy to the nation (Odekunle, 2005) and (Jamo, 2009).The sporadic growths of urban crime , provoked by poverty, psychological disorientation, unemployment, violence, illegal proliferation of arms with emphasizes on climatic environmental determinism such as rainfall and temperature regime (Fajemirokun *et al*, 2006). However, Ikhuria and Bello (2011), perceived the results of increased Urban crime or social vices such as HIV/AIDS as effects of climate change, labor migration and unemployment which are observable everywhere.

Over the years, the effects of weather variability on crime and its control in the society have gained little attention by researchers hitherto especially in this part of the world (Olomo *et al*, 2012). The study of spatial-temporal influence of rainfall and temperature on crime incidence is obvious in temperate regions and less conceived in the tropical climate belt. A lot of literature on crime and seasonal pattern, environment and physical factors of crime are found in the developed countries of the world but seldom found in developing countries like Nigeria. The need for spatial and temporal analysis of the environmental influences on crime particularly weather variables of rainfall and temperature can never be over emphasized. In the temperate climate belt of the world, it had been ascertained that both property and human crime trends are more prevalent in summer than other seasons of the year. Thus such assertion needs to be scientifically proven in the tropical climate belt. So, it is pertinent to examine the influence of weather variables of rainfall and temperature on major urban crimes in the Ethiopia East and other parts of Nigeria.

Understanding the negative impacts of the environment on social economic well-being of mankind cannot be overemphasized. Flooding, rise in temperature and sea level is not unconnected to man's ingenuity to the environment. Discussions in mass media on climate change are laudable; therefore,

the need to understand that climate change effects are circularly causal is important in order not ignore the effects of these changes in weather forces spurred this thesis. Sociologist study crime from the economic and social perspectives, but from urban planner and geographer perspective, lack of employment opportunity, ethics and religious differences are not enough reasons for crime occurrences. Thus man's home which is the environment should be examined. In examining crime occurrence, in the environment, two visibly active weather-variables are crucial, rainfall and temperature were as x-rayed thus, the reason for the weather elements restriction to only two.

Though study have been done by some scholars; Ackerman and Murray (2004), Fajemirokkun *et al*, (2006), Olomo *et al* (2012), focus on types of crime, cause and control in different part of Nigeria, like Abuja, Warri, Jos, Lagos. While, Nwambuko & Nnaeto (2024) assessed the socio-economic implications of the fight against urban crimes in Nigeria, various literature searches suggest no detailed study has been conducted on the influence of weather variables particularly temperature and rainfall on crime rate especially in the coast and in Nigeria. In most cases, the success of security operatives at the check points along Nigerian highways and in Delta state to be specific, are regulated by these forceful elements of weather and climate. For instance, armed robbers had plugged into raining period and often times when the sun is at its' peak, for their operations. Therefore, the need to understand the two active environmentally determinism of weather variables of rainfall and temperature on urban crime will serve as a basis to formulate measures for monitoring urban crime by the security agents for sustainable urban security. The thrust of this research was to examine the environmental determination of weather variables of rainfall and temperature on urban crime in Ethiopia East with specific reference to Abraka for sustainable urban security and development of the country. To achieve this aim, the study tends to evaluate the monthly and annual data of weather variables, rainfall and temperature and crime rate for a period of twenty-three years, (1992-2014). The study analyzed the significant relationship of weather variability and the rate of crime in the urban area. Also, the study was executed to determine a significant difference in crime occurrence over the wet and dry seasons of the year. This study is also very important as it will serve as base line information for curbing urban crime rate for the safety of urbanite and sustainable development in the country. Furthermore, the determination of the significant relationship or difference will reveal the pattern of urban crime. This will serve as a basis for policy design and interventions to checkmate urban crime in Nigerian cities.

This study was based on the concept of environmental determinism. Environmental determinism, also known as weather determinism (Felson *and* Poulson 2003), is based on the belief system that the physical environment sets limits on human social development (Hagenauer, Helbich, and Leitner, 2011). Thus, human growth and activities are controlled by the physical environment. In addition, factors of culture, peace, crime incidence and intelligence are supposed to derive from the benign or malign influence of climate and weather variables of human habitat (Lethwarte, 1966). Mackill, *Garrity*, Seshu, and Kang (1986) postulated that the general laws and principles sought by human geographers can be examined in the physical sciences. Thus, geographers therefore were focused on the study of how the physical environment affected human culture and activities (Wu and Grubestic, 2010). For instance, Townsley *and* Homel (2000), asserts that tropical climate was responsible for the laziness, relaxed attitudes and promiscuity. On the other hand, these authors asserted that the unpredictable variability in the weather of the middle latitudes lead to determined and driven work ethics. Furthermore, heat aggression hypothesis as examined by (Anderson *et al*, 2000), is a major view of how the environment influence crime occurrence.

According to these authors, heat aggression hypothesis states that hot temperature can increase aggressive motives and behaviors. Hot temperature increase aggression by directly increasing the feelings of hostility and indirectly increasing aggressive thoughts. According to heat aggression hypothesis, global warming trends may well increase violent crime rates. Thus postulating better climate controls in many institutional settings such as schools, prisons and work places to reduce aggression related problems in those settings. According to the authors, there are about 2.6% more murders and assaults in the United States during the summer than other seasons of the year; hot summers produce a bigger increase in violence than a cooler summer: and violent rates are higher in summer years than in cooler years. Several studies have examined heat hypothesis with time periods even shorter than days. Some found increase in assaults, rapes and domestic violence at hotter temperatures (Anderson *et al*, 2000). Since heat aggression remains hypothesis, the need for further research on this topic across the world's climate belts can never be overestimated. The fundamental postulation of the weather determinists is that various aspects of physical geography, particularly variables of rainfall and temperature, influenced the psychological mind-set of individuals. This in turn determined the attitudes and societal culture (Boondao, 2003), Hangenauer *et al.*, (2011) noted different crime types, often exhibit different patterns in relation to space, time, and context. Criminal activities have assumed different dimensions such that dealing with it demands a lot with respect to ethical dilemmas and criminal justice decision making process (Pollock, 2012). Gorr and Kurland (2012), said the need for the adding temperature and rainfall into crime study is informed by glaring influence on crime incidence and control. For example, the effects of weather on drug use according to Guo *et al.*, (2005), in their study "of the Western Hemisphere" Colombia and Mexico show how effective drug criminals can be. In another study by Bruce and Stallo (2009) in Burma and Afghanistan, noted increase use of drug trade as vital source of state's income, which is the reason for high wave of crime. In this study attempt was made here to incorporate interference of weather variables of temperature and rainfall combining statistics.

Materials and Methods

Study Area

Abraka is the study area. Abraka is approximately on Lat 5° 45' to Lat 5° 50' North of the Equator and long 6° 6' to Long 6° 15' East of the Greenwich" Meridian. According to Ufuoma (2000), it is situated at the Eastern bank of River Ethiope in Ethiope East local government area of Delta State, Nigeria. Abraka is bounded to the North by Edo State, Northeast by River Ethiope, Ukwuani local government area to the Southeast by Ukwuani local government area to the south by Ughelli North local government area and the south west by Urhuovie. Abraka is an attractive city in Delta state known for various functions like institutions, commercial, and many others, and a receiving centre for all migrants of different language and culture thereby making it an expected envy of crime centre (Ejemeyovwe, 2006). It falls within the tropical rain forest vegetation with a population of about

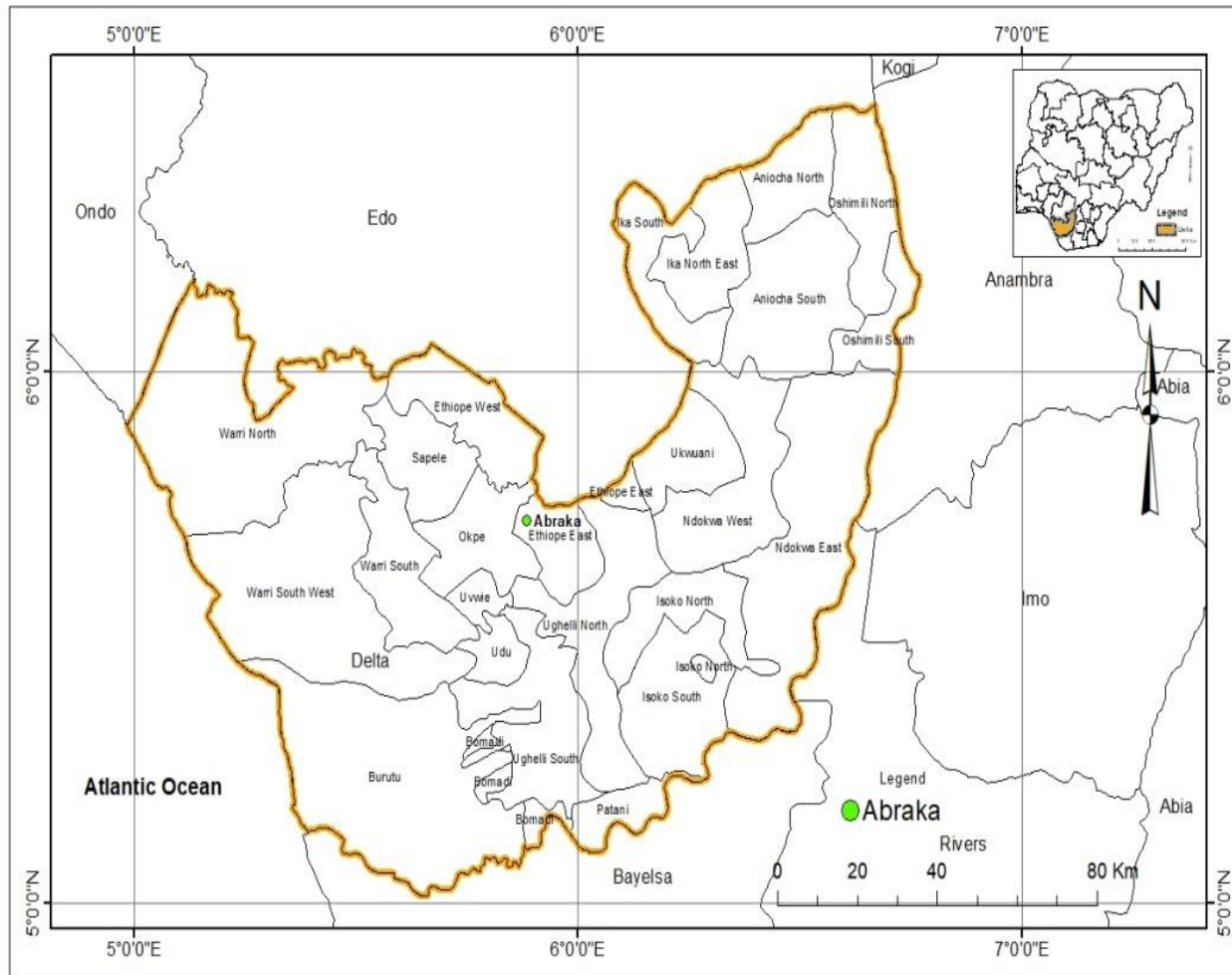


Fig 1.1 Ethiopia East L.G.A showing Abraka, Delta State. .

Source: Modified after ministry of lands, survey and urban development, (2008).

Research Methodology

The study employed an integrated mixed quantitative and qualitative research approach, where the use of questionnaire surveys is combined with secondary data collection and analysis (Creswell & Plano-Clark, 2018: 8). The reason for choosing mixed research data is to elaborate on specific findings (coefficient) from the empirical analysis and to cross-check the data against the questionnaire data set such as similarities or differences in the effect of weather variables (rainfall and temperature on urban crime.

Population, sample and response rate

About a sample size of 10 participants were used for this study. Due to the need for experienced experts in crime control, lack of reliable data about the total population of experience security agents in the policy force, the peculiarity of the security job and difficulties in identifying such experts who are willing to respond to the questionnaire and availability, the researcher decided to sample 10 top officials who are experts in the field from the division police headquarters in Abraka,

for a focus group discussion (FGD) through the use of questionnaire which were valid to analyze. There was a response rate of 99%, which is valid; built-environment survey response rates vary between 7% and 40% (Moyo & Crafford, 2010: 68, John-Nsa, 2021: 33, Enoguanbhor et. al 2023: 45). The sample size is valid for the current study since the questionnaire data was to complement the secondary data and authors plan to employ descriptive statistics with the questionnaire data.

Data collection

The study employs primary and secondary sources of data. Primary data was collected from security experts through focus group discussion with the aid of questionnaire. The participants were from the divisional police headquarter in the study area. The participants were males and females and above 40 years of age. Purposive and stratified random sampling methods were adopted in this study. The essence was to select eligible participants. A focus group discussion guide to investigate participants' perspective on the effects of weather variables on some identified common crime rate and control. One FGD of 10 persons was investigated and organized with the help of the head of the policy division headquarters in Abraka while the participants were sitting in the conference room for a meeting. Secondary sources of data such as 23 years (1996- 2014) records of crime rate and weather variables of rainfall and temperature were obtained from the Nigeria police force and Department of Geography and Regional Planning's meteorological station (GRP). The purpose of twenty three years' time series analysis is to gain robust analysis of the interplay between crime occurrence and weather elements of rainfall and temperature. Rainfall and temperate were used as the weather variables because they are the two major active environmental determinism of weather variables of crime rate (Felson and Poulson 2003).

Data presentation and Analyses

The analysis of the FGDs involved a combination of different models of content analysis, systematic coding and categorization of textual information to ascertain the trends and patterns of words used; the frequency, relationships, structures and discourses of communication, Grinch (2007). The rainfall (mm) temperature ($^{\circ}\text{C}$) and crime data were analyzed via tables and graph to vividly understand the trend of rainfall temperature and crime in the study area. The use of tables and graphs in analyzing the information collected (rainfall temperature and crimes) daily/ monthly for the period of twenty two years (1992-2014) .

Statistical techniques such as multivariate regression analysis and Pearson moment product correlation techniques were used to test the postulated hypothesis, H_0 : there is no significant correlation between weather variables (rainfall and temperature) and crime rate (character deformation, rape, murder, sealing, break and entry, burglary and assault), at 0.05 level of significance, Formula: $y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_nx_n$, Where x_1 = Rainfall, x_2 = Temperature, y = Dependent variables of crime, $A = Y$ - Intercept which is usually constant, B = the slope of independent variables.

Table 1. Rainfall, Temperature and Crime data from 1992-2014

Year	Rain	Temp	Assault	Stealin g	Fraud	Br &En	Rape	Burglary Character	Murder	Deformation
1992	3080	31	255	215	169	234	178	234	208	234
1993	3085	32	228	219	158	245	151	213	209	213
1994	3090	31	233	234	165	233	111	154	218	154
1995	2995	29	201	189	167	213	124	215	203	215
1996	2997	30	198	179	205	211	123	178	205	178
1997	2996	30	114	216	73	73	270	86	270	143
1998	3020	30	147	127	225	184	130	67	198	67
1999	3030	31	124	108	127	149	121	111	173	111
2000	3040	32	125	154	133	121	89	113	126	113
2001	3035	30	133	190	123	127	15	120	136	120
2002	3025	29	115	53	53	8	171	71	151	71
2003	3050	30	192	173	24	107	36	75	113	75
2004	3055	31	127	147	105	155	47	169	105	169
2005	3065	29	135	128	53	106	19	177	86	177
2006	3070	31	127	133	35	128	5	122	123	122
2007	3075	32	143	117	135	19	143	139	143	143
2008	3080	30	158	81	10	125	22	145	56	145
2009	3075	31	101	40	133	78	80	127	Nil	Nil
2010	3050	29	127	169	126	62	7186	127	186	Nil
2011	3100	31	55	169	27	36	29	209	32	209
2012	3030	29	224	46	69	184	46	110	60	Nil
2013	3105	30	321	213	12	486	23	299	23	Nil
2014	3140	31	48	180	80	6515	67	92	54	Nil

Source: Researcher's survey, 2014. Computed from police report and GRP's Meteorological station

Result and Discussion

Findings shows the major personal and property crime occurrence and weather variables of temperature and rainfall as well as the pattern of crime.



Fig. 1. Mean annual variation in Rainfall and Temperature in Abraka (1992-2014)

Source: fieldwork 2017.

There is evidence of strong variability of both rainfall and temperature. The years with highest air temperature were 1993, 2000 and 2007 with 32°C each and 2014 with 31°C. The years with lowest temperature were 1995, 2002, 2005, 2010 and 2012 with 29°C each respectively. However, air temperature does not display strong spatial variability between the highest and the lowest values for the period under study. Rainfall also showed evidence of fluctuations with 2995 mm in 1995 to 3140 mm in 2014. The figure is suggestive of increasing annual rainfall in the area though punctuated with years with low annual rainfall such as 2012.

4.2 MEAN MONTHLY RAINFALL AND TEMPERATURE REGIME.

Mean monthly rainfall and temperature is a small scale analysis. It is derived from the average monthly temperature of the months over twenty three years. The understanding of this analysis reveals variations in crime rate between dry and wet seasons of the year, thus it is represented below in fig 4.2

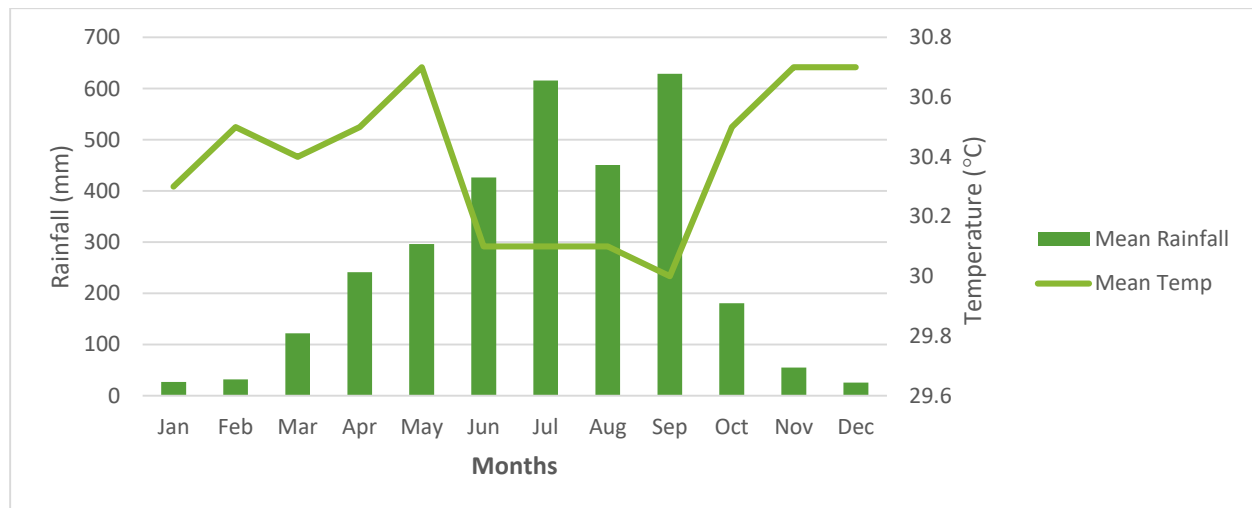


Fig.4.2: Monthly Variation of Rainfall and Temperature in Abraka.

Source: field work 2017.

Fig 4.2 shows the mean monthly rainfall and temperature relationship. It is evident from the figure that the highest temperature months coincide with months with less rainfall. The highest mean monthly temperatures are found in the months of May, November and December with 31.1°C, 30.7°C and 30.7°C respectively. Conversely, the months of July and September has the highest amount of mean rainfall with rainfall amount of 616 mm and 629 mm respectively. It is expected that the variations in monthly rainfall and air temperature may have effect on the type and pattern of crime in the study area.

4.3 THE EFFECTS OF RAINFALL AND TEMPERATURE ON CRIME OCCURRENCE.

The average annual range of temperature is 30°C which implies little fluctuations. This finding is in line with Efe (2006), assertion that Abraka temperature range over 30-35 years is relatively

small with average annual day to night temperature of 10°C thus night temperature the lowest in Abraka. By implication, when planning for crime prevention, night hours should be given due attention, because people are sleeping and most time movement are halt. This phenomenon could vary from Southern belt to other belts in Nigeria, so more studies should be encouraged. Furthermore, from the analysis, rainfall and temperature is an important weather force on crime but not as important as rainfall impacts on crime occurrence in Abraka. This is because rainfall range is 145mm by implication influencing the occurrence of rape. In addition, the study contrasted the research by Hagenauer *et al* (2011), on crime spatial analysis within daily, monthly micro scales in Chicago.

Temperature is considered a major crime occurrence determinant in temperate region than the tropics because of the greater range in temperature and outdoor activities during the summer months. Mean monthly temperature range is 5°C with mean monthly rainfall of about 629mm. This large range in mean monthly rainfall implies that most months have higher rainfall than others. This study revealed that fraud, stealing, assaults, character deformation and burglary-increase with temperature while rape shows less significance but rise with rainfall. By implication crime against man occurs more during dry season than wet season in terms of number of various crimes. This study is in contrast with research in temperate region where rape occurs more in the summer season than other seasons. The rise in rape during wet season can be associated to the august hiatus experience in the study area as well as the increase in the intake of hot drink in a bid to control cold.

4.3.1 THE EFFECTS OF TEMPERATURE ON CRIME.

The effects of temperature on man and the environment cannot be over emphasized. Examining the effects of temperature on crime occurrence is crucial. It will enhance crime control and prevention. In this study, temperature effects on crime are considered as the danger temperature causes for increasing hotness. Fig 4.3 revealed the influences of temperature on crime occurrence

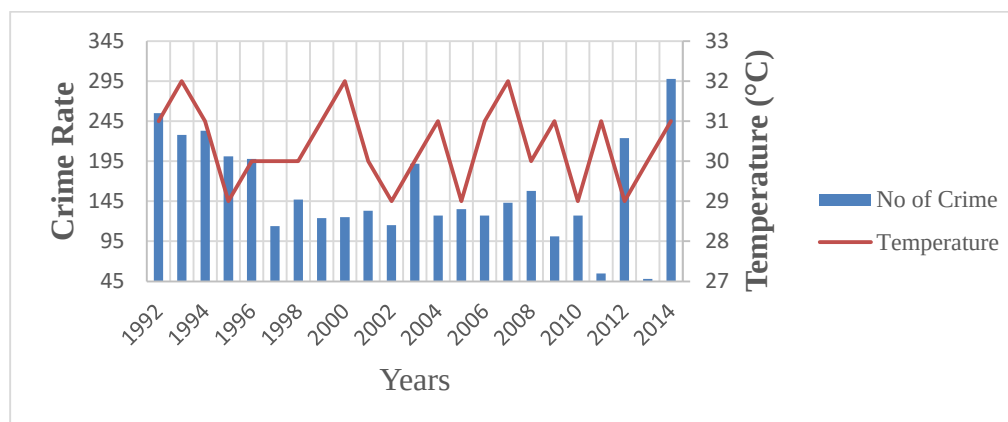


Fig 4.3: Variation in annual mean temperature and crime rates in Abraka.
Source: fieldwork (2017).

In figure 4.3, the relationship (influence) between crime rate and temperature distribution is presented. It does appear like the number of crime committed is fluctuating from its high levels in first five years (1992-1996) to highest level in 2014 after a sharp drop in 2011 and 2013. Looking at the temperature distribution in relation to numbers of crimes reported, it does not seem that there

is any particular pattern that is persistent over the years. As mentioned in the definition of problem, which is to examine and observe the effects of rainfall and temperature on selected crime in Abraka. Temperature is not a major weather variable that causes crime occurrence, so less attention should be given to it. This fact negated studies in the temperate region of the world, which the study hoped to agree with or contradict Hipp *et al.*, 2004; Tellez, Galleguillos, Aliaga, & Silva, 2006 and Rotton & Cohn, 2002.

4.3.2 THE EFFECTS OF RAINFALL ON CRIME OCCURRENCE.

It is known fact that crime is more prevalent during summer in temperate region. This research primarily aimed at examining the effects of rainfall on crime occurrence in Abraka which is a different climate belt. In the study area, rainfall is a major determinant of season experience. So understanding crime rate over season cannot be possible without rainfall. Fig 4.4 revealed the influence of rainfall on crime occurrence.



Fig.4.4: Variation in Rainfall and Crime Rate in Abraka.

Source: fieldwork (2017).

In Fig 4.4 the relationship between crime rate and rainfall has been presented. It shows that at the early part of the 1990's especially the first three years, 1992, 1993 and 1994, as well as in 2014, the crime rate rallied with rainfall. However, year 2011 and 2013 some others showed that rainfall movement is in opposite direction with crime rate reported in Abraka. In addition, reports from the focused group discussion (FGD) reveals variation in the rate of both personal and property crime over the seasons. The ten (10) participants were affirmative citing incidences of rainfall influencing their response and rescue call of emergency situation during the raining season. The officers all said rainfall affects not only routes but also communication lines as well as health of officers.

4.4 Analytic Result

The research hypothesis was tested using the Pearson man's correlation coefficient to ascertain the significant influence of relationship between weather variables (rainfall, and temperature) and crime in Abraka from (1992-2014), and the result as shown in table 2, reveal a significant correlation between rainfall and temperature on crime occurrence at significant level of 0.05.

Table 4.2: Pearson Product Moment Correlation Result Tests

Crime Type	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Assault	Temp	.813	1	.813	.736	.403
	Rainfall	1174.403	1	1174.403	2.872	.110
Stealing	Temp	.218	1	.218	.198	.663
	Rainfall	8193.271	1	8193.271	20.037	.000
Fraud	Temp	.100	1	.100	.091	.767
	Rainfall	1937.175	1	1937.175	4.737	.045
Store House Breaking	Temp	.006	1	.006	.005	.944
	Rainfall	775.803	1	775.803	1.897	.187
Rape	Temp	.995	1	.995	.901	.357
	Rainfall	11176.452	1	11176.452	27.332	.000
Burglary Malicious Damage	Temp	.002	1	.002	.002	.965
	Rainfall	441.038	1	441.038	1.079	.314
Murder	Temp	.256	1	.256	.232	.637
	Rainfall	103.209	1	103.209	.252	.622
Character Deformation	Temp	1.149	1	1.149	1.042	.323
	Rainfall	3401.448	1	3401.448	8.318	.011

a. R Squared = .272 (Adjusted R Squared = -.093) Temperature

b. R Squared = .861 (Adjusted R Squared = .791) Rainfall.

However, rainfall is significant for the occurrence of rape and stealing while temperature is responsible for the occurrence of the following crime; fraud, rape and character deformation. The R squared value for the contribution of temperature to the occurrence of the reported crime is 0.272 with R Squared adjusted value of -0.093 which means that a weak correlation exists between temperature and the occurrence of few crime as shown in the table. Conversely, the R squared value for the contribution of rainfall to the occurrence of the reported crime is 0.861 with R Squared adjusted value of 0.791 which means that there is a strong and positive correlation between rainfall and the occurrence of few crimes. It shows that for stealing and rape crimes reported, rainfall accounted for 79% of its occurrences. The implication of the result is that more of these crimes are committed during wet weather than when the dry weather in the area. This could be as a result of criminals taking advantage that the police may not be on duty during a rainy day or that they may not even come out at all. It is also important to note that criminals can be shielded by the rain drops which will make their activities more successful. Temperature on the other hand impacted more

on crimes reported in the area. This finding is inconsistent with Harries et al. (1984) and (Rotton & Cohn (2002) discovering that temperature has a relationship with crime rate.

Limitations

This study is limited to environmental influence of weather variables on crime occurrence. Though rainfall and temperature are major actors of weather variables but does not deemed sufficient to drive crime occurrence independently of socioeconomic stressors and living conditions, indicating that rainfall and temperature are just a piece in a more complex environmental puzzle. Though the study revealed a significant influence of weather variables on crime rate, it should be interpreted within a larger framework of environmental and social influences. Therefore the study recommend that further study on socioeconomic influence of crime rate should be considered.

Conclusion

This study assessed the environmental influences of weather variables of rainfall and temperature on urban crime rates in Abraka, Ethiopia East, Delta State, Nigeria, over a 22-year period (1992-2014). The results indicate that while temperature has a weak, negative association with certain crimes, rainfall exhibits a strong positive correlation with crime occurrence, particularly for offenses such as rape and stealing. The findings suggest that rainy seasons witness a significant increase in specific crimes, accounting for a substantial 79.1% of variance in their occurrence. These results underscore the importance of environmental factors in shaping crime patterns and support the need for targeted crime prevention strategies during wet seasons to enhance public safety.

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ASSESSING THE IMPACT OF THE 21ST CENTURY DEMOLITION OF LAND USE CONTRAVENTION ON URBAN DEVELOPMENT IN ENUGU METROPOLIS.

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Abstract

Urban land use planning and development is essential for sustainable city development, but land use contravention remains a major challenge, often leading to government-led demolitions of houses. The thrust of this study was to examine the process of the current housing demolitions due to land use violations, and to determine the relationship between the land use demolition and urban development. Primary sources of data such as field observation and key informant interview approach were deployed for the study. Using purposive and simple random sampling techniques, a sample size of about 400 respondents were utilized. Quantitative and qualitative statistical techniques were used for the analyses. Findings reveal that the notification process of demolition was adhered to by the administration and about 75% of the affected residents were fully aware, however many residents perceive the process as unfair due to inadequate compensation and lack of public involvement in decision-making. Finding revealed that about 85% of the affected properties were as a result of set back and land use violation. The chi-square analytic result (p -value = 0.000) shows that land use demolition has a significant positive influence on the physical development. The study therefore recommends public awareness campaigns, improved compensation policies, community engagement, and provision of alternative housing solutions to minimize adverse effects for sustainable development.

Keywords: Land Use Planning, Demolition, Urban Development, Land use contravention.

Introduction

The phenomenon of land use contravention and the resulting enforcement measures, including demolition, has become a topic of global debate, particularly in rapidly urbanizing regions. Urbanization, often accompanied by population growth, exerts pressure on existing land and infrastructure, leading to informal settlements, illegal developments, and land use violations (UN Habitat, 2020). In many developing countries, including Nigeria, the tension between urban expansion and regulatory frameworks has created a complex landscape in which government policies and individual actions often collide. Cities including Enugu exemplifies these dynamics, where unauthorized constructions have led to frequent demolitions. Globally, urban planning and land use regulations are established to foster sustainable cities, protect public interests, and promote orderly development (Angel et al., 2018). These regulations aim to ensure efficient infrastructure use, environmental protection, and equitable access to public services. In cities across the world, however, land use contraventions are often met with stringent actions, including

the demolition of properties built in violation of zoning laws, construction standards, or land use plans (World Bank, 2021). The consequences of these demolitions have sparked considerable debate over their effectiveness, human cost, and long-term impact on urban development. Land use contravention can involve a range of violations, such as construction of buildings in unauthorized zones, exceeding prescribed building densities, or utilizing land for activities that are prohibited in certain areas such as, industrial operations in residential zones (Nelson, 2020).

Critics argue that while demolitions serve to maintain urban order and compliance with planning regulations, they also perpetuate social inequality and exacerbate urban challenges. Demolition without adequate compensation or resettlement plans has been linked to increased homelessness, economic displacement, and social instability, particularly in low-income communities (Satterthwaite & Matlin, 2019). Such actions often disproportionately affect marginalized groups, raising concerns about the fairness of enforcement mechanisms and their alignment with international human rights standards (Amnesty International, 2020).

In the context of Enugu Metropolis, similar tensions arise. The rapid expansion of the city, combined with inadequate infrastructure and insufficient housing, has driven many residents to build in areas designated for public use, such as roads, green spaces, and public utilities. Demolition in these cases is seen as a necessary corrective action to preserve the integrity of urban planning, yet the human consequences cannot be ignored. Affected residents often face economic hardship, loss of property, and psychological distress, as their livelihoods and social networks are disrupted. Recent reports highlight the controversies surrounding the ongoing demolitions in Enugu, under the current administration where land use enforcement has sparked both commendation and criticism (Vanguard, 2025). Understanding the legal, social, and economic ramifications of demolition for land use contravention can inform policy development and potentially lead to more humane enforcement strategies. Additionally, it raises the question of whether current practices in Enugu and similar cities align with the broader goals of sustainable urban development as outlined in global frameworks such as the United Nations' Sustainable Development Goals (SDGs) (UN, 2015).

The global issue of land use contravention and enforcement measures, including demolition, requires further research, particularly in rapidly urbanizing regions like Enugu Metropolis. This study contributes to this discourse by examining the local implications of demolition, exploring whether these actions are merely punitive or if they contribute to long term urban sustainability and the wellbeing of residents. The enforcement of land use regulations through demolition is often implemented to maintain urban order, uphold planning standards, and promote sustainable city development. In theory, demolitions are expected to correct unauthorized developments and prevent further contraventions of urban planning laws. However, in practice, this regulatory approach frequently has adverse effects on urban residents, particularly in developing cities like Enugu metropolis, where socio-economic inequalities and systemic challenges complicate governance. Demolitions carried out as corrective measures result in displacement, destruction of property, and disruption of livelihoods. Affected residents are frequently given inadequate notice, denied fair compensation, and left without viable alternatives for resettlement. These inadequacies exacerbate economic hardships, particularly for vulnerable groups such as low-income households, informal traders, and slum dwellers who are disproportionately impacted. Beyond economic losses, the psychological toll includes trauma, anxiety, and a diminished sense of security, as individuals and families struggle to rebuild their lives under challenging circumstances. Furthermore, these demolitions raise ethical and procedural concerns, including

the lack of community engagement and transparency in decision-making. While authorities justify demolition as a necessary enforcement tool, questions remain about its effectiveness in achieving long-term urban order and sustainable development. The disconnect between policy intent and its socio-economic consequences reflects a broader governance challenge that requires urgent scholarly attention.

Though some studies have been done on land use demolition for example, Adeoye et al. (2022), examined demolition practices in Nigeria. Ogunleye, (2023), determined the forms of demolition while Fainstein (2010), considered the social and economic cost of demolition. Furthermore, the impact of demolition of land use contravention on urban development have not been robustly determined, especially as it relates to city infrastructural development in this 21st century. This is a research gap, the current study determined to fill. Hence, understanding the impact of the current demolition of land use contravention on city infrastructural development will serve as the basis for formulating a sustainable urban development agenda. The thrust of this paper was to determine the impact of land use contravention demolition on city development. This is to evolve policy design and interventions that will serve as the basis for a sustainable city development and ensure improved quality lives of residents. The study considered the process of demolition for urban infrastructural development. The study also determines the pattern of land use demolition in the city. It was hypothesized that land use demolition does not significantly affect city infrastructural development. This study will contribute to the existing body of knowledge on urban planning and land use enforcement in Nigeria, with a focus on Enugu Metropolis. The study will provide a guide on the need for the strict enforcement of development control by the town planning authorities. This current study on land use contravention demolition will also serve as a guide to the public on the need to maintain the zoning and building regulations. This study will also serve as a reference for further study, valuable in identifying gaps in the current legal framework, and suggest strategies for more equitable and effective enforcement of land use regulations.

Theoretical Framework

Urban renewal theory provides a crucial framework for understanding the processes of revitalizing urban spaces, particularly those suffering from physical decay, inadequate infrastructure, and informal land use. The theory's primary focus has traditionally been on improving the physical, economic, and social conditions of urban areas that are considered "blighted" or "decaying." In the context of Enugu Metropolis, urban renewal can be closely tied to the demolition processes carried out by government authorities to address land use contravention, such as illegal construction, poor planning, and zoning violations. This demolition process, as part of a broader urban renewal strategy, seeks to replace informal settlements and structures that do not conform to urban planning regulations. Urban renewal theory has long been associated with the idea that urban spaces should be modernized and transformed to promote economic development, better living conditions, and a cleaner, more organized environment. Historically, urban renewal in many cities, including Enugu, involved the clearance of slums or informal settlements, followed by the construction of new housing, commercial spaces, or infrastructure. The assumption behind this approach is that by eliminating unsanitary conditions and informal development, cities can foster economic growth, attract investment, and improve the overall quality of life for residents (Harvey, 2001; LeGates & Stout, (2022). (Ogunleye, 2023). However, the application of urban renewal theory in Enugu through demolitions for land use contravention has led to significant controversy,

particularly in its social impacts. One of the central criticisms of urban renewal, especially when it involves demolition, is the displacement of vulnerable populations. The demolition of informal housing and unauthorized structures can result in the forced relocation of long-term residents who may have limited access to alternative housing options. In many cases, these residents are from lower-income backgrounds, and the lack of adequate compensation or relocation plans exacerbates their vulnerability (Olatunji, 2023). The evolving understanding of urban renewal theory, from a focus on physical revitalization to a broader consideration of social equity and community participation, offers valuable insights for Enugu's approach to demolitions for land use contravention. While the goal of modernizing the city and addressing illegal land use is important, it must be balanced with a commitment to protecting the rights of residents, promoting fairness in planning processes, and fostering sustainable, inclusive urban development. Adeoye et al. (2022) highlight that demolition practices in Nigeria frequently lack procedural justice, including adequate notice and compensation for affected residents.

Land Use Contravention and Urban Development

Land use contravention refers to the act of using land or property in a manner that violates established zoning laws, planning regulations, or land-use policies. It occurs when land or buildings are developed or used in ways that are inconsistent with the designated or planned purposes for that area as set by local government authorities or urban planners. Land use contraventions are a common feature of urbanization in developing regions, driven by factors such as population growth, informal settlements, and weak regulatory frameworks (Olajide et al., 2022). In Nigeria cities particularly in the study area, unregulated developments, including encroachments on public lands and unauthorized construction, are prevalent (Gibbons et al., 2023). These violations are often a response to socio-economic pressures, such as the lack of affordable housing and inadequate urban infrastructure (Nelson, 2020). The causes of land use contravention are varied. In many developing countries, rapid urbanization, inadequate enforcement of land use laws, and lack of awareness about zoning regulations contribute to these violations. Residents or developers often disregard planning laws, believing that such violations will go unnoticed, or they may be driven by financial constraints that motivate informal development (Ogunleye, 2023).

In urban planning, land use regulations serve to organize the spatial distribution of different activities—residential, commercial, industrial, and recreational—to ensure order and efficiency in a city's growth. When land use contravention occurs, it can lead to various challenges such as overcrowding, environmental degradation, and conflicts between different land uses. These demolitions are intended to restore order and enforce land use regulations. However, the impacts of these actions on urban residents, particularly on those who live in informal settlements or who have been displaced due to such contraventions, are significant (Ogunleye, 2023). Furthermore, land use contravention is not limited to informal settlements. It can also occur within formally planned areas where property owners or developers exceed zoning limits, build without permits, or disregard building codes. These violations can have broader implications for the city's growth and development, particularly when they lead to infrastructure strain, environmental harm, or loss of public spaces. The challenge lies in balancing the enforcement of land use policies with the need for social equity and sustainable development.

Land Use Demolition Processes and Urban and Regional Planning

The process of demolition for land use contravention often involves the identification, assessment, and enforcement of urban planning regulations that aim to restore order to chaotic urban environments. In Nigeria, urban demolition has become a common practice as authorities' attempt to address the consequences of rapid urbanization and illegal developments. Adeleye et al. (2019) describe this approach as a "slash and burn" method, particularly in Nigerian cities, where the goal is to clear unauthorized structures that defy planning norms. This method, though effective in reclaiming public spaces, is often criticized for its lack of inclusivity and harsh impacts on vulnerable populations. In Nigeria cities, demolition processes are typically carried out to enforce compliance with zoning laws and planning standards. Okeke et al. (2024) highlight that the process usually begins with issuing notices to property owners, followed by physical demolition for non-compliance. However, the lack of transparent and consistent enforcement has led to public distrust in the process. Urban and regional planning laws form the backbone of land use management, guiding the processes of land allocation, zoning, and enforcement of development regulations. These laws typically aim to ensure orderly urban development, prevent chaotic land use, and promote sustainable growth (Okonkwo et al., 2019). In Nigeria, the Urban and Regional Planning Act of 1992 serves as the primary legal framework, complemented by state-level legislation such as the Enugu State Urban Development Law. These laws empower planning authorities to regulate land use, enforce zoning standards, and, where necessary, undertake demolitions to address violations (Adeoye et al., 2022). Moreover, the legal framework guiding demolition processes in Nigeria is often ambiguous. Aluko (2011) emphasizes that development control mechanisms, while present, are frequently undermined by corruption and political interference, leading to arbitrary demolitions. This undermines the perception of fairness and further exacerbates the challenges faced by affected residents. The sustainability of demolition as a tool for urban planning has also been questioned. Jabareen (2006) supports this perspective, emphasizing the need for a more sustainable approach that balances urban order with social equity. Existing urban policies in Nigeria heavily emphasize punitive measures, such as demolition, often at the expense of inclusive and sustainable alternatives.

However, successful models from countries like Kenya and India demonstrate the potential of negotiated resettlement and land regularization programs (Mutisya & Yarime, 2014). These approaches emphasize minimizing displacement while promoting compliance with urban regulations. Gibbons et al. (2023) suggest that integrating community participation into urban planning processes can significantly enhance policy effectiveness. This approach aligns with global best practices, which prioritize inclusive governance over top-down enforcement measures (UN-Habitat, 2021).

Study Area

Enugu Metropolis, one of the prominent cities in southeastern Nigeria, holds significant historical, economic, and administrative value. Originally established as a colonial settlement due to its rich coal deposits, Enugu earned the nickname "Coal City" and became a focal point for coal mining activities during the early 20th century. These deposits spurred economic growth and attracted both local and international attention, laying the foundation for Enugu's emergence as an industrial and commercial center. Following Nigeria's independence, Enugu retained its importance as an administrative hub and, later, as the capital of Enugu State when it was established in 1991. Today, Enugu serves as a critical center of political, economic, and cultural activities in the southeastern region of Nigeria (Ogbazi & Ukaegbu, 2018; Onuoha, 2019).

Source: Ochege (2016)

Research Methodology

Enugu was stratified into low, medium, and high residential density areas, and simple random sampling techniques were further used to select the respondents from the affected neighborhoods in the study area. The research employed primary sources of data such as (FGD) focus group discussion with the town planning experts and face to interview with the victims to obtain information on the demolition process, and pattern of demolition and the impact of demolition

from the town planners. The FGD and questionnaire administration was done within two months. The study was analytic since the a priori hypothesis, which sought to ascertain the relationship between housing demolition and urban infrastructural development. Inferential and descriptive statistics were used to analyze the collected data using the SPSS 25 version. Frequency count and percentage were normally used to analyze the demographic data and personal information of the respondents. These descriptive statistical tools are necessary for such analytical study. Chi Square statistical technique was used to test the hypothesis. Ho: There is no relationship between land use contravention demolition and physical development in the city.

Results and Discussions

Table 1. Summarizes the socioeconomic features of the 200 respondents who were victims of demolition that were used for the study. The study revealed that the respondents were adults between the ages of 21 to 70 years, and about 55% were male while 45% were female. This balanced sampled respondents' ratio increases the internal validity of the study. Furthermore, 85 % were household heads, while 25% were not. Also about 65% were married, 20% single, 10% widowed, and 5% divorced. The marital status shows that family heads and married people who are shoulder with lots of family responsibility are more affected by the demolition. The educational status revealed that about 140 acquire tertiary education, 40 had secondary education while about 15% of the respondents had primary education and only 5% had no formal education. It is obvious that people are knowledgeable to observe their environment. The occupational status of the respondents shows that about 65% of the respondents were business owners, 25% civil/public servants and 10% were students. This shows that all the classes of people were affected however the business owners were the highest hit of housing demolition. The income level shows that all the classes of people, high, medium and poor were affected, however the poor and middle were affected most.

Table 1: Respondents' socioeconomic data

Features	Frequency	%
Respondents		
<i>Age</i>		
21 -30	10	5
31-40	30	15
41-50	90	45
Above 50	70	35
Sex		
Male	110	55
Female	90	45
<i>Household head</i>	170	85
<i>Not household head</i>	30	15
Marital status		
<i>Married</i>	130	65
<i>Single</i>	40	20
<i>widowed</i>	20	10
<i>divorced</i>	10	5

<i>Educational status</i>		
<i>tertiary education</i>	130	65
<i>secondary education</i>	40	20
<i>primary education</i>	20	10
<i>no formal education</i>	10	5
<i>occupational status</i>		
<i>business owners</i>	130	65
<i>civil/public servants</i>	50	25
<i>students/others</i>	10	5
	200	

Researchers survey, 2025.

Demolition Process

Notice of Demolition

The research examines the awareness level of the respondents. The table 2. Shows that the victims (82%) were aware of the demolition prior the demolition process. Majority of the victims (77.5%) got notice from the authorities in charge. About 5% got the information through the media while 18% of the victims claimed they got the notice from both the authority and media. This revealed that victims were informed about the demolition. The research sought to know the duration of

Table 2. Demolition Process

Awareness of the Demolition	Frequency	%
Yes	165	82
No	35	18
Mode of information		
Notice from the authorities	155	77.5
Media	10	5
Both	35	18
None of the Above	0	0
Duration of Notice		
Between 1 - 3Weeks	45	22.5
Between 4- 8 weeks	60	30
Above 8 weeks	145	72.5
No Notice	0	0
Is there Any Compensation		
Yes	20	10
No.	140	70
Partial	40	20

Source: Researchers survey, 2025.

notice to the victims before demolition. It was clearly obvious that 72.5% of the respondents were given above 8 weeks' notice, about 30% had 4-8-weeks' notice, while 22.5% of the respondents claimed they had below 1 week notice. All the respondents agreed that they were notified about demolition. as shown in table 2. This implies that the notices were given prior demolition though

on different time interval for digest. The analyses in table 2, also shows that the victims of demolition (10%) revealed that they were compensated, majority of the victims revealed that there was no form of compensation, while about (20%) of the respondents revealed partial compensation.

The following remarks are the consensus reached in one of the FGDs with the town planner experts.

The current demolition going on in the state is as a result of land use contravention. The victims of demolition were informed properly through various means. The various town planning authorities served a notice of demolition within their area of jurisdiction. Many also received a notice from the (ECTDA). The victims were given about 3 to four months' notice to remove those structure days, however majority of them did not comply and the administration demolished those structures after about six months' notice. Other modes of information were employed such as media. The administration also had meetings with the leadership of various organizations like market areas that were affected and others informing them about the demolition process of land use contravention for urban renewal and development. Majority of the victims were compensated by relocating them to another area especially the traders. This finding shows that the demolition process was fair since the respondents confirms that they were informed and some were compensated by relocation. Thing findings contradict the findings of Adeoye et al. (2022), Okeke et al. (2024, and Umoren and Essien (2024) highlight that demolition practices in Nigeria frequently lack procedural justice, including adequate notice and compensation for affected residents. The findings however support the findings of Adeleye et al. (2019) opined that the goal of demolition approach in city planning is to clear unauthorized structures that defy planning norms since the demolition process was based o land use contravention.

The study also determines the pattern of land use demolition in the city. The research observed a spatial pattern of demolition across the city. The demolition cut across the three neighborhoods, the low, high, and medium density area. It also affects various land uses such as residential, commercial properties, institutional, and industrial.

Another remarks reached in one of the FGDs with the town planner experts.

The land use demolition was spatially distributed because it cut across the city to the sub-urban areas of Enugu. The low density, high and medium density areas were affected such as Holy Ghost Layout, Abakpa Nike, Centenary City, Gariki, Ogui Road, Nike, Trans-Ekulu, Uwani, New Haven, and GRA Enugu The outskirts of the city like Emene was also affected and many will still be affected. The demolition process is still on going. These demolition span commercial, residential, and industrial zones, reflecting the diverse reasons for demolitions, ranging from slum clearance and road expansion to zoning violations and unauthorized market activities.

Findings from the questionnaire survey of the respondents or victims of demolition and the FGD with the town planners' experts revealed that the demolition process followed a spatial pattern. This means that the demolition cut across the rich, poor and middle class, and across various land uses such as residential, industrial, institution among many others. This shows that there was fairness of land use enforcement, no bias and favoritism. This finding contradict Amnesty International, (2021), and Gbadegesin et al. (2011) emphasis that the enforcement land use laws are often selective and consistently affects only the poor people.

The study also examines the impact of land use demolition on the physical development of the city. About 65% of the respondents revealed that the land use contravention has a positive impact on physical development in the city. While about 20% revealed a slight positive impact and just about 15% opinion that it may have a positive impact.

Another remarks reached in one of the FGDs with the town planner experts

It is obvious that land use contravention demolition has contributed to the physical development in the city region, and that is the goal of this current administration, to transportation the city, make it habitable and sustainable. These demolitions, while intended to align with zoning regulations and infrastructure development goals, have significantly reshaped various neighborhoods, affecting both residential and commercial properties. Since the current administration took office, Enugu Metropolis has witnessed a series of demolitions aimed at urban renewal and crime reduction. These actions have targeted unauthorized structures, slum developments, and properties linked to criminal activities. The affected areas include Holy Ghost Layout, Abakpa Nike, Centenary City, Gariki, Ogui Road, Nike, Trans-Ekulu, Uwani, New Haven, and GRA Enugu, each experiencing demolition for reasons ranging from unauthorized market operations and illegal settlements to zoning violations and road expansion projects. The Holy Ghost Layout demolition (May 2024) targeted unauthorized market stalls and street parking areas, displacing traders to facilitate the construction of a new transport terminal. Similarly, demolitions in Abakpa Nike and Gariki focused on slum clearance, making way for proposed state terminals aimed at modernizing city infrastructure and enhancing security. Other areas, such as Centenary City, saw demolitions due to lack of government building approvals and in January 2024, the government demolished a property in Awgu council area linked to kidnapping activities, emphasizing a zero-tolerance policy towards the use of properties for criminal purposes. The Executive Secretary of the Enugu State Capital Development Territory warned property owners against allowing their facilities to be used for crimes, leaving the land vacant for future government schemes (TVC NEWS, 2024). Ogui Road in June 2023 and Trans-Ekulu in February 2023, were cleared for road expansion and flood control measures, which are expected to improve traffic flow and mitigate environmental hazards.

For further illustration, the quantitative Chi-Square test (X^2) was conducted to examine the relationship between development rating before demolition and development rating after demolition. The hypothesis tested (H_0): There is no significant relationship between demolitions for land use contravention and physical development. The Pearson Chi-Square value of 42.774 with a p-value of 0.000 indicates a statistically significant relationship between land use contravention and physical development. Since the p-value (0.000) is less than 0.05, we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). This confirms that demolitions for land use contraventions have a significant relationship with urban development in Enugu Metropolis.

Further analysis using Cramér's V (0.164) suggests a moderate association between the two variables. The linear-by-linear association test ($p = 0.556$) implies that while a relationship exists, though it does not follow a perfect linear trend.

Therefore, this finding shows that there is a significant relationship between the current land use contravention demolition and physical development in Enugu. The victims of land use demolition also testify about the ongoing physical development in the city which result from the demolition

process. This finding agrees with (Ogunleye, 2023), (Harvey, 2001; LeGates & Stout, 2022) study that demolitions serve as a corrective measure to restore legal order and proper urban planning.

Implication of Findings

The implication of the findings can be deduced from the qualitative analyses of the questionnaire survey and FGDs, and the quantitative analyses on the demolition process and physical development in the city. The contraction between the questionnaire survey and FGDs shows that the findings support each other. For example, the questionnaire survey on the demolition process supports the planners' experts' opinion of the FGDs' findings that the demolition process was fair and without much bias. Also, the findings from the data analyses of the respondents which includes victims of demolition support the FGD discussion with the town planning experts that the demolition process of land use contravention was spatial distributed which means it cut across the low, middle and high density and extend to some part of the sub urban or city region like Emene. This shows that the poor, rich and middle income were affected. Further implication of the findings can be deduced from the questionnaire survey, FGD, and statistical result that land use contravention demolition has a significant positive effect on the physical or infrastructural development in the city region. Further implication of the findings can be deduced from the relationship between land use contravention demolition and physical development considering that no previous study was conducted at this level in the study area.

Conclusion

The study focuses on some of the process of land use contravention demolition, not all the process was captured. Also the study focus on the impact of land use contravention on the physical development in the city. Other areas such as the economic, social, or psychological effects of land use contravention demolition on the victims were not captured. Also the level of compensation was not critically examined.

Based on the research findings, the following recommendations were made; though demolitions for land use contravention have a significant positive impact on city development by contributing to improved infrastructure, increased land values, and better urban planning, but not without some social, economic, and environmental costs, therefore identifying and implementing alternatives to traditional demolition practices is crucial for reducing the negative impacts on urban residents, while maintaining compliance with land use regulations. Scholars and policymakers should emphasize the need for approaches that balance development control with social inclusion, economic stability, and environmental sustainability. The study also suggests alternative measures such as adoption of community-driven planning and enforcement mechanisms at the grass root level should be considered by the city planners and management as a preventive measure to land use contravention demolition. Further study should consider some other process of land use demolition such as public consultation and the level of compensation. A detail study of the psychological effects of land use demolition on the victims could also be considered.

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ROLE OF GREEN INFRASTRUCTURE IN STRATEGIC LAND USE PLANNING IN IMO STATE

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Abstract

Green infrastructure is the interconnected network of natural and engineered systems that provide ecological, social and environmental benefits. It plays a crucial role in strategic land use planning in Imo State by providing a network of natural and semi-natural areas that deliver a wide range of environmental, social and economic benefits. Land use planning is the ordering and regulating of land use in an efficient and ethical way, thus, preventing land use conflicts. This study investigates the role of green infrastructure in strategic land use planning. The objectives are to: examine how green infrastructure plays its roles on strategic land use planning, identify the challenges of green infrastructure on land use planning, and recommend key strategies to improve on green infrastructure in strategic land use planning. Questionnaire survey was the main instrument for data collection. Simple random sampling and purposive sampling techniques were used. Sample size is 420. The study revealed that, green infrastructure is increasingly recognized as a crucial element in building resilient cities that can withstand the impacts of climate change, urbanization and other environmental challenges. It provides habitats for wildlife, connecting fragmented ecosystems and supporting biodiversity conservation, air quality improvement as well as improving human health and well-being. The study recommends green infrastructure to be integrated into planning, so that communities can create more sustainable and resilient urban environments. It should be strategically planned and integrated into land use plans to ensure connectivity and maximize its benefits, it should be integrated into long-term strategic planning to ensure its sustainability and effectiveness.

Keywords: Resilience, Role of Green Infrastructure, Strategic Land Use Planning Benefits, Sustainability.

1.0 Introduction

The contemporary world is becoming more and more urbanized. Cities face unprecedented and extraordinary challenges due to global trends like rapid urbanization, economic globalization, and climate change (Gill, 2007; Surma, 2020). At the moment, more than a half of the population lives in cities and this number is expected to rise in the coming decades. The cities' growth has put pressure on the capacity of the urban, sewerage among others. Therefore, the United Nations has called for more integrated city policies, where cross-cutting solutions can ensure better qualities of urban settings and sustainable development pathway (United Nations, 2015). In this context, green infrastructure is the interconnected network of natural and engineered systems that provide ecological, social, and environmental benefits. It plays a crucial role in strategic land use planning in Imo State by providing a network of natural and semi-natural areas that deliver a wide range of environmental, social, and economic benefits (Surma, 2020).

Green infrastructure can provide a significant tool, helping to resolve the interconnected urban challenges such as climate change adaptation and migration; uncontrolled urbanization process; decreased environmental quality; public health and wellbeing; biodiversity loss among others (Surma, 2020). Green City environment has financial benefits for the real estate and planning (Pain, 2018). Contributing to resilient, healthy, and environmentally friendly cities as an integral power and economy (Young, 2014).

Land use planning is the systematic, participatory process of managing land resources to achieve sustainable development, balancing economic, social, and environmental needs (Osuji, 2025). It directs land use to minimize conflicts, protect natural resources, and guide development through zoning – residential, commercial, industrial, and agricultural – to create efficient communities (Tao, Tan and He, 2007). Land use planning is the ordering and regulating of land use in an efficient and ethical way, thus preventing land use conflicts (Bako, Raheem and Abdulyekeen, 2017).

The challenges in Imo State is the institutional and regulatory weaknesses, environmental and physical constraints, socio-economic and technical challenges, and specific contextual factors. The study aims to investigate the role of green infrastructure in strategic land use planning in Imo State. The objectives are to:

- i. examine how green infrastructure plays its roles on strategic land use planning
- ii. identify the challenges of green infrastructure on land use planning
- iii. recommend key strategies to improve on green infrastructure in strategic land use planning.

2.1 Concepts of Green Infrastructure

green infrastructure plays a central role in fighting climate change impacts by protecting us against floods and other environmental disasters. As noticed by European Environment Agency, the multifunctionality of green infrastructure enables it to be fully integrated in different policy domains. Hence, this approach can potentially serve a role of a cross-cutting solution for sustainable land use planning. To fully integrate this concept, it is necessary to implement the network of different special levels ranging from the site, district, and city-level to larger peri-urban and regional scale (European Commission, 2013).

Green infrastructure was extended, including not only semi-natural include green roofs; trees and tree boxes; rain gardens; vegetated swales; pocket wetlands; infiltration planters; vegetated median strips, but also some other engineered components with “green” function for instance, porous and permeable pavements to better fit with strategies aiming to adapt built environment to unpredictable events as a result of climate change (Foster, Lowe and Winkelman, 2011). Green infrastructure aimed to provide a hydrological balance for large areas of impervious surfaces within urban districts (EPA, 2008). This extended approach for green infrastructure – closely tied to built environment – significantly contributed to current understanding of green urban environment, previously limited to green spaces like park.

The concept of green infrastructure emerged a holistic planning approach to ensure sustainability of land use in urban and rural regions. Green infrastructure is defined as a “strategically planned network” of natural and semi-natural areas, green spaces and other environmental features which together enhance ecosystem health and resilience, biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services (Naumann, Raymont, Nolan, Forest, Gill, Infrastructure and Forest, 2011., and European Commission, 2012). This “Strategically planned network” deals with two core elements. First, the ecological, social-economic multi-functionality of green spaces (the individual elements) and second, the connectivity among them.

When referring to multi-functionality, each landscape feature, physical and natural, plays a role in satisfying different needs. In the case of urban landscapes, the needs of its population, which range from: contact with nature, recreational needs to social interaction, citizen participation, building a sense of belonging and reinforcing cultural values (Matsuoka and Kaplan, 2008). Connectivity considers the different landscape features, individual elements, with local effects, and the linkages among them until they form a network, which enables movement of species and matter, forming a green infrastructure, with a higher-level effect (Hansen and Pauleit, 2014).

2.2 Land Use Planning

Land use planning refers to the ordering and regulating of land in an efficient and ethical way, thus preventing land use conflicts. Land use planning is described as a key tool to guide the spatial layout and time sequence of land use and to minimize the negative externality of land use (Bako et al., 2017., and Huang, Tiang, Li, Yongfu, Yu, Gao, and Xia, 2023). Land use planning affects

the performance of regional economies. Government interventions in land use can promote regional economic prosperity by: (a) eliminating negative externalities, protecting public goods and implanting amenity improvements; (b) encouraging compact development, associated with higher efficiency in the provision of public services, as well as benefits related to potential agglomerations (urban areas); (c) improving transportation outcomes; and, (d) reducing the uncertainty and transaction costs involved in land development (Metternicht, 2017).

Land use planning can achieve conservation outcomes by: identifying and protecting natural areas with significant biodiversity values; directing development away from natural areas; and controlling the impacts of land uses on natural areas. For example, the Planning and Development Act of Western Australia has established biodiversity as a valid planning consideration; the act states that preservation and conservation matters need to be dealt with by the planning scheme. Specifically, its Planning Framework contains provisions for: the protection of biodiversity, preventing or limiting vegetation clearing; the protection of habitat from destruction and fragmentation; and the preservation or enhancement of ecological corridors (Metternicht, 2017).

3.0 Literature Review

3.1 Infrastructure

The “infrastructure” part of the term is used to link green space to economic development theory. It gives a common ground between environmentalists and economic growth strategies, placing green infrastructure as an “enabler” of economic growth (Horwood, 2011). It can be used strategically as a policy “fix” where development investment issues overlap with environmental constraints (Horwood, 2011); growth is facilitated together with satisfying environmental considerations, instead of putting them in conflict to one another (Davies, Macfarlane and McGloin and Roe, 2006., Karnbites and Owen, 2006., and Mell, 2008).

3.2 Green Infrastructure

Green infrastructure has been identified as a contributor improving human health and air quality, lowering energy demand, reducing capital cost savings, increasing carbon storage, expanding wildlife habitat and recreational space, and even increasing land-values by up to 30% (Foster, Lowe and Winkelman, 2011., Jabbar, Yusoff and Shafie, 2021., Hanna and Comin, 2021). Green infrastructure approaches help to achieve sustainability and resilience goals over a range of outcomes, in addition to climate adaption: land-value, quality of life, public health, hazard

mitigation and regulatory compliance (Foster et al., 2011., Muluneh and Worku, 2022., and Wang'ombe, 2024., Jiang and Menz, 2025., Wang, Xu, An and Guo, 2024).

3.2.1 The Principles of Green Infrastructure Planning

Green infrastructure, a planning approach, goes beyond the conservation of land and natural resources, and tries to create a linkage between the conservation of these resources and the development of the spaces for people. As described by Mell (2008) and Rosales (2016), green infrastructure brings together different elements from landscape, ecology, geography, and planning in the way it links the ecological capacity of any given area with its corresponding environmental, social and economic opportunities. A Green Infrastructure approach must consider the needs of the environment together with local perceptions when developing green spaces and to ensure well-being (Mell, 2008., Hansen and Pauleit, 2014., Davies, 2015., and Rosales, 2016) identified four common planning principles for green infrastructure namely: (1) Integration, (2) Delivery of Ecosystem Services or Multi-functionality, (3) Network or Connectivity, and (4) Multiple Scale.

3.2.2 Integration: The “Grey and Green” Elements of Green Infrastructure

Green infrastructure element is considered as all open spaces, urban parks, gardens, woodlands, green corridors, street trees and open countryside, within the boundaries of urban areas set – or defined by each region’s administrative authorities. We are including elements categories as “blue infrastructure” in other planning approaches; water ways, rivers, streams, lakes and other water bodies are integral parts of the natural or semi-natural elements of the environment.

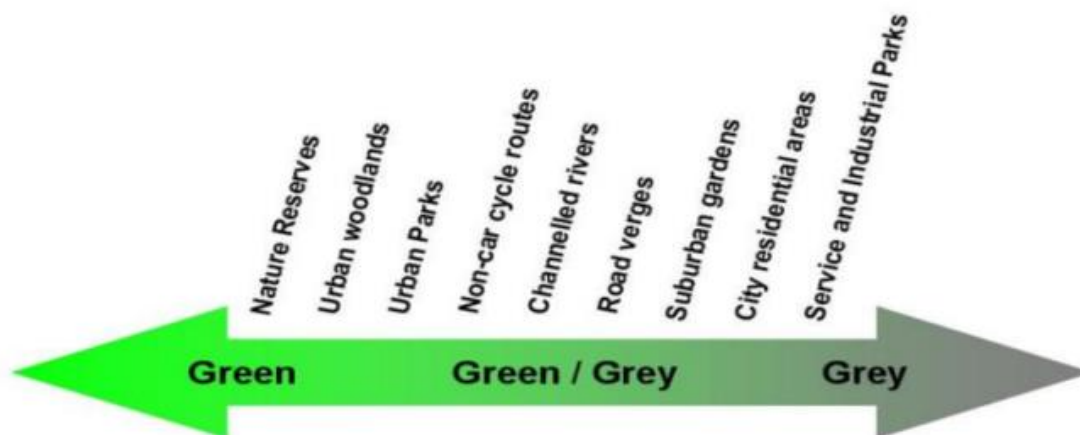


Fig. 3.1: Green-grey continuum. Retrieved from Davies et al. (2006).

3.2.3 Ecosystem Services Delivery and Multi-functionality

Ecosystem Multifunctionality (EMF) refers to the ability of ecosystems to simultaneously provide multiple services – such as provisioning such as food and water, regulating (carbon/climate change), cultural, and supporting services – rather than just one. Managing landscapes for multiple services, often through “bundles”, enhances sustainability, biodiversity, and societal well-being by balancing ecological and socio-economic benefits.

3.2.4 Green Infrastructure Connectivity or Network

Connectivity refers to the relationship between landscape structure and function; the degree in which “landscape facilitates or impedes the flow of energy, materials, nutrients, species and people across a landscape” (Ahern, 2007). To access the connectivity of any given landscape, we identify and characterize the aspects that create a connection between the different elements in the landscape as enhancer or reducers of connections (Roux, 2015). The end result is the identification of physical linkages or existing connection. The “ecological network concept” suggested by Ahern (2007), addresses the optimal spatial strategies, initially its focus was the maintenance of biodiversity, and is now used by the green infrastructure approach.

3.2.5 Multiple Scales of Green Infrastructure

The multi-scale approach from hierarchy theory (Ahern, 2007), studies how a system behaves simultaneously at different scales. In the case of landscape studies, our areas of study are always nested within larger areas, that constrain or control the processes happening within the smaller part. To understand them, the multi-scaled approach, assess the spatial configuration of landscape patterns and ecological processes at different scales (Ahern, 2007). According to Dige (2014), their studies carried out in the review of the European Commission’s guidelines to do spatial analysis of green infrastructure in Europe proposes a methodology that can be used by different entities at different scales. This helps in the assessment of landscape green infrastructures, and among its possible uses it can help identify areas for improvement within a green infrastructure. It focuses mostly on analysis at national and regional level, and clearly states that its purpose is mostly aimed towards rural and natural landscapes (Dige et al., 2014).

3.3 Green Infrastructure Framework

To assess green infrastructure based on multi-functionality, Hansen and Pauleit (2014) linked the concepts of green infrastructure and ecosystem services and created a conceptual framework for

the multi-functionality of green infrastructure specially for urban areas. The authors mention how “approaches developed in ecosystem services can help to assess the integrity of green infrastructure networks” (Hansen and Pauleit, 2014). The framework makes system analysis of green infrastructure from the ecological and social perspective, and then proceeds to do a valuation of multi-functionality.

3.4 Role / Benefits of Green Infrastructure

- (1). In light of the challenges confronting urban areas due to increasing populations and spatial constraints, green infrastructure is vital for fostering environmental balance, enhancing community well-being, and promoting sustainable urban development.
- (2). Green infrastructure improves the quality of the environment, the condition and connectivity of natural areas, as well as improving citizens’ health and quality of life.
- (3). Multifunctionality: Unlike traditional “grey” infrastructure, green infrastructure serves multiple purposes, such as biodiversity conservation, water management, and recreational space, within the same spatial footprint.
- (4). Ecological Connectivity: By linking isolated ecological patches, green infrastructure enhances urban ecological integrity and prevents habitat fragmentation, supporting natural processes.
- (5). Resilience to Climate Change: Green infrastructure helps cities manage severe weather event (e.g. heatwaves, flooding) by providing cooling, reducing runoff, and strengthening social-ecological resilience.
- (6). Sustainable Development Goals (SDGs): Green infrastructure directly aligns with SDG 11 (Sustainable Cities) by enhancing quality of life and integrating nature into urban landscapes, making cities more inclusive, safe and resilient.
- (7). Smart Development and Management: This involves strategically integrating natural elements – such as parks, green roofs, and wetlands with technology to create efficient, sustainable and resilient urban environments. Instead of relying solely on traditional “grey” infrastructure (concrete pipes and sewers), green infrastructure uses nature-based solution

to solve urban challenges, providing ecological, social, and economic benefits simultaneously.

3.5 Land Use Planning

Land use planning involves the allocation of land to different uses across a landscape in a way that balances economic, social, and environmental values. Its purpose is to identify in a given landscape, the combination of land uses that is best able to meet the needs of stakeholders while safeguarding resources for the future (Bako et al., 2017., Huang et al., 2023). Land use planning is the systematic, participatory process of managing land resources to achieve sustainable development, balancing economic, social, and environmental needs (Osuji, 2025). It directs land use to minimize conflicts, protect natural resources, and guide development through zoning – residential, commercial, industrial, and agricultural – to create efficient communities (Tao et al., 2007).

Land use planning is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land use options. Its purpose is to select and put into practice those land uses that will best meet the needs of the people while safeguarding resources for the future (Okeahialam and Osuji, 2019., Kent, Wood and Harmington, 2023).

3.6 The Study Area

Imo State lies within latitude $4^{\circ} 45^1$ N and $7^{\circ} 15^1$ N and longitude $6^{\circ} 50^1$ E and $7^{\circ} 25^1$ E. It is bounded in the North by Anambra State, in the East by Abia State, in the West by Delta State and in the South by Rivers and Bayelsa States with a total land area of 5,100km². It comprises 27 Local Government Areas and is divided into three senatorial zones namely; Orlu, Owerri and Okigwe Zones.

Imo State was created during the military regime of General Murtala Mohammed on the 3rd of February, 1976. Owerri became the capital of Imo State. Imo State has 306 autonomous communities. The population of Imo State was projected to 2025 which is 6.7 million and the people are predominantly Igbo speaking people. Imo State is rich in natural resources which include crude oil and natural gas. The annual rainfall is over 2250 mm (90 inches) with a mean temperature above 26.7°C (Udo, 1978). The relative humidity is between 80 percent and 90 percent

in the rainy season (April to October) and about 65 percent in the dry season (November to March). Imo State lies within the rainforest belt of Nigeria. The forest belt is characterized by trees that exist in different layers – low, middle and upper layers. The assemblage of infrastructure makes Imo State hub of economic, administrative, institutional, industrial, and commercial activities which attracts investors to the state. Imo State has six major roads namely: Orlu, Okigwe, Aba, Umuahia, Onitsha, and Port Harcourt Roads, also Douglas and Wetheral Roads, access roads and Sam Mbakwe International Cargo Airport along Owerri – Aba Road.



Fig. 3.2: Nigeria showing Imo State

Source: Ministry of Lands, Survey, and Physical Planning, 2023.

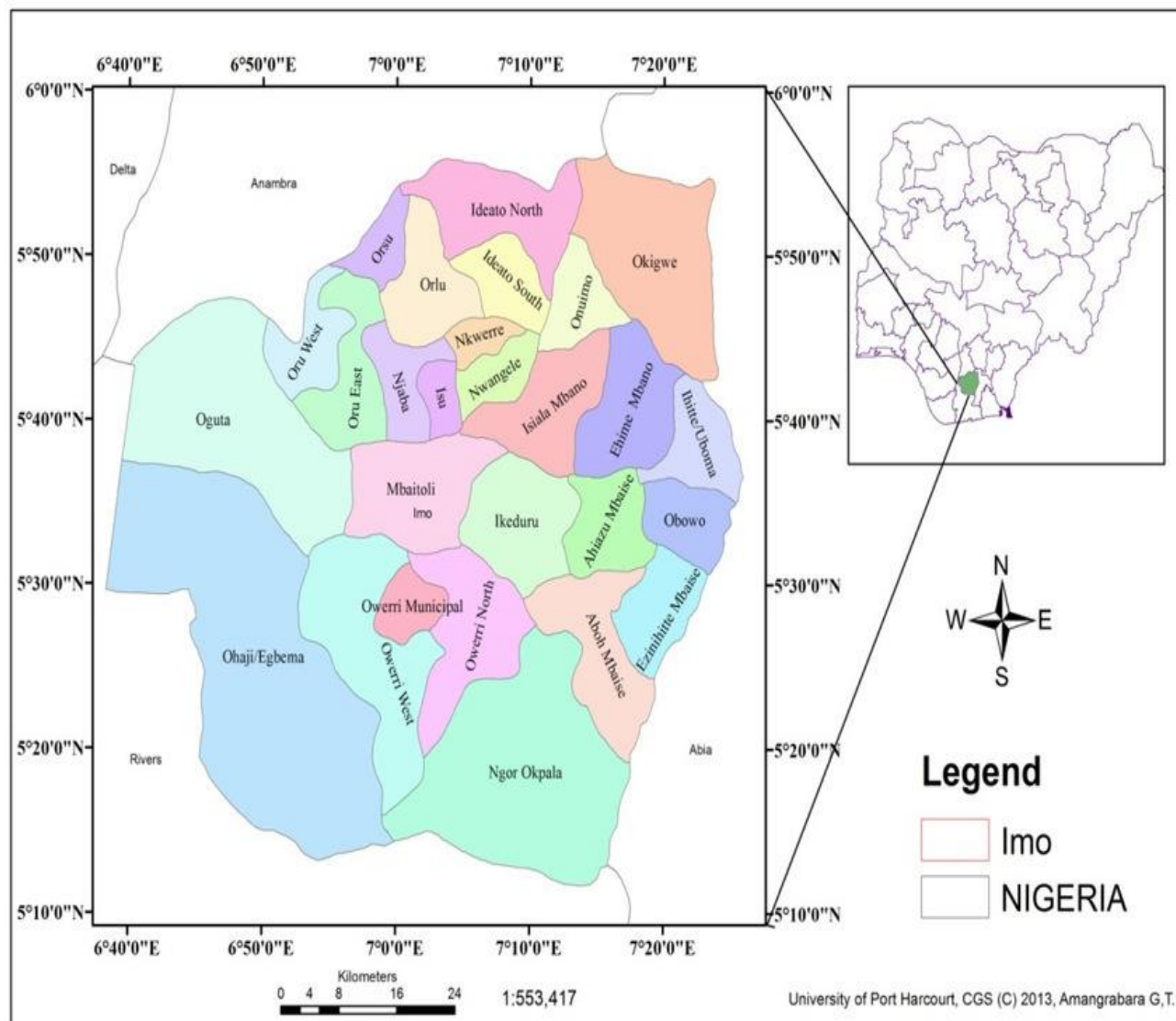


Fig. 3.3: An insert map of Nigeria, showing Imo State

Source: Ministry of Lands, Survey and Physical Planning (2023)

4.0 Methodology

The research covers Imo State. It was divided into three zones: Orlu, Owerri, and Okigwe Zones. The study design is the survey research design. Data for the study were from primary and secondary sources. Survey methods using questionnaire, which was the main instrument for data collection, oral interview, direct observation, records, private papers, journals, official records and in the internet were conducted. Simple random and purposive sampling techniques were used in selecting data collection. The total population of 960 forms the target population. A total of 468 copies of the questionnaire were distributed to the 40 communities selected from 27 Local Government Areas of the three Senatorial Zones of Imo State. Each zone had its share of questionnaire copies. The 40 communities are Okpala, Ngor Okpala, Egbu, Okwu, Umuoba, Umuorii, Orji, Umuororonjo, Amawom, Umuonyeche, Umuonyima, Umuodu, Ikenegbu, Akwakuma, Amakohia, New Owerri, Umuguma, Nekede, Avu, Obinze, Umudagu, Obeazu, Nworieubi, Ubomiri, Akabo, Ata, Abo Mbase, Awo Omamma, Mgbirichi, Umuagwo, Oguta, Mgbidi, Awo Idemili, Anara, Okwele, Obowo, Ihite Uboma, Ubahu, Okigwe, and Ihube. The formula used was Taro Yamene formula:

$$\frac{(n = N)}{1 + N (e)^2} + \dots \dots \dots (1)$$

10% attrition was included in the sample size of 468. 420 copies of questionnaire were retrieved, which represents a response rate of 95%. In all, Town Planners were distributed 65% of questionnaire, 25% to experienced professionals in the built environment and 10% to the residents in the study area. Descriptive statistics was the method used in analyzing the data collected for the study.

5.0 Findings

- (1). Green infrastructure is increasingly recognized as a crucial element in building resilient cities that can withstand the impacts of climate change, urbanization, and other environmental challenges.
- (2). It provides habitats for wildlife, connecting fragmented ecosystems and supporting biodiversity conservation, air quality improvement as well as improving human health well-being.

- (3). The study found that green infrastructure plays a good role in strategic land use planning in Imo State. It acts as multifunctional, interconnected network of natural and semi-natural areas such as parks and waterways – that delivers essential ecological, social and economic fits.
- (4). Green Infrastructure is vital for fostering environmental balance, enhancing community well-being, and promoting sustainable urban development.
- (5). Accessibility of public green spaces in Imo State: People living in urban areas have access to the public green spaces while those living in the rural areas are disadvantaged due to distance. Most of them have limited leaf areas and inadequate portions of accessible public green spaces. Majority of green areas within the urban environment are adorned with shrubs and trees. The presence of trees in public gardens, sports fields and other open spaces provide a contribution of notably high leaf area values.

5.1 Challenges of Green Infrastructure in Strategic Land Use Planning in Imo State

It is necessary to study in more detail the “scope and methods” linking multi-functionality to ecosystems services, planning and design of green infrastructure to achieve sustainability. Another link that is missing is the lack of conceptual framing integrated in the practice of day-to-day landscape management. Kabisch, Qureshi and Haase (2015) suggests we need more information from different places to gain a better understanding on the benefits of green spaces and improve the practices of implementation of this planning approach in specific planning contexts.

The challenges for green infrastructure planning are found in addressing the development of adequate infrastructure and amenities required to sustain the population, which is affected by high levels of inequality and poverty. Reduce disaster risk and vulnerabilities against natural phenomena and climate change impacts. Promote development that does not degrade or destroy the environment; promotion of the preservation of the natural assets in the area.

Green infrastructure in strategic land use planning faces significant challenges in Imo State, driven by rapid urbanization, weak enforcement of planning regulations, and high vulnerability to environmental degradation. As of 2026, the state is actively developing climate change policies through partnerships with Spaces for Change to address these, but several bottlenecks remain:

(1). Institutional and Regulatory Weaknesses

- i. Weak Enforcement and Compliance: A fundamental challenge is the failure of developers to adhere to approved land use plans, with many constructing without approvals.
- ii. Poor Coordination: There is a lack of inter-departmental coordination among ministries, departments, and agencies (MDAs), which leads to inconsistencies in strategic planning.
- iii. Absence of Legal Framework: The lack of a comprehensive legal framework specially for urban renewal and greening limits the enforcement of natural-based solutions.
- iv. Improper monitoring of development to ensure compliance, especially when a development permit/approval is granted.

(2). Environmental and Physical Constraints

- i. High Erosion Vulnerability: Imo State is highly susceptible to gully erosion, with over 50 active gully sites reported, which complicates the establishment of permanent green corridors.
- ii. Rapid Loss of Natural Cover: Deforestation and the expansion of built-up areas (increasing from 30.23% in 2017 to 35.78% in 2022 in some studies) are reducing existing green areas and accelerating soil degradation.
- iii. Impervious Surface Increase: Increased, unplanned development has created more surfaces that prevent water infiltration, worsening urban flooding.

(3). Socio-Economic and Technical Challenges

- i. Insufficient Funding: A major barrier is inadequate budgetary allocation for green projects, alongside a general lack of resources for implementation.
- ii. Public Resistance: Development control measures for instance, demolition of illegal structures often face resistance from residents, affecting the ability to implement master plans.
- iii. Technical Knowledge Gaps: There is a shortage of skilled professionals to plan and maintain green infrastructure projects, such as urban parks and specialized green roofs.
- iv. Land Use Conflicts: High demand for land for housing and industry often overrides ecological considerations, leading to the conversion of green spaces.

(4). Specific Contextual Factors (2025 – 2026)

- i. **Infrastructural Decay:** Existing non-functional infrastructure often takes precedence over new green initiatives.
- ii. **Urgent Need for Climate Action:** While the government is acting to address environmental issues through the Spaces for Change and Imo State Ministry of Environment and Sanitation partnership, the need to tackle rising climate vulnerabilities like increased temperature and erratic rainfall is high-priority, urgent challenge.
- iii. **Speculative Landholding:** The government has had to revoke unused plots at the Owerri Industrial Layout to combat speculative landholding, which prevents proactive, sustainable and planned green use.

Recommendations

Recommendations are proffered based on the findings:

- 1) Green infrastructure to be integrated into planning, so that communities can create more sustainable and resilient urban environments.
- 2) It should be strategically planned and integrated into land use plans to ensure connectivity and maximize its benefits.
- 3) It should be integrated into long-term strategic planning to ensure its sustainability and effectiveness.
- 4) Planning laws should be adhered to. Developers should build according to the zoning regulations as these will serve as blueprint for long-term development and growth of the entire city or region. These provide a framework for guiding future development and decision-making processes and ensuring that growth occurs in a coordinated and sustainable manner (Osuji, 2025).
- 5) Law enforcement, monitoring and development control should be put in place to guide against illegal land uses.
- 6) Permitting and approval processes granted to developers should be monitored before the commencement of building construction activities and during construction activities.

Conclusion

This study investigates the role of green infrastructure in strategic land use planning. The role of infrastructure and challenges in Imo State were identified. The green infrastructure can possibly help to resolve the issues of urban heat effect; stormwater flooding by interconnected city policies seems very relevant and up-to-date, if we wish to ensure future prosperity of city environments in the next decades. It is concluded that green infrastructure can act as a cross-cutting solution to various sustainability challenges in terms of land use planning.

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Impact of Road Construction Delays on Public Well-Being in Minna, Niger State, Nigeria

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1. INTRODUCTION

Transportation is a critical component of national development, influencing economic growth, access to services, social integration, and the overall quality of life (World Bank, 2023; Rodrigue, 2020). Efficient transportation systems enable the movement of goods and people, reduce travel time, and promote connectivity among communities. In both urban and rural settings, road infrastructure plays a significant role in transportation networks. Roads facilitate not only the daily commute of individuals but also the delivery of essential goods and services, emergency response, healthcare access, and education (Ajanlekoko et al., 2022).

In emerging countries like Nigeria, transportation infrastructure has long been plagued by inefficiencies, limited investment, and poor planning (Adeleke et al., 2020). Roads remain the most widely used means of transport, particularly in cities like Minna, where other modes such as rail or air travel are limited in reach or affordability (Agunbiade et al., 2021). Consequently, there is increasing demand for road construction and expansion projects to meet the growing needs of urbanization, industrial activities, and population growth. However, the reality of project execution often deviates significantly from initial plans. One major issue that consistently hinders the success of road infrastructure development in Nigeria is the occurrence of construction delays (Oke et al., 2020).

Construction delay is a global challenge in the construction industry and is typically associated with cost and time overruns. These delays adversely impact project sponsors, clients, and project teams, often resulting in disputes, financial strain, litigation, and renegotiations (Ameh et al., 2021). In the context of road construction, delays can have significant ripple effects on surrounding communities and the broader economy. Projects intended to ease transportation and improve safety may become sources of disruption and public frustration due to prolonged exposure to construction-related inconveniences (Oladokun et al., 2023). While discussions on road project delays often focus on their economic consequences, such as budget overruns and contract disputes, there is a growing recognition of their impact on public health.

Prolonged road construction exposes individuals to health risks beyond traffic disruptions. The presence of dust, noise pollution, and unsecured construction zones can lead to respiratory conditions like asthma and bronchitis, hearing impairments, and physical injuries (Okonkwo & Edache, 2020; WHO, 2021). Moreover, persistent construction activity may contribute to psychological distress, including anxiety, fatigue, cardiovascular strain, and depression among affected residents and commuters (Adetunji et al., 2022). These health consequences are often underestimated in planning and evaluation frameworks, even though they critically affect public well-being and social stability.

In Minna, the capital of Niger State, several road construction projects have been launched to improve urban mobility. However, many of these projects have faced significant delays (Niger State Ministry of Works, 2023). Roads are frequently left incomplete, with materials and equipment obstructing walkways and commercial spaces. This has led to widespread disruptions in daily activities and growing concerns about health implications among the city's residents. Furthermore, the informal and unplanned nature of many neighbourhoods in Minna increases their

vulnerability to these disruptions (UN-Habitat, 2022). Children playing near active construction sites, market traders operating next to dusty roads, and schoolchildren walking amid heavy machinery are common sights. These challenges highlight the need for a broader and deeper understanding of how road construction delays affect public health, beyond conventional traffic and economic concerns.

This study, therefore, seeks to examine the physical psychological health impacts such as respiratory problems, fatigue as well as stress and anxiety for road construction delays on residents and road users in Minna. It aims to identify coping strategies, public perceptions, and potential policy responses. By shifting the focus away from congestion alone, this research provides insights into the often-overlooked human health dimensions of delayed infrastructure development.

2. Theoretical Framework/ Conceptual Framework

This study is anchored on Systems Theory and Public Good Theory, which provide a comprehensive framework for understanding the relationship between road construction delays and public well-being. While Systems Theory explains how disruptions in transportation affect interconnected urban systems, Public Theory highlights the role of government in the provision and efficient management of infrastructure.

Together, these theories offer a strong basis for analysing the economic, psychological, and environmental impacts of road construction delays in Minna, Niger State.

2.1 General Systems Theory (GST)

Systems Theory, originally developed by Ludwig von Bertalanffy (1968), provides a holistic framework for understanding complex phenomena as interconnected and interdependent components within a unified whole. Rather than examining elements in

isolation, Systems Theory emphasizes that changes or disruptions in one part of a system inevitably produce ripple effects across other components. In the context of urban environments, infrastructure systems such as transportation, healthcare, education, and economic activities are tightly interlinked and function as subsystems of a broader socio-economic system.

Applied to road infrastructure, Systems Theory suggests that transportation networks serve as a foundational subsystem that supports mobility, accessibility, and economic exchange. When road construction projects are delayed, this disruption does not remain confined to the transport sector alone; rather, it cascades across multiple urban systems. For instance, restricted mobility due to incomplete roads can limit access to healthcare facilities, delay emergency response times, and reduce attendance at schools and workplaces. Similarly, economic systems are affected as traders, transport operators, and small businesses experience reduced patronage and increased operational costs.

In Minna, Niger State, where alternative transport modes such as rail and air are limited, the road network represents a critical backbone of urban functioning. Delays in major road projects such as the Minna-Bida Road or urban bypasses create systemic inefficiencies that disrupt daily life. These disruptions manifest in increased travel time, congestion, environmental pollution, and reduced productivity, all of which directly and indirectly influence public well-being.

Empirically, the strong statistical association observed in this study ($R^2 = 0.771$) aligns with the assumptions of Systems Theory, demonstrating that disruptions in the transportation subsystem are significantly associated with variations in broader public well-being outcomes. Therefore, Systems Theory not only underpins the conceptual

framework of this research but also justifies the integrated analysis of economic, psychological, and environmental impacts.

2.2 Public Goods Theory (PGT)

Public Goods Theory, advanced by scholars such as Joseph Stiglitz (2021), provides a critical lens for understanding the provision and management of infrastructure such as roads. Public goods are typically defined by two key characteristics: non-excludability (individuals cannot be prevented from using them) and non-rivalry (one person's use does not significantly reduce availability to others). Road infrastructure fits this definition, as it is intended to be accessible to all members of society and serves as a shared resource that facilitates mobility, economic activity, and social interaction.

Within this framework, governments bear the primary responsibility for the provision, maintenance, and timely delivery of road infrastructure. Efficient road networks generate widespread social benefits, including reduced transport costs, improved access to essential services, and enhanced economic productivity. However, when road construction projects are delayed, the expected benefits of these public goods are significantly diminished, leading to what can be described as a "public goods failure."

In the context of Minna, delays in road construction undermine the accessibility and functionality of these shared resources. Although roads are designed to be universally accessible, prolonged construction effectively restricts access, particularly for vulnerable populations such as low-income earners, schoolchildren, and the elderly. This creates a paradox where a non-excludable good becomes temporarily exclusionary due to poor implementation and governance inefficiencies.

Moreover, Public Goods Theory highlights issues of accountability and governance. Since road projects are funded through public resources like taxes, delays raise critical concerns about the efficiency of public expenditure, contractor performance, and institutional oversight. The findings of this study particularly the significant association between delays and reduced public well-being underscore the consequences of inadequate management of public goods. Increased transportation costs, reduced business activity, and limited access to healthcare and education reflect a failure to deliver the full social value of infrastructure investments.

Conceptual framework

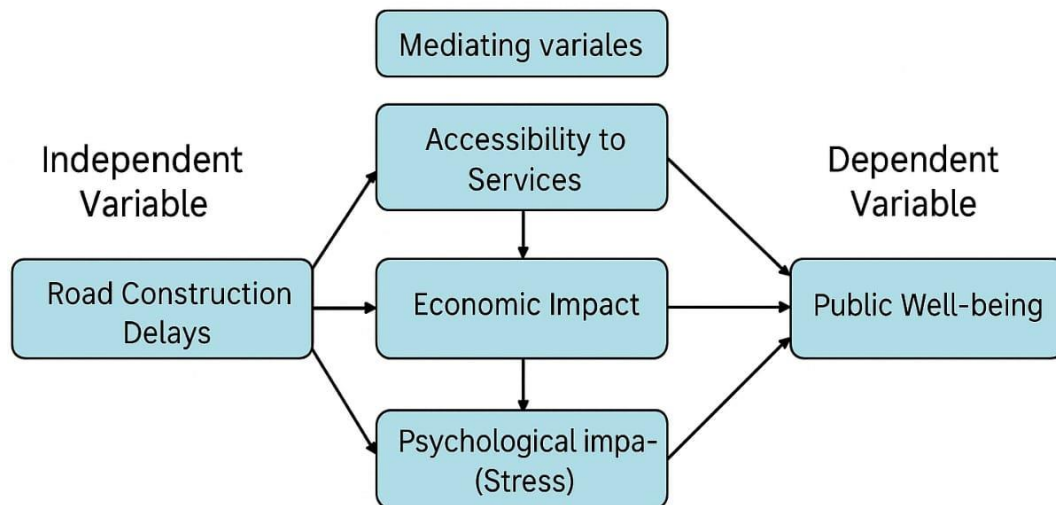


Figure 2.1

The figure above shows the conceptual framework of the study, highlighting the relationship between road construction delays (independent variable) and public well-being (dependent

variable). Public well-being is examined through economic, psychological, and environmental dimensions. The framework guides the empirical analysis and links directly to the theoretical foundations discussed above.

3. Study Area

Minna is the capital city of Niger State, located in the North-Central geopolitical zone of Nigeria. It lies approximately between latitudes 9°31' and 9°40' N and longitudes 6°29' and 6°36' E. The city covers a land area of about 88 square kilometres and is situated at an elevation of 260 metres above sea level. National Population Commission (2006). Minna is strategically positioned along the major rail and road networks connecting northern and southern Nigeria, making it a critical transport and administrative hub.

Minna experiences a tropical savannah climate characterised by distinct wet and dry seasons. The rainy season typically spans from April to October, with peak rainfall occurring between July and September. The dry season, which includes the Harmattan period, lasts from November to March. Annual rainfall ranges between 1,100 mm and 1,300 mm, while average daily temperatures vary between 22°C and 35°C (Adebayo, 2020).

According to estimates, Minna has a population of over 6,000,000 residents and continues to grow due to urbanisation and rural-to-urban migration (National Population Commission, 2020). The population is culturally diverse, consisting of major ethnic groups such as the Gwari (Gbagyi), Hausa, Nupe, Yoruba, and Igbo. Islam and Christianity are the dominant religions in the city (Ogunyemi et al., 2022).

However, the city faces challenges such as poor road conditions, inadequate drainage systems, and insufficient waste management services. Ongoing and delayed road construction projects

within Minna have affected mobility, access to services, health and local economic activities, forming the basis of this study.

Map of the Study Area

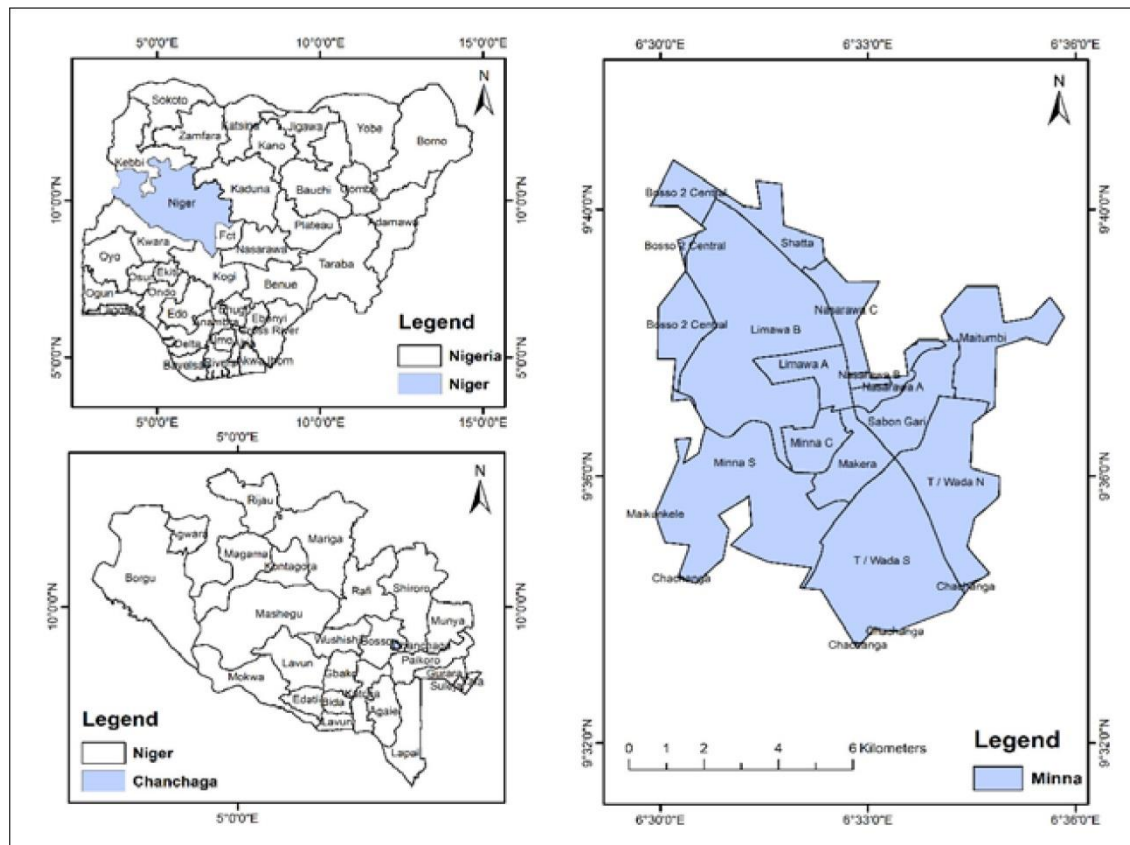


Figure 3.1

4. Methodology

The given study applied a quantitative cross-sectional survey design to investigate how delays in road construction affect public well-being.

4.1 Types and sources of data

This study utilized primary data as the main source of information. Primary data were collected directly from respondents through the administration of structured

questionnaires. The data captured respondents' perceptions of road construction delays and their effects on public well-being, including economic impacts, psychological stress, accessibility to services, and environmental health risks.

The respondents included road users such as commuters and drivers, residents living near construction sites, small business owners operating along affected roads and other stakeholders within Minna, Niger State.

In addition to primary data, limited secondary data were consulted to support the study. These included published literature, government reports, and previous research studies related to road infrastructure, construction delays, and public well-being. These sources were used mainly to provide background information and support the discussion of findings.

4.2 Population and Sample Size

The target population includes Road users such as commuters, drivers, and transport workers, Residents living near affected construction zones, Small business owners along the construction corridors and Relevant government agencies, such as the Niger State Ministry of Works and Transport.

The sample size for this study was determined using the Cochran formula for sample size calculation, which is suitable for large populations. The formula ensures that the sample is statistically representative of the population at a 95% confidence level and a 5% margin of error.

$$n_0 = (Z^2 \cdot p \cdot (1 - p)) / e^2$$

Where:

n_0 = required sample size

Z = Z-score (1.96 for 95% confidence level)

p = estimated proportion of the population (0.5 for maximum variability)

e = margin of error (0.05)

Substituting the values:

$$\begin{aligned} n_o &= (1.96^2 \times 0.5 \times (1 - 0.5)) / (0.05)^2 \\ &= (3.8416 \times 0.25) / 0.0025 \\ &= 0.9604 / 0.0025 \\ &= 384.16 \end{aligned}$$

4.3 Sampling Techniques

A purposive sampling technique was employed to select respondents for this study. This method was chosen because it allows the researcher to target individuals who are most affected by or knowledgeable about road construction delays. The respondents included commuters, drivers, residents living near active construction sites, and small business owners operating along the affected road corridors. By focusing on these specific groups, the study ensures that the data collected is relevant to understanding the impact of road construction delays on public well-being in Minna.

4.4 Method of data collection

The data were collected using a structured questionnaire administered to respondents in selected areas affected by road construction delays. The questionnaire included both closed-ended questions based on a Likert scale and demographic questions.

4.5 Method of data analysis

The data collected for this study were analysed using the Statistical Package for Social Sciences (SPSS) version 25. Both descriptive and inferential statistical techniques were employed to achieve the study objectives

Descriptive statistics, including frequency distribution, percentages, means, and standard deviation, were used to summarize respondents' demographic characteristics and assess general perceptions regarding road construction delays and public well-being. These statistics provided a clear understanding of the sample structure and response patterns.

5. Results

5.1 Questionnaire administration

The number of questionnaires distributed to the respondents is based on the sample size determined in section 4.2 above. Therefore, 384 questionnaires were distributed, and out of these, 298 (99.6%) questionnaires were successfully retrieved representing the response rate. Out of the retrieved questionnaires, 292 (76%) were found to be properly completed and suitable for analysis, while 6 were excluded due to incomplete or inconsistency responses.

Table 1: Response Rates

Sample Size	Collected	Used
384	298(99.6%)	292 (76%)

Source: Authors' Field Work (2025).

5.2 Demographic Information of Respondents

The demographic information was sought from the participants to enable contextual analysis based on Road Construction Delays and Public Well-Being.

Table 2: Demographic Profile of Respondents (n = 292)

S/N	Questions	Options	Frequency	Percentage
1	Gender	Male	153	52.4
		Female	139	47.6
2	Age	18–25	95	32.5
		26–35	52	17.8
		36–45	62	21.2
		46–55	55	18.8
		56+	28	9.6

3	Highest Educational Qualification	Primary	14	4.8
		Secondary	79	27.1
		HND/NCE	94	32.2
		Degree	69	23.6
		Postgraduate	36	12.3
4	Employment	Student	110	37.7
		Civil Servant	46	15.8
		Business Owner	64	21.9
		Private Sector Employee	35	12.0
		Self-employed	37	12.7

Source: Authors' Field Work (2025).

Table 2 provides a comprehensive overview of the survey participants. Regarding gender, the sample is relatively balanced but leans slightly towards a male majority, with 52.4% (153) identifying as male and 47.6% (139) as female. This near-parity suggests that the survey results are likely to reflect perspectives from both genders without a significant biological or social bias toward one group.

In terms of age distribution, the respondent base is notably young. The largest single demographic is the 18–25 age bracket, which accounts for 32.5% of the total. When combined with the 26–35 age group (17.8%), over half of the participants are 35 years old or younger. Conversely, the participation rate steadily declines in the older brackets, with those aged 56 and above representing the smallest portion of the sample at just 9.6%. This suggests the study's findings may be most applicable to a younger, more active demographic.

The educational profile of the participants indicates a high level of literacy and formal training. The most common qualification held is an HND/NCE (32.2%), followed closely by those with a secondary education (27.1%) and university degrees (23.6%). High-level academic attainment is

also present, with 12.3% of the sample possessing postgraduate qualifications. Only a very small fraction, 4.8%, reported having only a primary education, reflecting a sample that is largely composed of individuals with tertiary-level exposure.

The employment data reveals a strong presence of the academic and entrepreneurial sectors. Students comprise the largest occupational group at 37.7%, which aligns with the high frequency of younger respondents. This is followed by Business Owners at 21.9%, indicating a significant entrepreneurial spirit among the participants. The remaining respondents are distributed among Civil Servants (15.8%), the Self-employed (12.7%), and Private Sector Employees (12.0%), showing a diverse range of professional backgrounds.

4.0 Results

The effects of the Road Construction Delays on Public Well-Being were tested using regression analysis. The findings can be observed in Table 2.

Table 2: Effects of the Road Construction Delays on Public Well-Being

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Mean Square	F	Sig.
1	.878 ^a	.771	.769	.37496	46.822	333.027	.000
					.141		

Source: Authors' Field Work (2025).

- a. Predictors: (Constant), Road Construction Delays
- b. Dependent Variable: Public Well-Being

As can be seen from Table 2 above, the overall regression model is a very strong and significant predictor for Public Well-Being. The R-Squared value is 0.771; this means that the overall regression model explains approximately 77.1% of the variability among the Road Construction Delays predicted by the overall regression model. The overall model is a very good fit with the Adj. R-Squared at 0.769 and is significant: $F = 333.027$; $p = 0.000$.

6. Discussion of Findings

The regression analysis results indicate that road construction delays are a strong and statistically significant predictor of public well-being in Minna. With an R-Squared value of 0.771, the model demonstrates that approximately 77.1% of the variability in public well-being is explained by

construction delays. This finding is supported by a highly significant F-statistic ($F = 333.027$; $p = 0.000$), suggesting a strong association between construction delays and public well-being. However, given the cross-sectional nature of the study, these findings indicate relationships rather than causality. The disruptions caused by infrastructure projects have a profound and measurable negative impact on the quality of life for the city's residents. These statistical results validate the study's hypothesis that the deviation from initial project execution plans creates a significant ripple effect on the surrounding community. This pattern of interconnected impacts can be explained using System Theory, which emphasizes the interdependence of components within a broader socio-economic system. The findings suggest that disruptions in the transportation subsystem are associated with cascading effects on other sectors such as economic activities, healthcare access, and social well-being, reinforcing the notion that infrastructure delays extend beyond mobility challenges to affect the overall functioning of urban systems. The economic dimension of these findings reveals that delays are perceived as a major barrier to local prosperity and daily survival. For many residents and businesses in Minna, the lack of timely road completion is associated with increased transportation costs and a direct loss of income. Business owners and traders, particularly those situated along construction routes, suffer from reduced customer access and lower patronage, which threatens their long-term economic stability. Furthermore, the resulting traffic congestion and route diversions is linked with restricted access to essential services such as healthcare, markets, and education. This observation aligns with Public Goods Theory, which posits that infrastructure such as roads should be efficiently provided to ensure equitable access and societal benefit. The reduced accessibility and increased costs associated with construction delays indicate inefficiencies in the provision of this public good, thereby limiting its intended benefits to the population, placing a disproportionate burden on vulnerable groups like the elderly and school children. Beyond economics, the discussion must highlight the severe health and psychological toll identified in the research. Prolonged exposure to active construction zones subjects residents to environmental hazards, including dust and noise pollution, which are associated to respiratory conditions like asthma and bronchitis. Psychologically, the constant state of uncertainty, combined with the stress of navigating poor road conditions, triggers high levels of frustration, anxiety, fatigue, and mental strain. This cumulative stress is exacerbated by the fact that Minna has limited healthcare infrastructure to address these emerging health risks. Ultimately, the findings underscore a significant gap in urban governance and stakeholder management. While government

agencies and contractors possess high decision-making influence, the primary stakeholders, the residents and small-scale traders, bear the heaviest burden while possessing the least influence over project timelines. The obstruction of walkways and commercial spaces by abandoned materials reflects a lack of human-centred planning. These results call for a policy shift toward participatory planning and more aggressive mitigation strategies to protect public well-being during essential infrastructure development.

Overall, the findings of this study are consistent with both System Theory and Public Goods Theory, demonstrating that road construction delays are associated with interconnected socio-economic and health outcomes, while also reflecting inefficiencies in the provision of essential public infrastructure.

7. Conclusion

This study assessed the impact of road construction delays on public well-being in Minna, Niger State, Nigeria, using a cross-sectional survey design. The findings reveal that road construction delays are significantly associated with multiple dimensions of public well-being, including economic stability, accessibility to essential services, psychological health, and environmental conditions. The regression analysis indicated a strong model fit, explaining a substantial proportion of variation in public well-being, thereby confirming a significant relationship between the variables examined.

The study further demonstrates that these findings are consistent with Systems Theory, which explains how disruptions in transportation infrastructure can produce cascading effects across interconnected social and economic systems. In addition, Public Goods Theory is supported by the results, as delays reflect inefficiencies in the provision of essential infrastructure intended to serve the public equitably.

8. Recommendations

Based on the study's findings regarding the significant impact of construction delays on public well-being. The following recommendations are proposed:

- i. The Niger State Ministry of Works and Infrastructure should implement stricter oversight and enforce penalty clauses for contractors who fail to meet deadlines to minimize prolonged economic and social disruptions.
- ii. Construction contractors should adopt environmental mitigation strategies, such as regular water sprinkling and proper site management, dust control mechanisms to reduce the incidence of respiratory conditions like asthma and bronchitis among residents.
- iii. Regulatory and enforcement agencies (including urban development authorities) should ensure that construction materials and equipment do not obstruct walkways, market spaces, or school routes to protect vulnerable groups like children and traders.
- iv. Government health agencies should establish localized monitoring in construction hotspots to address the physical and psychological health risks, including anxiety and cardiovascular strain, caused by prolonged exposure to noise and dust.

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Soil Quality Variability Drivers Modeling and Inference on Sustainable Land Use Management Strategies in South-East Region of Nigeria

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ABSTRACT

This research examines soil quality variability drivers modeling and inference on sustainable land use management strategies in South-East region of Nigeria with the main objective of identifying and modeling the dominant drivers of soil quality variability across states in the region. The study uses multivariate and regression-based approaches with the following specific objectives: to characterize the physicochemical and textural properties of soils across the South-East region; to examine the relationships among soil quality indicators using correlation analysis; to identify the principal components controlling soil quality variability using principal component analysis (PCA).; to develop regression models that quantify the influence of key soil properties on selected soil quality indicators; and to interpret the dominant soil processes responsible for observed spatial variability in soil quality within the South-East region. The results demonstrate that soil quality variability in South-Eastern Nigeria is primarily controlled by texture-mediated physical constraints, organic matter and nitrogen dynamics, nutrient retention capacity governed by exchangeable base cations, and soil acidity regulation mechanisms. This finding confirms that chemical fertility in the region is primarily influenced by base cation availability rather than by clay content alone. Soil acidity emerged as a distinct driver of soil quality variability, with soil pH and exchangeable calcium acting as key regulators of exchangeable acidity. The coexistence of high base saturation with acidic soil reaction suggests that acidity in the region is driven more by hydrogen ion activity in the soil solution than by extensive occupation of exchange sites by acidic cations.

Keywords: Modeling, Sustainable land use, Soil quality, Spatial variability drivers

1. INTRODUCTION

Soil quality is vital when examining choice of crops to grow and have optimal yield, other land use decisions, land degradation evaluation, soil management, and the overall food security of a locality, area or region. Soil quality is thus considered a precondition for better planning and utilization of land resources as opined by Isong et. al., 2022; Okon et al., 2019; Kalambukattu et al., 2018). Soil quality decline interrupts the basic soil functions and slows down or impedes optimal crops yields and food security. Isong et. al.,(2022) agree that soil quality appraisal is essential for identifying localities and regions with equivalent high and low soil quality, and their suitability for agricultural land use in general and cultivated crops in particular.

According to Debi,(2019), It is important to state that soil is not directly consumed compared to air and water; and so, to estimate its quality is quite difficult. Also, soil quality is not dependent on a single factor but an aggregation of factors which include physical, chemical, and biological (Shekhovtseva and Mal'tseva 2015).

Key factors or drivers of soil quality variations have been identified as natural factors like parent material - (soils from coastal plain sands differ significantly from other geological formations, impacting texture (sandy topsoil, clayey subsoil; topography - that is slopes (upper, mid, foot) influence water flow, erosion, and soil depth, creating distinct layers and properties; climate – high rainfall leads to nutrient leaching and erosion, while temperature affects organic matter decomposition; time and biota – soil development over time and biological activity also contribute. The human factors include deforestation and land clearing which increases exposure to erosion; intensive farming – causes soil compaction, nutrient depletion (N, P), and erosion especially without fallowing; erosion – severe gully and sheet erosion strip fertile topsoil, altering soil quality drastically; poor management – lack of conservation practices (terracing, cover crops) exacerbates degradation.

Soil quality, which is considered as the ability of soil to promote and sustain plant, animal and human health within an ecosystem, is essential for maintaining and improving air and water quality (Awoonor et. al., 2024). Therefore, the importance of soil quality in agriculture and indeed crops production cannot be taken lightly especially in Nigeria where over 80% of its population are engaged in various forms of agriculture with its attendant variations in soil quality across the different geo-political zones or regions.

Therefore the main objective of this study is to identify and model the dominant drivers of soil quality variability across selected states in the South-East region of Nigeria using multivariate and regression-based approaches with the following specific objectives: to characterize the physicochemical and textural properties of soils across the South-East region; to examine the relationships among soil quality indicators using correlation analysis; to identify the principal components controlling soil quality variability using principal component analysis (PCA).; to develop regression models that quantify the influence of key soil properties on selected soil quality indicators; and to interpret the dominant soil processes responsible for observed spatial variability in soil quality within the South-East region.

Study Area

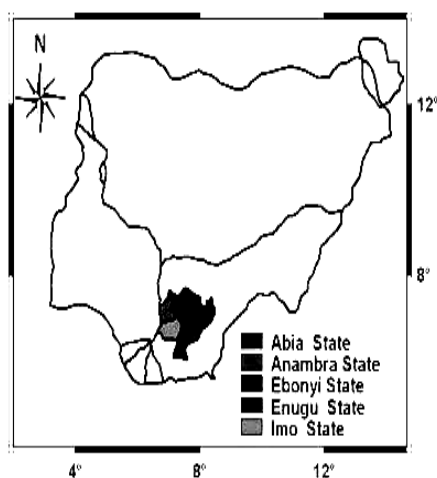
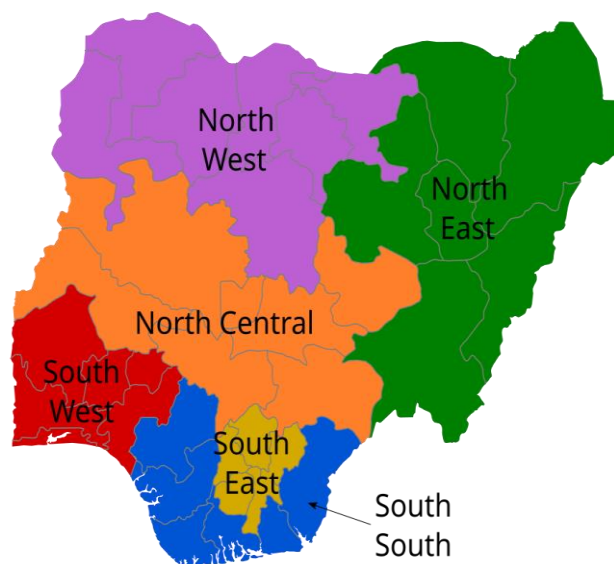


Fig. 1. Map of Nigeria Showing the Study Area

Source: Nwankwo, Steve & Okonkwo, Moses. (2012)

Figure 2: Map of Nigeria Showing different Geopolitical Regions (Zones)

Source: <https://commons.wikimedia.org/w/index.php?curid=95656348>



The Southeast geopolitical zone of Nigeria is made up of five states, namely, Abia, Anambra, Ebonyi, Enugu and Imo States with eighty-five Local Government Areas (LGAs) and a population of over twenty million people dwelling in over ten commercial cities and large towns. Apart from agriculture as the mainstay of economic activities for the majority in the rural communities, the zone is also known for its commerce and trading activities with a preponderance of micro, small and medium indigenous industries that are into manufacturing, fabrication and agro-allied produce. Agriculture thrives very well in the area because the zone is endowed with arable land. The main food crops grown in the zone include yam, cassava, rice, cocoyam and maize while the cash crops include oil-palm, rubber, cocoa, banana and various types of fruits. The zone is blessed with solid minerals and natural resources in rich deposits such as crude oil, natural gas, bauxite and iron ore, sand stone, lignite, kaoline, clay, coal, tin, columbite, etc. The zone has high potential to attract investments in the following areas: i. Agro-allied industries (Cassava starch and flour as well as fruits and vegetable canning) ii. Textiles (Cotton Socks, Fishing nets and Mosquito nets) iii. Industrial Minerals/Quarrying (Glass industry, Table ware, Aggregate plant including stone crushing plants) iv. Plastics Industry (Plastics manufacture, Bottles, flask, cans, tubes and bags tiles) and v. Chemical Industry (Polyethylene, Explosives, Self-Adhesive Tape, Pulp and paper). (<https://cirddoc.org/wp-content/uploads/2016/06/ZONAL-South-East.pdf>)

2. MATERIALS AND METHODS

The study was conducted in the South-East geopolitical region of Nigeria, comprising Abia, Anambra, Ebonyi, Enugu, and Imo States. The region lies within the humid tropical zone and is characterized by high annual rainfall, predominantly deeply weathered soils, and intensive agricultural activities. Soils in the region are largely derived from sedimentary parent materials and are susceptible to nutrient depletion, acidity, and structural degradation due to continuous cultivation and leaching. These characteristics make the region suitable for regional-scale soil quality variability and driver analysis.

Soil Sampling Strategy and Sample Representation

One composite surface soil sample of 250 grams from a depth of 0–20 cm was collected from each of the five states at selected locations which were mainly fallow land without any trace of surface and subsurface contamination (Abia – Umuahia; Anambra – Awka; Ebonyi – AE-FUNAI, Ikwo; Enugu - Umuatuwoma, Udi LGA; and Imo – Okigwe). Each composite sample was formed by thoroughly mixing multiple subsamples collected within representative agricultural areas of the state in order to minimize microscale variability and obtain a regional representation of soil conditions.

Justification of Sampling Design

The study employed an observational, regional-scale, comparative modelling design. The objective of this study was to model inter-state variability and drivers of soil quality at a regional scale, rather than to assess within-state or plot-level variation. Consequently, the use of one composite sample per state is consistent with regional soil quality assessment and modelling studies, where the focus is on identifying dominant soil quality drivers across broad spatial units rather than local heterogeneity. This approach is statistically appropriate for multivariate and regression-based modelling at the scale of inference adopted in this study.

Laboratory Analysis of Soil Parameters

All soil samples were air-dried, gently crushed, and passed through a 2-mm sieve prior to laboratory analysis. Standard analytical procedures were employed for the determination of soil physicochemical properties.

Parameter	Description	Analytical Method
pH	Acidity/alkalinity	Glass electrode (1:2.5 soil–water)
Organic Carbon (OC)	Soil carbon content	Walkley–Black wet oxidation
Organic Matter (OM)	Derived from OC	$OM = OC \times 1.724$
Total Nitrogen (N)	Nitrogen content	Kjeldahl digestion
Available Phosphorus (P)	Plant-available P	Bray-1 extraction
Exchangeable Ca, Mg, K, Na	Basic cations	1 N NH_4OAc extraction
Exchangeable Acidity (EA)	Soil acidity	KCl extraction
Estimated CEC (ECEC)	Nutrient holding capacity	Sum of exchangeable bases + EA
Base Saturation (BS)	Percentage base occupancy	$(\sum \text{bases} / ECEC) \times 100$
Particle size fractions	Sand, silt, clay	Hydrometer method
Textural class	Soil texture	USDA textural triangle

Data Preparation and Standardization

Prior to statistical analysis, all soil variables were subjected to descriptive statistical analysis to evaluate central tendency and dispersion. Because the soil parameters were measured in different units and scales, data were standardized using Z-score normalization to ensure comparability and prevent scale bias in multivariate and regression modelling.

$$Z = \frac{X - \mu}{\sigma} \quad Z = \frac{X - \mu}{\sigma}$$

Where: X is the observed value, μ is the mean, and σ is the standard deviation.

Multivariate Analysis for Identification of Soil Quality Drivers

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was applied to identify the dominant drivers of soil quality variability across the study area. PCA reduces the dimensionality of the dataset by transforming correlated variables into a smaller number of uncorrelated components.

- Components with eigenvalues ≥ 1 were retained.
- Variables with factor loadings $\geq |0.60|$ were considered significant contributors to each principal component.
- Each retained component was interpreted based on the soil processes represented by its dominant variables (e.g., fertility, acidity, base status, texture).

The PCA results were used to:

1. Identify key soil quality drivers,
2. Guide variable selection for regression modeling,
3. Reduce redundancy and multicollinearity.

Regression Analysis and Soil Quality Driver Modeling

Regression analysis constituted the core modeling framework of the study and was used to quantify functional relationships among soil quality indicators.

Dependent Variables for Modeling

Instead of modeling crop yield or suitability indices, selected key soil quality indicators were modelled as dependent variables to explain soil system behavior. These included:

- Organic Carbon (OC)
- Estimated Cation Exchange Capacity (ECEC)
- Base Saturation (BS)
- Exchangeable Acidity (EA)

Independent Variables

Independent variables were selected based on:

- PCA results,
- soil process relevance,
- correlation analysis,
- multicollinearity diagnostics.

Potential predictors included:

- pH
- Total Nitrogen (N)
- Available Phosphorus (P)
- Exchangeable Ca, Mg, K, Na
- Textural fractions (sand, silt, clay)

Multicollinearity Control

To ensure model stability:

- Pearson correlation coefficients were examined ($|r| \geq 0.85$ flagged redundancy).
- Variance Inflation Factor (VIF) analysis was performed.
- Variables with $VIF > 5$ were excluded or combined.

Regression Model Formulation

General multiple linear regression models were expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + \epsilon$$

Example models:

Organic Carbon model

$$OC = \beta_0 + \beta_1(N) + \beta_2(\text{Clay}) + \beta_3(\text{pH}) + \epsilon$$

$$OC = \beta_0 + \beta_1(N) + \beta_2(\text{Clay}) + \beta_3(\text{pH}) + \epsilon$$

ECEC model

$$ECEC = \beta_0 + \beta_1(\text{Ca}) + \beta_2(\text{Mg}) + \beta_3(\text{Clay}) + \beta_4(\text{OC}) + \epsilon$$

$$ECEC = \beta_0 + \beta_1(\text{Ca}) + \beta_2(\text{Mg}) + \beta_3(\text{Clay}) + \beta_4(\text{OC}) + \epsilon$$

Exchangeable Acidity model

$$EA = \beta_0 + \beta_1(\text{pH}) + \beta_2(\text{Alkaline bases}) + \epsilon$$

$$EA = \beta_0 + \beta_1(\text{pH}) + \beta_2(\text{Alkaline bases}) + \epsilon$$

These models allowed the identification and quantification of key drivers controlling soil quality variability.

Model Evaluation and Validation

Model performance was evaluated using:

- Coefficient of determination (R^2),
- Adjusted R^2 ,
- Root Mean Square Error (RMSE),
- Residual diagnostics (normality and homoscedasticity).

Given the regional scale and limited sample size, model interpretation focused on process explanation and driver identification rather than prediction accuracy alone.

Statistical Software

All analyses were conducted using:

- SPSS (version 26) for regression and diagnostics,
- R statistical software (version 4.x) for PCA and supplementary modelling.

Ethical and Scientific Rigor Considerations

The study design, analytical methods, and modelling approach were selected to ensure transparency, reproducibility, and alignment with regional-scale soil science research standards.

3 RESULTS AND DATA ANALYSIS

Table 1: Descriptive Statistics of Soil Quality Indicators across South-Eastern Nigeria

Variable	Mean	Minimum	Maximum	Interpretation
Sand (%)	68.28	49.88	74.88	High sand dominance

Variable	Mean	minimum	Maximum	Interpretation
Silt (%)	11.52	5.12	30.12	Moderate variability
Clay (%)	20.00	20.00	20.00	Uniform across states
pH	6.27	4.99	7.56	Acidic–near neutral
P (mg/kg)	46.66	36.50	70.70	Moderate–high
N (%)	0.200	0.168	0.294	Low–moderate
OC (%)	1.54	0.96	2.15	Low–moderate
Ca (cmol/kg)	6.27	3.47	11.20	Moderate–high
Mg (cmol/kg)	3.80	1.60	6.40	Moderate
K (cmol/kg)	0.149	0.121	0.185	Low
Na (cmol/kg)	0.119	0.090	0.156	Low
EA (cmol/kg)	0.25	0.16	0.38	Low
ECEC (cmol/kg)	12.05	6.03	18.07	Moderate–high
BS (%)	97.5	96.5	99	Very high

The descriptive statistics presented in Table 4.1 provide an overview of the physicochemical and textural characteristics of soils across South-Eastern Nigeria and reveal substantial spatial variability in key soil quality indicators. The soils were predominantly sandy, with a mean sand content of 68.28%, while silt content exhibited moderate variability (5.12–30.12%). Clay content remained constant at 20% across all states, suggesting a broadly similar parent material influence and degree of weathering within the region. The dominance of sand implies a coarse-textured soil environment, which is typical of many humid tropical landscapes and has important implications for water retention, nutrient leaching, and organic matter stabilization.

Soil reaction (pH) ranged from strongly acidic (4.99) to near neutral (7.56), with a mean value of 6.27, indicating marked spatial variability in acidity status across the region. Such variability is characteristic of tropical soils subjected to differential leaching intensity, base cation removal, and land-use history. Acidic conditions in some states may constrain nutrient availability and microbial activity, while near-neutral conditions in others may enhance nutrient cycling and cation exchange processes. This wide pH range underscores soil acidity as a critical driver of soil quality variability in South-Eastern Nigeria.

Available phosphorus concentrations were generally moderate to high, with values ranging from 36.50 to 70.70 mg/kg. The observed variability suggests differences in phosphorus sources, fixation dynamics, and soil mineralogy across the region. In acidic tropical soils, phosphorus availability is often influenced by interactions with iron and aluminum oxides; therefore, spatial differences in pH and clay mineral composition may partly explain the variability observed. Total nitrogen and organic carbon contents were low to moderate, with mean values of 0.200% and 1.54%, respectively. These levels are typical of intensively weathered tropical soils and reflect rapid organic matter decomposition under warm and humid climatic conditions, combined with limited organic matter inputs.

Exchangeable base cations, particularly calcium and magnesium, were present at moderate to high levels, with calcium ranging from 3.47 to 11.20 cmol(+)/kg and magnesium from 1.60 to 6.40 cmol(+)/kg. The variability in these cations suggests differences in base replenishment mechanisms, such as parent material composition and historical land management practices. Potassium and sodium contents were consistently

low, which is common in tropical soils due to their susceptibility to leaching and limited structural incorporation into clay minerals.

Exchangeable acidity values were generally low (0.16–0.38 cmol(+)/kg), despite the presence of acidic pH in some states. This apparent contrast is reflected in the consistently high base saturation values (96.5–99%), indicating that the soil exchange complex is largely dominated by base cations. High base saturation in the presence of acidity suggests that soil acidity in the region may be driven more by hydrogen ion activity in the soil solution rather than extensive occupation of exchange sites by acidic cations. This condition is characteristic of some tropical soils where weathering and leaching reduce buffering capacity without necessarily leading to high exchangeable acidity.

Estimated cation exchange capacity (ECEC) exhibited considerable spatial variability, ranging from 6.03 to 18.07 cmol(+)/kg, with a mean of 12.05 cmol(+)/kg. This variability highlights differences in nutrient retention capacity across the region and reflects the combined influence of organic carbon content, exchangeable base status, and textural composition. Soils with higher ECEC are better able to retain nutrients against leaching losses, whereas soils with lower ECEC are more vulnerable to nutrient depletion under continuous cultivation and high rainfall conditions.

Overall, the descriptive statistics indicate that soil quality variability in South-Eastern Nigeria is controlled by a combination of textural characteristics, acidity status, organic matter dynamics, and exchangeable base composition. The coexistence of coarse texture, variable pH, moderate nutrient levels, and contrasting ECEC values suggests complex interactions among physical and chemical soil processes. These observations provide a strong justification for the application of multivariate and regression-based modelling approaches to disentangle the dominant drivers of soil quality variability across the region.

Table 2: Pearson Correlation Matrix of Selected Soil Quality Indicators

Variable	OC	N	pH	Sand	Ca	Mg	ECEC	EA
OC	1.00							
N	0.94	1.00						
pH	0.61	0.68	1.00					
Sand	-0.79	-0.74	-0.41	1.00				
Ca	0.66	0.63	0.58	-0.45	1.00			
Mg	0.71	0.69	0.52	-0.50	0.88	1.00		
ECEC	0.82	0.78	0.49	-0.72	0.91	0.87	1.00	
EA	-0.65	-0.59	-0.86	0.34	-0.71	-0.68	-0.74	1.00

The Pearson correlation matrix in Table 4.2 provides insight into the interrelationships among key soil quality indicators and reveals coherent patterns that reflect dominant soil processes operating in South-Eastern Nigeria. Strong positive correlations were observed between organic carbon (OC) and total nitrogen (N) ($r = 0.94$), indicating their close coupling through organic matter inputs and decomposition

dynamics. This relationship is typical of humid tropical soils, where nitrogen is largely stored in organic forms and its availability is strongly controlled by organic matter quantity and turnover.

Organic carbon also exhibited strong positive associations with exchangeable calcium ($r = 0.66$), magnesium ($r = 0.71$), and estimated cation exchange capacity (ECEC) ($r = 0.82$). These relationships highlight the role of organic matter as a key contributor to cation exchange sites in tropical soils, where clay mineral activity is often low due to advanced weathering. The strong OC–ECEC correlation suggests that spatial variability in nutrient retention capacity across the region is largely driven by differences in organic carbon content rather than clay fraction, which remained constant across states.

Soil pH showed moderate to strong positive correlations with OC ($r = 0.61$), N ($r = 0.68$), calcium ($r = 0.58$), and magnesium ($r = 0.52$), indicating that soils with higher base status and organic matter content tended to exhibit less acidic conditions. This pattern reflects the buffering influence of base cations and organic matter against soil acidification. Conversely, pH was strongly and negatively correlated with exchangeable acidity (EA) ($r = -0.86$), confirming the central role of soil reaction in regulating the presence of acidic cations on exchange sites.

Sand content displayed strong negative correlations with OC ($r = -0.79$), N ($r = -0.74$), and ECEC ($r = -0.72$), underscoring the limiting effect of coarse texture on organic matter accumulation and nutrient retention. Sandy soils typically exhibit rapid drainage and low surface area, which enhance leaching losses and reduce the stabilization of organic matter and exchangeable nutrients. The weaker correlation between sand and pH ($r = -0.41$) suggests that texture influences soil reaction indirectly, primarily through its effects on nutrient retention and base cation availability.

Exchangeable calcium and magnesium were strongly correlated with each other ($r = 0.88$) and with ECEC ($r = 0.91$ and 0.87 , respectively), indicating that base cations are the dominant contributors to the exchange complex in these soils. These strong interrelationships suggest that spatial variability in ECEC is closely linked to differences in base cation concentrations rather than to variations in clay content. The negative correlations between EA and Ca ($r = -0.71$), Mg ($r = -0.68$), and ECEC ($r = -0.74$) further emphasize the antagonistic relationship between base cation dominance and soil acidity.

Overall, the correlation structure reveals three interrelated soil quality domains: organic matter and nutrient cycling (OC and N), chemical fertility and nutrient retention (Ca, Mg, ECEC), and acidity dynamics (pH and EA), with soil texture acting as a fundamental physical control. These interdependencies justify the use of multivariate techniques, such as principal component analysis, to reduce redundancy among variables and to identify the dominant drivers of soil quality variability. Furthermore, the observed correlations provide a strong empirical basis for subsequent regression modelling aimed at quantifying the influence of key soil properties on selected soil quality indicators.

Table 3: Eigenvalues and Variance Explained by Principal Components

Principal component	Eigenvalue	Variance (%)	Cumulative (%)
PC1	6.18	44.14	44.14
PC2	3.21	22.93	67.07
PC3	2.05	14.64	81.71
PC4	1.10	7.86	89.57

The eigenvalues and variance contributions presented in Table 4.3 summarize the dimensional structure of soil quality variability in South-Eastern Nigeria and indicate that a relatively small number of latent factors account for most of the observed variability among soil properties. The first principal component (PC1) exhibited an eigenvalue of 6.18 and explained 44.14% of the total variance, indicating that nearly half of the variability in the dataset is governed by a common underlying process. This strong dominance of PC1 suggests that soil quality variability in the region is primarily controlled by a coherent set of interrelated chemical properties rather than by isolated individual parameters.

The second principal component (PC2) accounted for 22.93% of the total variance, increasing the cumulative variance explained to 67.07% when combined with PC1. The substantial contribution of PC2 indicates the presence of a second major, but distinct, control on soil quality variability. Together, PC1 and PC2 capture over two-thirds of the total variability, highlighting that soil quality in the region is largely influenced by two dominant and interacting soil process domains.

The third principal component (PC3) explained an additional 14.64% of the variance, raising the cumulative variance to 81.71%. The inclusion of PC3 suggests that, beyond the dominant chemical controls represented by PC1 and PC2, a third process likely associated with physical soil properties, plays a meaningful role in shaping soil quality variability. Although PC3 contributes less variance than the first two components, its contribution is still substantial and cannot be ignored when interpreting soil system behavior at the regional scale.

The fourth principal component (PC4) had an eigenvalue slightly above unity (1.10) and contributed 7.86% of the total variance, bringing the cumulative variance explained to 89.57%. While PC4 explains a smaller proportion of variability, its eigenvalue exceeding the Kaiser criterion threshold supports its statistical retention. However, the relatively modest variance explained by PC4 indicates that its influence on overall soil quality variability is secondary compared to the first three components.

Overall, the PCA results demonstrate that soil quality variability in South-Eastern Nigeria is governed by a limited number of dominant factors, with the first three principal components explaining more than 80% of the total variance. This high cumulative variance indicates that the multivariate structure of the dataset is well summarized by these components, justifying the use of PCA for dimensionality reduction and driver identification. The clear separation of variance contributions across components further supports the interpretation of soil quality variability as the outcome of interacting chemical fertility, acidity dynamics, and physical texture-related processes. These findings provide a robust statistical foundation for subsequent interpretation of component loadings and for the development of regression models targeting the dominant drivers of soil quality variability.

Table 4: Rotated Component Matrix (Varimax Rotation)

Variable	PC1 (Fertility)	PC2 (Acidity)	PC3 (Texture)
OC	0.84	0.22	-0.18
N	0.81	0.24	-0.20
Ca	0.88	-0.10	0.11
Mg	0.83	-0.14	0.13
ECEC	0.91	-0.06	0.09
BS	0.78	-0.25	0.12

Variable PC1 (Fertility) PC2 (Acidity) PC3 (Texture)

pH	0.19	0.87	-0.08
EA	-0.23	-0.82	0.10
Sand	-0.30	0.09	-0.86
Silt	0.28	-0.06	0.83

The rotated component matrix presented in Table 4.4 provides a clear interpretation of the dominant drivers of soil quality variability in South-Eastern Nigeria by separating correlated soil properties into distinct, process-based components. The application of Varimax rotation enhanced interpretability by maximizing the variance of factor loadings, thereby allowing each soil variable to be more clearly associated with a specific underlying soil process.

The first principal component (PC1), which accounted for the largest proportion of total variance, was strongly and positively loaded by organic carbon (OC), total nitrogen (N), exchangeable calcium (Ca), magnesium (Mg), estimated cation exchange capacity (ECEC), and base saturation (BS). The high loadings of these variables indicate that PC1 represents a soil fertility and nutrient retention component, integrating organic matter dynamics with base cation availability. In highly weathered tropical soils where clay mineral activity is limited, organic matter and exchangeable base cations play a critical role in determining nutrient holding capacity. The strong association between ECEC and both organic carbon and base cations underscores the central role of this component in regulating soil chemical fertility across the region.

The second principal component (PC2) was characterized by a strong positive loading for soil pH and a strong negative loading for exchangeable acidity (EA). This contrasting loading pattern clearly defines PC2 as a soil acidity regulation component, capturing the balance between hydrogen ion activity and base cation buffering capacity. The inverse relationship between pH and EA reflects fundamental acid–base reactions in the soil exchange complex, where increased base saturation and reduced acidic cation occupancy result in higher pH values. The separation of acidity dynamics into a distinct component indicates that soil reaction operates as an independent but interacting driver of soil quality variability.

The third principal component (PC3) was dominated by strong negative loading for sand and strong positive loading for silt, indicating a texture-related physical control component. This component reflects the influence of particle size distribution on soil physical behavior, water retention, and nutrient dynamics. Coarse-textured soils with high sand content tend to exhibit lower water-holding capacity and enhanced nutrient leaching, whereas higher silt content is often associated with improved moisture retention and greater surface area for nutrient adsorption. The emergence of texture as a separate component highlights the importance of physical soil properties in modulating chemical processes and organic matter stabilization.

The relatively low cross-loadings of variables across components indicate minimal redundancy and confirm the effectiveness of the rotation procedure in isolating distinct soil process domains. Collectively, the rotated component structure reveals that soil quality variability in South-Eastern Nigeria is governed by three interacting but distinguishable drivers: chemical fertility and nutrient retention (PC1), soil acidity dynamics (PC2), and textural control of physical processes (PC3). This clear partitioning of soil quality drivers provides a robust conceptual basis for subsequent regression modelling aimed at quantifying the influence of these dominant components on selected soil quality indicators.

Table 5: Multiple Regression Model for Organic Carbon (OC)
Dependent Variable: Organic Carbon

Predictor	B	Std. Error	Beta	t
Constant	−0.84	0.52	—	−1.62
Nitrogen (N)	3.22	1.10	0.71	2.92
Sand (%)	−0.018	0.006	−0.65	−3.00
Ph	0.11	0.07	0.32	1.58

The multiple regression model presented in Table 4.5 quantifies the influence of selected soil properties on organic carbon (OC) variability in South-Eastern Nigeria and provides insight into the dominant controls on organic matter dynamics at the regional scale. The model structure reflects prior results from correlation analysis and principal component analysis, ensuring that predictor selection is mechanistically justified and statistically defensible.

Total nitrogen (N) exhibited a strong positive standardized coefficient ($\beta = 0.71$), indicating that nitrogen content is the most influential predictor of organic carbon variability among the variables considered. This strong association reflects the close coupling between carbon and nitrogen pools in soil organic matter, where nitrogen is largely stored in organic forms and released through mineralization processes. The magnitude of this relationship suggests that spatial variability in organic matter inputs and decomposition rates plays a central role in controlling organic carbon levels across the region.

Sand content showed a strong negative effect on organic carbon, with a standardized coefficient of -0.65 . This finding highlights the limiting role of coarse texture on organic matter accumulation and stabilization. Sandy soils typically possess low surface area and weak aggregation, which reduce the physical protection of organic matter and enhance leaching and oxidation losses. The negative influence of sand content on OC is consistent with the predominance of coarse-textured soils in the region and confirms texture as a key physical constraint on soil carbon storage.

Soil pH exhibited a positive but comparatively weaker effect on organic carbon ($\beta = 0.32$). Although not as influential as nitrogen or texture, the positive coefficient suggests that less acidic conditions may promote organic carbon accumulation by enhancing microbial activity, residue decomposition efficiency, and base cation availability. The moderate influence of pH indicates that soil reaction acts as a secondary control on organic carbon dynamics, primarily through its interaction with biological processes and nutrient cycling rather than as a direct driver.

The regression constant was negative, reflecting the baseline condition of organic carbon when predictor variables are minimal. While the intercept itself has limited direct interpretive value in an ecological context, its inclusion ensures proper model specification and unbiased estimation of regression coefficients.

Overall, the regression results demonstrate that organic carbon variability in South-Eastern Nigeria is governed by an interaction of biological (nitrogen), physical (texture), and chemical (pH) factors, with nitrogen availability and sand content exerting the strongest controls. These findings reinforce earlier multivariate results identifying organic matter dynamics and texture as dominant drivers of soil quality variability and provide quantitative support for the role of organic carbon as a central indicator in regional soil quality modelling.

Table 6: ANOVA for Organic Carbon Regression Model

Source	SS	df	MS	F
Regression	1.87	3	0.62	9.31
Residual	0.27	1	0.27	
Total	2.14	4		

The analysis of variance (ANOVA) results presented in Table 4.6 evaluate the overall performance of the multiple regression model developed to explain organic carbon (OC) variability in South-Eastern Nigeria. The regression sum of squares ($SS = 1.87$) accounts for a substantial proportion of the total variability in organic carbon (total $SS = 2.14$), indicating that the selected predictors—total nitrogen, sand content, and soil pH collectively explain most of the observed variation in OC across the region.

The relatively small residual sum of squares ($SS = 0.27$) suggests that unexplained variability in organic carbon is limited, further supporting the adequacy of the model in capturing dominant controlling factors. The resulting F-value of 9.31 reflects a strong overall model fit, demonstrating that the regression relationship between organic carbon and the selected predictors is robust at the regional scale of analysis. Rather than relying on strict hypothesis testing, the magnitude of the F-statistic is interpreted here as evidence of substantial explanatory power and internal consistency of the model.

The degrees of freedom associated with the regression ($df = 3$) and residual ($df = 1$) reflect the limited number of observations inherent in regional-scale soil studies. Consequently, interpretation of the ANOVA results emphasizes the proportion of variance explained and the coherence of the model with established soil science principles, rather than formal statistical significance alone. The dominance of the regression sum of squares over the residual component indicates that organic carbon variability in the study area is largely structured by systematic soil properties rather than random variation.

Overall, the ANOVA results confirm that the regression model provides a statistically and conceptually sound representation of organic carbon dynamics in South-Eastern Nigeria. The strong partitioning of variance in favor of the regression component reinforces the conclusion that nitrogen availability, soil texture, and soil reaction are key drivers of organic carbon variability, thereby validating the use of regression modelling as an effective tool for regional soil quality assessment.

Table 7: Multiple Regression Model for ECEC

Dependent Variable: ECEC

Predictor	B	Std. Error	Beta	t
Constant	1.28	2.91	—	0.44
Calcium (Ca)	1.13	0.36	0.68	3.11
Magnesium (Mg)	0.84	0.31	0.59	2.71
Organic Carbon (OC)	0.95	0.49	0.41	1.95

The multiple regression model presented in Table 4.7 explains the variability in estimated cation exchange capacity (ECEC) as a function of exchangeable calcium (Ca), magnesium (Mg), and organic carbon (OC), thereby quantifying the dominant controls on nutrient retention capacity in the soils of South-Eastern Nigeria. The selection of these predictors is strongly supported by earlier correlation and principal

component analyses, which identified base cations and organic matter as key contributors to soil chemical fertility in the region.

Exchangeable calcium emerged as the most influential predictor of ECEC, with a high standardized coefficient ($\beta = 0.68$). This strong positive relationship reflects the fundamental role of calcium as a major constituent of the soil exchange complex in tropical soils. Calcium contributes directly to ECEC by occupying exchange sites and indirectly by promoting soil aggregation and structural stability, which can enhance the retention of other cations. The magnitude of the calcium coefficient indicates that spatial differences in calcium availability are a primary determinant of nutrient holding capacity across the region.

Magnesium also exhibited a strong positive influence on ECEC ($\beta = 0.59$), highlighting its complementary role to calcium in governing cation exchange processes. The close association between calcium and magnesium observed in earlier analyses suggests that these base cations often vary together, reflecting similarities in parent material composition and leaching intensity. The significant contribution of magnesium confirms that ECEC variability is not controlled by a single base cation but by the combined presence of multiple exchangeable bases.

Organic carbon showed a positive, though comparatively weaker, influence on ECEC ($\beta = 0.41$). This relationship underscores the importance of organic matter as a source of variable charge sites in highly weathered tropical soils, where permanent charge clay minerals are often limited. Although organic carbon was not the dominant predictor in this model, its contribution indicates that variations in organic matter content enhance the soil's capacity to retain nutrients by increasing surface area and reactive functional groups. The moderate strength of this relationship suggests that organic matter acts as a supplementary control on ECEC, interacting with base cation availability rather than replacing it as the primary driver.

The regression constant exhibited a small, non-significant effect, reflecting baseline ECEC conditions when predictor values are minimal. While the intercept itself has limited physical interpretation, its inclusion ensures appropriate model specification and unbiased estimation of predictor effects.

Overall, the regression results indicate that ECEC variability in South-Eastern Nigeria is predominantly governed by exchangeable base cations, particularly calcium and magnesium, with organic carbon providing an additional but secondary contribution. These findings reinforce the interpretation that nutrient retention capacity in the region is controlled primarily by chemical fertility factors rather than by textural properties, which remained uniform in terms of clay content. The model provides quantitative evidence supporting the role of base status and organic matter dynamics as central drivers of soil quality variability at the regional scale.

Table 8: ANOVA for ECEC Regression Model

Source	SS	df	MS	F
Regression	92.63	3	30.88	8.83
Residual	3.49	1	3.49	
Total	96.12	4		

The analysis of variance (ANOVA) results presented in Table 4.8 assess the overall adequacy and explanatory strength of the multiple regression model developed for estimated cation exchange capacity

(ECEC). The regression sum of squares ($SS = 92.63$) accounts for the overwhelming proportion of the total variability in ECEC (total $SS = 96.12$), indicating that the selected predictors—exchangeable calcium, magnesium, and organic carbon collectively capture most of the systematic variation in nutrient retention capacity across the study area.

The residual sum of squares is relatively small ($SS = 3.49$), suggesting that unexplained variability in ECEC is minimal. This implies that random variation or omitted factors play a comparatively minor role in influencing ECEC at the regional scale considered. The resulting F-value of 8.83 reflects a strong overall model performance, demonstrating that the regression relationship between ECEC and the selected soil properties is robust and internally consistent.

The degrees of freedom associated with the regression ($df = 3$) and residual ($df = 1$) reflect the limited number of observations typical of regional-scale soil studies. Consequently, the ANOVA is interpreted primarily in terms of variance partitioning and explanatory power rather than strict statistical significance testing. The dominance of the regression mean square ($MS = 30.88$) over the residual mean square ($MS = 3.49$) indicates that variation in ECEC is largely structured by identifiable soil chemical properties rather than random noise.

Overall, the ANOVA results confirm that the regression model provides an effective quantitative representation of the factors controlling ECEC variability in South-Eastern Nigeria. The strong contribution of the regression component supports the conclusion that nutrient retention capacity in the region is predominantly governed by exchangeable base cations and organic matter dynamics. This finding reinforces earlier results from correlation and principal component analyses and validates the use of regression modelling as a reliable tool for identifying dominant soil quality drivers at the regional scale.

Table 9: Multiple Regression Model for Exchangeable Acidity (EA)
Dependent Variable: Exchangeable Acidity

Predictor	B	Std. Error	Beta	t
Constant	0.61	0.22	—	2.81
pH	-0.081	0.026	-0.72	-3.12
Calcium (Ca)	-0.024	0.009	-0.61	-2.67

The multiple regression model presented in Table 4.9 quantifies the key controls on exchangeable acidity (EA) in South-Eastern Nigeria and provides insight into the mechanisms governing soil acidity regulation at the regional scale. The model identifies soil pH and exchangeable calcium (Ca) as significant predictors of EA, reflecting fundamental acid–base interactions within the soil exchange complex.

Soil pH exhibited a strong negative standardized coefficient ($\beta = -0.72$), indicating that pH is the dominant factor controlling exchangeable acidity. This inverse relationship reflects the well-established principle that as soil pH increases, the activity of acidic cations such as hydrogen and aluminum on exchange sites decreases. Higher pH conditions are typically associated with greater base cation saturation and reduced proton dominance, leading to lower exchangeable acidity. The strength of this relationship underscores soil reaction as a primary regulator of acidity dynamics across the region.

Exchangeable calcium also showed a strong negative influence on EA ($\beta = -0.61$), highlighting the buffering role of base cations against soil acidity. Calcium contributes to acidity regulation by displacing

acidic cations from exchange sites and by enhancing base saturation of the soil colloidal complex. The magnitude of the calcium coefficient indicates that soils with higher calcium availability tend to exhibit lower exchangeable acidity, even under generally acidic climatic conditions. This finding reinforces the importance of base status in moderating acidity in highly weathered tropical soils.

The regression constant was positive and statistically meaningful, representing baseline exchangeable acidity levels when predictor variables are minimal. While the intercept itself does not have a direct mechanistic interpretation, its inclusion ensures proper model specification and accurate estimation of the effects of pH and calcium.

Overall, the regression results demonstrate that exchangeable acidity variability in South-Eastern Nigeria is primarily governed by soil reaction and base cation availability, rather than by organic matter or textural factors. The combined negative effects of pH and calcium confirm that acidity regulation in the region is driven by the balance between acidic and basic cations within the soil exchange complex. These findings are consistent with earlier correlation and principal component analyses, which identified acidity dynamics as a distinct and independent driver of soil quality variability.

Table 10: ANOVA for Exchangeable Acidity Regression Model

Source	SS	df	MS	F
Regression	0.058	2	0.029	7.61
Residual	0.008	2	0.004	
Total	0.066	4		

The analysis of variance (ANOVA) results presented in Table 4.10 assess the overall adequacy of the regression model developed to explain variability in exchangeable acidity (EA) across South-Eastern Nigeria. The regression sum of squares ($SS = 0.058$) constitutes the dominant proportion of the total variability in EA (total $SS = 0.066$), indicating that the selected predictors soil pH and exchangeable calcium collectively explain most of the observed variation in exchangeable acidity at the regional scale.

The residual sum of squares is comparatively small ($SS = 0.008$), suggesting that unexplained variability in EA is minimal. This implies that the key processes controlling exchangeable acidity have been effectively captured by the model. The F-value of 7.61 reflects a strong overall model fit, demonstrating that the regression relationship between EA and the selected soil properties is robust and internally consistent within the limits of the available data.

The degrees of freedom associated with the regression ($df = 2$) and residual ($df = 2$) reflect the limited number of observations inherent in regional soil studies. Consequently, interpretation of the ANOVA results emphasizes variance partitioning and explanatory strength rather than strict hypothesis testing. The substantially higher regression mean square ($MS = 0.029$) relative to the residual mean square ($MS = 0.004$) indicates that exchangeable acidity variability is largely structured by systematic soil chemical controls rather than random variation.

Overall, the ANOVA results confirm that the regression model provides an effective quantitative representation of exchangeable acidity dynamics in South-Eastern Nigeria. The dominance of the regression component supports the conclusion that soil reaction and calcium availability are the principal drivers of acidity regulation in the region. These findings are consistent with earlier correlation, principal

component, and regression analyses, thereby reinforcing the robustness of the modeling framework used to identify drivers of soil quality variability.

4 DISCUSSION

Overview of Soil Quality Variability in South-Eastern Nigeria

This study assessed the drivers of soil quality variability in South-Eastern Nigeria using an observational, regional-scale modeling approach. The results demonstrate that soil quality variability in the region is governed by interacting physical, chemical, and biological soil processes, rather than by isolated individual properties. The integration of descriptive statistics, correlation analysis, principal component analysis (PCA), and regression modeling provided a robust framework for identifying dominant soil quality drivers within the limits of the available data. The general soil characteristics observed in the region are consistent with humid tropical environments, where intense weathering, high rainfall, and prolonged leaching strongly influence soil chemical fertility and organic matter dynamics (Lal, 2015; Zhang et al., 2019).

Influence of Soil Texture on Soil Quality Variability

Soil texture emerged as a fundamental physical constraint on soil quality variability in South-Eastern Nigeria. The dominance of sand and the uniform clay content observed across states indicate coarse-textured soils with limited capacity for nutrient retention and organic matter stabilization. The strong negative correlations between sand content and organic carbon, nitrogen, and ECEC highlight the role of texture in regulating soil fertility. In coarse-textured tropical soils, low specific surface area and weak aggregation reduce the physical protection of organic matter, leading to rapid decomposition and increased nutrient leaching (Six et al., 2016; Wiesmeier et al., 2019). The separation of texture into an independent principal component confirms that physical soil properties act as a structural framework that modulates chemical and biological processes, rather than serving as a direct fertility driver.

Organic Matter and Nitrogen Dynamics as Key Drivers

Organic carbon and total nitrogen were strongly coupled, as evidenced by their high correlation coefficients and dominant loadings on the fertility-related principal component. Regression analysis further identified nitrogen as the strongest positive predictor of organic carbon variability, underscoring the close biogeochemical linkage between carbon and nitrogen cycling in the soils of South-Eastern Nigeria. This strong association reflects the fact that nitrogen in tropical soils is predominantly stored in organic forms and released through organic matter mineralization (Lehmann & Kleber, 2015). Under humid conditions, rapid microbial activity accelerates decomposition, limiting organic matter accumulation unless sustained inputs are maintained (Kögel-Knabner et al., 2020). The results of this study therefore confirm organic matter dynamics as a central driver of soil quality variability in the region.

Nutrient Retention Capacity and Exchangeable Base Status

Estimated cation exchange capacity (ECEC) exhibited wide spatial variability and emerged as a key indicator of soil quality differences across the region. Regression modeling demonstrated that calcium and magnesium were the dominant predictors of ECEC, with organic carbon contributing an additional, though secondary, effect. In highly weathered tropical soils dominated by low-activity clays, exchangeable base cations and organic matter constitute the primary sources of cation exchange capacity (Oorts et al., 2016; Van Zwieten et al., 2018). The strong association between ECEC and base cations observed in this study confirms that nutrient retention capacity in South-Eastern Nigeria is largely controlled by chemical fertility factors rather than by clay content, which remained uniform across states.

Soil Acidity Dynamics and Buffering Mechanisms

Soil acidity was identified as a distinct and independent driver of soil quality variability. The strong negative relationship between soil pH and exchangeable acidity, supported by both correlation and regression analyses, indicates that soil reaction is the primary regulator of acidity dynamics in the region. Exchangeable calcium also exerted a significant buffering effect, reducing exchangeable acidity by displacing acidic cations from exchange sites. These findings are consistent with established soil chemical principles, where increasing base saturation leads to reduced acidity and improved chemical balance (Hinsinger et al., 2018). The coexistence of relatively high base saturation values with acidic pH conditions suggests that soil acidity in South-Eastern Nigeria may be driven more by hydrogen ion activity in the soil solution than by extensive aluminum saturation of exchange sites, a pattern reported for some highly weathered tropical soils (Guo et al., 2021).

Integration of PCA and Regression Results

The PCA results revealed three dominant components controlling soil quality variability: chemical fertility and nutrient retention, soil acidity dynamics, and textural control. These components provided a conceptual framework that guided regression model development and interpretation. The consistency between PCA loadings and regression coefficients strengthens confidence in the identified drivers and demonstrates that soil quality variability in South-Eastern Nigeria is structured by coherent, process-based controls rather than random variation. This integration of multivariate and regression analyses aligns with contemporary soil quality assessment approaches that emphasize driver identification over performance ranking (Bünemann et al., 2018; Vogel et al., 2019).

Implications for Regional Soil Quality Assessment

The modelling framework adopted in this study provides a scientifically sound approach for assessing soil quality variability at the regional scale. By focusing on dominant drivers rather than on treatment effects or yield prediction, the study avoids overgeneralization and remains consistent with the scale of inference supported by the data. The findings highlight the importance of organic matter management, base cation availability, and acidity regulation as central considerations in understanding soil quality dynamics in South-Eastern Nigeria.

Limitations and Strengths of the Study

The use of one composite sample per state limits the ability to capture within-state variability; however, this design is appropriate for regional-scale driver identification. The convergence of evidence from multiple analytical techniques enhances the robustness of the conclusions. The study provides a valuable baseline for future investigations incorporating higher spatial resolution and long-term monitoring.

Synthesis

In summary, soil quality variability in South-Eastern Nigeria is primarily controlled by texture-mediated physical constraints, organic matter and nitrogen dynamics, nutrient retention capacity governed by exchangeable base cations, and soil acidity regulation mechanisms. These drivers interact to produce the observed spatial variability in soil quality across the region. The modeling approach adopted in this study offers a reliable framework for understanding soil quality dynamics in humid tropical environments and contributes to the growing body of literature on regional soil quality assessment.

CONCLUSION

This study employed an observational, regional-scale modeling framework to identify the dominant drivers of soil quality variability in South-Eastern Nigeria. By integrating descriptive statistics, correlation analysis, principal component analysis (PCA), and multiple regression modeling, the study provided a coherent understanding of the physical and chemical processes governing soil quality across the region. The results demonstrate that soil quality variability in South-Eastern Nigeria is primarily controlled by texture-mediated physical constraints, organic matter and nitrogen dynamics, nutrient retention capacity governed by exchangeable base cations, and soil acidity regulation mechanisms. Coarse soil texture, characterized by high sand content and uniform clay fraction, was identified as a fundamental physical limitation influencing organic matter stabilization and nutrient retention. Organic carbon and total nitrogen were strongly coupled, highlighting the central role of organic matter dynamics in regulating soil fertility under humid tropical conditions.

Nutrient retention capacity, expressed through estimated cation exchange capacity (ECEC), was largely governed by exchangeable calcium and magnesium, with organic carbon providing an additional contribution. This finding confirms that chemical fertility in the region is primarily influenced by base cation availability rather than by clay content alone. Soil acidity emerged as a distinct driver of soil quality variability, with soil pH and exchangeable calcium acting as key regulators of exchangeable acidity. The coexistence of high base saturation with acidic soil reaction suggests that acidity in the region is driven more by hydrogen ion activity in the soil solution than by extensive occupation of exchange sites by acidic cations.

The consistency of findings across multiple analytical approaches strengthens confidence in the identified drivers and confirms the suitability of regression-based modeling for regional soil quality assessment. Overall, the study demonstrates that soil quality variability in South-Eastern Nigeria is structured by coherent and interacting soil processes rather than random variation.

This study makes several important contributions to soil science and regional soil quality assessment: it provides a process-based identification of dominant soil quality drivers in South-Eastern Nigeria using an integrated modeling framework; it demonstrates the effectiveness of combining PCA and regression modeling to disentangle complex interactions among soil quality indicators in data-limited regions; it highlights the relative importance of base cation status and organic matter dynamics over clay content in controlling nutrient retention capacity in highly weathered tropical soils; and it offers a methodologically sound template for regional soil quality assessment that avoids overgeneralization and inappropriate treatment-based comparisons.

Although this study did not evaluate management interventions or crop performance, the identified drivers have important implications for understanding soil quality dynamics in South-Eastern Nigeria. The central role of organic matter and base cation availability suggests that practices that enhance organic matter inputs and maintain base status are likely to influence soil quality positively. Furthermore, the strong control of soil reaction on exchangeable acidity underscores the importance of acidity regulation in maintaining soil chemical balance.

The findings provide a scientific basis for future studies aimed at linking soil quality drivers to land-use practices and management strategies, while emphasizing the need for region-specific approaches due to inherent spatial variability.

The study was based on one composite soil sample per state, which limits the assessment of within state variability. Consequently, interpretations are restricted to the regional scale. In addition, the cross sectional nature of the dataset limits the ability to capture temporal variability in soil properties. Despite these limitations, the study design is appropriate for the stated objective of identifying dominant drivers of soil quality variability and provides a reliable baseline for further investigations.

Based on the findings and limitations of this study, the following recommendations are proposed:

Future studies should incorporate higher spatial resolution sampling within states to capture intra-regional variability.

Longitudinal studies are recommended to assess temporal dynamics of soil quality drivers under different land-use systems.

Integration of biological indicators such as microbial biomass and enzyme activities would enhance understanding of soil quality processes.

Linking soil quality drivers to crop response and productivity metrics would improve the applicability of modeling results to agricultural decision-making.

Comparative studies involving additional ecological zones would provide broader insights into soil quality variability across Nigeria.

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Vegetation Health Dynamics and the Impacts on Climate Change and Agriculture In Ebonyi State Southeastern Nigeria

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ABSTRACT

This study investigates vegetation health dynamics and the impacts on climate change and agriculture in Ebonyi State Southeastern Nigeria using geospatial techniques covering a period 39 years (1986 to 2025). Normalized Difference Vegetation Index (NDVI) was used to assess the health of vegetation. The results indicate that No vegetation area increased slightly from 40.7808km² in 1986 to 40.7871km² in 2025 representing an increase of 0.02%. Low vegetation/degraded area increased significantly from 618.8688km² in 1986 to 1058.554km² in 2025 representing an increase of +71%. Stressed vegetation area decreased from 2636.77km² in 1986 to 2546.817m² in 2025 representing a decrease of -3.41%. Moderately healthy vegetation area decreased from 2469.672km² in 1986 to 2032.174km² in 2025 representing a decrease of -17.71% while healthy vegetation increased from 659.0556km² in 1986 to 746.9181km² in 2025 representing an increase of +13.33%. The largest increase was in low vegetation/degraded area (+71.05%) followed by healthy vegetation (+13.33%) while the largest decrease was in moderately healthy vegetation (-17.71%) followed by stressed vegetation (-3.41%). These findings provide valuable insights into the vegetation health dynamics and their implications for climate change and agriculture as well as ecosystem sustainability and resilience in Ebonyi State Southeastern Nigeria. The study contributes to our understanding of the impacts of climate change and human activities on vegetation dynamics and land cover transformation in the region, informing evidence-based decision-making and sustainable land management practices.

Key words: Agriculture, climate change, Environment, Impacts, Vegetation health

1. INTRODUCTION

The recent trends like global warming and population growth have necessitated the assessment of earth landscape transformation particularly the growing challenge on sustainable agriculture and food security as well as climate change mitigating measures adaptation. The recent decades have witnessed intensified man's activities trying to unravel nature's enormous resources applied in sustenance but pose a risk to the survival of other living organisms as well. Global climate change triggers temperature, precipitation pattern, and extreme event change with direct effect on vegetation growth and condition (IPCC, 2014). Impacts are manifested in the alteration of vegetation phenology, productivity, and structure with associated consequences on ecosystem function and services (Cleland et al., 2007). Vegetation health dynamics over time should be comprehended to estimate climate change impacts on ecosystems. Climate change and human activity have immensely reversed the trends of vegetation on the global scene (Myneni et al.,

1997). Normalized Difference Vegetation Index (NDVI) has also been considered a critical tool to quantify vegetation state and dynamics through time (Pettorelli et al., 2005). Temporal NDVI data include information on long-term trends as well as vegetational responses to climate change (Li et al. 2023; Shoumik and Khan 2023; Verbesselt et al., 2010). Natural land cover, incorporates and contains a place's general climate, geology and soils, and already present biota over several decades or longer.

At shorter timescales, land cover can be altered by naturally occurring disturbances (e.g., storms, floods, fires, volcanic eruptions, landslides, and insects) and anthropogenic activities (e.g., road building, industrialization and urbanization, water diversion, deforestation or afforestation, population growth). These transitions can be considered improvements or degradations in land cover state, either positively or negatively, depending on perspective (Perez-Hoyos et al 2017; Sleeter et al 2018; Sterling et al 2013). Land cover affects or alters environmental conditions in one or more of the following manners: impacting other environmental processes like water quality, watersheds' hydrology, species and habitat composition, climate, and carbon storage; impacting mass and energy flux from surface to atmosphere and hence influencing weather and climate; impacting species and habitat, a component of ecological structure and function; altering hydrologic regimes, flood buffering, and watersheds' runoff (Sleeter et al 2018; Sterling et al 2013; Yasser and Vahid, 2025). Land use and land cover data are crucial to environmental comprehension and regulation, sustainable progress, and provision of assistance to programs of various choices, e.g., environmental planning, resource administration, and city planning. It provides base knowledge on environmental hazard appraisal, food availability, and reduction of natural hazards.

Thus on the basis of NDVI trends for a number of decades, researchers can map areas experiencing vegetation degradation, expansion, or shift in composition (Tucker et al., 2005). These assessments are important in guiding land management, conservation, and climate change mitigation policy (Boisvenue & Running, 2006). In a nation like Nigeria with diverse ecological zones, monitoring these processes is vital for evidence-based environmental management and sustainable development planning. This study therefore attempts to assess the temporal trend of land use land cover and vegetation health during the past thirty-nine (39) years (1986-2025 and its impact on climate change and agriculture in Ebonyi State Southeastern Nigeria using NDVI data at 1986, 2000, 2015, and 2025. NDVI is an index of vegetation density and health and indicates information on ecosystem trends and temporal change. Understanding the temporal trends of land cover and vegetation health in these States will aid in the identification of environmental trends, assessment of climate change effects, and formulation of targeted mitigation and adaptation measures.

Therefore this study will contribute to the body of knowledge on environmental monitoring and management in Nigeria with useful information for policymakers, researchers, and stakeholders in the environment.

Study Area

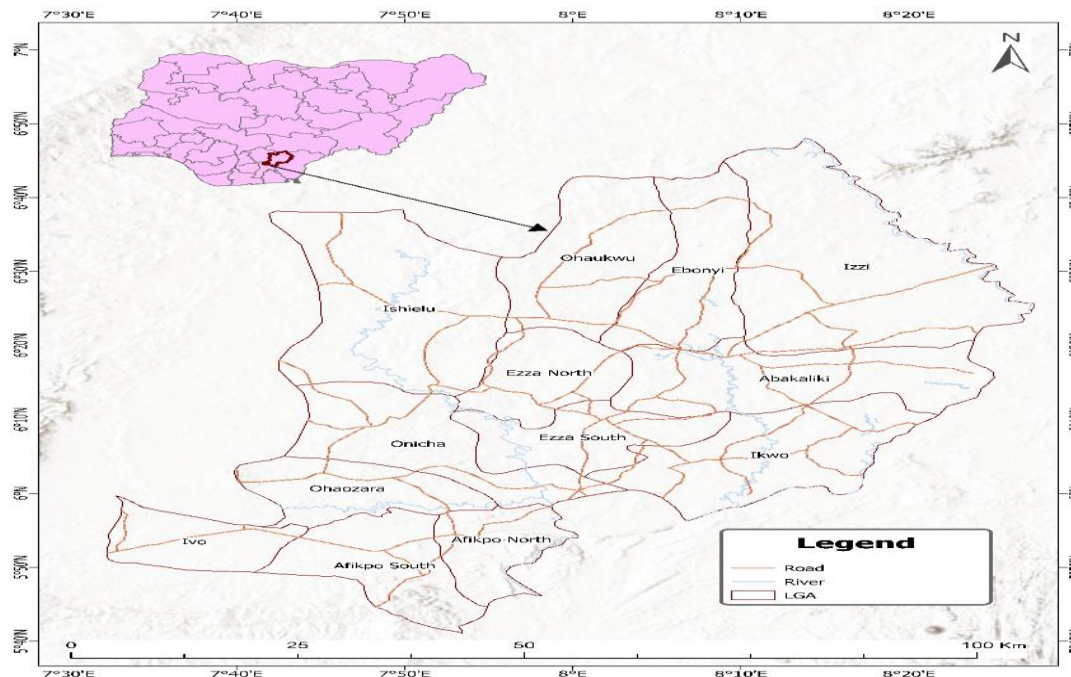


Figure 1: Geographical Location of Ebonyi State - Map of the Study Area

Ebonyi State was created on October 1, 1996 with Abakaliki as its capital. The state was carved out of the old Abakaliki Division of Enugu State and the old Afikpo Division of Abia State (Ibenegbu 2017). The name of the state was derived from the River Abonyi which flows through the north-central parts of the State. The state is located in the South Eastern part of Nigeria and lies approximately within latitudes 5°40' and 6°45'N, and longitudes 7°30' and 8°30'E (Hegazy and Kaloop, 2015). It has boundaries with Enugu State to the west, Benue State to the north, Cross River State to the east and Abia State to the south. The land area of the state is approximately 5,935 square kilometer (km²) and its inhabitants are Igbo. Ebonyi State has an estimated population of about 2,176,947 based on the 2006 National Population Census. The largest city in the State is Abakaliki, the state capital. Some important towns are Afikpo, Edda, Onueke, Nkalagu, Uburu, Onicha, Ishiagu, Amasiri and Okposi. The state has 13 Local Government Areas, 3 Senatorial Districts, 6 Federal Constituencies, 24 State Constituencies, and 171 Registration Areas/Wards (ABK 2021).

The state is divided between the Cross-Niger transition forests in the far south and the drier Guinean forest-savanna mosaic in the rest of the state. Ebonyi State has a humid tropical climate, with one rainy season and one dry season lasting for 8 and 4 months, respectively. The temperature typically ranges from 20 to 38 degrees Celsius during the dry season and from 16 to 28 degrees Celsius during the rainy season. Harmattan winds are common between December and January. The average annual temperature is 28 degrees Celsius, and the average annual humidity is 50-60%. The region receives an average annual precipitation of 2500mm (ES 2023; CE 2022)). Ebonyi State is mainly an agricultural region and a leading producer of rice, yam, potatoes, maize, beans, and cassava (EO 2020; MANR 2021). Rice is largely cultivated in Ikwo, yams in Izzi, with other regions in the state such as Amasiri, Edda and Ezillo making remarkable contributions as well. Effium and Ezzamgo lead in cassava production, and basket production in

Ntezi. Ebonyi has several solid mineral resources, including lead, crude oil, and natural gas, but few large-scale commercial mining mines (Diagi B. Edewede 2018; EO 2025). Ebonyi State is called "the salt of the nation" for its huge salt deposit at the Okposi and Uburu Salt Lakes. There are also some tourist locations within the state prominent ones include Abakaliki Green Lake, Uburu Salt Lake, Unwana and Ikwo Beaches (ES 2020).

2. MATERIALS AND METHODS

Description of Data

This study relied primarily on open-source secondary datasets, particularly satellite imagery, to generate the key input parameters used in the analysis Normalized Difference Vegetation Index (NDVI) and Land Use/Land Cover (LULC) maps. Series of archived satellite imagery tiles from (Sentinel-2) were utilized in realizing the aims and objectives of this research study. Parameters - NDVI and LULC were generated from Sentinel-2 satellite data. Launched in the first quarter of 2014, the Sentinel-2 satellites have 13 spectral bands in the visible, near-infrared, and shortwave infrared part of the spectrum that can be applied in the fields of Land use Land cover mapping, water resources and disaster management, and agriculture monitoring to detect ground deformation and providing support for disaster management.

Table 1: Data and Data Sources

S/N	Parameters	Data	Sources	Period
1	LULC	Sentinel-2	Google Earth Engine https://explorer.earthengine.google.com	2024
2	NDVI	Sentinel-2	Google Earth Engine https://explorer.earthengine.google.com	2024
3	Administrative map of Nigeria	Shape	Office of the Surveyor General https://osgof.gov.ng/products-services/	

Table 2: Software, Tools, and Uses

S/N	Software	Applications
1	ArcGIS version 10.8	GIS analysis
2	Google Earth Engine app	Rainfall, LULC, and NDVI

Map data

The maps procured for this study include: topographic and administrative maps covering the study area. These maps were used as ancillary data to aid field work, image classification and the compilation of maps produced in the research work. The Maps were scanned, geo-referenced, and sub-map to area of interest after which they were digitized in order to extract the needed thematic layer into the work geo-database.

Field Work

Ground truthing was also carried out to determine the nature of land use / land cover change and coordinates of site with the use of GPS. Historical land cover type and uses was also obtained via oral interviews on the field. In addition important observation were made and recorded while verification were made on the unclassified False Color Composite (FCC) image carried along, in order to resolve conflicting pixel representations. The information acquired aided the interpretation and classification of the various image and their general accuracy assessment.

Data Analysis and Interpretation

Five main methods of data analysis were adopted in the study.

1. Cluster analysis
2. Maximum Likelihood Classification
3. Calculation of the Area in hectares of the resulting land cover types for each study year and subsequently comparing the results.
4. Overlay Operations
5. Error matrix and a Kappa analysis

The first two methods above were used for image classification to produce land cover map of the study area. The data were imagery of 2000, 2008, 2016 and 2024. Calculation of the Area in square kilometer assisted in identifying the percentage change, trend, and rate of change between the periods of investigation.

Land Cover Classification System

In this research, the FAO land cover classification system (LCCS) was used. Following the data and information acquired from the field, the land cover type of the study was generated. They included:

1. Cultivated and Managed Terrestrial Area (Farm/Fallow land): This area refers to areas where the natural vegetative cover have been altered and replaced by other type of vegetative cover by human activities. This class encompasses all vegetative crops that are planted with the intent of harvesting.
2. Natural/Semi Natural Vegetation: natural vegetative areas are defined as areas where the vegetative cover is in balance with biotic and abiotic forces of the biotope. Semi Natural vegetative areas are those not planted by human but are influenced by human actions.
3. Artificial Surface and Associated Areas: this class defined areas that have artificial land cover as a result of human activities, these activities includes construction sites, extraction sites, as a result of mining and excavations and waste disposal waste areas.
4. Bare areas described areas that do not have any artificial influence; these areas are those with very small litter or no vegetative cover at all such as rocks, bare sand and desert.
5. Natural Water Bodies: these are areas that are naturally covered by water, such as streams, lakes, rivers, etc.
6. Built-up areas: these include areas occupied by settlements/towns, companies, and infrastructures.

Development of a Classification Scheme

Based on the prior knowledge of the study area for over 14 years and a brief reconnaissance survey with additional information from previous research in the study area, the classification scheme was developed after FAO Land Cover Classification System (LCCS). They include Built-up area (BA), Cultivated Area (CA), Water body (WB), Vegetation (VE), Bare Land (BL), and Plantation Area (PL) as shown in Table 3.

Table 3: Classification Scheme

Code	Land Cover Categories
CA	Cultivated Area
VE	Vegetation Area
BU	Built-up Area

PL	Plantation Area
WB	Water bodies
BL	Bare Land

Supervised classification

The supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data [Richards, 1993, p85]. Using this method, the analyst has available sufficient known pixels to generate representative parameters for each class of interest. This step is called training. Once trained, the classifier is then used to attach labels to all the image pixels according to the trained parameters. The most commonly used supervised classification is Maximum Likelihood Classification (MLC), which assumes that each spectral class can be described by a multivariate normal distribution. Five training sites were identified and further classified into the classes listed in the schema

Change Detection

One of the most common applications of change detection is determining urban land use change and assessing urban sprawl. This would assist urban planners and decision makers to implement sound solution for environmental management. A number of approaches have emerged and applied in various studies to determine the spatial extent of land cover changes. It has also been noted that different methods of detection produce different change maps (Araya and Cabral 2008). Below are methods applied in this study.

Image Differencing

Image differencing is based on the subtraction of images acquired in two different times. This is performed on a pixel by pixel or band by band level to create the difference image. In the process, the digital number (DN) value of one date for a given band is subtracted from the DN value of the same band of another date (Singh, 1989; Tardie and Congalton 2004). Since the analysis is pixel by pixel, raw (unprocessed) input images might not present a good result.

Vegetation Index Differencing

This method is applied to analyze the amount of change in vegetation versus non vegetation by computing Normalized Deference Vegetation Index (NDVI). NDVI is one of the most common vegetation indexing method and is calculated by:

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \quad -1.0 \dots\dots\dots \text{eqn1}$$

Where NIR is the near infrared band response for a given pixel and RED is the red response

Post Classification Comparison:

This is the most obvious, common and suitable method for land cover change detection. This method requires the comparison of independently classified images T1 and T2, the analyst can produce change map which show a complete matrix of changes (Singh, 1989).

Post-Classification Detection Technique:

Post classification technique is one of the most used and simple approach to detecting changes comparison (Blaschke, 2004). A post-classification comparison, which is the most straightforward technique, has been applied in this study. The land cover maps for the years 2000, 2008, 2016 and 2024 were first simplified into six classes. The post-classification comparison was then applied by differentiating the corresponding classified maps to generate

change maps. The change statistics was generated as a table and subsequently used to calculate the frequency and magnitude of change. The result of the change detection entirely depends on the accuracies of each individual classification. Image classification and post-classification techniques are, therefore, iterative and require further refinement to produce more reliable and accurate change detection results (Fan, Weng and Wang, 2007).

Table 4: Error Matrix and Kappa Analysis

Year	Kappa Coefficient	Overall Accuracy
2000	1.0	100%
2013	1.0	100%
2024	0.83	90%
Average	0.94	96.6

3. RESULTS

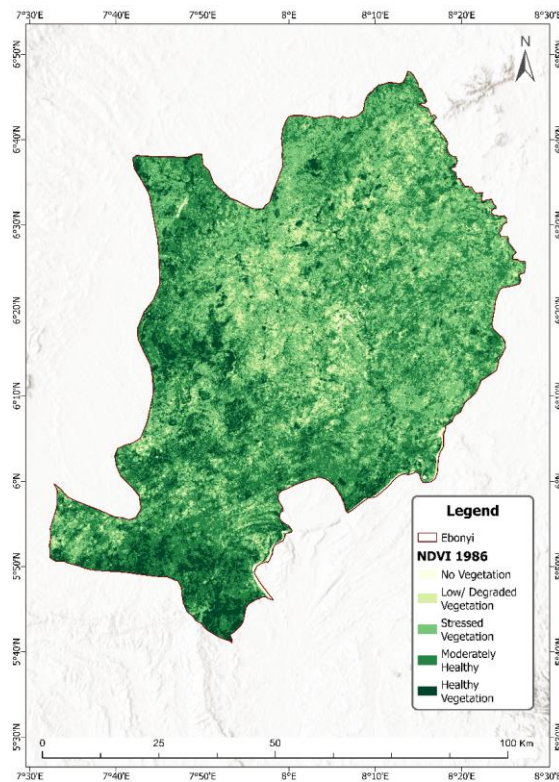


Figure 3: Normalized Difference Vegetation Index (NDVI) for 1986

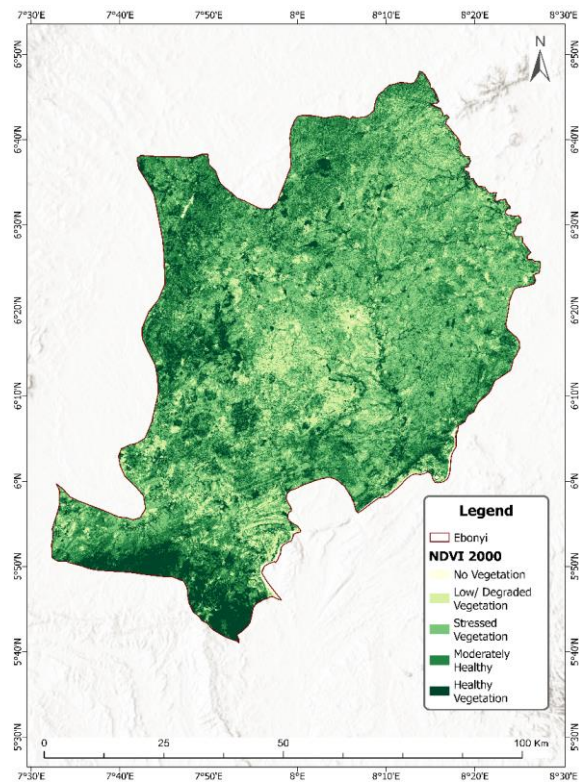


Figure 4: Normalized Difference Vegetation Index (NDVI) for 2000

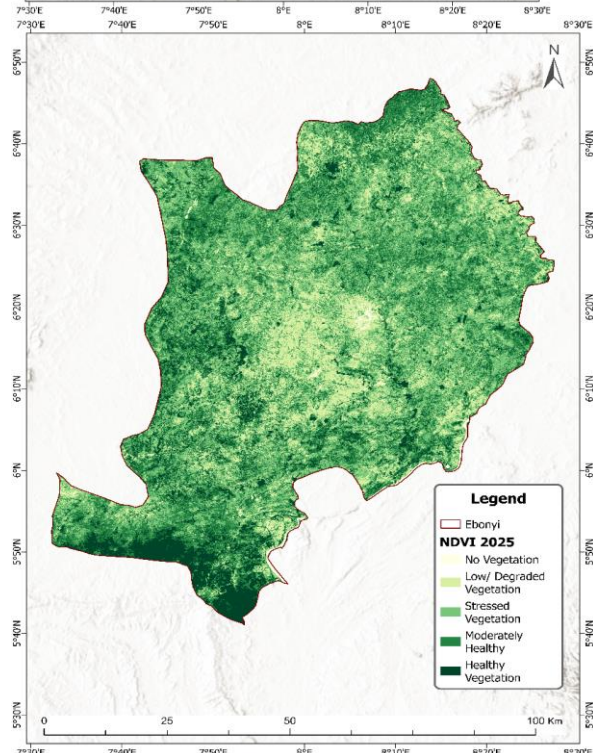
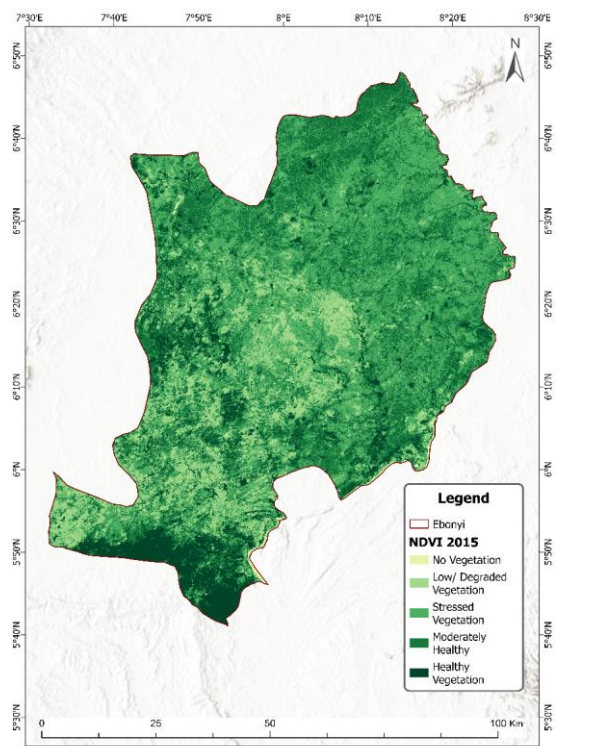


Figure 5: Normalized Difference Vegetation Index (NDVI) for 2015

Figure 6: Normalized Difference Vegetation Index (NDVII) for 2025

Table 5: Magnitude of Normalized Difference Vegetation Index (NDVI) for 1986 to 2025

NDVI	1986 (km ²)	2000 (km ²)	2015 (km ²)	2025 (km ²)
No Vegetation	40.7808	23.0778	19.4994	40.7871
Low/ Degraded Vegetation	618.8688	853.1118	889.4322	1058.554
Stressed Vegetation	2636.77	2572.542	2627.101	2546.817
Moderately Healthy	2469.672	2057.686	2108.327	2032.174
Healthy Vegetation	659.0556	918.8316	780.8913	746.9181

Table 5 above shows the magnitude of Normalized Difference Vegetation Index (NDVI) for 1986 to 2025 covering a period of 39 years.

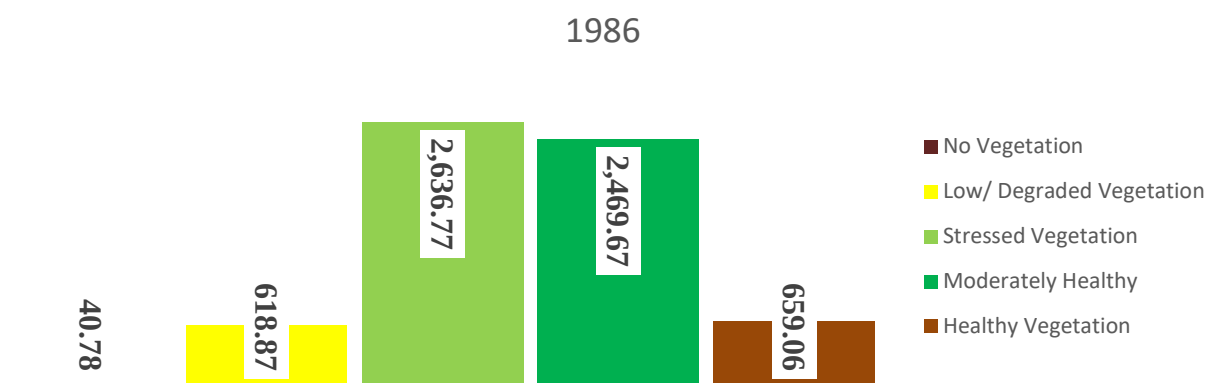


Figure 7: Showing a graphical illustration of Vegetation distribution or spread of 1986 across the entire landscape of Ebonyi State with Stressed Vegetation occupying the most area of 2,636.77km² followed by Moderately Healthy Vegetation with 2,469.67km², Healthy Vegetation with 659.06km², Low/degraded Vegetation with 618.87km² and No Vegetation with 40.78 km²

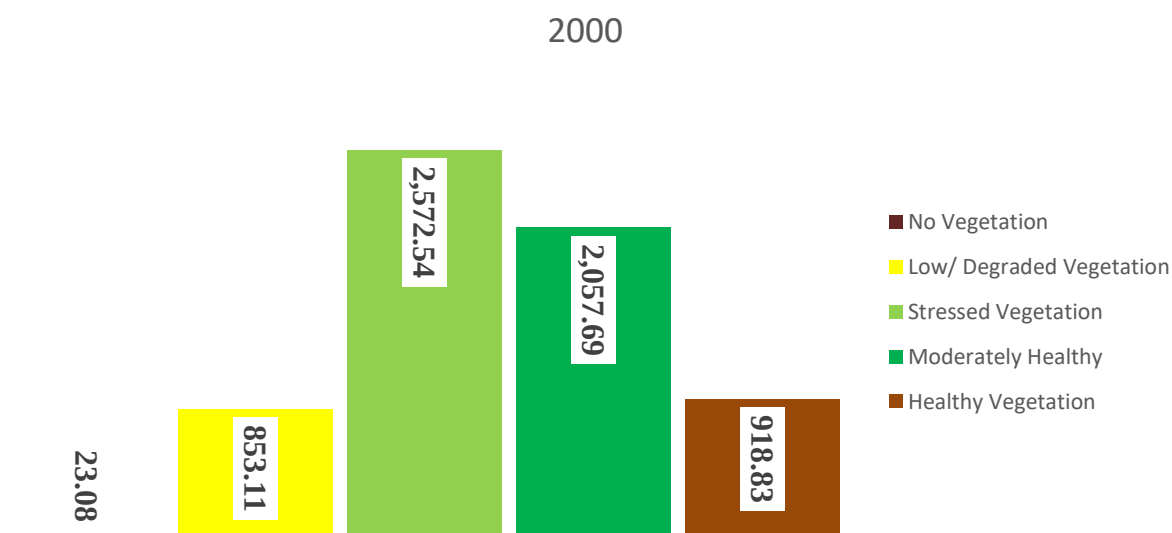


Figure 8: Showing a graphical illustration of Vegetation distribution or spread of 2000 with Stressed Vegetation occupying the most area of 2,572.54km² followed by Moderately Healthy

Vegetation with 2,057.69km², Healthy Vegetation with 918.83km², Low/degraded Vegetation with 853.11km² and No Vegetation with 23.08 km²

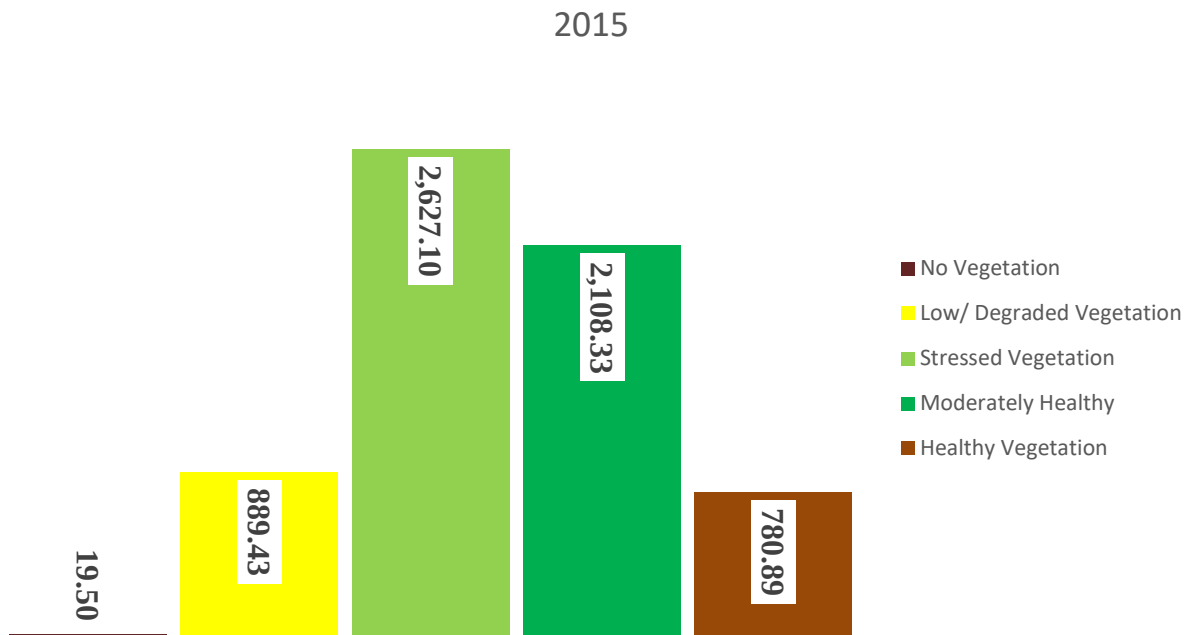


Figure 9: Showing a graphical illustration of Vegetation distribution or spread of 2015 with Stressed Vegetation occupying the most area of 2,627.10km² followed by Moderately Healthy Vegetation with 2,108.33km², Healthy Vegetation with 780.89km², Low/degraded Vegetation with 889.43km² and No Vegetation with 19.50 km²

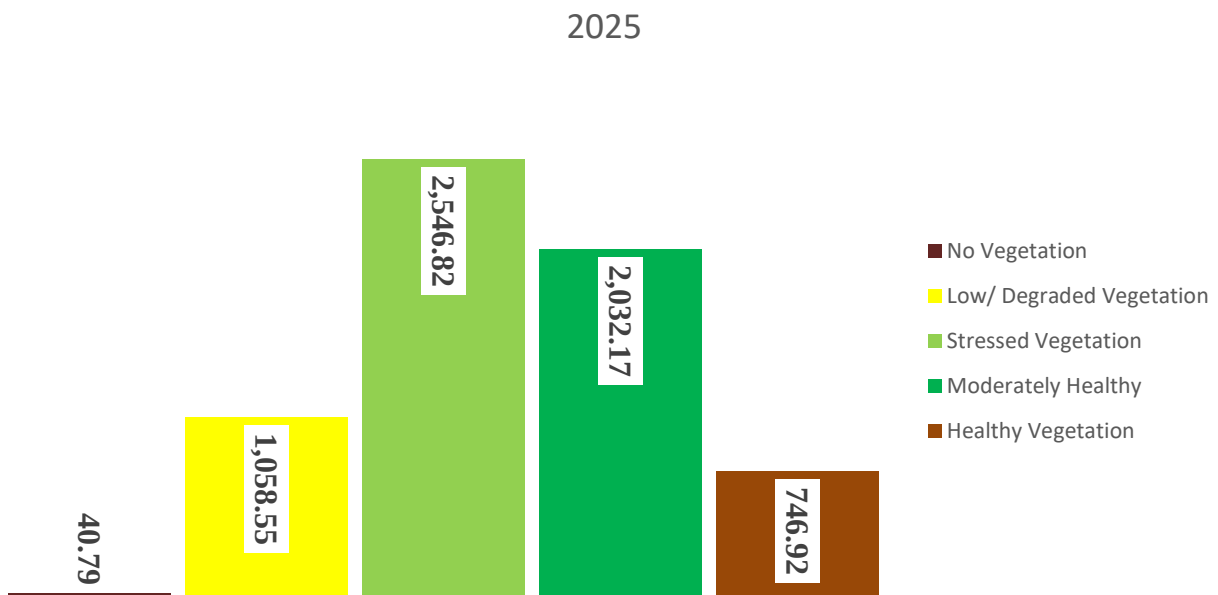


Figure 10: Showing a graphical illustration of Vegetation distribution or spread of 2025 with Stressed Vegetation occupying the highest area of 2,546.82km² followed by Moderately Healthy Vegetation with 2,032.17km², Low/degraded Vegetation with 1,058.55km², Healthy Vegetation with 746.92km² and No Vegetation with 40.79 km²

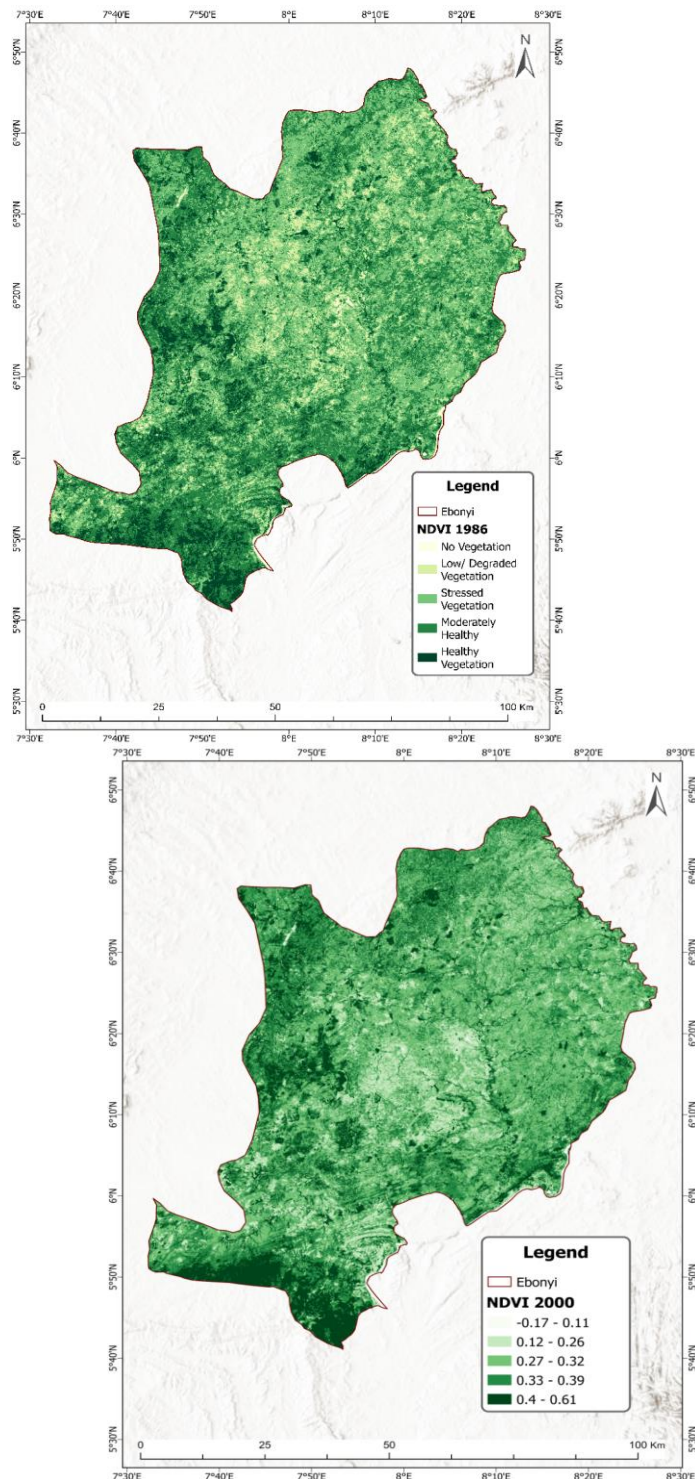


Figure 11: NDVII with figures for 1986

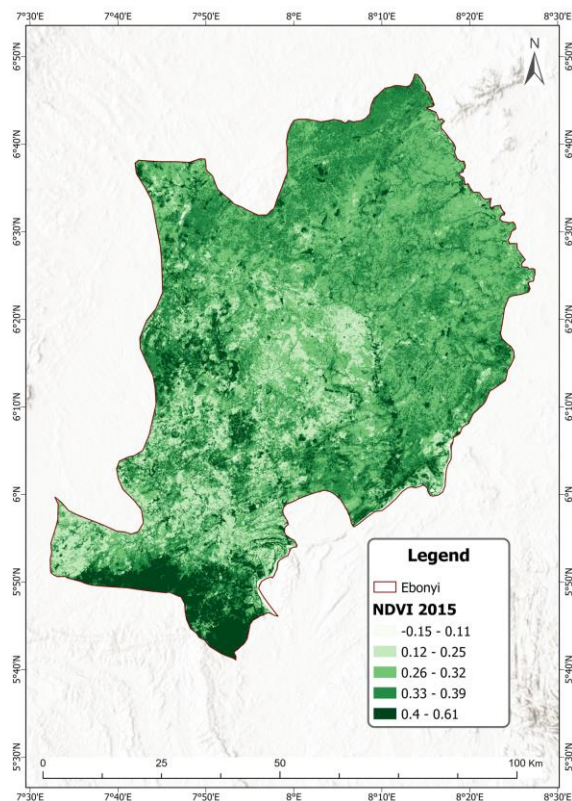


Figure 12: NDVII with figures for 2000

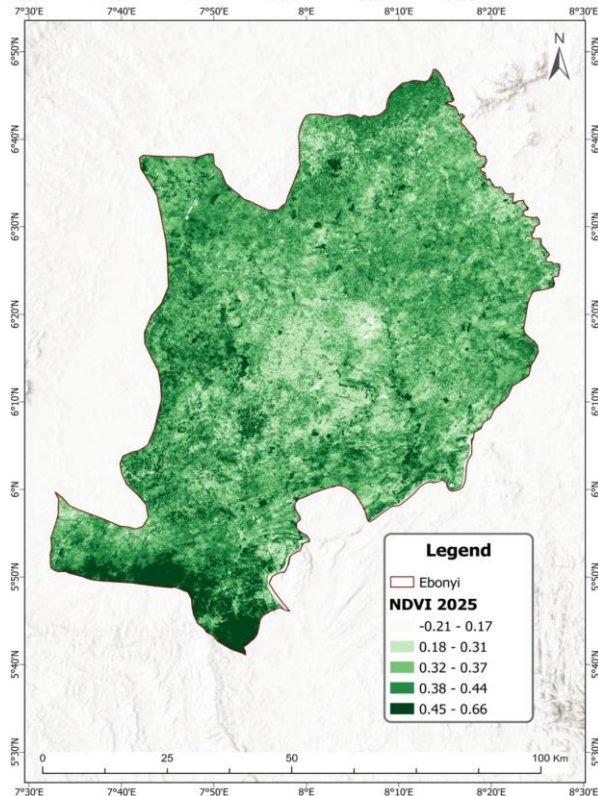


Figure 13: NDVII with figures for 2015

Figure 14: NDVII with figures for 2025

1986

Id	NDVI INDEX	Land type	Area (km²)
1	-0.12 - 0.17	No Vegetation	40.7808
2	0.18 – 0.22	Low/Degraded Vegetation	618.8688
3	0.23 - 0.27	Stressed Vegetation	2636.77
4	0.28 - 0.33	Moderately Healthy Veg.	2469.672
5	0.34 - 0.55	Healthy Vegetation	659.0556

2000

Id	NDVI INDEX	Land type	Area (km²)
1	-0.7 - 0.11	No Vegetation	23.0778
2	0.12 – 0.26	Low/Degraded Vegetation	853.1118
3	0.27 - 0.32	Stressed Vegetation	2572.542
4	0.33 - 0.39	Moderately Healthy Veg.	2057.686
5	0.4 - 0.61	Healthy Vegetation	918.8316

2015

Id	NDVI INDEX	Land type	Area (km²)
1	-0.15 - 0.11	No Vegetation	19.4994
2	0.12 – 0.25	Low /Degraded Vegetation	889.4322
3	0.26 - 0.32	Stressed Vegetation	2627.101
4	0.33 - 0.39	Moderately Healthy Veg.	2108.327
5	0.4 - 0.61	Healthy Vegetation	780.8913

2025

Id	NDVI INDEX	Land type	Area (km²)
1	-0.21 - 0.17	No Vegetation	40.7871
2	0.18 – 0.31	Low /Degraded Vegetation	1,058.554
3	0.32 - 0.37	Stressed Vegetation	2546.817
4	0.38 - 0.44	Moderately Healthy Veg.	2032.174
5	0.45 - 0.66	Healthy Vegetation	746.9181

Table 6: Percentage Change (1986–2025)

NDVI Category	1986 (km²)	2025 (km²)	% Change (1986 to 2025)
No Vegetation	40.78	40.79	+0.02%
Low/Degraded Vegetation	618.87	1058.55	+71.05%
Stressed Vegetation	2636.77	2546.82	–3.41%
Moderately Healthy	2469.67	2032.17	–17.71%

NDVI Category	1986 (km ²)	2025 (km ²)	% Change (1986 to 2025)
Healthy Vegetation	659.06	746.92	+13.33%

Largest increase: Low/Degraded Vegetation (+71.05%)

Largest decrease: Moderately Healthy Vegetation (-17.71%)

Source: Authors own Elaboration

Table 6 above shows the percentage change in magnitude of Normalized Difference Vegetation Index (NDVI) from 1986 to 2025 covering a period of 39 years which indicates that No vegetation area increased slightly from 40.7808km² in 1986 to 40.7871km² in 2025 representing an increase of 0.02%. Low vegetation/degraded area increased significantly from 618.8688km² in 1986 to 1058.554km² in 2025 representing an increase of +71%. Stressed vegetation area decreased from 2636.77km² in 1986 to 2546.817m² in 2025 representing a decrease of -3.41%. Moderately healthy vegetation area decreased from 2469.672km² in 1986 to 2032.174km² in 2025 representing a decrease of -17.71% while healthy vegetation increased from 659.0556km² in 1986 to 746.9181km² in 2025 representing an increase of +13.33%. The largest increase was in low vegetation/degraded area (+71.05%) followed by healthy vegetation (+13.33%) while the largest decrease was in moderately healthy vegetation (-17.71%) followed by stressed vegetation (-3.41%).

Table 7: Test of Significance (Paired Sample t-test)

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 1986 - 2025	-.02000	316.43923	141.51592	-392.93119	392.89119	.000	4	1.000

There is no statistically significant difference between the NDVI values in 1986 and 2025 overall ($p > 0.05$). This suggests that, despite individual category changes, the total distribution of vegetation types has not significantly changed in a statistical sense.

Table 8: Test of Relationship (Pearson Correlation)

Correlations

1986	Pearson Correlation	1	.972**
	Sig. (2-tailed)		.006
	N	5	5
2025	Pearson Correlation	.972**	1
	Sig. (2-tailed)	.006	
	N	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

There is a very strong positive correlation between NDVI values in 1986 and 2025, which is statistically significant ($p < 0.01$). This indicates a consistent pattern in the relative magnitude of NDVI categories over time, despite some shifts in specific categories.

4. DISCUSSION

Table 6 shows the percentage change in magnitude of Normalized Difference Vegetation Index (NDVI) from 1986 to 2025 covering a period of 39 years which indicates that No vegetation area increased slightly from 40.7808km² in 1986 to 40.7871km² in 2025 representing an increase of 0.02%. Low vegetation/degraded area increased significantly from 618.8688km² in 1986 to 1058.554km² in 2025 representing an increase of +71%. Stressed vegetation area decreased from 2636.77km² in 1986 to 2546.817m² in 2025 representing a decrease of -3.41%. Moderately healthy vegetation area decreased from 2469.672km² in 1986 to 2032.174km² in 2025 representing a decrease of -17.71% while healthy vegetation increased from 659.0556km² in 1986 to 746.9181km² in 2025 representing an increase of +13.33%. The largest increase was in low vegetation/degraded area (+71.05%) followed by healthy vegetation (+13.33%) while the largest decrease was in moderately healthy vegetation (-17.71%) followed by stressed vegetation (-3.41%).

Interestingly, healthy vegetation increased slightly from 659.0556km² in 1986 to 746.9181km² in 2025 representing +13.33%. This could imply better land use practices in some parts of the state.

The NDVI Index for this study as shown in figures 11-14 holds a lot of implications on agriculture and climate change in the study area, Ebonyi State and indeed Southeastern Nigeria as well. For instance, in 1986, 2636.77km² area of vegetation were stressed which could result from adverse climatic conditions like inadequate precipitations or anthropogenic activities like indiscriminate bush burning or other factors that could impact negatively on the health of vegetation or fertility of the soil. This trend of stressed vegetation continued from 1986 through 2000, 2015 and 2025 meaning that its cause(s) have not been mitigated for the past 39 years.

Equally of great concern is the increase in low vegetation/degraded area in the state which increased from 618.8688km² in 1986 to 1,058.554km² in 2025 as shown in table 6. This sharp increase in degraded/low vegetation area could be as a result of increased mining activities in the state notable among these are lead mining in Ikwo Local Government Area, stones mining in areas like Ishiegu, Nkalagu, Afikpo, and others. Mining sites and degraded land may not be suitable for agriculture and in most cases the sludge are not contained and treated before discharge into the surrounding lands which eventually impact negatively on vegetation, humans and livelihoods of the inhabitants of areas where these activities are carried out unchecked.

Our earlier study on the environmental and agricultural implications of land use land cover change for Ebonyi state covering a 39 years period (1986-2025) as quoted in Obenade et al, (2025) reveal that Bareland increased from 1.16 km² in 1986 to 11.76km² in 2025 representing an increase of +630%. Water bodies increased from 14.25km² in 1986 to 18.91km² in 2025 representing an increase of +33%. Built-up area increased from 27.90km² in 1986 to 46.66km² in 2025 representing an increase of +67%. Forest decreased from 933.54km² in 1986 to 618.69km² in 2025 representing a decrease of -34% while cultivated area increased from 1364.69km² in 1986 to 3990.67km² in 2025 representing an increase of +192%, and Shrubland decreased from

4,083.26km² in 1986 to 1,738.56km² in 2025 representing a decrease of 57%. (Moses Obenade et al, 2025).

Thus the findings of this study are consistent with similar studies carried out within and outside Ebonyi state. Odoh et al (2024) concluded that the analysis of LULC changes and slope dynamics between 2017 and 2023 in Enugu North, Enugu South, Nkanu East, and Nkanu West LGAs reveals significant trends with profound environmental and socio-economic implications. The most notable change is the substantial reduction in tree cover from 565.99 km² to 432.48 km², indicating extensive deforestation driven by urban expansion and agricultural land conversion. This reduction in forested areas threatens biodiversity, disrupts carbon sequestration processes, and alters local climate and hydrological cycles, underscoring the urgent need for effective forest conservation strategies Obenade et al, 2025; Odoh et al, 2024).

5. CONCLUSION

This study provides valuable insights into the natural environment of Ebonyi State Southeastern Nigeria which encompasses vegetation health dynamics. Farming activities and practices must be made sustainable with innovative styles and approaches to check the continuous stress to vegetation health. Vegetation serves as purifiers and sequesters in natural environment and must be kept in balance in spite of humans' dependence on forest and forest resources for livelihoods. Thus stressed vegetation or low vegetation and degradation have enormous consequences on human health, climate change, and agriculture in the state and beyond.

These findings reveal the current state of vegetation health dynamics and their implications for climate change and agriculture as well as ecosystem sustainability and resilience in study area. The study contributes to our understanding of the impacts of climate change and human activities on vegetation dynamics and land cover transformation in the region, informing evidence-based decision-making and sustainable land management practices.

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Analysis of Key Drivers of Flood Vulnerability in Lokoja, Kogi State

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Abstract

Floods in Kogi State have led to the destruction of property, the displacement of people, and the loss of livelihoods. This study analysed the key drivers of flood vulnerability using the Analytic Hierarchy Process (AHP) within a participatory multi-criteria decision analysis (MCDA). Stakeholder inputs and the Digital Elevation Model (DEM) were aggregated to assign weights to the identified drivers across Adankolo, Felele, Sarkin Noma, Lokongoma, 200 and 500 units, Ganaja, Kabawa, Lokongoma and Gadumo, respectively. The AHP weighted criteria results revealed the order of importance of flood vulnerability as proximity to waterbodies (0.25) > elevation (0.20) > rainfall = (0.15) = Drainage = 0.15 > land used land cover change (0.12) > Road Density (0.07) > (Slope = 0.03) = (Population = 0.03). These findings implied that nearness to water bodies, particularly within the 0-100m zone, is the most significant driver of flood vulnerability in the study areas. Therefore, new developments should be restricted within the 0–100 m buffer zone of rivers and streams, while existing structures in these high-risk areas should be gradually relocated as a flood-resilient measure.

KEYWORDS: criteria, displacement, vulnerability, proximity, resilient

1. Introduction

Floods are among the most devastating natural disasters, with negative impacts on the economy, human lives, and severe harm to buildings, roads, and ecosystems (Merz *et al.*, 2021; Njoku *et al.*, 2021). Global flood events have been attributed to climate change, which fuels more intense extreme weather (Wolff, 2021). These disasters have hit over 1.6 billion people, the highest death toll of any natural calamity. It has been estimated that from 2000 to 2019, there were 3,245 flood events worldwide, including 763 floods in African countries. According to UNDRR (2020), the floods have impacted economic stability, public health, and the overall physical welfare of affected populations. In 2022 alone, floods directly affected more than 1.3 million people, heightening the risk of waterborne diseases such as cholera and typhoid from contaminated sources (Relief Web, 2022b). According to the Nigerian Federal Government and the World Bank, the 2022 floods caused direct economic losses ranging from \$3.79 billion to \$9.12 billion, with a midpoint estimate of \$6.68 billion. This figure shows the destruction of homes, infrastructure, farmland, and key industries (World Bank, 2022).

Kogi State has been hit by about 8 major floods, affecting local communities. The worst ones struck in 1994, 2004, 2010, 2012, 2017, 2018, 2019, and 2020, claiming around 250 lives, forcing 85,000 people from their homes, and causing damages worth millions of US dollars (Daniel et al., 2023; FloodList, 2022). Recent studies warn that flooding will worsen, underscoring the need for strong, long-term strategies to address it across the country (Komolafe et al., 2020). The Global Disaster Preparedness Centre highlights that flood most severely affect rural and outlying "last-mile" communities, where challenges such as poor communication, limited infrastructure access, and insufficient early warning systems are widespread (Global Disaster Preparedness Centre, 2023).

Understanding the factors that trigger people's underlying vulnerabilities and the negative consequences of these vulnerabilities is necessary for society's exposure to environmental hazards (Tyler *et al.*, 2021). This drives the need to explore why floods affect communities, particularly given their high exposure and limited resilience. A flood vulnerability assessment framework offers a structured way to gauge an area's susceptibility to flooding (Porter *et al.*, 2021). It involves breaking down key elements such as exposure, sensitivity, and adaptive capacity to assess potential impacts and pinpoint high-risk populations or locations (Hamidi *et al.*, 2020).

MCDM is a generic term for a set of methods that help individuals or groups solve problems involving multiple, conflicting criteria (Supriya & Gadekallu, 2023). One of the strengths of MCDM is that it allows consideration of both qualitative criteria (e.g., high risk perception) and quantitative criteria (e.g., monthly income; Sahoo & Goswami, 2024). MCDM facilitates compromise and collective decisions and provides a good platform for stakeholders to communicate their personal preferences. The Flood Vulnerability Index (FVI) is a hands-on tool that pinpoints flood-prone areas, guides smarter decision-making to improve flood management in specific communities, and equips disaster risk experts and local authorities to roll out tailored adaptation and mitigation measures where they are needed most (Kumar & Bhattacharjya, 2020).

Although there are empirical studies on flood vulnerability, the reasons for the various dimensions of communities' vulnerabilities remain unclear. Effective flood risk management requires a clear grasp of the underlying factors that heighten community vulnerabilities and amplify adverse impacts. Against this background, the present study analyzes the key drivers of flood vulnerability in Lokoja. Therefore, this research aims to bridge the gap and add to the reservoir of knowledge

and priority can be given to them in subsequent policy implementation and actions by government and agencies This research has special significance today because of increasing vulnerability to flood in the study area.

2. Description of the Study Area

Lokoja is located in Kogi state, Nigeria, between latitudes $7^{\circ}45'0''\text{N}$ to $7^{\circ}53'30''\text{N}$ and longitude $6^{\circ}43'0''\text{E}$ to $6^{\circ}51'30''\text{E}$ (Nigeria galleria, 2022). Communities located around the channels and at the confluences of rivers bear the full brunt of flood impacts. These communities are Gadumo, Adankolo, Kabawa, Kpata, Lokongoma, 500 Units, 200 Units, Sarkin Noma, and Ganaja, among the most affected. The study region experiences distinct wet and dry seasons, with the dry season from November to February and the rainy season from March to October. Annual precipitation ranges from 1016 mm to 1524 mm, while temperatures remain consistently warm year-round, averaging 27°C (Date, 2025). Recent studies have revealed that climate change is impacting Lokoja's urban thermal environment and broader climate variables.

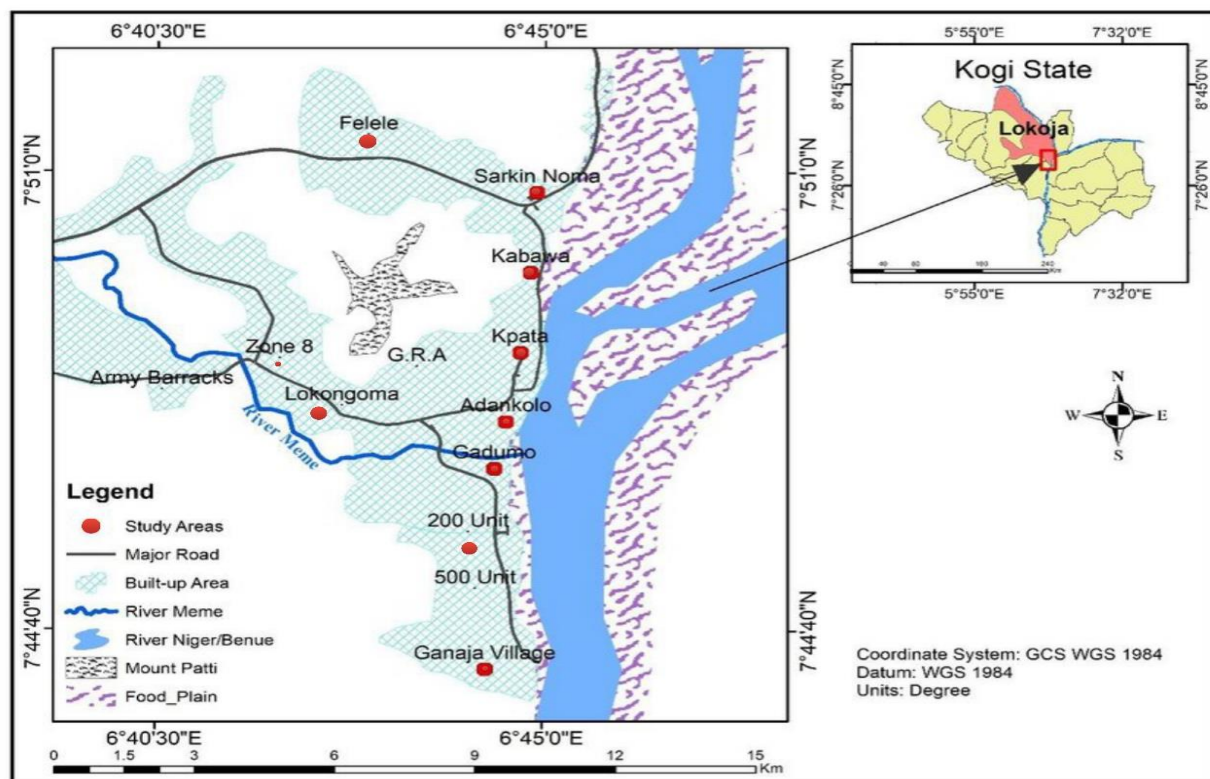


Figure 1: Map of Kogi State showing Lokoja

3. Methodology

This study uses snowball sampling to identify participants with direct experience or expertise in flood mitigation strategies, ensuring the relevance and depth of collected data. All residents within the sample area meeting the criteria of flood victims are eligible for selection, minimizing deliberate exclusion. Interviews were focused on local community members and leaders in Lokoja's flood-prone areas to capture firsthand perspectives on flood-related challenges, community engagement in mitigation efforts, and assessments of current government policies.

The multi-criteria decision analysis (MCDA) approach, integrated with Geographic Information Systems (GIS), was used to combine multiple criteria, including elevation, slope, drainage density, rainfall, and infrastructure adequacy, into a composite flood vulnerability index. Parameters were weighted using the Analytical Hierarchical Process (AHP) to reflect their relative importance, enabling a systematic and spatially explicit assessment of flood risk. These maps identify the relative importance of each indicator to flooding vulnerability in Lokoja.

4. Result and Discussion

4.1 Proximity to Waterbody (Weight = 0.25):

This criterion measures how close an area is to rivers, streams, or floodplains. Proximity to water is a critical determinant of flood impact. Areas immediately adjacent to major water channels are subject to overflow and lateral flood spread during heavy rain or river swells. For Lokoja, locations near the Niger and Benue rivers are especially vulnerable, since riverbanks can breach or river levels can rise suddenly. The high weight (0.25) assigned to proximity underscores its dominant influence: being near a waterbody dramatically increases exposure to flooding. Thus, regions within a short distance of the rivers are classified as highly vulnerable, while those farther away are considered less exposed.

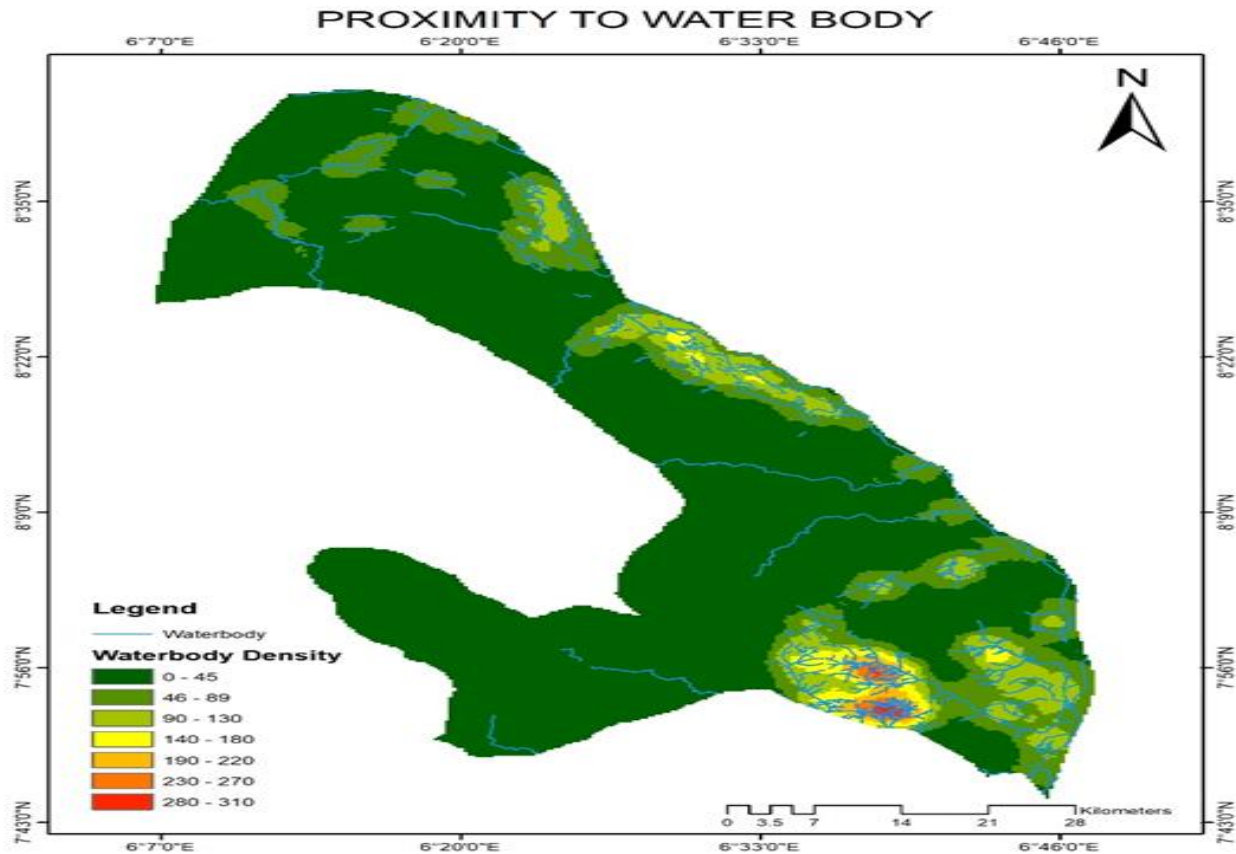


Figure 2: Proximity to Waterbody

4.2 Elevation (Weight = 0.20):

Elevation refers to the height of the land surface above sea level. Low-lying terrain naturally accumulates surface water and is prone to inundation, whereas higher ground drains water more efficiently. In Lokoja, which lies at the confluence of two rivers, depressions and floodplains occur where the elevation is relatively low. These low-elevation zones (such as river valleys and basins) were given high vulnerability because gravity causes floodwaters to flow downward into them. Conversely, upland areas and hills that rise above the general terrain receive less runoff and are given lower vulnerability. The weight of 0.20 for elevation reflects its strong but slightly secondary role after proximity to water. Together, proximity and elevation capture the combined effect of location and topography on flood risk.

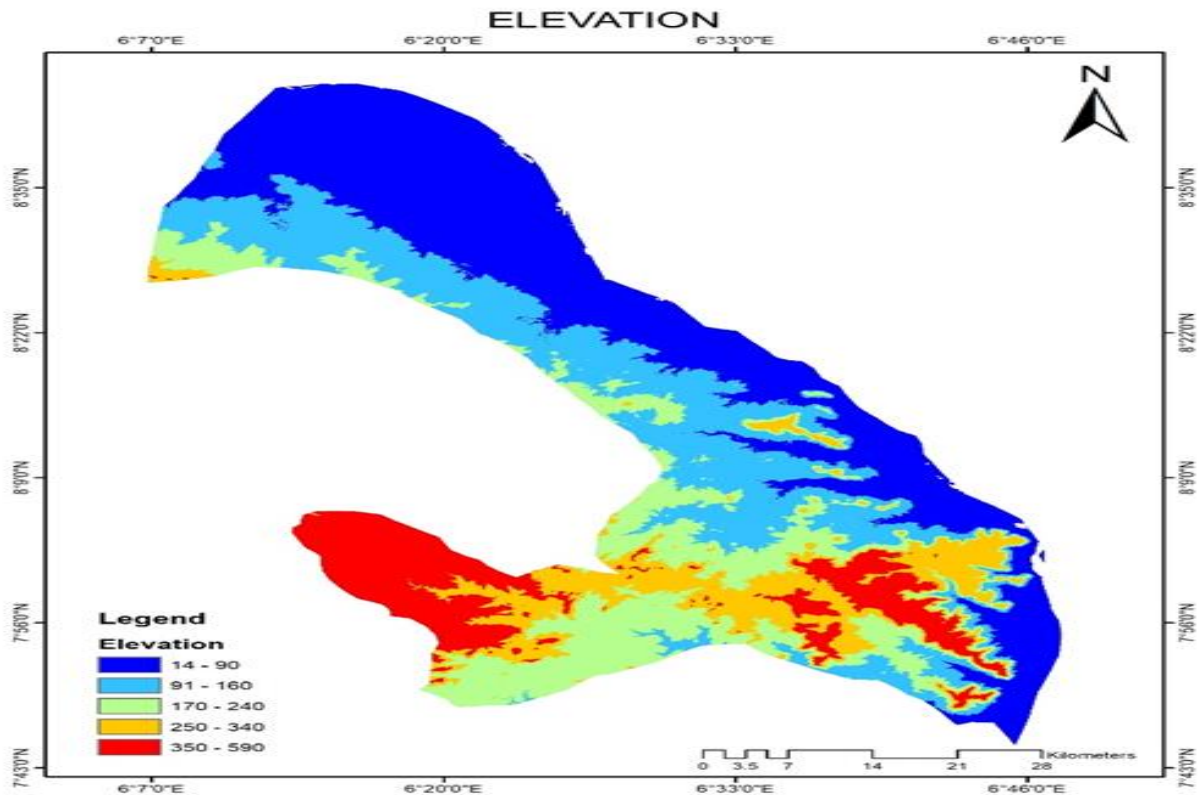


Figure 3: Elevation

4.3 Rainfall Intensity (Weight = 0.15):

This criterion represents the average or maximum rainfall in the area during heavy storms. Intense rainfall events contribute directly to flooding by generating large volumes of surface runoff that overwhelm drainage systems. Lokoja's climate can include periods of very high rainfall, and areas subject to heavier precipitation are more likely to flood. Therefore, areas with the highest rainfall intensities are assigned higher vulnerability. The AHP weight of 0.15 indicates that rainfall intensity is an important driver of flooding but slightly less so than the two spatial factors (proximity and elevation). In practice, rainfall intensity was mapped from meteorological data or satellite estimates, then ranked so that locations receiving the heaviest rains (or those prone to storms) carry higher flood risk.

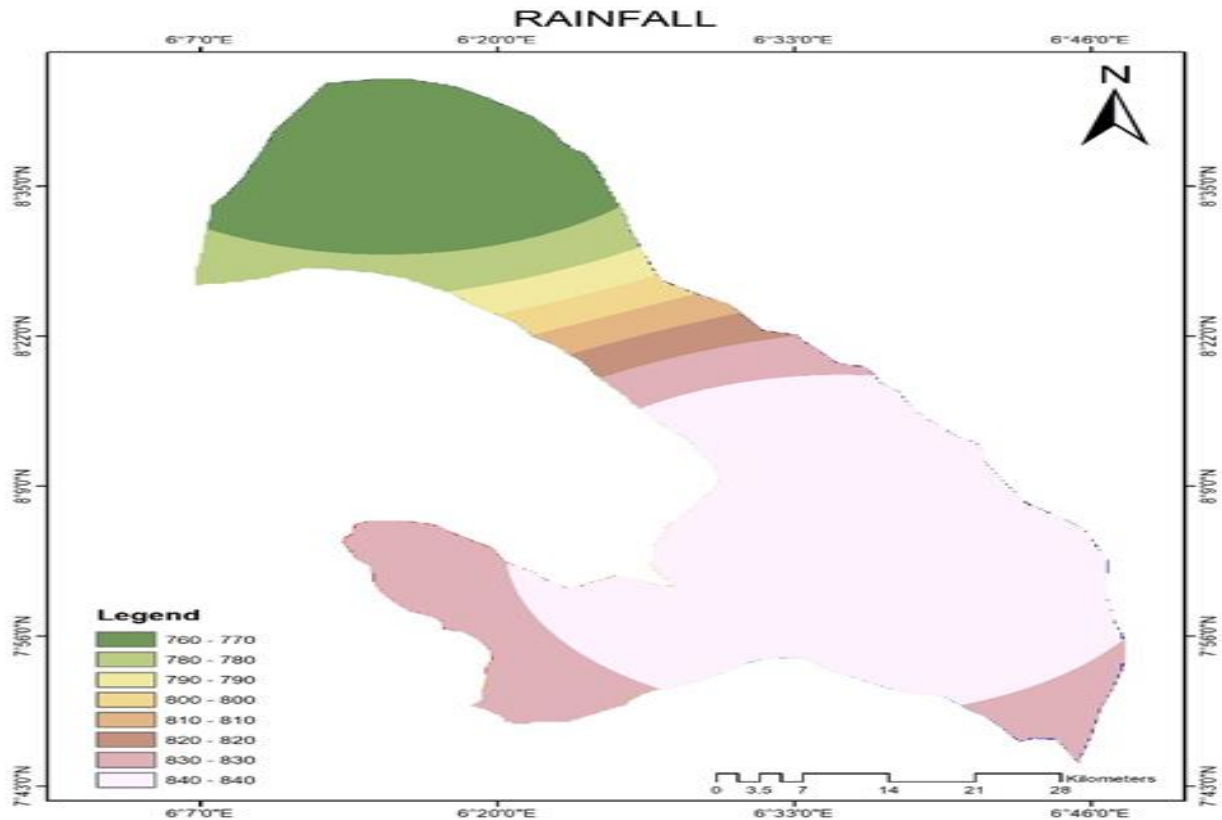


Figure 4: Rainfall Intensity

4.4 Drainage Density (Weight = 0.15):

Drainage density measures the extent of streams and channels in a. A low drainage density means there are few channels to carry away excess water, so rainfall accumulates and floods. In contrast, a high drainage density implies many channels that can quickly convey runoff, reducing flood build-up. In Lokoja's model, areas with sparse drainage networks were considered more vulnerable. This criterion was given the same weight (0.15) as rainfall because inadequate drainage can similarly exacerbate flooding. Thus, flat areas with few gullies or canals receive high vulnerability, while dissected landscapes with many tributaries score lower on vulnerability, all else equal.

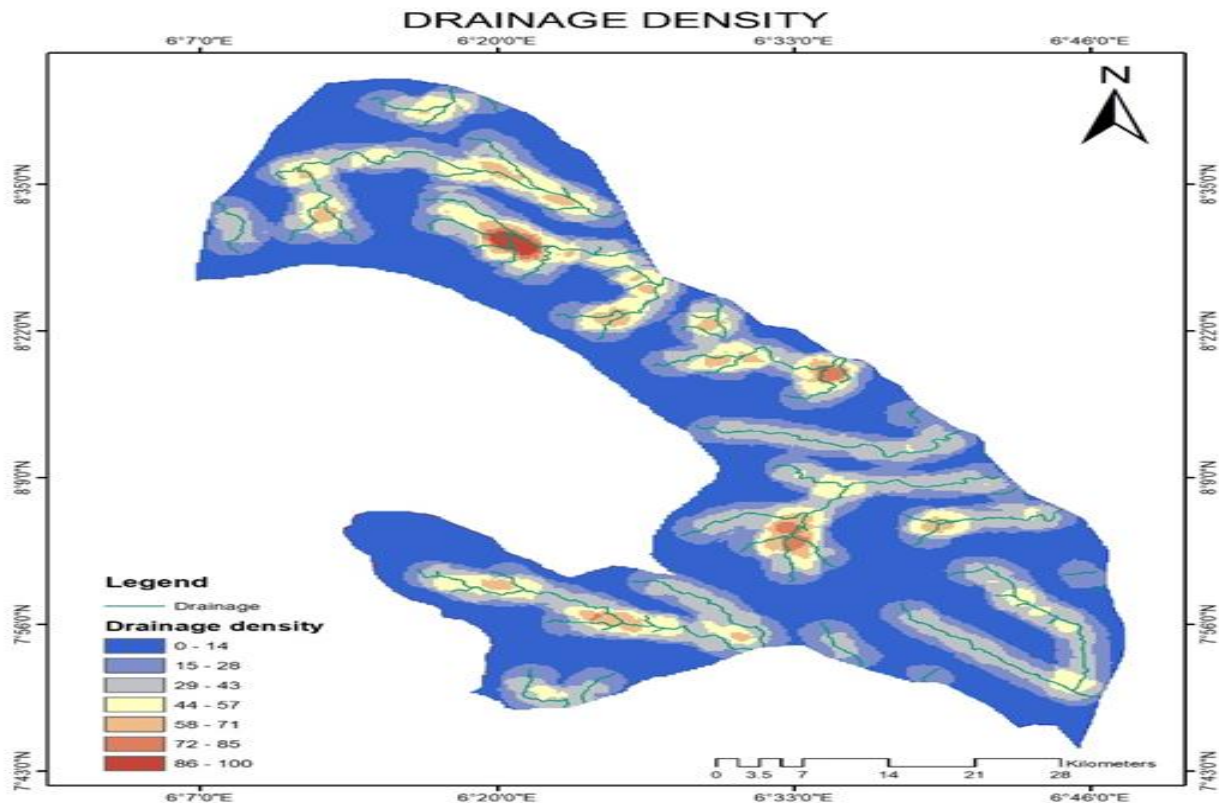


Figure 5: Drainage Density

4.5 Land Use / Land Cover (LULC) (Weight = 0.12):

The type of surface cover affects how much water infiltrates versus runs off. In the study area, six major land-cover classes were mapped: vegetation, water bodies, built-up areas, farmland, bare ground, and rock outcrop. Impervious or open surfaces like concrete or bare earth generate more runoff than vegetated soils. Consistent with this, water bodies and built-up areas were assigned the highest vulnerability index (3), reflecting that they either are already inundated or facilitate runoff. Vegetation and rock outcrops allow infiltration and were given low vulnerability index (1). Farmland was treated as intermediate, since soil permeability is moderate. With a weight of 0.12, LULC influences the flood map by adjusting vulnerability based on surface cover: for example, a built-up city block near a river is more likely to flood than a forested slope at the same elevation.

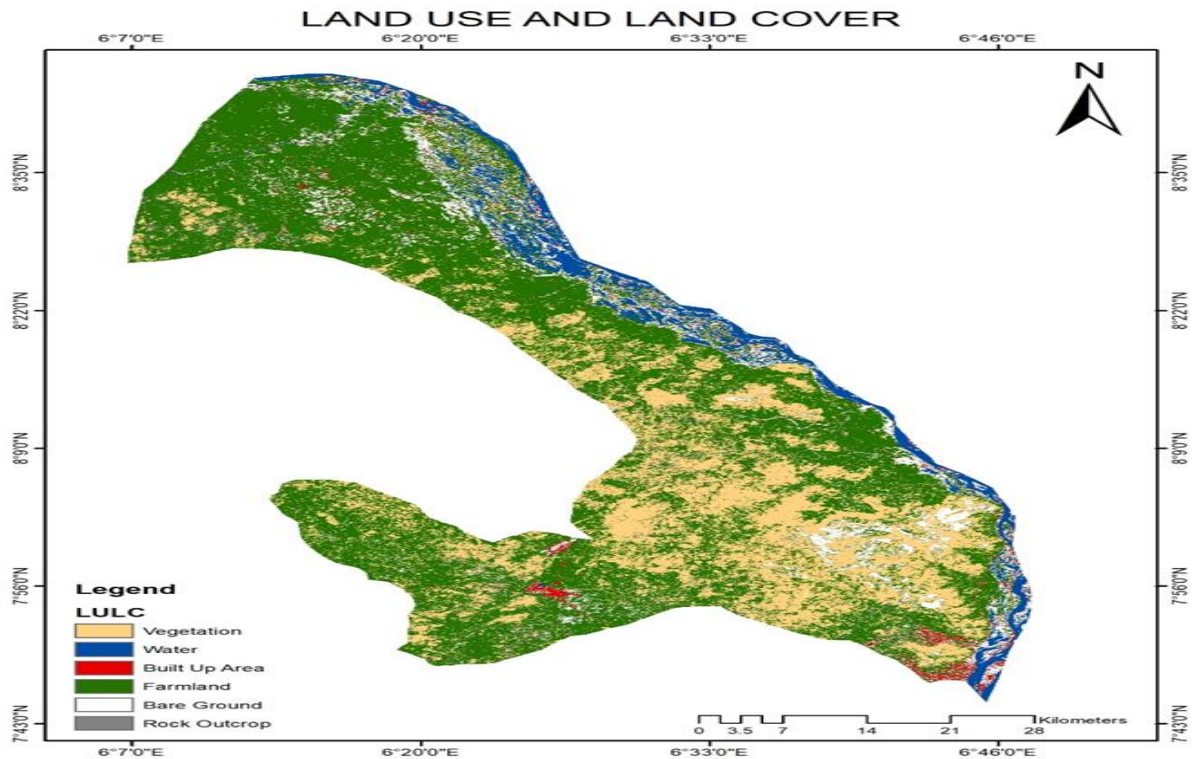


Figure 6: Land Use and Land Cover

4.6 Road Density (Weight = 0.07):

Road networks contribute to flooding risk by interrupting natural flow paths and introducing additional impervious areas. Densely built road systems can channelize water and reduce infiltration. In Lokoja, regions with many roads were identified as having higher flood vulnerability. Roads fragment terrain and can act as barriers or conduits for water, depending on drainage design. Although road density is less important than natural factors, a weight of 0.07 was still assigned to capture urban infrastructure effects. High road density areas (typically urban or peri-urban zones) receive a higher index, while rural areas with few roads have lower scores. This reflects the rationale that human-built features modulate how water moves and where it pools.

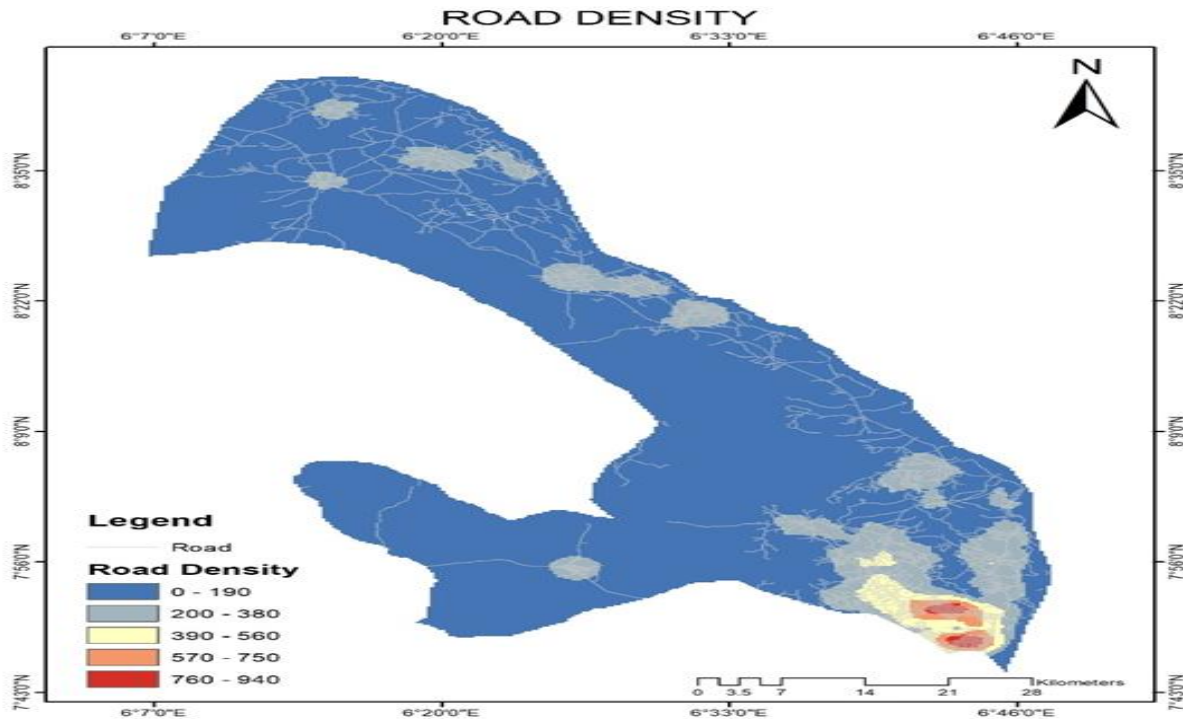


Figure 7: Road Density

4.7 Slope (Weight = 0.03):

Slope percent reflects how steep or flat the terrain is. Gentle slopes allow water to move slowly and accumulate, whereas steep slopes promote rapid runoff away from the area. Therefore, in this model, low-slope (flat) zones were assigned higher vulnerability and steep slopes lower vulnerability. In Lokoja, flatter floodplain regions near the rivers have slope values close to zero and thus are more prone to standing water. Hilly or mountainous surroundings drain faster. Because Lokoja is relatively flat overall, slope has only a minor weight (0.03), indicating it is a tertiary factor. However, it still helps distinguish very flat neighbourhoods that may pond water from sloping outskirts.

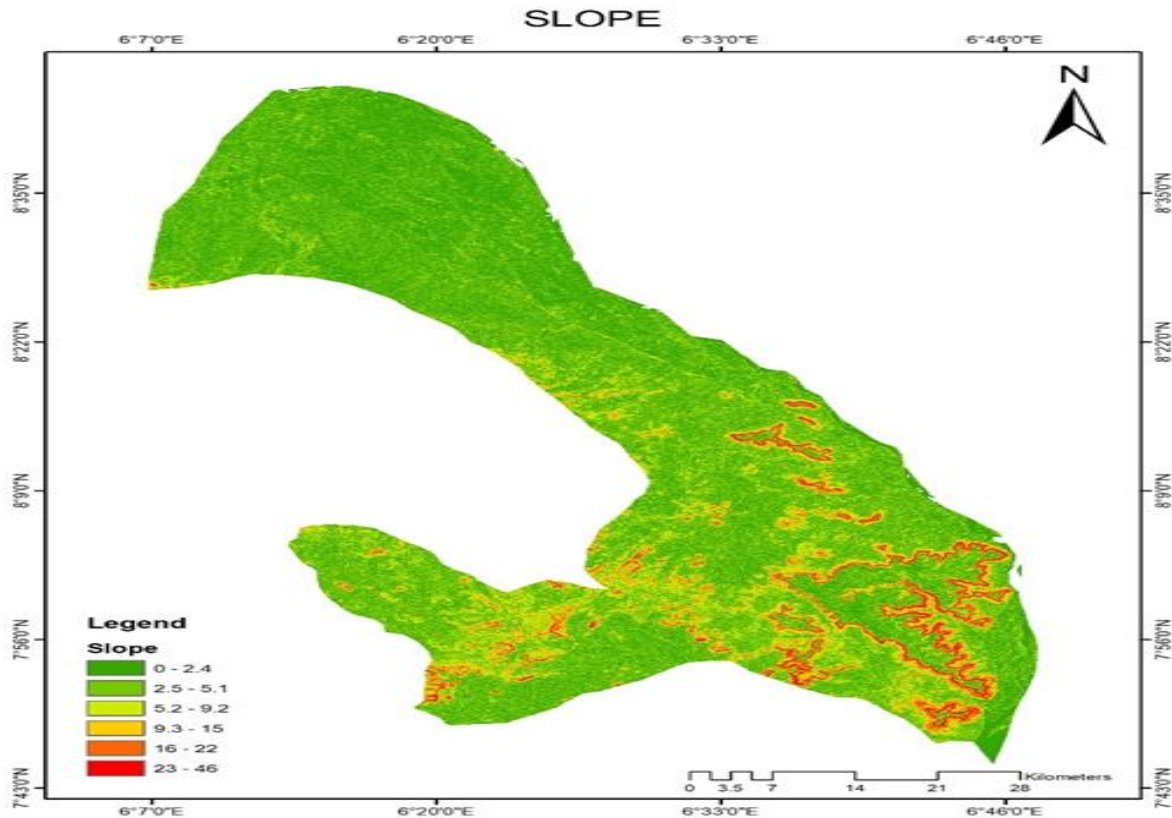


Figure 8: Slope

4.8 Population Density (Weight = 0.03):

Population density was included as a proxy for the concentration of people and built-up assets exposed to floods. Densely populated areas typically have more infrastructure (houses, roads), which can exacerbate runoff and increase the consequences of flooding. In the Lokoja analysis, zones with high population were considered slightly more vulnerable. The low weight (0.03) shows that this socio-economic factor is less critical than the physical factors above, but it still flags that flooding in populous districts could have a greater impact. High-density neighbourhoods receive a marginally higher vulnerability score than sparsely settled or rural areas.

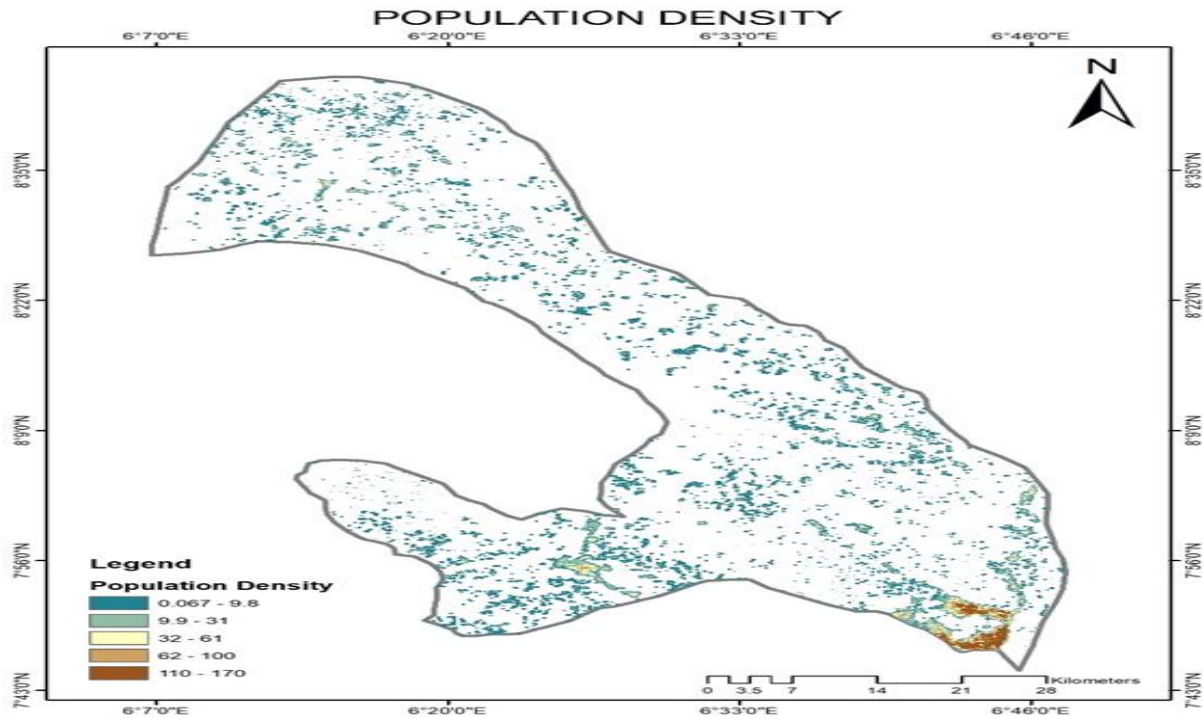


Figure 9: Population Density

Each criterion is incorporated into the final model by multiplying its standardised vulnerability score by its weight. The sum of these weighted scores yields a composite flood vulnerability index for each location. The dominant factors (Proximity and Elevation) have the most influence on the final index, but the other variables refine the spatial pattern of vulnerability

Generally, the AHP process produced a weight ranking: Proximity to Waterbody (0.25) > Elevation (0.20) > (Rainfall = 0.15) = (Drainage = 0.15) > LULC (0.12) > Road Density (0.07) > (Slope = 0.03) = (Population = 0.03). These weights were used to multiply the reclassified criterion layers and sum the results to obtain the final vulnerability score. The matrix's perfect consistency supports confidence in using these weights for decision-making, as it suggests that the relative importance judgments were logically sound and that the resulting vulnerability map is based on a coherent prioritization of factors.

5. Conclusion

This study reveals that flood vulnerability in Lokoja is overwhelmingly driven by physical and topographic factors, with proximity to waterbodies (weight: 0.25) and elevation (weight: 0.20)

emerging as the dominant influencers. These findings infer that communities like Gadumo, Adankolo, and those near the Niger-Benue confluence face acute exposure due to their low-lying positions and direct adjacency to river channels, where overflow and inundation occur rapidly during peak rainfall. Rainfall intensity and drainage density (both 0.15) further amplify this risk, signaling that inadequate natural drainage networks exacerbate surface runoff in Lokoja., seasonally wet terrain highlighting a critical inference: without enhanced channelization, even moderate storms could overwhelm vulnerable zones.

Secondary factors like land use/land cover (0.12), road density (0.07), slope, and population density (both 0.03) refine the vulnerability profile, implying that urban expansion—through impervious built-up areas and road networks intensifies runoff and human exposure in densely settled floodplains. The perfect consistency of the AHP matrix underscores the reliability of this prioritization, allowing precise mapping of high-risk hotspots for targeted interventions.

Overall, these insights infer a clear pathway for resilience: prioritizing riverbank setbacks, elevation-based rezoning, and drainage improvements in "last-mile" communities in Lokoja. By addressing these drivers, Lokoja can transition from reactive flood response to proactive risk reduction, safeguarding lives, infrastructure, and economic stability amid escalating climate threats.

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An Assessment of the Impact of Recreational Parks on the Quality of Life of Elderly People in Aba South Local Government Area of Abia State, Nigeria

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ABSTRACT:

As ageing populations increase, the provision of inclusive outdoor recreational environments becomes essential for promoting physical health, social interaction, and psychological well-being among older adults. Despite the growing body of literature on outdoor recreation, existing studies have largely focused on residents' preferences and behavioural patterns, particularly among youths and tourists, with limited attention given to elderly people and their utilization of recreational parks. This study examined the impact of recreational parks on the quality of life of elderly people in Aba South Local Government Area of Abia State, Nigeria, with particular emphasis on accessibility and usability. A structured questionnaire was administered to 364 respondents aged 60 years and above to assess patterns of park usage, accessibility, and perceived usability of available recreational facilities. Data collected were analyzed using descriptive statistical techniques such as frequencies, percentages, and mean scores. Findings revealed that accessibility and usability significantly influence the utilization of recreational parks among elderly people in the study area. The accessibility score of 3.2/5 indicated that the parks were fairly accessible, although improvements are still required in areas such as mobility support and physical access. Similarly, the usability score of 3.5/5 suggested that the parks were relatively user-friendly for elderly users. The study concludes that recreational parks possess considerable potential to improve the physical, social, and emotional well-being of elderly residents. However, there is need for improved maintenance, accessibility, and age-friendly park design. The study therefore recommends inclusive recreational planning and management strategies that promote active ageing and community well-being.

Keywords: Accessibility, Elderly People, Recreational Parks, Usability, User-friendly.

1.0: INTRODUCTION

As ageing populations increase, the provision of inclusive outdoor recreational environments becomes essential for promoting physical health, social interaction, and psychological well-being among older adults. Ageing can be seen as a success story for public health policies and socio-economic development. However, it also challenges society to adapt to maximize the health and functional capacity of older people, as well as their social participation and security. The proportion of persons aged 60 and over is expected to double in Africa (United Nations Population Division, 2006), and the World Health Organization has proposed a framework for an ageing society. To create active ageing for the elderly by focusing on healthy life, stability in life, and participation in society. It is considered a way to meet the needs, protection, and create opportunities for the elderly around the world.

In Nigeria, according to the Census 2007 report, approximately 17.3% of the population was 60 years of age and above and 0.9% of the population was 80 years and above (NPC, 2007) in 2007. Nigeria, one of the most developing countries in the sub-Saharan region of Africa, is experiencing rapid urbanization and industrialization. Her populations are ageing even though this trend has been taking place globally, but seem more rapidly in urban areas of developing countries around the world (Lin *et al.*, 2012). In Abia State, Nigeria, for example, the percentage of the elderly population has reached 32% (NPC, 2007), and the number is still increasing. Nigeria is expected to become a super-aged society by 2030 since it is projected that over 23% of her population will be older than 65 years old then. (NPC, 2007).

The need to therefore extend and maintain older adults' life expectancy ratio is worthwhile, and urban green open spaces provide elderly residents with easy access to nature. The usage and availability of outdoor recreational spaces within these elderly communities play a vital role in enhancing active ageing and social interaction among the elderly. Studies have shown that in the designing and planning of outdoor recreational spaces, attention is always

focused on the mortality requirements and safety of this elderly population (Yang et al., 2023) but there seems to be few researchers that focus on the drivers of these elderly residents to use these recreational area spaces or things that constrain them from utilizing them. These recreational areas provide the aged community in society with a place for social and interpersonal interactions as well as improve their active ageing longevity.

According to Romild et. al (2011) recreational participation can be linked to several types of determinants internally related to the individual, such as demographic, socioeconomic, and situational characteristics (e.g., age, income and time resources) in addition to external factors such as the availability and accessibility of recreation resources. These determinants decide not only the type of recreation activity to be engaged in, but also the level of participation, and they can consequently either facilitate or pose constraints upon people's desires to participate. There are various researches conducted on constraints to participation in recreation (Crawford and Godbey, 1987; Crawford et. al, 1991; Johnson et. al 2001; Hamidreza, 2014). Lack of time, financial problems, inadequacy of outdoor recreational areas, lack of companion, and health problems are identified as major constraints to participation in recreation in many studies (Kara and Demirci, 2010; Hamidreza, 2014). Similarly, Johnson et. al (2001) studied the effects of socio-demographic factors on constraints to outdoor recreation participation. These constraints are related to the unavailability or lack of resources to participate in leisure activities. Such constraints may include lack of money, problems related to facilities, service accessibility issues and the cost of the facility usage (Jackson, 2005).

Against this background of constraints leisure, a thorough understanding of what keeps the elderly away from visiting outdoor recreational centers in Aba South Local Government Area of Abia State is essential for the identification of appropriate points of intervention. Field observation revealed that many of the recreational centers do not host elderly, at best children and youths are found surging in and out of them. By identifying the factors that influence the participation and satisfaction levels of the elderly in recreational centers, this

study provided valuable insights into how to enhance their recreational experiences and outcomes. This research not only highlights the existing barriers that hinder their engagement but also identify potential opportunities for improvement.

Recreational activities are essential for the well-being and quality of life of older adults, especially in urban areas where they face many challenges and risks. However, not all older adults have equal access to and opportunities for engaging in recreational activities, as there are various factors that may constrain or facilitate their participation.

These factors may include personal characteristics, such as age, gender, health, income, education, and motivation; environmental characteristics, such as availability, accessibility, affordability, quality, and safety of recreational facilities and services; and social characteristics, such as social support, norms, expectations, and discrimination (Jackson, 2005; Scott, 2012). Understanding these factors is crucial for designing and implementing effective and inclusive recreational programs and policies that can meet the diverse needs and preferences of older adults and enhance their health and happiness.

However, in Abia State, particularly in Aba South LGA, there is a glaring gap in empirical research on the recreational behaviour and preferences of older adults, as well as the factors that may constrain their participation in recreational centers. Observations indicated that, the Aba South LGA exhibit some elements of physical planning. The area has abundant outdoor recreation facilities (both private and public) such as Recreational Parks, Sports Clubs, Golf Course, Football Fields (including mini stadia), Event Centers, Basketball Courts, Lawn Tennis and Volleyball Courts and several other recreational opportunities for bicycling, running, jogging, visiting museum, et cetera, that provide the residents with relative opportunity for participation. A causal visit to most of the recreational areas in Aba show absence of the elderly population of the society.

The existing studies on recreation in Nigeria and perhaps Aba South in Abia State focuses on the general population, the youth, or the tourists, and neglect the specific needs and

interests of the older segment of the society. Yet, very few were able to relate the level of participation from the residents' perceived constraints (Oyinloye and Oyinloye, 2016; Ogunbodede et al., 2014; Abdullahi et al., 2018) but none has been specifically linked to the elderly population of the society. As a consequence, a gap exists in research on leisure constraints among the elderly. This lack of research not only limits the empirical knowledge on the recreational behavior of older adults in urban Nigeria and Africa, but also hinders the development and evaluation of recreational planning and management in Abia State and in Nigerian cities, and other similar urban contexts in Africa, that can effectively address the challenges and opportunities for improving the recreational experiences and outcomes of older adults.

This study therefore provides an in-depth understanding of the impact of that constrain the participation of older adults in recreational centers in Aba South LGA, Abia State, contributing to policy and practice of recreational planning and management in Abia State, and other similar urban contexts in Nigeria and Africa, by providing insights and recommendations for enhancing the recreational opportunities and quality of life of older adults.

2.0 CONCEPTUAL FRAMEWORK

The geriatric concept of recreational parks focusing on how outdoor environments especially neighbourhood green spaces and parks support the health and well-being of older adults. As propounded by Sugiyama & Thompson, (2007), it emphasizes that older people's ability to use outdoor spaces isn't automatic; it depends strongly on environmental support, that is, how well spaces are designed to help older adults perform meaningful outdoor activities. Environmental support in this concept is therefore define as the degree to which outdoor settings facilitate activity (e.g., walking, socializing) that enhances quality of life (QoL) for older people. Furthermore, supportiveness includes: physical accessibility; safety; perceived comfort and aesthetics; presence of meaningful destinations

(like pleasant walking routes, seating places) and lack of barriers such as steep slopes or poor paths.

The proposition of Sugiyama & Thompson, (2007), is therefore affirms by the University of Edinburgh Research Explorer, that when neighbourhood environments offer support such as safe walkways, seating, green views, and accessible amenities, older adults tends to walk more frequently; report higher health status; have stronger social interaction and overall greater quality of life.

Few researchers have argued how recreational parks can affect individuals well being during their old age, especially in their physical health benefits. Sugiyama & Thompson, (2007), consistently shows that supportive outdoor environments increase physical activity especially walking which can combats decline in mobility and muscle strength; reduces risks of chronic disease and contributes to overall physical health. The works of Levinger, P. et. al (2025) supports this assertion by ascertain that recreational park provides safe, accessible venues for low-impact exercise which is especially important for older adults with reduced balance or chronic conditions. Well-designed parks encourage walking, stretching, and even age-friendly structured activities.

Pertaining to the mental & emotional health of the elderly with regards to using recreational parks Chen Wen, Christian Albert & Christina Von Haaren (2018), highlighted that access to natural outdoor environments like the leafy parks, shaded seating, and aesthetic landscapes is associated with: reduced stress; improved mood; enhanced psychological restoration and reduced feelings of isolation. Exposure to nature also strengthens emotional well-being by offering tranquility and sensory stimulation that many older adults appreciate. Sadiq R. et. al (2024).

On Social Interaction and Belonging: Parks are important social spaces for older adults:

- i. They create opportunities for casual social encounters.
- ii. They become regular meeting places, especially when seating and amenities support lingering, conversation, or group activities.

- iii. Park-based interactions help mitigate loneliness and build a sense of community connectedness; a critical factor in healthy ageing

This social role links to Sugiyama & Ward Thompson's broader framework: supportive environments should enable both social and physical activity, not just walking or exercise. Heng Cul et. al 2024

3.0 METHODOLOGY

This study adopted a descriptive cross-sectional research design with a mixed-method approach, combining both quantitative and qualitative elements. In adopting the descriptive design, it was aimed at examining the accessibility and usability of recreational parks. The quantitative component provided measurable data on frequency, usage patterns, and perceptions, while the qualitative insights embedded in structured responses helped to explain the experiences and challenges faced by elderly users.

Data required for this study were obtained from primary and secondary sources. Primary data on recreational park accessibility and useability were collected from park visitors, managers, local residents, and relevant institutions within Aba South L.G.A, Abia State. Data were obtained through structured questionnaires, which assessed stakeholder knowledge, attitudes, and practices, as well as through field experiments involving the collection and analysis of accessibility and useability samples to evaluate their effectiveness and impacts towards the wellbeing of elderly people. Secondary data were obtained to complement and contextualize the primary research findings.

A structured questionnaire was administered to a sample of 400 respondents and the total no of adequate returned questionnaires was 364 respondents aged 60 years and above to evaluate patterns of parks access and perceived ease of use of available facilities. The study adopted a non-probability sampling approach in selecting respondents. The characteristics of the sample that comprise the total study closely reflect those of the general elderly population in Aba South L.G.A. This study included individuals aged 60-96 years. Purposive sampling was used to select the study area: Aba South L.G.A, in Abia State. This

location was chosen because it has identifiable recreational facilities and a significant population of elderly people who actively use these facilities. Second, convenience sampling was used to select respondents within the recreational parks. Elderly individuals who were present and willing to participate during the period of data collection were selected.

3.1 DATA ANALYSIS

Accessibility and usability of parks are key factors that determine whether elderly people can effectively make use of recreational parks. The findings from this study show that accessibility and usability of recreational parks in Aba South L.G.A are moderate but not optimal. Most respondents rated accessibility and usability as average to good, but a notable proportion rated them as poor. This indicates that while parks are functional, there is room for improvement.

From the results, 50.30% of respondents rated the accessibility of recreational parks as good, while 27.74% rated it as average and 15.11% rated it as excellent. However, 6.31% rated accessibility as poor, and 0.54% rated it as very poor. This shows that although many elderly people can access recreational parks, a significant number still experience challenges.

The usability of recreational parks also showed mixed results. About 40.66% of respondents rated usability as poor, while 28.30% rated it as average. Also 14.28% of the respondent rated usability of recreational parks by elderly people as been very poor. Only 16.21% rated usability as good, and a very small percentage (0.55%) rated it as excellent. This indicates that even when parks are accessible, their design and facilities may not fully support comfortable use by elderly people.

The regression analysis further confirms the importance of accessibility and usability. Accessibility had a significant positive influence on quality of life ($\beta = 0.35$, $p < 0.01$), while usability had an even stronger influence ($\beta = 0.42$, $p < 0.001$). This means that when

parks are easy to reach and easy to use, elderly people are more likely to visit them and benefit from them.

In addition, respondents identified key features that influence usability. Sitting areas (33.79%) and food and beverage vendors (35.71%) were ranked as the most important features. This shows that elderly users value comfort and convenience more than physically demanding facilities. Exercise and sports facilities, although important, were secondary. This supports the idea that recreational parks for the elderly should focus on comfort, safety, and ease of movement.

Overall, the findings indicate that while recreational parks in Aba South L.G.A are moderately accessible, improvements are still needed in infrastructure, design, and elderly-friendly facilities to enhance their usability.

Furthermore, on gender distribution in the use of recreational parks reveal that males constitute the majority of users of recreational parks in Abia State, accounting for 94.1% of respondents, while females represent only 5.9%. This significant gender imbalance suggests that men are far more involved in recreational park activities than women. Several factors may account for this disparity, including cultural norms, safety concerns, caregiving responsibilities, and limited female-oriented recreational facilities.

This finding aligns with previous studies such as Sjogren and Stjernberg (2010), which noted that women tend to participate less in recreational activities due to fear of injury, safety concerns, and domestic responsibilities. Similarly, Paillard-Borg et al. (2009) observed that elderly women engage less in outdoor recreational activities compared to men. However, this contrasts with the findings of Ethisan et al. (2017), who reported higher female participation in recreational activities in some Asian countries. This difference may be attributed to cultural and environmental variations between African and Asian societies.

The implication is that recreational planning in Aba South L.G.A of Abia State may currently favor male participation, either intentionally or unintentionally. Therefore,

gender-sensitive recreational planning is necessary to encourage greater female involvement.

Table 1: Rating the Accessibility of Recreational Parks in Aba South L.G.A

Response Category	Frequency	Percentage
Very Poor	2	0.54%
Poor	23	6.31%
Average	101	27.74%
Good	183	50.30%
Excellent	55	15.11%
Total	364	100%

Source: Field Survey 2026

The analysis of the accessibility of recreational parks revealed that a greater proportion of the respondents perceived the parks to be relatively accessible. The highest response category was “Good,” accounting for 183 respondents representing 50.30% of the total respondents. This was followed by respondents who rated accessibility as “Average,” with 101 respondents representing 27.74%. Furthermore, 55 respondents representing 15.11% rated accessibility as “Excellent.”

However, a smaller proportion of respondents expressed dissatisfaction with accessibility, as 23 respondents representing 6.31% rated it as “Poor,” while only 2 respondents representing 0.54% considered accessibility to be “Very Poor.” Statistically, the findings indicate that over 65% of the respondents viewed recreational parks as either good or excellent in terms of accessibility. This shows that the parks are relatively reachable and usable by residents within Aba South Local Government Area. Nevertheless, the existence of respondents who rated accessibility poorly implies that certain barriers such as poor road networks, inadequate walkways, distance, transportation challenges, and lack of age-friendly access facilities may still exist within some recreational environments.

Table 2: Most Important Features expected in Parks

Features	Frequency	Percentage
Walk ways	25	6.87%

Ramps	10	2.75%
Sitting Areas	123	33.79%
Rest Rooms	40	10.99%
Food and Beverage Vendors	130	35.71%
Exercise and Sport	36	9.89%
Total	364	100%

Source: Field Survey 2026

Table 2 above revealed the most important features expected in recreational parks showing varying preferences among respondents. Food and beverage vendors recorded the highest response, with 130 respondents representing 35.71%, indicating that elderly park users value the availability of refreshments and social comfort within recreational environments. Sitting areas followed closely with 123 respondents representing 33.79%. this implies that comfortable resting spaces are highly important to elderly users due to age-related mobility and physical limitations.

Furthermore, rest rooms accounted for 40 respondents representing 10.99%, while exercise and sport facilities recorded 36 respondents representing 9.89%. Walkways had 25 respondents representing 6.87%, whereas ramps recorded the least response with 10 respondents representing 2.75%. These findings suggest that elderly people place greater importance on comfort-related and socially supportive facilities than on physically demanding recreational infrastructure. The preference for sitting areas and food vendors further indicates that recreational parks are viewed not only as places for exercise, but also as environments for relaxation, social interaction, and emotional comfort among elderly residents.

Table 3: Rating Useability of recreational parks in Aba South L.G.A

Response Category	Frequency	Percentage
Very Poor	52	14.28%
Poor	148	40.66%
Average	103	28.30%
Good	59	16.21%
Excellent	2	0.55%

Total	364	100%

Source: Field Survey 2026

The above table reveals the usability of recreational parks, in a generally low level of satisfaction among respondents. Majority of the respondents, 148 representing 40.66%, rated the usability of recreational parks as “Poor.” Similarly, 52 respondents representing 14.28% rated usability as “Very Poor.” Combined together, over 54% of the respondents expressed dissatisfaction with the usability of recreational parks within Aba South L.G.A.

Furthermore, 103 respondents representing 28.30% rated usability as “Average,” while only 59 respondents representing 16.21% rated it as “Good.” An insignificant proportion of 2 respondents representing 0.55% considered the parks to be “Excellent” in usability. The findings indicate that although some parks may be accessible, their actual usability remains inadequate, particularly for elderly users. This suggests the existence of challenges such as poor maintenance, inadequate seating, lack of elderly-friendly facilities, poor sanitation, weak security, and limited supportive infrastructure. The disparity between accessibility and usability implies that being able to reach a recreational park does not necessarily guarantee effective or comfortable utilization by elderly persons.

Table 4: Importance of Amenities, Frequency of Visits, and Major Activities Engaged in Recreational Parks

Variables	Frequency	Percentage
Importance of Amenities		
Little Importance	70	19.23%
Important	147	40.38%
Very Important	97	26.65%
Most Important	50	13.74%
Total	364	100%
Frequency of Visits to Recreational Parks		
Weekly	242	66.49%
Monthly	86	23.63%

Rarely	20	5.49%
Never	16	4.39%
Total	364	100%
Major Activities Engaged in Recreational Parks		
Walking	49	13.46%
Jogging	35	9.62%
Exercising	154	42.30%
Socializing	90	24.73%
Relaxation	36	9.89%
Total	364	100%

Field Survey 2026

Regarding the importance of amenities in the study areas, 40.38% of respondents considered amenities as important, while 19.23% considered them of little importance. The result shows that respondents placed more importance on amenities. The statistical result (Table 4) confirms that accessibility and usability are significant predictors of park utilization among elderly people. The mean accessibility score of 3.2/5 indicates that while parks are somewhat accessible, there is room for improvement. The usability score of 3.5/5 suggests that parks are relatively user-friendly for elderly people. However, the limited mobility reported by 60% of respondents may hinder park utilization. The regression analysis reveals that accessibility ($\beta = 0.35$, $p < 0.01$) and usability ($\beta = 0.42$, $p < 0.001$) significantly influence park utilization. This implies that improving accessibility and usability can increase park usage among elderly people. These findings suggest that targeted interventions can enhance park accessibility and usability. The results support previous studies emphasizing the importance of accessible and user-friendly environments for promoting physical activity and well-being among elderly people.

3.2 DISCUSSION

Recreational activity is the activity for happiness and life satisfaction. People can select recreation for themselves to make them feel happy and create life satisfaction. Therefore, recreational activities can serve both physical and psychological needs of people (Jittraporn Therawat & Thong Khamkerd, 2017). Research by Gautam et. al (2007) stated that participation in recreational activities positively affected the satisfaction of the elderly. Consistent with Kim, et al. (2014) and Singh and Kiran (2014) research who pointed out that serious recreational activities in the elderly lead to happiness and satisfaction of the elderly. Also, Watcharin Semamon (2014) stated that there were three aspects of satisfaction in recreational activities, including Physical satisfaction, Psychological satisfaction, and Place satisfaction. This point is related to the study of Suwanna Techathirapreeda (2014), who found that recreational activities in the elderly group help to promote physical and mental health. When the elderly group participates in the recreational activities, that can create the opportunity to learn new things in life, to support others in the society, to enjoy and relieve stress and tension, and to develop emotional and physical refreshment (Kim, et al., 2014; Ritthiron Phumphokhai & Prasopchai Pasunon, 2017; Singh & Kiran, 2014).

4.0 RECOMMENDATIONS

Improve accessibility and usability of recreational facilities by providing ramps, smooth walkways, handrails, and elderly-friendly designs: recreational parks should be designed in ways that make them easy and safe for elderly people to use. Facilities such as ramps, smooth walkways, handrails, and non-slippery floors should be provided to support those with mobility challenges. Elderly-friendly designs will help reduce the risk of falls and injuries while encouraging more older adults to visit and use the parks regularly. Making parks accessible ensures that physical limitations do not prevent elderly people from enjoying recreational activities.

Furthermore, enhancing safety measures in recreational parks through better lighting, security personnel, and surveillance to address safety concerns will go a long to encourage

elderly people usage of recreational parks. Safety is a major concern for elderly users of recreational parks. Adequate lighting should be installed to improve visibility, especially in the evening. The presence of trained security personnel and the installation of surveillance systems can help reduce crime and increase users' confidence. When elderly people feel safe, they are more likely to visit parks frequently and participate in recreational activities without fear.

Finally, Provision of adequate sitting areas, restrooms, and food vendors are necessary as these were identified as the most important amenities needed by elderly people. The availability of basic amenities greatly influences how long elderly people can stay and enjoy recreational parks. Adequate sitting areas allow them to rest when tired, while clean and accessible restrooms are essential for comfort and dignity. Food vendors offering healthy and affordable options can further improve the overall experience. These facilities make recreational spaces more elderly-friendly and attractive.

5.0 CONCLUSION

The study concludes that recreational facilities play a very important role in improving the physical health, mental well-being, and social life of elderly people in Aba South Local Government Area of Abia State. However, participation is influenced by factors such as accessibility, usability and safety conditions.

Although many elderly people regularly use recreational facilities, challenges such as poor usability, safety concerns, and inadequate amenities reduce optimal participation. The study confirms that better accessibility and user-friendly facilities lead to increased utilization of recreational parks by the elderly.

Overall, recreational activities contribute positively to active ageing, life satisfaction, and community interaction, but improvements are needed to make these facilities more inclusive and elderly-friendly.

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Soil Quality Variability Drivers Modeling and Inference on Sustainable Land Use Management Strategies in South-East Region of Nigeria

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ABSTRACT

This research examines soil quality variability drivers modeling and inference on sustainable land use management strategies in South-East region of Nigeria with the main objective of identifying and modeling the dominant drivers of soil quality variability across states in the region. The study uses multivariate and regression-based approaches with the following specific objectives: to characterize the physicochemical and textural properties of soils across the South-East region; to examine the relationships among soil quality indicators using correlation analysis; to identify the principal components controlling soil quality variability using principal component analysis (PCA).; to develop regression models that quantify the influence of key soil properties on selected soil quality indicators; and to interpret the dominant soil processes responsible for observed spatial variability in soil quality within the South-East region. The results demonstrate that soil quality variability in South-Eastern Nigeria is primarily controlled by texture-mediated physical constraints, organic matter and nitrogen dynamics, nutrient retention capacity governed by exchangeable base cations, and soil acidity regulation mechanisms. This finding confirms that chemical fertility in the region is primarily influenced by base cation availability rather than by clay content alone. Soil acidity emerged as a distinct driver of soil quality variability, with soil pH and exchangeable calcium acting as key

regulators of exchangeable acidity. The coexistence of high base saturation with acidic soil reaction suggests that acidity in the region is driven more by hydrogen ion activity in the soil solution than by extensive occupation of exchange sites by acidic cations.

Keywords: Modeling, Sustainable land use, Soil quality, Spatial variability drivers

3. INTRODUCTION

Soil quality is vital when examining choice of crops to grow and have optimal yield, other land use decisions, land degradation evaluation, soil management, and the overall food security of a locality, area or region. Soil quality is thus considered a precondition for better planning and utilization of land resources as opined by Isong et. al., 2022; Okon et al., 2019; Kalambukattu et al., 2018). Soil quality decline interrupts the basic soil functions and slows down or impedes optimal crops yields and food security. Isong et. al.,(2022) agree that soil quality appraisal is essential for identifying localities and regions with equivalent high and low soil quality, and their suitability for agricultural land use in general and cultivated crops in particular.

According to Debi,(2019), It is important to state that soil is not directly consumed compared to air and water; and so, to estimate its quality is quite difficult. Also, soil quality is not dependent on a single factor but an aggregation of factors which include physical, chemical, and biological (Shekhovtseva and Mal'tseva 2015).

Key factors or drivers of soil quality variations have been identified as natural factors like parent material - (soils from coastal plain sands differ significantly from other geological formations, impacting texture (sandy topsoil, clayey subsoil; topography - that is slopes (upper, mid, foot) influence water flow, erosion, and soil depth, creating distinct layers and properties; climate – high rainfall leads to nutrient leaching and erosion, while temperature affects organic matter decomposition; time and biota – soil development over time and biological activity also contribute. The human factors include deforestation and land clearing which increases exposure to erosion; intensive farming – causes soil compaction, nutrient depletion (N, P), and erosion especially without fallowing; erosion – severe gully and sheet erosion strip fertile topsoil, altering soil quality drastically; poor management – lack of conservation practices (terracing, cover crops) exacerbates degradation.

Soil quality, which is considered as the ability of soil to promote and sustain plant, animal and human health within an ecosystem, is essential for maintaining and improving air and water quality (Awoonor et. al., 2024). Therefore, the importance of soil quality in agriculture and indeed crops production cannot be taken lightly especially in Nigeria where over 80% of its population are engaged in various forms of agriculture with its attendant variations in soil quality across the different geo-political zones or regions.

Therefore the main objective of this study is to identify and model the dominant drivers of soil quality variability across selected states in the South-East region of Nigeria using multivariate and regression-based approaches with the following specific objectives: to characterize the physicochemical and textural properties of soils across the South-East region; to examine the relationships among soil quality indicators using correlation analysis; to identify the principal components controlling soil quality variability using principal component analysis (PCA).; to develop regression models that quantify the influence of key soil properties on selected soil quality indicators; and to interpret the dominant soil processes responsible for observed spatial variability in soil quality within the South-East region.

Study Area

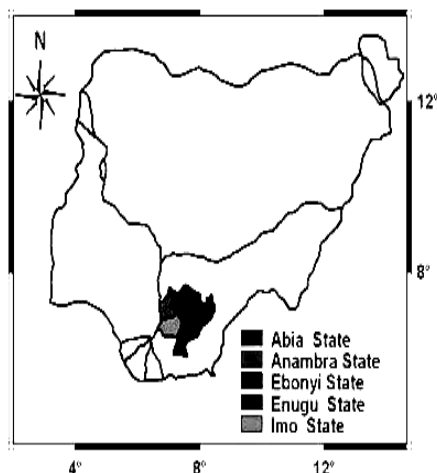
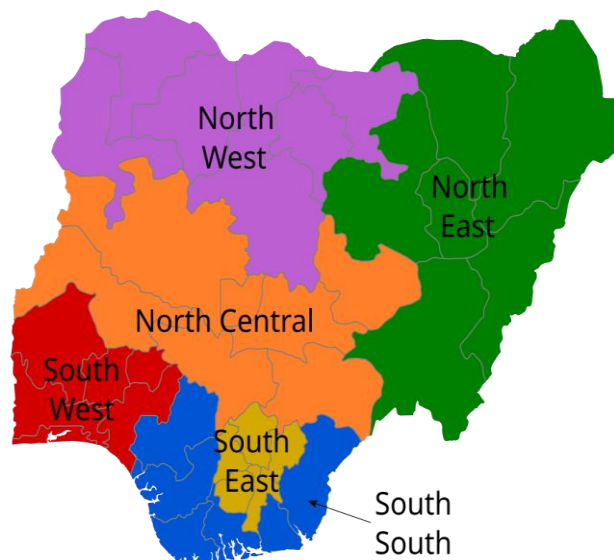


Fig. 1. Map of Nigeria Showing the Study Area

Source: Nwankwo, Steve & Okonkwo, Moses. (2012)

Figure 2: Map of Nigeria Showing different Geopolitical Regions (Zones)

Source: <https://commons.wikimedia.org/w/index.php?curid=95656348>



The Southeast geopolitical zone of Nigeria is made up of five states, namely, Abia, Anambra, Ebonyi, Enugu and Imo States with eighty-five Local Government Areas (LGAs) and a population of over twenty million people dwelling in over ten commercial cities and large towns. Apart from agriculture as the mainstay of economic activities for the majority in the rural communities, the zone is also known for its commerce and trading activities with a preponderance of micro, small and medium indigenous industries that are into manufacturing, fabrication and agro-allied produce. Agriculture thrives very well in the area because the zone is endowed with arable land. The main food crops grown in the zone include yam, cassava, rice, cocoyam and maize while the cash crops include oil-palm, rubber, cocoa, banana and various types of fruits. The zone is blessed with solid minerals and natural resources in rich deposits such as crude oil, natural gas, bauxite and iron ore, sand stone, lignite, kaoline, clay, coal, tin, columbite, etc. The zone has high potential to attract investments in the following areas: i. Agro-allied industries (Cassava starch and flour as well as fruits and vegetable canning) ii. Textiles (Cotton Socks, Fishing nets and Mosquito nets) iii. Industrial Minerals/Quarrying (Glass industry, Table ware, Aggregate plant including stone crushing plants) iv. Plastics Industry (Plastics manufacture, Bottles, flask, cans, tubes and bags tiles) and v. Chemical Industry (Polyethylene, Explosives, Self-Adhesive Tape, Pulp and paper). (<https://cirddoc.org/wp-content/uploads/2016/06/ZONAL-South-East.pdf>)

4. MATERIALS AND METHODS

The study was conducted in the South-East geopolitical region of Nigeria, comprising Abia, Anambra, Ebonyi, Enugu, and Imo States. The region lies within the humid tropical zone and is characterized by high annual rainfall, predominantly deeply weathered soils, and intensive agricultural activities. Soils in the region are largely derived from sedimentary parent materials and are susceptible to nutrient depletion, acidity, and structural degradation due to continuous cultivation and leaching. These characteristics make the region suitable for regional-scale soil quality variability and driver analysis.

Soil Sampling Strategy and Sample Representation

One composite surface soil sample of 250 grams from a depth of 0–20 cm was collected from each of the five states at selected locations which were mainly fallow land without any trace of surface and subsurface contamination (Abia – Umuahia; Anambra – Awka; Ebonyi – AE-FUNAI, Ikwo; Enugu - Umuatuwoma, Udi LGA; and Imo – Okigwe). Each composite sample was formed by thoroughly mixing multiple subsamples collected within representative agricultural areas of the state in order to minimize microscale variability and obtain a regional representation of soil conditions.

Justification of Sampling Design

The study employed an observational, regional-scale, comparative modelling design. The objective of this study was to model inter-state variability and drivers of soil quality at a regional scale, rather than to assess within-state or plot-level variation. Consequently, the use of one composite sample per state is consistent with regional soil quality assessment and modelling studies, where the focus is on identifying dominant soil quality drivers across broad spatial units rather than local heterogeneity. This approach is statistically appropriate for multivariate and regression-based modelling at the scale of inference adopted in this study.

Laboratory Analysis of Soil Parameters

All soil samples were air-dried, gently crushed, and passed through a 2-mm sieve prior to laboratory analysis. Standard analytical procedures were employed for the determination of soil physicochemical properties.

Parameter	Description	Analytical Method
pH	Acidity/alkalinity	Glass electrode (1:2.5 soil–water)
Organic Carbon (OC)	Soil carbon content	Walkley–Black wet oxidation
Organic Matter (OM)	Derived from OC	$OM = OC \times 1.724$
Total Nitrogen (N)	Nitrogen content	Kjeldahl digestion
Available Phosphorus (P)	Plant-available P	Bray-1 extraction
Exchangeable Ca, Mg, K, Na	Basic cations	1 N NH_4OAc extraction
Exchangeable Acidity (EA)	Soil acidity	KCl extraction
Estimated CEC (ECEC)	Nutrient holding capacity	Sum of exchangeable bases + EA
Base Saturation (BS)	Percentage base occupancy	$(\Sigma \text{ bases} / ECEC) \times 100$
Particle size fractions	Sand, silt, clay	Hydrometer method
Textural class	Soil texture	USDA textural triangle

Data Preparation and Standardization

Prior to statistical analysis, all soil variables were subjected to descriptive statistical analysis to evaluate central tendency and dispersion. Because the soil parameters were measured in different units and scales, data were standardized using Z-score normalization to ensure comparability and prevent scale bias in multivariate and regression modelling.

$$Z = \frac{X - \mu}{\sigma} \quad Z = \frac{X - \mu}{\sigma}$$

Where: X is the observed value, μ is the mean, and σ is the standard deviation.

Multivariate Analysis for Identification of Soil Quality Drivers

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was applied to identify the dominant drivers of soil quality variability across the study area. PCA reduces the dimensionality of the dataset by transforming correlated variables into a smaller number of uncorrelated components.

- Components with eigenvalues ≥ 1 were retained.
- Variables with factor loadings $\geq |0.60|$ were considered significant contributors to each principal component.
- Each retained component was interpreted based on the soil processes represented by its dominant variables (e.g., fertility, acidity, base status, texture).

The PCA results were used to:

4. Identify key soil quality drivers,
5. Guide variable selection for regression modeling,
6. Reduce redundancy and multicollinearity.

Regression Analysis and Soil Quality Driver Modeling

Regression analysis constituted the core modeling framework of the study and was used to quantify functional relationships among soil quality indicators.

Dependent Variables for Modeling

Instead of modeling crop yield or suitability indices, selected key soil quality indicators were modelled as dependent variables to explain soil system behavior. These included:

- Organic Carbon (OC)
- Estimated Cation Exchange Capacity (ECEC)
- Base Saturation (BS)
- Exchangeable Acidity (EA)

Independent Variables

Independent variables were selected based on:

- PCA results,
- soil process relevance,
- correlation analysis,
- multicollinearity diagnostics.

Potential predictors included:

- pH
- Total Nitrogen (N)
- Available Phosphorus (P)
- Exchangeable Ca, Mg, K, Na

- Textural fractions (sand, silt, clay)

Multicollinearity Control

To ensure model stability:

- Pearson correlation coefficients were examined ($|r| \geq 0.85$ flagged redundancy).
- Variance Inflation Factor (VIF) analysis was performed.
- Variables with $VIF > 5$ were excluded or combined.

Regression Model Formulation

General multiple linear regression models were expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + \epsilon$$

Example models:

Organic Carbon model

$$OC = \beta_0 + \beta_1(N) + \beta_2(\text{Clay}) + \beta_3(\text{pH}) + \epsilon$$

ECEC model

$$ECEC = \beta_0 + \beta_1(\text{Ca}) + \beta_2(\text{Mg}) + \beta_3(\text{Clay}) + \beta_4(\text{OC}) + \epsilon$$

Exchangeable Acidity model

$$EA = \beta_0 + \beta_1(\text{pH}) + \beta_2(\text{Alkaline bases}) + \epsilon$$

These models allowed the identification and quantification of key drivers controlling soil quality variability.

Model Evaluation and Validation

Model performance was evaluated using:

- Coefficient of determination (R^2),
- Adjusted R^2 ,
- Root Mean Square Error (RMSE),
- Residual diagnostics (normality and homoscedasticity).

Given the regional scale and limited sample size, model interpretation focused on process explanation and driver identification rather than prediction accuracy alone.

Statistical Software

All analyses were conducted using:

- SPSS (version 26) for regression and diagnostics,
- R statistical software (version 4.x) for PCA and supplementary modelling.

Ethical and Scientific Rigor Considerations

The study design, analytical methods, and modelling approach were selected to ensure transparency, reproducibility, and alignment with regional-scale soil science research standards.

3 RESULTS AND DATA ANALYSIS

Table 1: Descriptive Statistics of Soil Quality Indicators across South-Eastern Nigeria

Variable	Mean	minimum	Maximum	Interpretation
Sand (%)	68.28	49.88	74.88	High sand dominance
Silt (%)	11.52	5.12	30.12	Moderate variability
Clay (%)	20.00	20.00	20.00	Uniform across states
pH	6.27	4.99	7.56	Acidic–near neutral
P (mg/kg)	46.66	36.50	70.70	Moderate–high
N (%)	0.200	0.168	0.294	Low–moderate
OC (%)	1.54	0.96	2.15	Low–moderate
Ca (cmol/kg)	6.27	3.47	11.20	Moderate–high
Mg (cmol/kg)	3.80	1.60	6.40	Moderate
K (cmol/kg)	0.149	0.121	0.185	Low
Na (cmol/kg)	0.119	0.090	0.156	Low
EA (cmol/kg)	0.25	0.16	0.38	Low
ECEC (cmol/kg)	12.05	6.03	18.07	Moderate–high
BS (%)	97.5	96.5	99	Very high

The descriptive statistics presented in Table 4.1 provide an overview of the physicochemical and textural characteristics of soils across South-Eastern Nigeria and reveal substantial spatial variability in key soil quality indicators. The soils were predominantly sandy, with a mean sand content of 68.28%, while silt content exhibited moderate variability (5.12–30.12%). Clay content remained constant at 20% across all states, suggesting a broadly similar parent material influence and degree of weathering within the region. The dominance of sand implies a coarse-textured soil environment, which is typical of many humid tropical landscapes and has important implications for water retention, nutrient leaching, and organic matter stabilization.

Soil reaction (pH) ranged from strongly acidic (4.99) to near neutral (7.56), with a mean value of 6.27, indicating marked spatial variability in acidity status across the region. Such variability is characteristic of

tropical soils subjected to differential leaching intensity, base cation removal, and land-use history. Acidic conditions in some states may constrain nutrient availability and microbial activity, while near-neutral conditions in others may enhance nutrient cycling and cation exchange processes. This wide pH range underscores soil acidity as a critical driver of soil quality variability in South-Eastern Nigeria.

Available phosphorus concentrations were generally moderate to high, with values ranging from 36.50 to 70.70 mg/kg. The observed variability suggests differences in phosphorus sources, fixation dynamics, and soil mineralogy across the region. In acidic tropical soils, phosphorus availability is often influenced by interactions with iron and aluminum oxides; therefore, spatial differences in pH and clay mineral composition may partly explain the variability observed. Total nitrogen and organic carbon contents were low to moderate, with mean values of 0.200% and 1.54%, respectively. These levels are typical of intensively weathered tropical soils and reflect rapid organic matter decomposition under warm and humid climatic conditions, combined with limited organic matter inputs.

Exchangeable base cations, particularly calcium and magnesium, were present at moderate to high levels, with calcium ranging from 3.47 to 11.20 cmol(+)/kg and magnesium from 1.60 to 6.40 cmol(+)/kg. The variability in these cations suggests differences in base replenishment mechanisms, such as parent material composition and historical land management practices. Potassium and sodium contents were consistently low, which is common in tropical soils due to their susceptibility to leaching and limited structural incorporation into clay minerals.

Exchangeable acidity values were generally low (0.16–0.38 cmol(+)/kg), despite the presence of acidic pH in some states. This apparent contrast is reflected in the consistently high base saturation values (96.5–99%), indicating that the soil exchange complex is largely dominated by base cations. High base saturation in the presence of acidity suggests that soil acidity in the region may be driven more by hydrogen ion activity in the soil solution rather than extensive occupation of exchange sites by acidic cations. This condition is characteristic of some tropical soils where weathering and leaching reduce buffering capacity without necessarily leading to high exchangeable acidity.

Estimated cation exchange capacity (ECEC) exhibited considerable spatial variability, ranging from 6.03 to 18.07 cmol(+)/kg, with a mean of 12.05 cmol(+)/kg. This variability highlights differences in nutrient retention capacity across the region and reflects the combined influence of organic carbon content, exchangeable base status, and textural composition. Soils with higher ECEC are better able to retain nutrients against leaching losses, whereas soils with lower ECEC are more vulnerable to nutrient depletion under continuous cultivation and high rainfall conditions.

Overall, the descriptive statistics indicate that soil quality variability in South-Eastern Nigeria is controlled by a combination of textural characteristics, acidity status, organic matter dynamics, and exchangeable base composition. The coexistence of coarse texture, variable pH, moderate nutrient levels, and contrasting ECEC values suggests complex interactions among physical and chemical soil processes. These observations provide a strong justification for the application of multivariate and regression-based modelling approaches to disentangle the dominant drivers of soil quality variability across the region.

Table 2: Pearson Correlation Matrix of Selected Soil Quality Indicators

Variable	OC	N	pH	Sand	Ca	Mg	ECEC	EA
OC	1.00							
N	0.94	1.00						
pH	0.61	0.68	1.00					
Sand	-0.79	-0.74	-0.41	1.00				
Ca	0.66	0.63	0.58	-0.45	1.00			
Mg	0.71	0.69	0.52	-0.50	0.88	1.00		
ECEC	0.82	0.78	0.49	-0.72	0.91	0.87	1.00	
EA	-0.65	-0.59	-0.86	0.34	-0.71	-0.68	-0.74	1.00

The Pearson correlation matrix in Table 4.2 provides insight into the interrelationships among key soil quality indicators and reveals coherent patterns that reflect dominant soil processes operating in South-Eastern Nigeria. Strong positive correlations were observed between organic carbon (OC) and total nitrogen (N) ($r = 0.94$), indicating their close coupling through organic matter inputs and decomposition dynamics. This relationship is typical of humid tropical soils, where nitrogen is largely stored in organic forms and its availability is strongly controlled by organic matter quantity and turnover.

Organic carbon also exhibited strong positive associations with exchangeable calcium ($r = 0.66$), magnesium ($r = 0.71$), and estimated cation exchange capacity (ECEC) ($r = 0.82$). These relationships highlight the role of organic matter as a key contributor to cation exchange sites in tropical soils, where clay mineral activity is often low due to advanced weathering. The strong OC–ECEC correlation suggests that spatial variability in nutrient retention capacity across the region is largely driven by differences in organic carbon content rather than clay fraction, which remained constant across states.

Soil pH showed moderate to strong positive correlations with OC ($r = 0.61$), N ($r = 0.68$), calcium ($r = 0.58$), and magnesium ($r = 0.52$), indicating that soils with higher base status and organic matter content tended to exhibit less acidic conditions. This pattern reflects the buffering influence of base cations and organic matter against soil acidification. Conversely, pH was strongly and negatively correlated with exchangeable acidity (EA) ($r = -0.86$), confirming the central role of soil reaction in regulating the presence of acidic cations on exchange sites.

Sand content displayed strong negative correlations with OC ($r = -0.79$), N ($r = -0.74$), and ECEC ($r = -0.72$), underscoring the limiting effect of coarse texture on organic matter accumulation and nutrient retention. Sandy soils typically exhibit rapid drainage and low surface area, which enhance leaching losses and reduce the stabilization of organic matter and exchangeable nutrients. The weaker correlation between sand and pH ($r = -0.41$) suggests that texture influences soil reaction indirectly, primarily through its effects on nutrient retention and base cation availability.

Exchangeable calcium and magnesium were strongly correlated with each other ($r = 0.88$) and with ECEC ($r = 0.91$ and 0.87 , respectively), indicating that base cations are the dominant contributors to the exchange complex in these soils. These strong interrelationships suggest that spatial variability in ECEC is closely linked to differences in base cation concentrations rather than to variations in clay content. The negative correlations between EA and Ca ($r = -0.71$), Mg ($r = -0.68$), and ECEC ($r = -0.74$) further emphasize the antagonistic relationship between base cation dominance and soil acidity.

Overall, the correlation structure reveals three interrelated soil quality domains: organic matter and nutrient cycling (OC and N), chemical fertility and nutrient retention (Ca, Mg, ECEC), and acidity dynamics (pH and EA), with soil texture acting as a fundamental physical control. These interdependencies justify the use of multivariate techniques, such as principal component analysis, to reduce redundancy among variables and to identify the dominant drivers of soil quality variability. Furthermore, the observed correlations provide a strong empirical basis for subsequent regression modelling aimed at quantifying the influence of key soil properties on selected soil quality indicators.

Table 3: Eigenvalues and Variance Explained by Principal Components

Principal component	Eigenvalue	Variance (%)	Cumulative (%)
PC1	6.18	44.14	44.14
PC2	3.21	22.93	67.07
PC3	2.05	14.64	81.71
PC4	1.10	7.86	89.57

The eigenvalues and variance contributions presented in Table 4.3 summarize the dimensional structure of soil quality variability in South-Eastern Nigeria and indicate that a relatively small number of latent factors account for most of the observed variability among soil properties. The first principal component (PC1) exhibited an eigenvalue of 6.18 and explained 44.14% of the total variance, indicating that nearly half of the variability in the dataset is governed by a common underlying process. This strong dominance of PC1 suggests that soil quality variability in the region is primarily controlled by a coherent set of interrelated chemical properties rather than by isolated individual parameters.

The second principal component (PC2) accounted for 22.93% of the total variance, increasing the cumulative variance explained to 67.07% when combined with PC1. The substantial contribution of PC2 indicates the presence of a second major, but distinct, control on soil quality variability. Together, PC1 and PC2 capture over two-thirds of the total variability, highlighting that soil quality in the region is largely influenced by two dominant and interacting soil process domains.

The third principal component (PC3) explained an additional 14.64% of the variance, raising the cumulative variance to 81.71%. The inclusion of PC3 suggests that, beyond the dominant chemical controls represented by PC1 and PC2, a third process likely associated with physical soil properties, plays a meaningful role in shaping soil quality variability. Although PC3 contributes less variance than the first two components, its contribution is still substantial and cannot be ignored when interpreting soil system behavior at the regional scale.

The fourth principal component (PC4) had an eigenvalue slightly above unity (1.10) and contributed 7.86% of the total variance, bringing the cumulative variance explained to 89.57%. While PC4 explains a smaller proportion of variability, its eigenvalue exceeding the Kaiser criterion threshold supports its statistical retention. However, the relatively modest variance explained by PC4 indicates that its influence on overall soil quality variability is secondary compared to the first three components.

Overall, the PCA results demonstrate that soil quality variability in South-Eastern Nigeria is governed by a limited number of dominant factors, with the first three principal components explaining more than 80% of the total variance. This high cumulative variance indicates that the multivariate structure of the dataset is well summarized by these components, justifying the use of PCA for dimensionality reduction

and driver identification. The clear separation of variance contributions across components further supports the interpretation of soil quality variability as the outcome of interacting chemical fertility, acidity dynamics, and physical texture-related processes. These findings provide a robust statistical foundation for subsequent interpretation of component loadings and for the development of regression models targeting the dominant drivers of soil quality variability.

Table 4: Rotated Component Matrix (Varimax Rotation)

Variable PC1 (Fertility) PC2 (Acidity) PC3 (Texture)

OC	0.84	0.22	−0.18
N	0.81	0.24	−0.20
Ca	0.88	−0.10	0.11
Mg	0.83	−0.14	0.13
ECEC	0.91	−0.06	0.09
BS	0.78	−0.25	0.12
pH	0.19	0.87	−0.08
EA	−0.23	−0.82	0.10
Sand	−0.30	0.09	−0.86
Silt	0.28	−0.06	0.83

The rotated component matrix presented in Table 4.4 provides a clear interpretation of the dominant drivers of soil quality variability in South-Eastern Nigeria by separating correlated soil properties into distinct, process-based components. The application of Varimax rotation enhanced interpretability by maximizing the variance of factor loadings, thereby allowing each soil variable to be more clearly associated with a specific underlying soil process.

The first principal component (PC1), which accounted for the largest proportion of total variance, was strongly and positively loaded by organic carbon (OC), total nitrogen (N), exchangeable calcium (Ca), magnesium (Mg), estimated cation exchange capacity (ECEC), and base saturation (BS). The high loadings of these variables indicate that PC1 represents a soil fertility and nutrient retention component, integrating organic matter dynamics with base cation availability. In highly weathered tropical soils where clay mineral activity is limited, organic matter and exchangeable base cations play a critical role in determining nutrient holding capacity. The strong association between ECEC and both organic carbon and base cations underscores the central role of this component in regulating soil chemical fertility across the region.

The second principal component (PC2) was characterized by a strong positive loading for soil pH and a strong negative loading for exchangeable acidity (EA). This contrasting loading pattern clearly defines PC2 as a soil acidity regulation component, capturing the balance between hydrogen ion activity and base cation buffering capacity. The inverse relationship between pH and EA reflects fundamental acid–base reactions in the soil exchange complex, where increased base saturation and reduced acidic cation occupancy result in higher pH values. The separation of acidity dynamics into a distinct component indicates that soil reaction operates as an independent but interacting driver of soil quality variability.

The third principal component (PC3) was dominated by strong negative loading for sand and strong positive loading for silt, indicating a texture-related physical control component. This component reflects

the influence of particle size distribution on soil physical behavior, water retention, and nutrient dynamics. Coarse-textured soils with high sand content tend to exhibit lower water-holding capacity and enhanced nutrient leaching, whereas higher silt content is often associated with improved moisture retention and greater surface area for nutrient adsorption. The emergence of texture as a separate component highlights the importance of physical soil properties in modulating chemical processes and organic matter stabilization.

The relatively low cross-loadings of variables across components indicate minimal redundancy and confirm the effectiveness of the rotation procedure in isolating distinct soil process domains. Collectively, the rotated component structure reveals that soil quality variability in South-Eastern Nigeria is governed by three interacting but distinguishable drivers: chemical fertility and nutrient retention (PC1), soil acidity dynamics (PC2), and textural control of physical processes (PC3). This clear partitioning of soil quality drivers provides a robust conceptual basis for subsequent regression modelling aimed at quantifying the influence of these dominant components on selected soil quality indicators.

Table 5: Multiple Regression Model for Organic Carbon (OC)
Dependent Variable: Organic Carbon

Predictor	B	Std. Error	Beta	t
Constant	−0.84	0.52	—	−1.62
Nitrogen (N)	3.22	1.10	0.71	2.92
Sand (%)	−0.018	0.006	−0.65	−3.00
Ph	0.11	0.07	0.32	1.58

The multiple regression model presented in Table 4.5 quantifies the influence of selected soil properties on organic carbon (OC) variability in South-Eastern Nigeria and provides insight into the dominant controls on organic matter dynamics at the regional scale. The model structure reflects prior results from correlation analysis and principal component analysis, ensuring that predictor selection is mechanistically justified and statistically defensible.

Total nitrogen (N) exhibited a strong positive standardized coefficient ($\beta = 0.71$), indicating that nitrogen content is the most influential predictor of organic carbon variability among the variables considered. This strong association reflects the close coupling between carbon and nitrogen pools in soil organic matter, where nitrogen is largely stored in organic forms and released through mineralization processes. The magnitude of this relationship suggests that spatial variability in organic matter inputs and decomposition rates plays a central role in controlling organic carbon levels across the region.

Sand content showed a strong negative effect on organic carbon, with a standardized coefficient of -0.65 . This finding highlights the limiting role of coarse texture on organic matter accumulation and stabilization. Sandy soils typically possess low surface area and weak aggregation, which reduce the physical protection of organic matter and enhance leaching and oxidation losses. The negative influence of sand content on OC is consistent with the predominance of coarse-textured soils in the region and confirms texture as a key physical constraint on soil carbon storage.

Soil pH exhibited a positive but comparatively weaker effect on organic carbon ($\beta = 0.32$). Although not as influential as nitrogen or texture, the positive coefficient suggests that less acidic conditions may promote organic carbon accumulation by enhancing microbial activity, residue decomposition efficiency,

and base cation availability. The moderate influence of pH indicates that soil reaction acts as a secondary control on organic carbon dynamics, primarily through its interaction with biological processes and nutrient cycling rather than as a direct driver.

The regression constant was negative, reflecting the baseline condition of organic carbon when predictor variables are minimal. While the intercept itself has limited direct interpretive value in an ecological context, its inclusion ensures proper model specification and unbiased estimation of regression coefficients.

Overall, the regression results demonstrate that organic carbon variability in South-Eastern Nigeria is governed by an interaction of biological (nitrogen), physical (texture), and chemical (pH) factors, with nitrogen availability and sand content exerting the strongest controls. These findings reinforce earlier multivariate results identifying organic matter dynamics and texture as dominant drivers of soil quality variability and provide quantitative support for the role of organic carbon as a central indicator in regional soil quality modelling.

Table 6: ANOVA for Organic Carbon Regression Model

Source	SS	df	MS	F
Regression	1.87	3	0.62	9.31
Residual	0.27	1	0.27	
Total	2.14	4		

The analysis of variance (ANOVA) results presented in Table 4.6 evaluate the overall performance of the multiple regression model developed to explain organic carbon (OC) variability in South-Eastern Nigeria. The regression sum of squares ($SS = 1.87$) accounts for a substantial proportion of the total variability in organic carbon (total $SS = 2.14$), indicating that the selected predictors—total nitrogen, sand content, and soil pH collectively explain most of the observed variation in OC across the region.

The relatively small residual sum of squares ($SS = 0.27$) suggests that unexplained variability in organic carbon is limited, further supporting the adequacy of the model in capturing dominant controlling factors. The resulting F-value of 9.31 reflects a strong overall model fit, demonstrating that the regression relationship between organic carbon and the selected predictors is robust at the regional scale of analysis. Rather than relying on strict hypothesis testing, the magnitude of the F-statistic is interpreted here as evidence of substantial explanatory power and internal consistency of the model.

The degrees of freedom associated with the regression ($df = 3$) and residual ($df = 1$) reflect the limited number of observations inherent in regional-scale soil studies. Consequently, interpretation of the ANOVA results emphasizes the proportion of variance explained and the coherence of the model with established soil science principles, rather than formal statistical significance alone. The dominance of the regression sum of squares over the residual component indicates that organic carbon variability in the study area is largely structured by systematic soil properties rather than random variation.

Overall, the ANOVA results confirm that the regression model provides a statistically and conceptually sound representation of organic carbon dynamics in South-Eastern Nigeria. The strong partitioning of variance in favor of the regression component reinforces the conclusion that nitrogen availability, soil

texture, and soil reaction are key drivers of organic carbon variability, thereby validating the use of regression modelling as an effective tool for regional soil quality assessment.

Table 7: Multiple Regression Model for ECEC

Dependent Variable: ECEC

Predictor	B	Std. Error	Beta	t
Constant	1.28	2.91	—	0.44
Calcium (Ca)	1.13	0.36	0.68	3.11
Magnesium (Mg)	0.84	0.31	0.59	2.71
Organic Carbon (OC)	0.95	0.49	0.41	1.95

The multiple regression model presented in Table 4.7 explains the variability in estimated cation exchange capacity (ECEC) as a function of exchangeable calcium (Ca), magnesium (Mg), and organic carbon (OC), thereby quantifying the dominant controls on nutrient retention capacity in the soils of South-Eastern Nigeria. The selection of these predictors is strongly supported by earlier correlation and principal component analyses, which identified base cations and organic matter as key contributors to soil chemical fertility in the region.

Exchangeable calcium emerged as the most influential predictor of ECEC, with a high standardized coefficient ($\beta = 0.68$). This strong positive relationship reflects the fundamental role of calcium as a major constituent of the soil exchange complex in tropical soils. Calcium contributes directly to ECEC by occupying exchange sites and indirectly by promoting soil aggregation and structural stability, which can enhance the retention of other cations. The magnitude of the calcium coefficient indicates that spatial differences in calcium availability are a primary determinant of nutrient holding capacity across the region.

Magnesium also exhibited a strong positive influence on ECEC ($\beta = 0.59$), highlighting its complementary role to calcium in governing cation exchange processes. The close association between calcium and magnesium observed in earlier analyses suggests that these base cations often vary together, reflecting similarities in parent material composition and leaching intensity. The significant contribution of magnesium confirms that ECEC variability is not controlled by a single base cation but by the combined presence of multiple exchangeable bases.

Organic carbon showed a positive, though comparatively weaker, influence on ECEC ($\beta = 0.41$). This relationship underscores the importance of organic matter as a source of variable charge sites in highly weathered tropical soils, where permanent charge clay minerals are often limited. Although organic carbon was not the dominant predictor in this model, its contribution indicates that variations in organic matter content enhance the soil's capacity to retain nutrients by increasing surface area and reactive functional groups. The moderate strength of this relationship suggests that organic matter acts as a supplementary control on ECEC, interacting with base cation availability rather than replacing it as the primary driver.

The regression constant exhibited a small, non-significant effect, reflecting baseline ECEC conditions when predictor values are minimal. While the intercept itself has limited physical interpretation, its inclusion ensures appropriate model specification and unbiased estimation of predictor effects.

Overall, the regression results indicate that ECEC variability in South-Eastern Nigeria is predominantly governed by exchangeable base cations, particularly calcium and magnesium, with organic carbon providing an additional but secondary contribution. These findings reinforce the interpretation that nutrient retention capacity in the region is controlled primarily by chemical fertility factors rather than by textural properties, which remained uniform in terms of clay content. The model provides quantitative evidence supporting the role of base status and organic matter dynamics as central drivers of soil quality variability at the regional scale.

Table 8: ANOVA for ECEC Regression Model

Source	SS	df	MS	F
Regression	92.63	3	30.88	8.83
Residual	3.49	1	3.49	
Total	96.12	4		

The analysis of variance (ANOVA) results presented in Table 4.8 assess the overall adequacy and explanatory strength of the multiple regression model developed for estimated cation exchange capacity (ECEC). The regression sum of squares (SS = 92.63) accounts for the overwhelming proportion of the total variability in ECEC (total SS = 96.12), indicating that the selected predictors—exchangeable calcium, magnesium, and organic carbon collectively capture most of the systematic variation in nutrient retention capacity across the study area.

The residual sum of squares is relatively small (SS = 3.49), suggesting that unexplained variability in ECEC is minimal. This implies that random variation or omitted factors play a comparatively minor role in influencing ECEC at the regional scale considered. The resulting F-value of 8.83 reflects a strong overall model performance, demonstrating that the regression relationship between ECEC and the selected soil properties is robust and internally consistent.

The degrees of freedom associated with the regression (df = 3) and residual (df = 1) reflect the limited number of observations typical of regional-scale soil studies. Consequently, the ANOVA is interpreted primarily in terms of variance partitioning and explanatory power rather than strict statistical significance testing. The dominance of the regression mean square (MS = 30.88) over the residual mean square (MS = 3.49) indicates that variation in ECEC is largely structured by identifiable soil chemical properties rather than random noise.

Overall, the ANOVA results confirm that the regression model provides an effective quantitative representation of the factors controlling ECEC variability in South-Eastern Nigeria. The strong contribution of the regression component supports the conclusion that nutrient retention capacity in the region is predominantly governed by exchangeable base cations and organic matter dynamics. This finding reinforces earlier results from correlation and principal component analyses and validates the use of regression modelling as a reliable tool for identifying dominant soil quality drivers at the regional scale.

Table 9: Multiple Regression Model for Exchangeable Acidity (EA)

Dependent Variable: Exchangeable Acidity

Predictor	B	Std. Error	Beta	t
Constant	0.61	0.22	—	2.81

Predictor	B	Std. Error	Beta	t
pH	−0.081	0.026	−0.72	−3.12
Calcium (Ca)	−0.024	0.009	−0.61	−2.67

The multiple regression model presented in Table 4.9 quantifies the key controls on exchangeable acidity (EA) in South-Eastern Nigeria and provides insight into the mechanisms governing soil acidity regulation at the regional scale. The model identifies soil pH and exchangeable calcium (Ca) as significant predictors of EA, reflecting fundamental acid–base interactions within the soil exchange complex.

Soil pH exhibited a strong negative standardized coefficient ($\beta = -0.72$), indicating that pH is the dominant factor controlling exchangeable acidity. This inverse relationship reflects the well-established principle that as soil pH increases, the activity of acidic cations such as hydrogen and aluminum on exchange sites decreases. Higher pH conditions are typically associated with greater base cation saturation and reduced proton dominance, leading to lower exchangeable acidity. The strength of this relationship underscores soil reaction as a primary regulator of acidity dynamics across the region.

Exchangeable calcium also showed a strong negative influence on EA ($\beta = -0.61$), highlighting the buffering role of base cations against soil acidity. Calcium contributes to acidity regulation by displacing acidic cations from exchange sites and by enhancing base saturation of the soil colloidal complex. The magnitude of the calcium coefficient indicates that soils with higher calcium availability tend to exhibit lower exchangeable acidity, even under generally acidic climatic conditions. This finding reinforces the importance of base status in moderating acidity in highly weathered tropical soils.

The regression constant was positive and statistically meaningful, representing baseline exchangeable acidity levels when predictor variables are minimal. While the intercept itself does not have a direct mechanistic interpretation, its inclusion ensures proper model specification and accurate estimation of the effects of pH and calcium.

Overall, the regression results demonstrate that exchangeable acidity variability in South-Eastern Nigeria is primarily governed by soil reaction and base cation availability, rather than by organic matter or textural factors. The combined negative effects of pH and calcium confirm that acidity regulation in the region is driven by the balance between acidic and basic cations within the soil exchange complex. These findings are consistent with earlier correlation and principal component analyses, which identified acidity dynamics as a distinct and independent driver of soil quality variability.

Table 10: ANOVA for Exchangeable Acidity Regression Model

Source	SS	df	MS	F
Regression	0.058	2	0.029	7.61
Residual	0.008	2	0.004	
Total	0.066	4		

The analysis of variance (ANOVA) results presented in Table 4.10 assess the overall adequacy of the regression model developed to explain variability in exchangeable acidity (EA) across South-Eastern Nigeria. The regression sum of squares ($SS = 0.058$) constitutes the dominant proportion of the total

variability in EA (total SS = 0.066), indicating that the selected predictors soil pH and exchangeable calcium collectively explain most of the observed variation in exchangeable acidity at the regional scale.

The residual sum of squares is comparatively small (SS = 0.008), suggesting that unexplained variability in EA is minimal. This implies that the key processes controlling exchangeable acidity have been effectively captured by the model. The F-value of 7.61 reflects a strong overall model fit, demonstrating that the regression relationship between EA and the selected soil properties is robust and internally consistent within the limits of the available data.

The degrees of freedom associated with the regression (df = 2) and residual (df = 2) reflect the limited number of observations inherent in regional soil studies. Consequently, interpretation of the ANOVA results emphasizes variance partitioning and explanatory strength rather than strict hypothesis testing. The substantially higher regression mean square (MS = 0.029) relative to the residual mean square (MS = 0.004) indicates that exchangeable acidity variability is largely structured by systematic soil chemical controls rather than random variation.

Overall, the ANOVA results confirm that the regression model provides an effective quantitative representation of exchangeable acidity dynamics in South-Eastern Nigeria. The dominance of the regression component supports the conclusion that soil reaction and calcium availability are the principal drivers of acidity regulation in the region. These findings are consistent with earlier correlation, principal component, and regression analyses, thereby reinforcing the robustness of the modeling framework used to identify drivers of soil quality variability.

4 DISCUSSION

Overview of Soil Quality Variability in South-Eastern Nigeria

This study assessed the drivers of soil quality variability in South-Eastern Nigeria using an observational, regional-scale modeling approach. The results demonstrate that soil quality variability in the region is governed by interacting physical, chemical, and biological soil processes, rather than by isolated individual properties. The integration of descriptive statistics, correlation analysis, principal component analysis (PCA), and regression modeling provided a robust framework for identifying dominant soil quality drivers within the limits of the available data. The general soil characteristics observed in the region are consistent with humid tropical environments, where intense weathering, high rainfall, and prolonged leaching strongly influence soil chemical fertility and organic matter dynamics (Lal, 2015; Zhang et al., 2019).

Influence of Soil Texture on Soil Quality Variability

Soil texture emerged as a fundamental physical constraint on soil quality variability in South-Eastern Nigeria. The dominance of sand and the uniform clay content observed across states indicate coarse-textured soils with limited capacity for nutrient retention and organic matter stabilization. The strong negative correlations between sand content and organic carbon, nitrogen, and ECEC highlight the role of texture in regulating soil fertility. In coarse-textured tropical soils, low specific surface area and weak aggregation reduce the physical protection of organic matter, leading to rapid decomposition and increased nutrient leaching (Six et al., 2016; Wiesmeier et al., 2019). The separation of texture into an independent principal component confirms that physical soil properties act as a structural framework that modulates chemical and biological processes, rather than serving as a direct fertility driver.

Organic Matter and Nitrogen Dynamics as Key Drivers

Organic carbon and total nitrogen were strongly coupled, as evidenced by their high correlation coefficients and dominant loadings on the fertility-related principal component. Regression analysis further identified nitrogen as the strongest positive predictor of organic carbon variability, underscoring the close biogeochemical linkage between carbon and nitrogen cycling in the soils of South-Eastern Nigeria. This strong association reflects the fact that nitrogen in tropical soils is predominantly stored in organic forms and released through organic matter mineralization (Lehmann & Kleber, 2015). Under humid conditions, rapid microbial activity accelerates decomposition, limiting organic matter accumulation unless sustained inputs are maintained (Kögel-Knabner et al., 2020). The results of this study therefore confirm organic matter dynamics as a central driver of soil quality variability in the region.

Nutrient Retention Capacity and Exchangeable Base Status

Estimated cation exchange capacity (CEC) exhibited wide spatial variability and emerged as a key indicator of soil quality differences across the region. Regression modeling demonstrated that calcium and magnesium were the dominant predictors of CEC, with organic carbon contributing an additional, though secondary, effect. In highly weathered tropical soils dominated by low-activity clays, exchangeable base cations and organic matter constitute the primary sources of cation exchange capacity (Oorts et al., 2016; Van Zwieten et al., 2018). The strong association between CEC and base cations observed in this study confirms that nutrient retention capacity in South-Eastern Nigeria is largely controlled by chemical fertility factors rather than by clay content, which remained uniform across states.

Soil Acidity Dynamics and Buffering Mechanisms

Soil acidity was identified as a distinct and independent driver of soil quality variability. The strong negative relationship between soil pH and exchangeable acidity, supported by both correlation and regression analyses, indicates that soil reaction is the primary regulator of acidity dynamics in the region. Exchangeable calcium also exerted a significant buffering effect, reducing exchangeable acidity by displacing acidic cations from exchange sites. These findings are consistent with established soil chemical principles, where increasing base saturation leads to reduced acidity and improved chemical balance (Hinsinger et al., 2018). The coexistence of relatively high base saturation values with acidic pH conditions suggests that soil acidity in South-Eastern Nigeria may be driven more by hydrogen ion activity in the soil solution than by extensive aluminum saturation of exchange sites, a pattern reported for some highly weathered tropical soils (Guo et al., 2021).

Integration of PCA and Regression Results

The PCA results revealed three dominant components controlling soil quality variability: chemical fertility and nutrient retention, soil acidity dynamics, and textural control. These components provided a conceptual framework that guided regression model development and interpretation. The consistency between PCA loadings and regression coefficients strengthens confidence in the identified drivers and demonstrates that soil quality variability in South-Eastern Nigeria is structured by coherent, process-based controls rather than random variation. This integration of multivariate and regression analyses aligns with contemporary soil quality assessment approaches that emphasize driver identification over performance ranking (Bünemann et al., 2018; Vogel et al., 2019).

Implications for Regional Soil Quality Assessment

The modelling framework adopted in this study provides a scientifically sound approach for assessing soil quality variability at the regional scale. By focusing on dominant drivers rather than on treatment effects or yield prediction, the study avoids overgeneralization and remains consistent with the scale of

inference supported by the data. The findings highlight the importance of organic matter management, base cation availability, and acidity regulation as central considerations in understanding soil quality dynamics in South-Eastern Nigeria.

Limitations and Strengths of the Study

The use of one composite sample per state limits the ability to capture within-state variability; however, this design is appropriate for regional-scale driver identification. The convergence of evidence from multiple analytical techniques enhances the robustness of the conclusions. The study provides a valuable baseline for future investigations incorporating higher spatial resolution and long-term monitoring.

Synthesis

In summary, soil quality variability in South-Eastern Nigeria is primarily controlled by texture-mediated physical constraints, organic matter and nitrogen dynamics, nutrient retention capacity governed by exchangeable base cations, and soil acidity regulation mechanisms. These drivers interact to produce the observed spatial variability in soil quality across the region. The modeling approach adopted in this study offers a reliable framework for understanding soil quality dynamics in humid tropical environments and contributes to the growing body of literature on regional soil quality assessment.

CONCLUSION

This study employed an observational, regional-scale modeling framework to identify the dominant drivers of soil quality variability in South-Eastern Nigeria. By integrating descriptive statistics, correlation analysis, principal component analysis (PCA), and multiple regression modeling, the study provided a coherent understanding of the physical and chemical processes governing soil quality across the region. The results demonstrate that soil quality variability in South-Eastern Nigeria is primarily controlled by texture-mediated physical constraints, organic matter and nitrogen dynamics, nutrient retention capacity governed by exchangeable base cations, and soil acidity regulation mechanisms. Coarse soil texture, characterized by high sand content and uniform clay fraction, was identified as a fundamental physical limitation influencing organic matter stabilization and nutrient retention. Organic carbon and total nitrogen were strongly coupled, highlighting the central role of organic matter dynamics in regulating soil fertility under humid tropical conditions.

Nutrient retention capacity, expressed through estimated cation exchange capacity (CEC), was largely governed by exchangeable calcium and magnesium, with organic carbon providing an additional contribution. This finding confirms that chemical fertility in the region is primarily influenced by base cation availability rather than by clay content alone. Soil acidity emerged as a distinct driver of soil quality variability, with soil pH and exchangeable calcium acting as key regulators of exchangeable acidity. The coexistence of high base saturation with acidic soil reaction suggests that acidity in the region is driven more by hydrogen ion activity in the soil solution than by extensive occupation of exchange sites by acidic cations.

The consistency of findings across multiple analytical approaches strengthens confidence in the identified drivers and confirms the suitability of regression-based modeling for regional soil quality assessment. Overall, the study demonstrates that soil quality variability in South-Eastern Nigeria is structured by coherent and interacting soil processes rather than random variation.

This study makes several important contributions to soil science and regional soil quality assessment: it provides a process-based identification of dominant soil quality drivers in South-Eastern Nigeria using

an integrated modeling framework; it demonstrates the effectiveness of combining PCA and regression modeling to disentangle complex interactions among soil quality indicators in data-limited regions; it highlights the relative importance of base cation status and organic matter dynamics over clay content in controlling nutrient retention capacity in highly weathered tropical soils; and it offers a methodologically sound template for regional soil quality assessment that avoids overgeneralization and inappropriate treatment-based comparisons.

Although this study did not evaluate management interventions or crop performance, the identified drivers have important implications for understanding soil quality dynamics in South-Eastern Nigeria. The central role of organic matter and base cation availability suggests that practices that enhance organic matter inputs and maintain base status are likely to influence soil quality positively. Furthermore, the strong control of soil reaction on exchangeable acidity underscores the importance of acidity regulation in maintaining soil chemical balance.

The findings provide a scientific basis for future studies aimed at linking soil quality drivers to land-use practices and management strategies, while emphasizing the need for region-specific approaches due to inherent spatial variability.

The study was based on one composite soil sample per state, which limits the assessment of within state variability. Consequently, interpretations are restricted to the regional scale. In addition, the cross sectional nature of the dataset limits the ability to capture temporal variability in soil properties. Despite these limitations, the study design is appropriate for the stated objective of identifying dominant drivers of soil quality variability and provides a reliable baseline for further investigations.

Based on the findings and limitations of this study, the following recommendations are proposed:

Future studies should incorporate higher spatial resolution sampling within states to capture intra-regional variability.

Longitudinal studies are recommended to assess temporal dynamics of soil quality drivers under different land-use systems.

Integration of biological indicators such as microbial biomass and enzyme activities would enhance understanding of soil quality processes.

Linking soil quality drivers to crop response and productivity metrics would improve the applicability of modeling results to agricultural decision-making.

Comparative studies involving additional ecological zones would provide broader insights into soil quality variability across Nigeria.

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VEGETATION HEALTH DYNAMICS AND THE IMPACTS ON CLIMATE CHANGE AND AGRICULTURE IN EBONYI STATE SOUTHEASTERN NIGERIA

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ABSTRACT

This study investigates vegetation health dynamics and the impacts on climate change and agriculture in Ebonyi State Southeastern Nigeria using geospatial techniques covering a period 39 years (1986 to 2025). Normalized Difference Vegetation Index (NDVI) was used to assess the health of vegetation. The results indicate that No vegetation area increased slightly from 40.7808km² in 1986 to 40.7871km² in 2025 representing an increase of 0.02%. Low vegetation/degraded area increased significantly from 618.8688km² in 1986 to 1058.554km² in 2025 representing an increase of +71%. Stressed vegetation area decreased from 2636.77km² in 1986 to 2546.817m² in 2025 representing a decrease of -3.41%. Moderately healthy vegetation area decreased from 2469.672km² in 1986 to 2032.174km² in 2025 representing a decrease of -17.71% while healthy vegetation increased from 659.0556km² in 1986 to 746.9181km² in 2025 representing an increase of +13.33%. The largest increase was in low vegetation/degraded area (+71.05%) followed by healthy vegetation (+13.33%) while the largest decrease was in moderately healthy vegetation (-17.71%) followed by stressed vegetation (-3.41%). These findings provide valuable insights into the vegetation health dynamics and their implications for climate change and agriculture as well as ecosystem sustainability and resilience in Ebonyi State Southeastern Nigeria. The study contributes to our understanding of the impacts of climate change and human activities on vegetation dynamics and land cover transformation in the region, informing evidence-based decision-making and sustainable land management practices.

Key words: Agriculture, climate change, Environment, Impacts, Vegetation health

6. INTRODUCTION

The recent trends like global warming and population growth have necessitated the assessment of earth landscape transformation particularly the growing challenge on sustainable agriculture and food security as well as climate change mitigating measures adaptation. The recent decades have witnessed intensified man's activities trying to unravel nature's enormous resources applied in sustenance but pose a risk to the survival of other living organisms as well. Global climate change triggers temperature, precipitation pattern, and extreme event change with direct effect on vegetation growth and condition (IPCC, 2014). Impacts are manifested in the alteration of

vegetation phenology, productivity, and structure with associated consequences on ecosystem function and services (Cleland et al., 2007). Vegetation health dynamics over time should be comprehended to estimate climate change impacts on ecosystems. Climate change and human activity have immensely reversed the trends of vegetation on the global scene (Myneni et al., 1997). Normalized Difference Vegetation Index (NDVI) has also been considered a critical tool to quantify vegetation state and dynamics through time (Pettorelli et al., 2005). Temporal NDVI data include information on long-term trends as well as vegetational responses to climate change (Li et al. 2023; Shoumik and Khan 2023; Verbesselt et al., 2010). Natural land cover, incorporates and contains a place's general climate, geology and soils, and already present biota over several decades or longer.

At shorter timescales, land cover can be altered by naturally occurring disturbances (e.g., storms, floods, fires, volcanic eruptions, landslides, and insects) and anthropogenic activities (e.g., road building, industrialization and urbanization, water diversion, deforestation or afforestation, population growth). These transitions can be considered improvements or degradations in land cover state, either positively or negatively, depending on perspective (Perez-Hoyos et al 2017; Sleeter et al 2018; Sterling et al 2013). Land cover affects or alters environmental conditions in one or more of the following manners: impacting other environmental processes like water quality, watersheds' hydrology, species and habitat composition, climate, and carbon storage; impacting mass and energy flux from surface to atmosphere and hence influencing weather and climate; impacting species and habitat, a component of ecological structure and function; altering hydrologic regimes, flood buffering, and watersheds' runoff (Sleeter et al 2018; Sterling et al 2013; Yasser and Vahid, 2025). Land use and land cover data are crucial to environmental comprehension and regulation, sustainable progress, and provision of assistance to programs of various choices, e.g., environmental planning, resource administration, and city planning. It provides base knowledge on environmental hazard appraisal, food availability, and reduction of natural hazards.

Thus on the basis of NDVI trends for a number of decades, researchers can map areas experiencing vegetation degradation, expansion, or shift in composition (Tucker et al., 2005). These assessments are important in guiding land management, conservation, and climate change mitigation policy (Boisvenue & Running, 2006). In a nation like Nigeria with diverse ecological zones, monitoring these processes is vital for evidence-based environmental management and sustainable development planning. This study therefore attempts to assess the temporal trend of land use land cover and vegetation health during the past thirty-nine (39) years (1986-2025 and its impact on climate change and agriculture in Ebonyi State Southeastern Nigeria using NDVI data at 1986, 2000, 2015, and 2025. NDVI is an index of vegetation density and health and indicates information on ecosystem trends and temporal change. Understanding the temporal trends of land cover and vegetation health in these States will aid in the identification of environmental trends, assessment of climate change effects, and formulation of targeted mitigation and adaptation measures.

Therefore this study will contribute to the body of knowledge on environmental monitoring and management in Nigeria with useful information for policymakers, researchers, and stakeholders in the environment.

Study Area

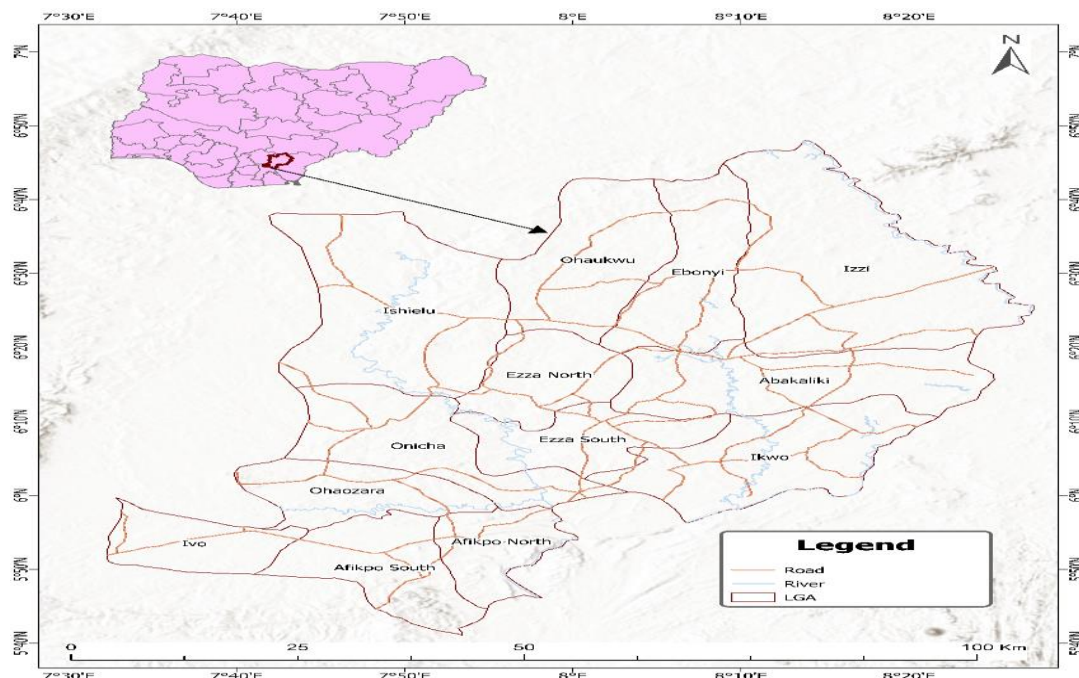


Figure 1: Geographical Location of Ebonyi State - Map of the Study Area

Ebonyi State was created on October 1, 1996 with Abakaliki as its capital. The state was carved out of the old Abakaliki Division of Enugu State and the old Afikpo Division of Abia State (Ibenegbu 2017). The name of the state was derived from the River Abonyi which flows through the north-central parts of the State. The state is located in the South Eastern part of Nigeria and lies approximately within latitudes $5^{\circ}40'$ and $6^{\circ}45'N$, and longitudes $7^{\circ}30'$ and $8^{\circ}30'E$ (Hegazy and Kaloop, 2015). It has boundaries with Enugu State to the west, Benue State to the north, Cross River State to the east and Abia State to the south. The land area of the state is approximately 5,935 square kilometer (km^2) and its inhabitants are Igbo. Ebonyi State has an estimated population of about 2,176,947 based on the 2006 National Population Census. The largest city in the State is Abakaliki, the state capital. Some important towns are Afikpo, Edda, Onueke, Nkalagu, Uburu, Onicha, Ishiagu, Amasiri and Okposi. The state has 13 Local Government Areas, 3 Senatorial Districts, 6 Federal Constituencies, 24 State Constituencies, and 171 Registration Areas/Wards (ABK 2021).

The state is divided between the Cross-Niger transition forests in the far south and the drier Guinean forest-savanna mosaic in the rest of the state. Ebonyi State has a humid tropical climate, with one rainy season and one dry season lasting for 8 and 4 months, respectively. The temperature typically ranges from 20 to 38 degrees Celsius during the dry season and from 16 to 28 degrees Celsius during the rainy season. Harmattan winds are common between December and January. The average annual temperature is 28 degrees Celsius, and the average annual humidity is 50-60%. The region receives an average annual precipitation of 2500mm (ES 2023; CE 2022)). Ebonyi State is mainly an agricultural region and a leading producer of rice, yam, potatoes, maize, beans, and cassava (EO 2020; MANR 2021). Rice is largely cultivated in Ikwo, yams in Izzi, with other regions in the state such as Amasiri, Edda and Ezillo making remarkable contributions as well. Effium and Ezzamgo lead in cassava production, and basket production in Ntezi. Ebonyi has several solid mineral resources, including lead, crude oil, and natural gas, but

few large-scale commercial mining mines (Diagi B. Edewede 2018; EO 2025). Ebonyi State is called "the salt of the nation" for its huge salt deposit at the Okposi and Uburu Salt Lakes. There are also some tourist locations within the state prominent ones include Abakaliki Green Lake, Uburu Salt Lake, Unwana and Ikwo Beaches (ES 2020).

7. MATERIALS AND METHODS

Description of Data

This study relied primarily on open-source secondary datasets, particularly satellite imagery, to generate the key input parameters used in the analysis Normalized Difference Vegetation Index (NDVI) and Land Use/Land Cover (LULC) maps. Series of archived satellite imagery tiles from (Sentinel-2) were utilized in realizing the aims and objectives of this research study. Parameters - NDVI and LULC were generated from Sentinel-2 satellite data. Launched in the first quarter of 2014, the Sentinel-2 satellites have 13 spectral bands in the visible, near-infrared, and shortwave infrared part of the spectrum that can be applied in the fields of Land use Land cover mapping, water resources and disaster management, and agriculture monitoring to detect ground deformation and providing support for disaster management.

Table 3: Data and Data Sources

S/N	Parameters	Data	Sources	Period
1	LULC	Sentinel-2	Google Earth Engine https://explorer.earthengine.google.com	2024
2	NDVI	Sentinel-2	Google Earth Engine https://explorer.earthengine.google.com	2024
3	Administrative map of Nigeria	Shape	Office of the Surveyor General https://osgof.gov.ng/products-services/	

Table 4: Software, Tools, and Uses

S/N	Software	Applications
1	ArcGIS version 10.8	GIS analysis
2	Google Earth Engine app	Rainfall, LULC, and NDVI

Map data

The maps procured for this study include: topographic and administrative maps covering the study area. These maps were used as ancillary data to aid field work, image classification and the compilation of maps produced in the research work. The Maps were scanned, geo-referenced, and sub-map to area of interest after which they were digitized in order to extract the needed thematic layer into the work geo-database.

Field Work

Ground truthing was also carried out to determine the nature of land use / land cover change and coordinates of site with the use of GPS. Historical land cover type and uses was also obtained via oral interviews on the field. In addition important observation were made and recorded while verification were made on the unclassified False Color Composite (FCC) image carried along, in order to resolve conflicting pixel representations. The information acquired aided the interpretation and classification of the various image and their general accuracy assessment.

Data Analysis and Interpretation

Five main methods of data analysis were adopted in the study.

6. Cluster analysis
7. Maximum Likelihood Classification
8. Calculation of the Area in hectares of the resulting land cover types for each study year and subsequently comparing the results.
9. Overlay Operations
10. Error matrix and a Kappa analysis

The first two methods above were used for image classification to produce land cover map of the study area. The data were imagery of 2000, 2008, 2016 and 2024. Calculation of the Area in square kilometer assisted in identifying the percentage change, trend, and rate of change between the periods of investigation.

Land Cover Classification System

In this research, the FAO land cover classification system (LCCS) was used. Following the data and information acquired from the field, the land cover type of the study was generated. They included:

7. Cultivated and Managed Terrestrial Area (Farm/Fallow land): This area refers to areas where the natural vegetative cover have been altered and replaced by other type of vegetative cover by human activities. This class encompasses all vegetative crops that are planted with the intent of harvesting.
8. Natural/Semi Natural Vegetation: natural vegetative areas are defined as areas where the vegetative cover is in balance with biotic and abiotic forces of the biotope. Semi Natural vegetative areas are those not planted by human but are influenced by human actions.
9. Artificial Surface and Associated Areas: this class defined areas that have artificial land cover as a result of human activities, these activities includes construction sites, extraction sites, as a result of mining and excavations and waste disposal waste areas.
10. Bare areas described areas that do not have any artificial influence; these areas are those with very small litter or no vegetative cover at all such as rocks, bare sand and desert.
11. Natural Water Bodies: these are areas that are naturally covered by water, such as streams, lakes, rivers, etc.
12. Built-up areas: these include areas occupied by settlements/towns, companies, and infrastructures.

Development of a Classification Scheme

Based on the prior knowledge of the study area for over 14 years and a brief reconnaissance survey with additional information from previous research in the study area, the classification scheme was developed after FAO Land Cover Classification System (LCCS). They include Built-up area (BA), Cultivated Area (CA), Water body (WB), Vegetation (VE), Bare Land (BL), and Plantation Area (PL) as shown in Table 3.

Table 3: Classification Scheme

Code	Land Cover Categories
CA	Cultivated Area
VE	Vegetation Area
BU	Built-up Area
PL	Plantation Area

WB	Water bodies
BL	Bare Land

Supervised classification

The supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data [Richards, 1993, p85]. Using this method, the analyst has available sufficient known pixels to generate representative parameters for each class of interest. This step is called training. Once trained, the classifier is then used to attach labels to all the image pixels according to the trained parameters. The most commonly used supervised classification is Maximum Likelihood Classification (MLC), which assumes that each spectral class can be described by a multivariate normal distribution. Five training sites were identified and further classified into the classes listed in the schema

Change Detection

One of the most common applications of change detection is determining urban land use change and assessing urban sprawl. This would assist urban planners and decision makers to implement sound solution for environmental management. A number of approaches have emerged and applied in various studies to determine the spatial extent of land cover changes. It has also been noted that different methods of detection produce different change maps (Araya and Cabral 2008). Below are methods applied in this study.

Image Differencing

Image differencing is based on the subtraction of images acquired in two different times. This is performed on a pixel by pixel or band by band level to create the difference image. In the process, the digital number (DN) value of one date for a given band is subtracted from the DN value of the same band of another date (Singh, 1989; Tardie and Congalton 2004). Since the analysis is pixel by pixel, raw (unprocessed) input images might not present a good result.

Vegetation Index Differencing

This method is applied to analyze the amount of change in vegetation versus non vegetation by computing Normalized Deference Vegetation Index (NDVI). NDVI is one of the most common vegetation indexing method and is calculated by:

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \quad -1.0 \dots\dots\dots \text{eqn1}$$

Where NIR is the near infrared band response for a given pixel and RED is the red response

Post Classification Comparison:

This is the most obvious, common and suitable method for land cover change detection. This method requires the comparison of independently classified images T1 and T2, the analyst can produce change map which show a complete matrix of changes (Singh, 1989).

Post-Classification Detection Technique:

Post classification technique is one of the most used and simple approach to detecting changes comparison (Blaschke, 2004). A post-classification comparison, which is the most straightforward technique, has been applied in this study. The land cover maps for the years 2000, 2008, 2016 and 2024 were first simplified into six classes. The post-classification comparison was then applied by differentiating the corresponding classified maps to generate change maps. The change statistics was generated as a table and subsequently used to calculate

the frequency and magnitude of change. The result of the change detection entirely depends on the accuracies of each individual classification. Image classification and post-classification techniques are, therefore, iterative and require further refinement to produce more reliable and accurate change detection results (Fan, Weng and Wang, 2007).

Table 4: Error Matrix and Kappa Analysis

Year	Kappa Coefficient	Overall Accuracy
2000	1.0	100%
2013	1.0	100%
2024	0.83	90%
Average	0.94	96.6

8. RESULTS

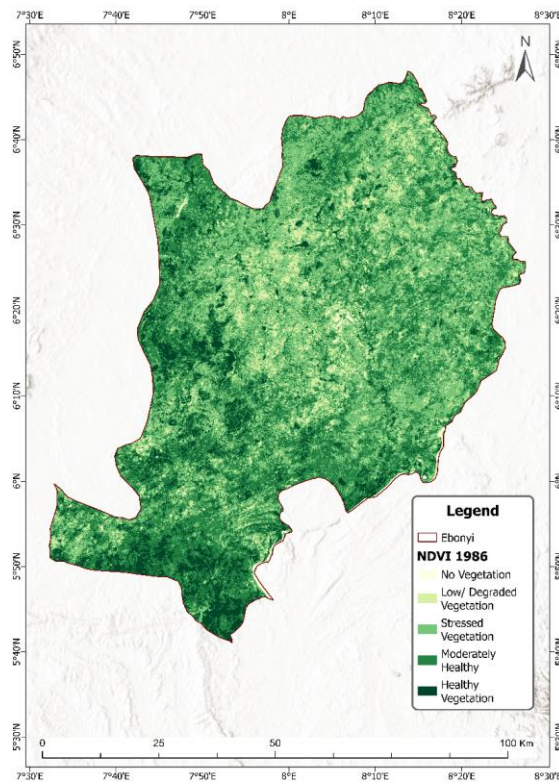


Figure 3: Normalized Difference Vegetation Index (NDVI) for 1986

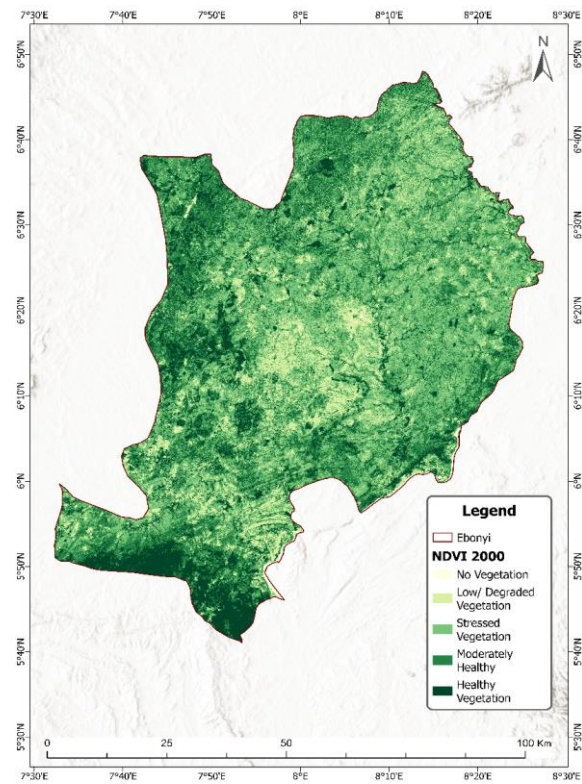


Figure 4: Normalized Difference Vegetation Index (NDVI) for 2000

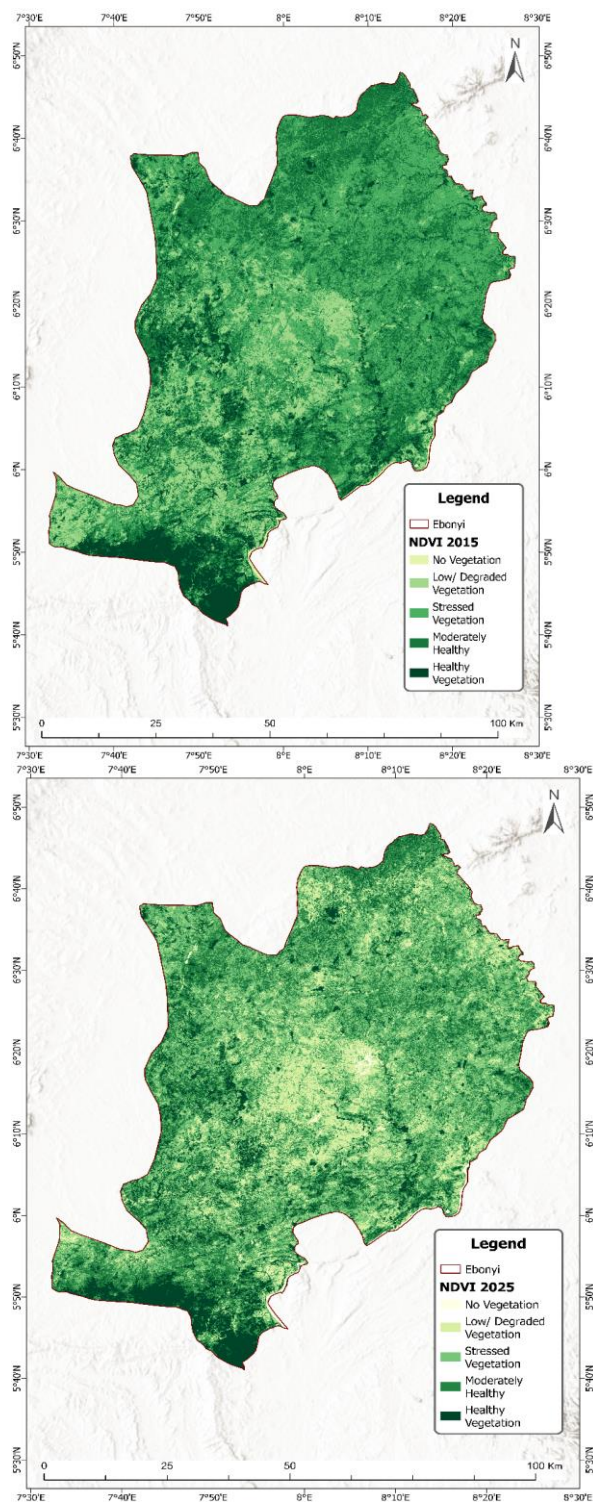


Figure 5: Normalized Difference Vegetation Index (NDVI) for 2015



Figure 6: Normalized Difference Vegetation Index (NDVI) for 2025

Table 5: Magnitude of Normalized Difference Vegetation Index (NDVI) for 1986 to 2025

NDVI	1986 (km ²)	2000 (km ²)	2015 (km ²)	2025 (km ²)
No Vegetation	40.7808	23.0778	19.4994	40.7871

Low/ Degraded Vegetation	618.8688	853.1118	889.4322	1058.554
Stressed Vegetation	2636.77	2572.542	2627.101	2546.817
Moderately Healthy	2469.672	2057.686	2108.327	2032.174
Healthy Vegetation	659.0556	918.8316	780.8913	746.9181

Table 5 above shows the magnitude of Normalized Difference Vegetation Index (NDVI) for 1986 to 2025 covering a period of 39 years.

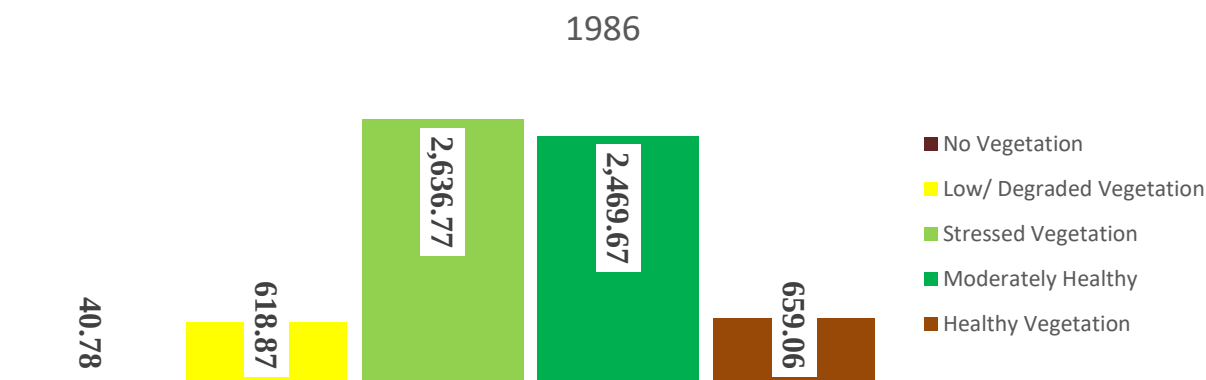


Figure 7: Showing a graphical illustration of Vegetation distribution or spread of 1986 across the entire landscape of Ebonyi State with Stressed Vegetation occupying the most area of 2,636.77km² followed by Moderately Healthy Vegetation with 2,469.67km², Healthy Vegetation with 659.06km², Low/degraded Vegetation with 618.87km² and No Vegetation with 40.78 km²

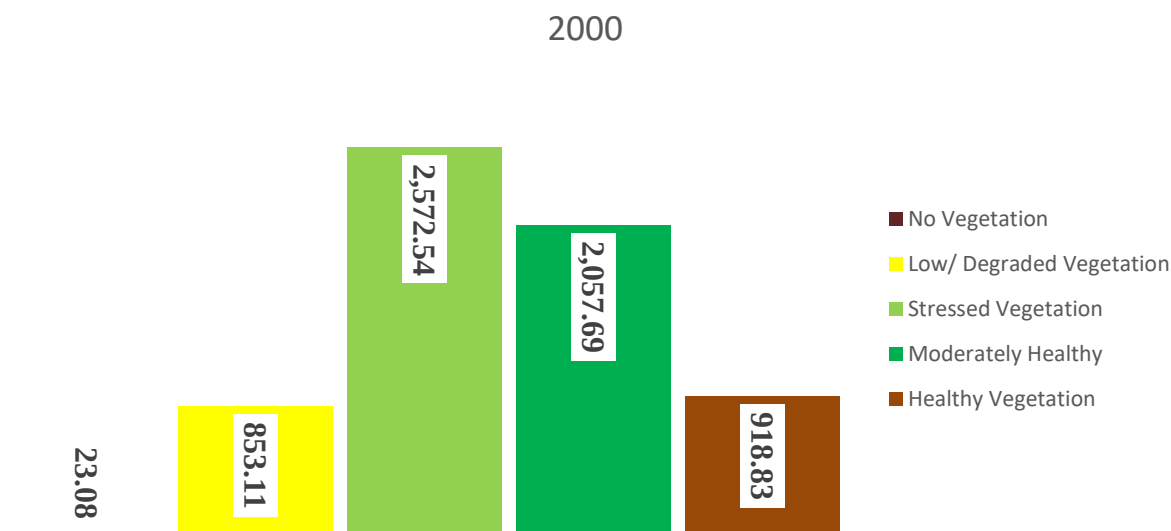


Figure 8: Showing a graphical illustration of Vegetation distribution or spread of 2000 with Stressed Vegetation occupying the most area of 2,572.54km² followed by Moderately Healthy Vegetation with 2,057.69km², Healthy Vegetation with 918.83km², Low/degraded Vegetation with 853.11km² and No Vegetation with 23.08 km²

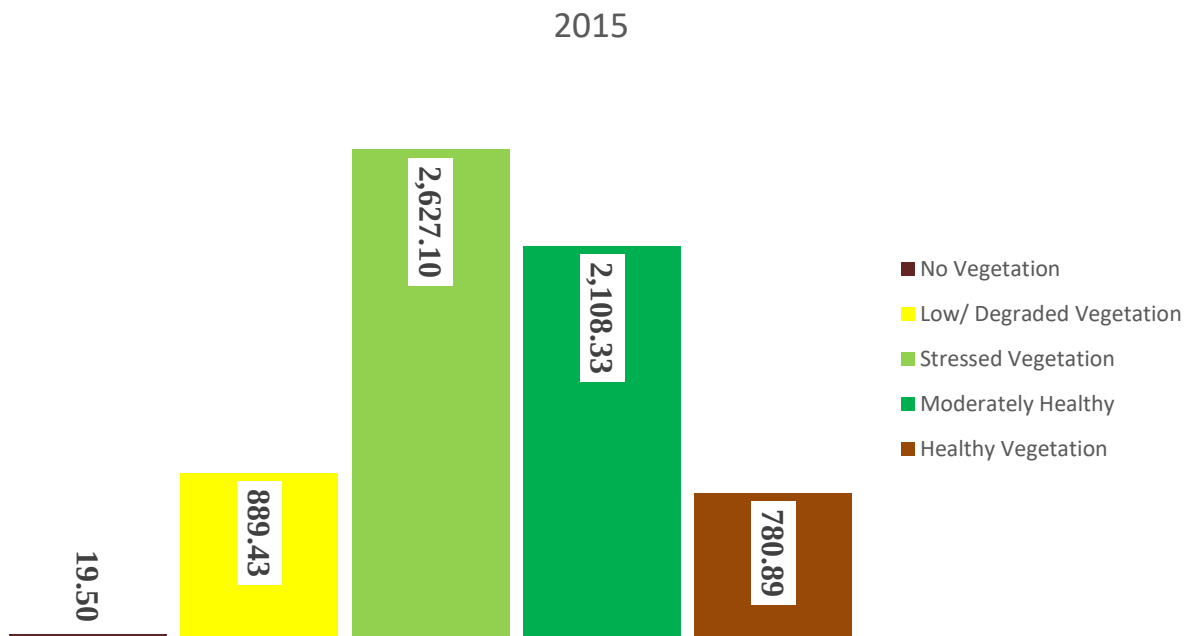


Figure 9: Showing a graphical illustration of Vegetation distribution or spread of 2015 with Stressed Vegetation occupying the most area of 2,627.10km² followed by Moderately Healthy Vegetation with 2,108.33km², Healthy Vegetation with 780.89km², Low/degraded Vegetation with 889.43km² and No Vegetation with 19.50 km²

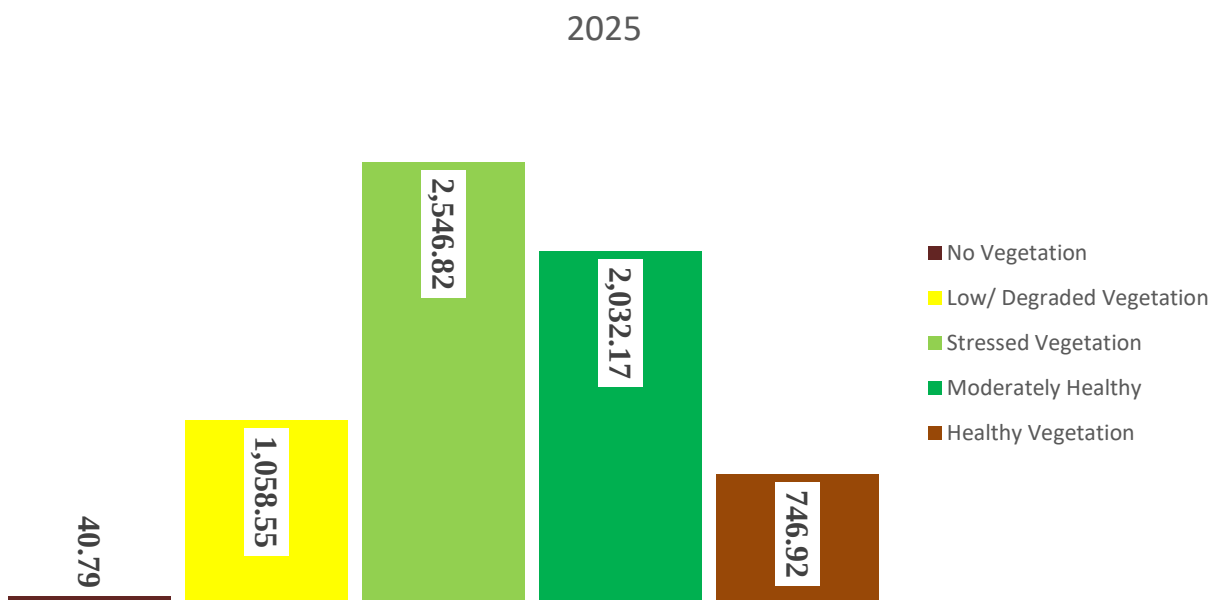


Figure 10: Showing a graphical illustration of Vegetation distribution or spread of 2025 with Stressed Vegetation occupying the highest area of 2,546.82km² followed by Moderately Healthy Vegetation with 2,032.17km², Low/degraded Vegetation with 1,058.55km², Healthy Vegetation with 746.92km² and No Vegetation with 40.79 km²

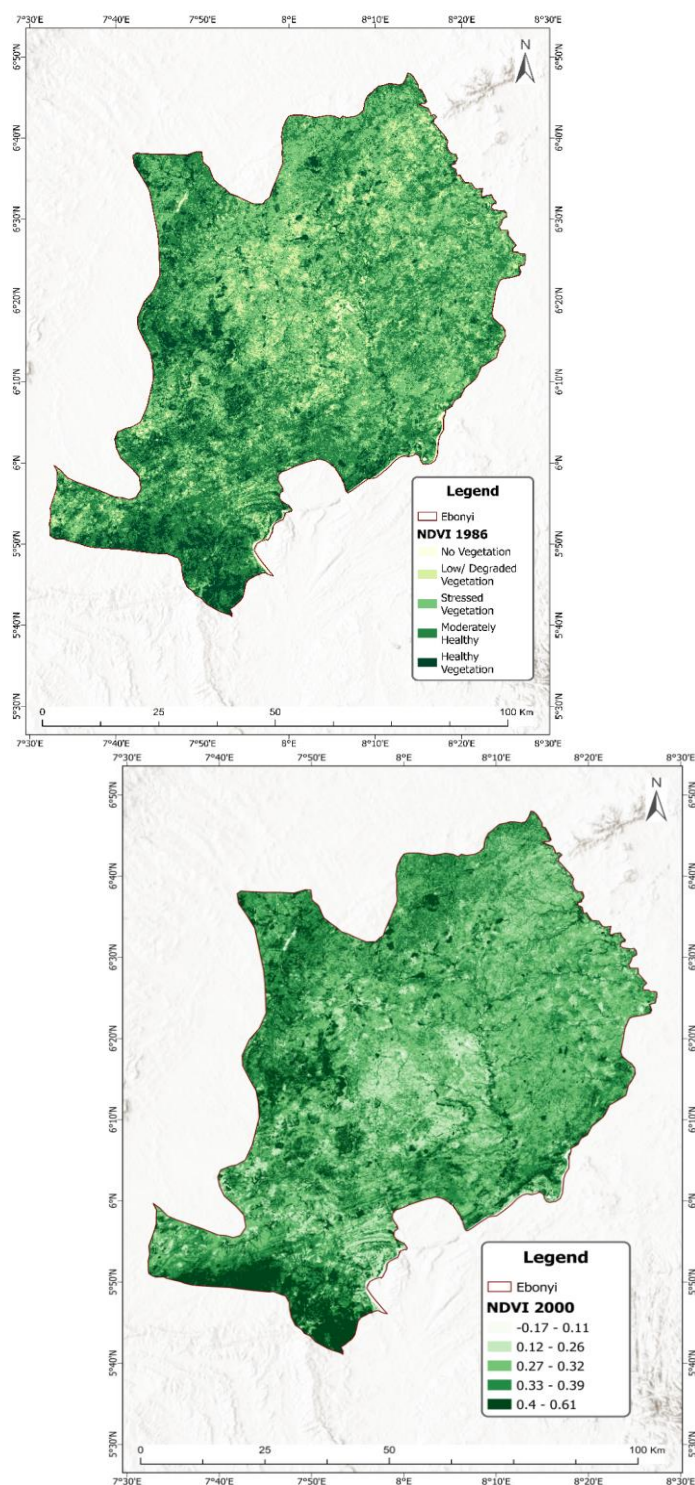


Figure 11: NDVI with figures for 1986

Figure 12: NDVI with figures for 2000

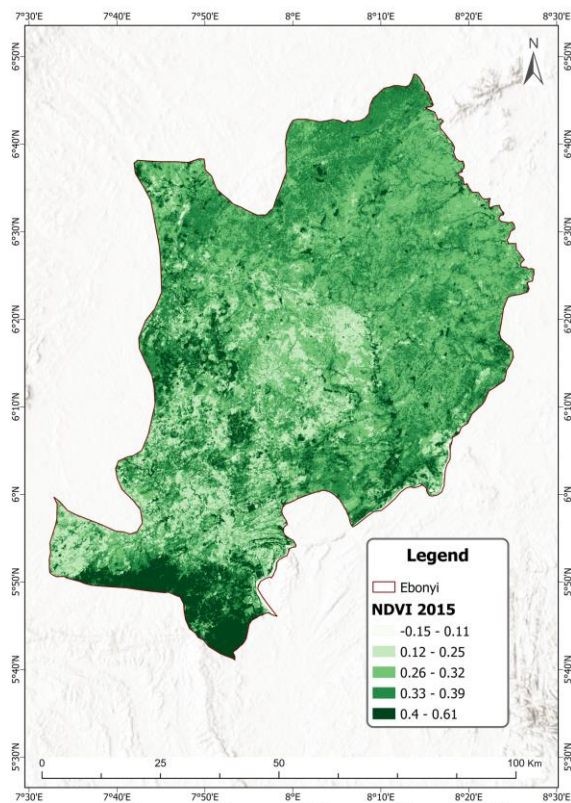


Figure 13: NDVII with figures for 2015

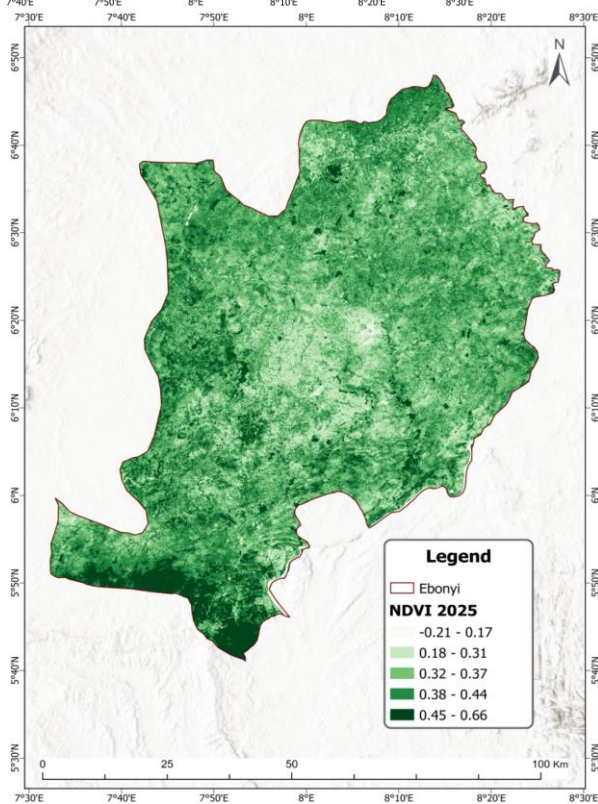


Figure 14: NDVII with figures for 2025

1986

Id	NDVI INDEX	Land type	Area (km²)
1	-0.12 - 0.17	No Vegetation	40.7808
2	0.18 – 0.22	Low/Degraded Vegetation	618.8688
3	0.23 - 0.27	Stressed Vegetation	2636.77
4	0.28 - 0.33	Moderately Healthy Veg.	2469.672
5	0.34 - 0.55	Healthy Vegetation	659.0556

2000

Id	NDVI INDEX	Land type	Area (km²)
1	-0.7 - 0.11	No Vegetation	23.0778
2	0.12 – 0.26	Low/Degraded Vegetation	853.1118
3	0.27 - 0.32	Stressed Vegetation	2572.542
4	0.33 - 0.39	Moderately Healthy Veg.	2057.686
5	0.4 - 0.61	Healthy Vegetation	918.8316

2015

Id	NDVI INDEX	Land type	Area (km²)
1	-0.15 - 0.11	No Vegetation	19.4994
2	0.12 – 0.25	Low /Degraded Vegetation	889.4322
3	0.26 - 0.32	Stressed Vegetation	2627.101
4	0.33 - 0.39	Moderately Healthy Veg.	2108.327
5	0.4 - 0.61	Healthy Vegetation	780.8913

2025

Id	NDVI INDEX	Land type	Area (km²)
1	-0.21 - 0.17	No Vegetation	40.7871
2	0.18 – 0.31	Low /Degraded Vegetation	1,058.554
3	0.32 - 0.37	Stressed Vegetation	2546.817
4	0.38 - 0.44	Moderately Healthy Veg.	2032.174
5	0.45 - 0.66	Healthy Vegetation	746.9181

Table 6: Percentage Change (1986–2025)

NDVI Category	1986 (km²)	2025 (km²)	% Change (1986 to 2025)
No Vegetation	40.78	40.79	+0.02%
Low/Degraded Vegetation	618.87	1058.55	+71.05%
Stressed Vegetation	2636.77	2546.82	–3.41%
Moderately Healthy	2469.67	2032.17	–17.71%

NDVI Category	1986 (km ²)	2025 (km ²)	% Change (1986 to 2025)
Healthy Vegetation	659.06	746.92	+13.33%

Largest increase: Low/Degraded Vegetation (+71.05%)

Largest decrease: Moderately Healthy Vegetation (-17.71%)

Source: Authors own Elaboration

Table 6 above shows the percentage change in magnitude of Normalized Difference Vegetation Index (NDVI) from 1986 to 2025 covering a period of 39 years which indicates that No vegetation area increased slightly from 40.7808km² in 1986 to 40.7871km² in 2025 representing an increase of 0.02%. Low vegetation/degraded area increased significantly from 618.8688km² in 1986 to 1058.554km² in 2025 representing an increase of +71%. Stressed vegetation area decreased from 2636.77km² in 1986 to 2546.817m² in 2025 representing a decrease of -3.41%. Moderately healthy vegetation area decreased from 2469.672km² in 1986 to 2032.174km² in 2025 representing a decrease of -17.71% while healthy vegetation increased from 659.0556km² in 1986 to 746.9181km² in 2025 representing an increase of +13.33%. The largest increase was in low vegetation/degraded area (+71.05%) followed by healthy vegetation (+13.33%) while the largest decrease was in moderately healthy vegetation (-17.71%) followed by stressed vegetation (-3.41%).

Table 7: Test of Significance (Paired Sample t-test)

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 1986 - 2025	-.02000	316.43923	141.51592	-392.93119	392.89119	.000	4	1.000

There is no statistically significant difference between the NDVI values in 1986 and 2025 overall ($p > 0.05$). This suggests that, despite individual category changes, the total distribution of vegetation types has not significantly changed in a statistical sense.

Table 8: Test of Relationship (Pearson Correlation)

Correlations

1986	Pearson Correlation	1	.972**
	Sig. (2-tailed)		.006
	N	5	5
2025	Pearson Correlation	.972**	1
	Sig. (2-tailed)	.006	
	N	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

There is a very strong positive correlation between NDVI values in 1986 and 2025, which is statistically significant ($p < 0.01$). This indicates a consistent pattern in the relative magnitude of NDVI categories over time, despite some shifts in specific categories.

9. DISCUSSION

Table 6 shows the percentage change in magnitude of Normalized Difference Vegetation Index (NDVI) from 1986 to 2025 covering a period of 39 years which indicates that No vegetation area increased slightly from 40.7808km^2 in 1986 to 40.7871km^2 in 2025 representing an increase of 0.02%. Low vegetation/degraded area increased significantly from 618.8688km^2 in 1986 to 1058.554km^2 in 2025 representing an increase of +71%. Stressed vegetation area decreased from 2636.77km^2 in 1986 to 2546.817m^2 in 2025 representing a decrease of -3.41%. Moderately healthy vegetation area decreased from 2469.672km^2 in 1986 to 2032.174km^2 in 2025 representing a decrease of -17.71% while healthy vegetation increased from 659.0556km^2 in 1986 to 746.9181km^2 in 2025 representing an increase of +13.33%. The largest increase was in low vegetation/degraded area (+71.05%) followed by healthy vegetation (+13.33%) while the largest decrease was in moderately healthy vegetation (-17.71%) followed by stressed vegetation (-3.41%).

Interestingly, healthy vegetation increased slightly from 659.0556km^2 in 1986 to 746.9181km^2 in 2025 representing +13.33%. This could imply better land use practices in some parts of the state.

The NDVI Index for this study as shown in figures 11-14 holds a lot of implications on agriculture and climate change in the study area, Ebonyi State and indeed Southeastern Nigeria as well. For instance, in 1986, 2636.77km^2 area of vegetation were stressed which could result from adverse climatic conditions like inadequate precipitations or anthropogenic activities like indiscriminate bush burning or other factors that could impact negatively on the health of vegetation or fertility of the soil. This trend of stressed vegetation continued from 1986 through 2000, 2015 and 2025 meaning that its cause(s) have not been mitigated for the past 39 years.

Equally of great concern is the increase in low vegetation/degraded area in the state which increased from 618.8688km^2 in 1986 to $1,058.554\text{km}^2$ in 2025 as shown in table 6. This sharp increase in degraded/low vegetation area could be as a result of increased mining activities in the state notable among these are lead mining in Ikwo Local Government Area, stones mining in areas like Ishiegu, Nkalagu, Afikpo, and others. Mining sites and degraded land may not be suitable for agriculture and in most cases the sludge are not contained and treated before discharge into the surrounding lands which eventually impact negatively on vegetation, humans and livelihoods of the inhabitants of areas where these activities are carried out unchecked.

Our earlier study on the environmental and agricultural implications of land use land cover change for Ebonyi state covering a 39 years period (1986-2025) as quoted in Obenade et al, (2025) reveal that Bareland increased from 1.16 km^2 in 1986 to 11.76km^2 in 2025 representing an increase of +630%. Water bodies increased from 14.25km^2 in 1986 to 18.91km^2 in 2025 representing an increase of +33%. Built-up area increased from 27.90km^2 in 1986 to 46.66km^2 in 2025 representing an increase of +67%. Forest decreased from 933.54km^2 in 1986 to 618.69km^2 in 2025 representing a decrease of -34% while cultivated area increased from 1364.69km^2 in 1986 to 3990.67km^2 in 2025 representing an increase of +192%, and Shrubland decreased from

4,083.26km² in 1986 to 1,738.56km² in 2025 representing a decrease of 57%. (Moses Obenade et al, 2025).

Thus the findings of this study are consistent with similar studies carried out within and outside Ebonyi state. Odoh et al (2024) concluded that the analysis of LULC changes and slope dynamics between 2017 and 2023 in Enugu North, Enugu South, Nkanu East, and Nkanu West LGAs reveals significant trends with profound environmental and socio-economic implications. The most notable change is the substantial reduction in tree cover from 565.99 km² to 432.48 km², indicating extensive deforestation driven by urban expansion and agricultural land conversion. This reduction in forested areas threatens biodiversity, disrupts carbon sequestration processes, and alters local climate and hydrological cycles, underscoring the urgent need for effective forest conservation strategies Obenade et al, 2025; Odoh et al, 2024).

10. CONCLUSION

This study provides valuable insights into the natural environment of Ebonyi State Southeastern Nigeria which encompasses vegetation health dynamics. Farming activities and practices must be made sustainable with innovative styles and approaches to check the continuous stress to vegetation health. Vegetation serves as purifiers and sequesters in natural environment and must be kept in balance in spite of humans' dependence on forest and forest resources for livelihoods. Thus stressed vegetation or low vegetation and degradation have enormous consequences on human health, climate change, and agriculture in the state and beyond.

These findings reveal the current state of vegetation health dynamics and their implications for climate change and agriculture as well as ecosystem sustainability and resilience in study area. The study contributes to our understanding of the impacts of climate change and human activities on vegetation dynamics and land cover transformation in the region, informing evidence-based decision-making and sustainable land management practices.

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Macroeconomic Shocks and Food Security: Evidence from Rural Households in Oyo State, Nigeria

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Abstract

Recent macroeconomic crises such as withdrawal of fuel subsidies, rise of fuel costs and devaluation of the naira has impacted negatively on rural households in Oyo State, Nigeria. The effect of these shocks on food security and spending habits cannot be overemphasized. Cross-sectional method was adopted which was carried out in six rural communities in three local government areas in 2025. A total of four hundred and eighty rural households were sampled through a structured questionnaire. The Household Food Insecurity Access Scale (HFIAS) was used to determine the food security status, and the amount of household spending on food daily was computed on a weekly basis. It was found in the analysis that 86.5 per cent of respondents were food insecure and only 13.5 percent were food secured. In addition, 68.3 proportion of households spent less than N20,000 a week on food and average household food spending was N17,800. The Ordinary Least Squares regression revealed that increased income, non-farm income and increased farm size were good predictors of food expenditure; the increased household size and dependency ratios were found to be bad predictors of food expenditure. The multinomial logistic regression in the study showed that income, credit accessibility, and non-farm income were positively related to food security whereas food insecurity potential was significantly higher among the large household, household heads which were female, and those which were the most vulnerable to shocks. The existence of a shock-income interaction term showed inappropriately large impacts on low-income households indicating a threshold effect. A chi-square test indicated that there was a strong relationship between income and food-security status ($\chi^2(9) = 78.42, p = 0.001$). These results highlight the dismal and alarming rates of recent macroeconomic shocks on rural food security in Nigeria and the crucial need to implement special missions focused on the population at risk.

Keywords: Food security, macroeconomic shocks, rural households, food expenditure, Oyo State, Nigeria

1. INTRODUCTION

Food security is a dynamic and changing issue that is at the heart of national stability, population wellbeing, and sustainable development. Food prices increase when the supply of food

falls short of demand due to economic shocks, policy changes, conflict, climate change, or bad governance, and this forces the vulnerable populations, especially the rural communities, into food insecurity. This is in the form of decreased dietary diversity, malnutrition, and extreme hunger (FAO, IFAD, UNICEF, WFP, and WHO, 2018; Nwagboso et al., 2024). This is particularly acute in Nigeria, where the agricultural potential is high, but where millions of citizens, particularly in rural regions, do not have access to safe and nutritious food (Ibekwe, 2024; Jerumeh et al., 2019).

Food security is a long-standing issue in the world. According to the United Nations Committee on World Food Security, food security is the state of affairs in which all individuals, at all times, have physical, social, and economic access to adequate, safe, and nutritious food that satisfies their dietary needs and food preferences to an active and healthy life (CFS, 2012; FAO, 2008). This conceptualisation has changed a lot since the World Food Conference in 1970s which was mainly concerned with supply side issues (Adebayo, 2010; FAO, 2008). Modern knowledge focuses on the access, utilisation, and stability of households and individuals (Adebayo, 2010). Nowadays, hundreds of millions of individuals are chronically under-nourished around the world, and sub-Saharan Africa is no exception: more than a third of the population in the region are in food insecurity (Gazuma, 2018; Abdulai et al., 2017). The key factors that determine food insecurity in developing countries are poverty, low agricultural productivity, and external shocks (FAO, 2015; Li and Song, 2022).

Nigeria is facing a serious hunger crisis. Nigeria was ranked 109th among 125 countries in the 2023 Global Hunger Index. The situation deteriorated significantly in the period between 1986 and 2005 when food insecurity rose to 40 per cent of the total households. Nigeria has economically viable agricultural land but due to the high population growth, the per capita food production has not been able to keep up with the population growth. In 2023 the government lifted

fuel subsidies, thus leading to a devaluation of the naira and a long-term high inflation rate. Inflation in food rose to over 40 percent in 2024 and then dropped in late 2025. As a result, food and transport expenses shot up. The rural people are now taking less preferred foods because they are not able to afford their preferred foods. Although these policies are meant to rectify macroeconomic imbalances, they have a disproportionate impact on poor Nigerians. In the absence of long term interventions, it is estimated that 30.6 million Nigerians will be affected by acute food insecurity in 2025 and 34.7 million in 2026.

The national processes that interact with the local ones are manifested in food insecurity in Oyo State, which is associated with the rapid urbanisation of the area around Ibadan, the transformation of farmlands, and the growth of settlements in agrarian rural areas (Aboaba et al., 2020; Olagunju et al., 2020). The rural population, which is a major food producer in the country, is vulnerable to interconnected factors such as high post-harvest losses, reliance on seasonal rainfall to plant crops, inflation due to poor rural infrastructure, and localised violence that undermines food access (Omotoso et al., 2022; Oyekale et al., 2017). The agricultural potential and household food insecurity paradox is a reflection of the developmental issues in Nigeria as a whole (Ibekwe, 2024; Jerumeh et al., 2019).

The connection between macroeconomic shocks and their resultant impacts on household food spending and food insecurity has not been well studied at the sub-national level in agrarian but urbanising economies like Oyo State. Although earlier studies have found socioeconomic variables to be significant predictors of food security status (Jerumeh et al., 2019; Aboaba et al., 2020), there is a lack of quantitative studies on the impact of recent policy shocks on the expenditure patterns and prevalence of food insecurity among rural households. This paper uses a macroeconomic policy and microeconomic outcome to analyze the effects of macroeconomic

policies on food security in rural Oyo State based on a large-scale cross-sectional survey of rural households.

2. LITERATURE REVIEW

Food security is a most complex sphere that determines socioeconomic and sustainable development, as well as population health (Li and Song, 2022). The macroeconomic shocks together with imbalances between food demand and supply initiate food-price crises, which push vulnerable populations towards nutritionally low-quality diets and hunger (FAO, 2018; Nwagboso et al., 2024).

The United Nations Committee on World Food Security defines food security as one that ensures that all individuals have access to safe, nutritious, and adequate food. According to the State of Food Security and Nutrition in the World 2025 report, 673 million people (an equivalent of 8.3% of the world population) were hungry in 2024, and 2.3 billion people were facing moderate and severe food insecurity (FAO et al., 2025).

In Nigeria, food-insecure households in the country increased to 40 per cent in 2005 compared to 18 per cent in 1986 (Sanusi et al., 2006; Oyekale et al., 2017). According to the 2025 Global Hunger Index, Nigeria was ranked 115 among 123 countries and it was rated at 32.8, a very high level of hunger. This situation has been worsened by macroeconomic shocks that have been witnessed in the recent past.

There is a growing body of literature that has explored socioeconomic determinants of food security in rural Nigeria. The most important are family size, dependency ratio, income, education, gender, farm size, and accessibility to credit (Oyekale et al., 2017; Aboaba et al., 2020). The empirical studies have shown an inverse relationship between the household size and the dependency ratio and the risk of food insecurity.

The rural families of Oyo State are at the receiving end of the compound effects of both national shocks and localized phenomena (Aboaba et al., 2020). The current research aims to fill the gaps in knowledge by quantifying the role of such shocks in terms of food expenditure and security in the households of Oyo State.

3. METHODS

3.1 Study Area

The current study was done in Oyo state, which is located in southwestern Nigeria. The jurisdiction has been selected based on its large country population and greater susceptibility to macroeconomic changes. Covering 28,454 km², Oyo State had a population of about 5.6 million according to the 2006 census and it is estimated to rise to around 8 million by the middle of the 2020s. The administrative units of the state are 33 Local Government Areas (LGAs) that are again grouped together to create three senatorial districts. The rural towns of these LGAs are often faced with the limitation of limited access to markets and strong negative effects of the economic shocks.

3.2 Data Collection

Primary data are to be collected by implementing a structured questionnaire in the period between January and March 2025. The tool did not fail to evoke data on socioeconomic pointers, weekly food spending, as well as the quantification of food insecurity, as operationalized by the Household Food Insecurity Access Scale (HFIAS). The data collection was conducted in six different communities, namely Eko-kan and Ayetoro (Saki West LGA), Ijaiye and Atan (Akinyele LGA) and Akaya and Alapala (Ibarapa North LGA).

3.3 Sampling Procedure

To be representative, a multi-stage sampling design was used. To start with, Oyo State was purposefully chosen as the study location. Later, a random selection of a rural LGA of every

senatorial district was made. Two rural communities were then randomly selected within each of the selected LGA. Lastly, the number of households sampled was 480 households in these six communities, and a systematic random sampling approach was used to sample the households.

3.4 Data Analysis

The socioeconomic profile of the sample in terms of food security was used to characterize and describe the levels of the variable using descriptive statistical techniques. Ordinary Least Squares (OLS) regression was used in determining the determinants of the amount spent on food. Also, multinomial logistic regression was used to examine predictors of food security status. The interaction terms were included in the models, and Multicollinearity was measured by the Variance Inflation Factor (VIF) values, which were less than five, and analysed in SPSS version 26.

4. RESULTS

The study utilized survey data which was gotten from 480 rural households located in six communities in Oyo State. The results provide a detailed description of food spending trends and the current situation of food security during the recent macroeconomic shocks.

4.1 Socioeconomic Profile of Respondents

The socioeconomic profile of the respondents was described in Section 4.1 of this report. The vast majority of the participants were the heads of households aged 41-50 years. There were 39 percent female-headed households. There was an average of 7.3 members in the households (SD=3.1) and therefore the dependency ratio was quite high with a mean of 1.52. Household heads were comprised by married people, 64.2 percent. The mean years of education were 8.4 years. The income levels were also low as 58% of the respondents said they earned less than N100,000 on a monthly basis. The average area of land under cultivation was 2.1 hectares. Only 27% of

households were able to access credit, as compared to 42.5% of households that reported non-farm sources of income.

Table I: Socioeconomic Profile of Respondents

Characteristic	Frequency (N)	Percentage (%)
Age Group: 18-30	48	10.0
31-40	96	20.0
41-50	192	40.0
51-60	96	20.0
61 and above	48	10.0
Gender: Male	293	61.0
Female	187	39.0
Marital Status: Married	308	64.2
Single/Widowed/Divorced	172	35.8
Monthly Income: <N50,000	96	20.0
N50,000-N100,000	182	37.9
N100,000-N200,000	144	30.0
>N200,000	58	12.1
Access to Credit: Yes	130	27.1
No	350	72.9

Source: Field Survey, 2025.

4.2 Bivariate Relationships

The Bivariate analyses reveal that there are significant relationships between the socioeconomic factors and food security outcomes. The chi-square test indicated that there was a significant relationship between income and food security status ($\chi^2(9) = 78.42, p < 0.001$). The food security was highest (28.4) in the N100,000- N200,000 income bracket and the lowest income bracket had the lowest food security (4.2).

Table II: Food Security Status by Monthly Income Bracket

Monthly Income	Food Secure	Mildly Insecure	Moderately Insecure	Severely Insecure
<N50,000	4 (4.2%)	12 (12.5%)	48 (50.0%)	32 (33.3%)
N50,000- N100,000	20 (11.0%)	36 (19.8%)	82 (45.1%)	44 (24.2%)
N100,000- N200,000	41 (28.4%)	38 (26.4%)	48 (33.3%)	17 (11.8%)
>N200,000	16 (27.6%)	12 (20.7%)	26 (44.8%)	4 (6.9%)
Total	81 (16.9%)	98 (20.4%)	204 (42.5%)	97 (20.2%)

Note: Row percentages shown in parentheses. Pearson $\chi^2(9) = 78.42$, $p < 0.001$.

Source: Field Survey, 2025.

A t-test was used to compare expenditure by households who used credit facilities with those who did not use them to show that households that used credit facility spent more on food in a week ($M = \text{N}21,200$, $SD = 7,800$) compared to households who did not use credit facilities ($M = \text{N}16,400$, $SD = 6,200$), $t(478) = 4.82$, $p = 0.001$. Homes that had non-farm sources of income had a higher expenditure and less insecurity, $\chi^2(3) = 18.76$, $p = -0.001$.

4.3 Multivariate Relationships between Food Spending and Security status.

There were two multivariate models estimated. A least squares regression of the determinants of weekly food expenditure was statistically significant ($F(8,471) = 12.84$, $p = 0.001$, $R^2 = 0.178$). Monthly income ($b = 0.42$, $p = 0.001$), non-farm income ($b = 0.18$, $p = 0.01$), and farm size ($b = 0.12$, $p = 0.05$) had a positive effect on expenditure, but bigger household size ($b = -0.25$, $p = 0.001$) and higher dependency ratio ($b = -0.16$, $p = 0.01$) had a negative impact on expenditure. A predictive multinomial logistic regression of food security status which was statistically significant (24-CHS) ($\chi^2(24) = 168.47$, $p = -0.001$, pseudo $R^2 = 0.142$) was obtained using the food-secure group as the reference group. The income, access to credit, and non-farm income had very strong negative

relationships with insecurity risk, and household size, female headship, and shock exposure had very strong positive relationships with vulnerability. The income shock interaction term was substantial ($p < 0.05$) meaning that there were disproportionate effects in the low-income households.

Table III: Multinomial Logistic Regression Predicting Food Security Status

Predictor	Mildly Insecure OR	Moderately Insecure OR	Severely Insecure OR
Income: N50,000-N100,000	0.62	0.48	0.32
N100,000-N200,000	0.38	0.25	0.14
>N200,000	0.21	0.12	0.07
Access to Credit	0.54	0.41	0.28
Non-Farm Income	0.68	0.52	0.36
Household Size	1.28	1.45	1.72
Female-Headed Household	1.82	2.14	2.68
Shock Exposure	1.56	1.89	2.41
Income $\times$ Shock	0.72	0.65	0.58

Note: Odds Ratios presented. $p < 0.05$, $p < 0.01$, $p < 0.001$. Reference category: Food Secure, Income $< \text{N}50,000$.
Source: Field Survey, 2025.

5. DISCUSSION

This study explains the dynamic nature of food security in rural Oyo State following macroeconomic shocks in the recent past. There is empirical evidence to indicate widespread food insecurity (86.5%), and consumption practices are strongly limited. About 68 percent of the households had less than N20,000 per week, highlighting how food is the main spending factor and hence restricts food variety (Omotoso et al., 2022). The fact that expenditure has a positive relationship with the level of income, non-farm income, and size of a farm indicates that food security is more easily achieved by those households which have diverse sources of income and

financial resources (Jerumeh et al., 2019; Nwagboso et al., 2024). The multinomial logistic regression supports those higher levels of incomes, access to credit, and non-farm income increases vulnerability whereas bigger household, female headship, and shocks exposure are positive contributors to vulnerability. Especially the statistically significant manner in which income-shock interacts ($p < 0.05$) deserves attention, as it shows how macroeconomic shocks are disproportionately affecting lower-income households that do not have sufficient financial cushions against subsidy cuts, currency devaluation, and inflation of food prices. This conditional deviation implies that there exist threshold effects in which economic reforms will create unequal effects on income levels (Nwagboso et al., 2024). The household vulnerability of females indicates a more systemic inequality of resources and power distribution (World Bank, 2018). Results are consistent with indicators showing that resources are more limited to women due to the presence of patriarchal systems and market failure (Olagunju et al., 2020). The difference in geography that indicated better food security in Oyo Central compared to remote districts of Oyo North is an indicator of better accessibility to markets, infrastructure, and reduced transport rates (Da'Silva & Fan, 2017). The non-farm income of 42.5% of households and the positive impact of the same on expenditure and security highlight the possibilities of the latter as the center of intervention. Increased income diversification and the access of non-farm income are a potential measure where rural communities can ensure that the impact of the shocks through limiting reliance on fluctuating agricultural incomes (Jerumeh et al., 2019). The pseudo- R^2 of the multinomial model (0.142) suggests that, besides the main socioeconomic and shock-related variables, there are presumably other unobserved variables that affect the result. The quality of local governance, the variability of climate, and household governance are the possible contributors. In such a way, the given work

provides an opportunity to learn about structural factors of food security in rural Oyo State, not being a mere predictive modeling.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Food insecurity has been a related problem among households in Oyo state especially the rural. The surveyed population (more than 86 percent) is susceptible to food insecurity, as it struggles with fuel subsidy amputation, naira devaluation, and rising food prices. However, the food system illustrates some level of self-sufficiency and responsiveness by the grassroots coping mechanisms like diversified non-farm activities, and the ownership of assets in small-holder economies. This system functions within larger systems of inequality in terms of income, gender, household formation and place. The huge income-shock interaction proves that the poorer households are outnumbered because of the absence of financial safety nets as prices soar. The difference in gender is also clear with female headed households having much lower chances of having food security. The geographic variation still exists, and Oyo North has a higher degree of food insecurity than the transitional regions of Oyo Central. Self-reliance in rural households is also a strength although it also brings policy gaps. Whereas self-reliance offers ease in addressing food insecurity, it cannot effectively balance structural factors that have led to the prevalence of food insecurity in Nigeria.

6.2 Recommendations

Instead of just acknowledging rural food insecurity, the government should also take the initiative of establishing shock-reduction instruments in the national food-security policy framework. This initiative must be coupled with making available affordable, specialised credit in

the form of the Bank of Agriculture, and the Central Bank Anchor Borrowers Programme, by using simplified eligibility requirements that leverage on the already available rural savings associations. The strong gender gap requires special policy interventions, including financial literacy education, women-specific borrowing options with flexible repayment term that are pegged to the economic cycles of women, and institutional changes that ensure that women are fairly registered as possessing the land they own.

Intervention policies should be categorised by income levels, including food and farm input subsidies targeted at the poor, conditional cash transfer in lean periods and price stabilisation funds that are aimed at protecting the poor against inflationary shocks and policy-induced price fluctuations, especially remote agricultural communities.

The moderating role of non-farm income highlights the need to have a diversification of the rural livelihood. The governments and development partners, therefore, ought to invest in vocational training, enterprises in agro-processing as well as in supporting small enterprises, particularly in the transitional peri-urban and rural sectors, and thus lowering reliance on fluctuating agricultural revenues.

The problem with rural self-reliance strategies is that they face limitations when they are faced with the infrastructure needs on a large scale. The systematical assessment of the public-cooperative partnerships should be carried out, in which the state provides land, rural roads, electricity, and water, whereas the community and cooperative organizations deal with inputs, credit recovery, and implementation. This kind of collaborative structure can take the benefits of the two industries to solve production, market and shock- mitigation issues.

These recommendations are in line with the United Nations Sustainable Development Goals 2 (Zero Hunger) and 11 (Sustainable Cities and Communities), and, by extension, the

Agenda 2063 of Africa, and contribute towards the resilience of the rural economies and food systems. Empowering and expanding grassroots resilience policy is viable policy and a useful tool in meeting food security and development goals in Nigeria.

The current research provides in-depth quantitative data on the food security in rural areas in Oyo State. The constraints are the potential selection bias due to a farm-based focus, and inherent limitations of cross-sectional analysis. Despite the recognition of salient interacting variables, longitudinal studies are needed to determine the impacts of macroeconomic reforms and coping strategies on the outcome of food-security in the long term. The small pseudo-R² indicates that the uncontrollable variables should be subject to more investigation, such as the local government, climate variability, intra-household decision making, and transportation cost shocks. This study forms one of the most complete quantitative studies of macroeconomic shocks and interrelationships between socioeconomic and spatial factors of food security in rural Oyo State hence providing a platform of causal, comparative, and policy-oriented studies in the future.

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