FACULTY OF ENVIRONMENTAL SCIENCES
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THEME:

ENVIRONMENTAL SCIENCES EDUCATION AND SUSTAINABLE DEVELOPMENT, ISSUES CHALLENGES AND PROSPECTS IN THE NIGER DELTA, NIGERIA.

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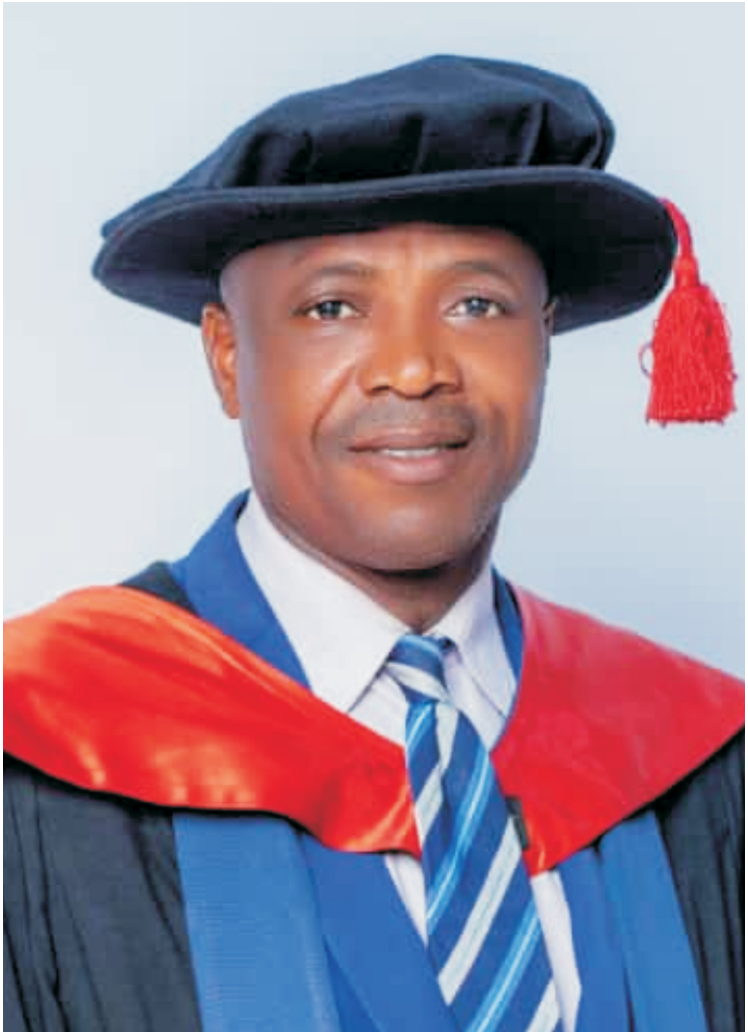

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Lead Paper

Land Resource Governance and Compensation: Research Methodology

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Abstract

A multi-methods approach was used in a study on land governance issues in contaminated land valuation, for compensation. The study combined pragmatist and phenomenological philosophies with participatory action research (PAR) strategies to address issues of inadequate compensation to oil spill victims in Nigeria. The aim of the study was two-fold, first, to build consensus through a community-of-practice, on the need to develop a more scientific approach to the valuation of economic losses to farmers, owners, and occupiers of farmlands contaminated because of oil spill pollution. Secondly, to develop a framework for the development of a contaminated land valuation (CLV) model and code that could contribute to an improved land governance system for damage assessment and compensation valuation in the oil and gas industry in Nigeria. The research project had five key objectives, each designed as mutually exclusive and independent studies (research work packages) from which the consolidated findings would be integrated together to develop the contaminated land valuation (CLV) model and practice code. By using a multi-methods approach, stakeholders and potential implementers of the study's findings participated in shaping the research, contributed to framing specific research questions and validated the methods and findings. Group data was generated which helped to further refine the study scope and objectives until data saturation was achieved with no additional findings from subsequent group interactions. The findings confirm that oil spill victims are under-compensated when compensation is paid only for the immediate losses, such as crops on the land at the time of impact, and not for sustained losses over time. This under-compensation is more pronounced where the paid compensation does not consider the loss of soil ecosystem services or provide for future ecosystem restoration as a vital component of compensation. A comprehensive approach to compensation is recommended, which includes payments for immediate economic losses, provision for loss of ecosystem services, and a commitment to ecosystem restoration, as a necessary component of compensation, and not discretionary to the polluter. The study contributes to the development of a framework for a CLV model and code by documenting the inefficiencies of the current situation. The deployed methodology contributed to achieving this and is replicable in similar research contexts where multiple data sources are required to draw meaningful conclusions for policy transformation, particularly in land governance.

Keywords: Contaminated Land, Compensation, Multi-Methods Research, Valuation Code, Facilitated Sessions, Participatory Action Research

Introduction

Crude oil and other forms of contamination of farmland soils, often results in loss of livelihoods by farmers as experienced in oil producing communities in the Niger Delta region of Nigeria. According to the National Oil Detection and Response Agency (NOSDRA), in Nigeria in 2022, there were around 585 publicly available oil spill records of which 201 had no estimated quantity of oil spilled provided by the operating company. However, based on reports available 18,904.815 barrels of oil (2,986,960.848 liters) was spilled in 2022 alone (NOSDRA 2023). The associated issues of clean-up, remediation and financial compensation as provided for in Nigeria's regulatory framework are fraught with a plethora of issues (Akujuru and Ruddock 2014). Ambiguity in statutes leading to multiple interpretation; incompleteness in content, inadequacy and poor application of valuation methods are

part of these issues (Kakulu, 2014). This paper discusses a subset of the comprehensive study on land resource governance and statutory valuation of hydrocarbon contaminated farmlands for Compensation. The study was undertaken to further explore the issue and provide workable solutions. It was designed as a multifaceted and multimethods study involving stakeholders and using different research strategies and methods.

One of the key challenges associated with oil spill valuation involving farmland, is the fact that the items to be valued are usually non-existent at the time of the valuation, because they would most probably, have been destroyed by the spill itself, or destroyed by fires because of the spill. In the absence of a basis for valuation, contaminated farmland valuation, it is at best based on guesstimates or reconstructive valuation through comparative analysis of what could have been visible, had the spill not occurred in the first place. This process in Nigeria would have been less complex if there were existing databases in place, from which reference could be made for reconstructive valuation. Lack of accurate farm records and data is a major challenge to the assessment of damaged farmlands and valuation for compensation. It is also true that most local farmers do not keep record of farm input; sales and yield from their farm monthly or annually (Deebom and Kakulu 2021). In the absence of clear tangible evidence of what was previously on the land, or scientific and methodical systems in place to reinvent them, there is an increasing preference for negotiation over valuation. The study focused on the Niger Delta region of Nigeria, where there is increasing pressure from oil spill victims to be adequately compensated.

Nigeria lacks a distinct compensation code which specifies the processes and methods that are to be used in compensation assessment under different circumstances, and that is compiled into one single document for reference purposes. What exists are a series of separate enactments relevant to operators in different sectors and often subject to multiple interpretations (Kakulu, Okorji, et al. 2014). The background to this study is the pressing need to act on the existing and recurring problems associated with the inadequacy of compensation payments paid to owners of contaminated farmlands due to oil spill pollution. This is not a new research frontier but a topic in which different researchers have identified the issues without providing action-based or clear solutions for resolving them. The researchers believe that there is the need for closure to this phenomenon and a new trajectory. This can be achieved through participatory policy and action research that is undertaken by not just the researchers but with inputs from a wider community-ofpractice. This community can suggest actionable steps to be taken beyond problem identification done by various authors (I. I. Kakulu 2014); (UNEP 2011), (Akujuru and Ruddock 2014), (Adewale 1989), (Onyije and Akujuru 2016). Some authors have addressed it within the context of conflict in the Niger Delta and the associated disruption to livelihoods and economic returns, (Mustapha and Ayodele 2016). Others have reviewed methodological issues in the assessment of oil spill damage for compensations (Kakulu, 2018).

This exploratory phase of the larger research project addresses objectives 1 and 2 of the main projects' five key objectives in an exploratory manner and its findings inform the remaining three objectives. The comprehensive objectives of the main study were as follows:

1. To review the gaps in legislation and regulatory guidelines for the valuation of damaged lands with particular emphasis on croplands contaminated with petroleum hydrocarbons, in Nigeria.

2. To identify and produce a comprehensive list of components that would constitute the heads-of-claim in an innovative valuation model.

3. To determine through pilot farm projects, the predominant farming methods, and crop mix patterns for the development of a contaminated land valuation database.

4. To review the intervention values for contaminated soil remediation through controlled experiments and ascertain optimal intervention values for sustainable agriculture and livelihoods.

5. To develop a model framework for contaminated land valuation (CLV) and develop the accompanying practice code.

Objectives 1 and 2 reviewed the gaps in legislation, policy, regulatory and methodological guidelines in the valuation of contaminated lands to determine the direction of travel and the required policy reforms required to address them. The authors provide details about how qualitative data was generated and analyzed to address these two objectives. Although the findings of the overall comprehensive study do not form part of this paper, its contribution to other parts of the study are enumerated. The methodology can however be replicated and hence this paper. The study proceeded with five specific sub-objectives as follows:

1. To review existing international protocols, standards and codes connected with oil spill damage assessment and compensation to farmlands and obtain a better understanding of the problem, with inputs from multiple international and national stakeholders.
2. To identify the stakeholders in governance who are currently implementing the existing statutory processes in the valuation of hydrocarbon contaminated farmlands and get their inputs into the overall direction of the research, as participant observers.
3. To engage other national stakeholders, professional practitioners, and academia in strategic brainstorms in search of workable solutions to compensation inadequacy.
4. Together with the identified stakeholders, review the approved methods of valuation of hydrocarbon contaminated farmlands in Nigeria to identify their limitations in terms of adequacy of compensation.
5. Identify the required areas for reforms that will form the basis of the CLV model and code development.

Conceptual Framework

This study builds on existing research through literature and theoretical reviews, it examines previous research reports and analyzes empirical data obtained from facilitated sessions and highlevel policy brainstorms with key stakeholders. Using a collective understanding of compensation adequacy, derived from literature and these empirical interactions, it compares the expectations for compensation adequacy with the provisions of existing statutes and other regulatory guidelines operational in Nigeria to establish the gaps. The study also builds on the recommendations of a landmark Environmental Assessment report published in 2011, by the United Nations Environment Programme (UNEP) on Nigeria. The UNEP report shows the extent of damage to the environment caused by oil related pollution (UNEP 2011). Their independent scientific assessment identified the full extent of the effects of oil pollution on land and the environment. This includes contaminated drinking water, contaminated farmlands, creeks, and important ecosystems such as mangroves (UNEP 2011). Identifying the nature and magnitude of damage is a crucial first step in bringing up claims for compensation and ascribing value to such claims. Valuation for compensation that proceeds without a comprehensive damage assessment survey is unlikely to satisfy the requirements for adequacy. The contextual framework examines four key concepts which are statutory valuation, resource governance, damage assessment and contaminated land valuation.

Statutory Valuation

Statutory valuation describes the process of valuing landed property for which the parameters and methods are specified by statute (legislation, regulations, or policies) of government. Such statutes override the use of alternate valuation methods based on the discretion of professional valuers. Over time these statutes may become outdated and require updating, modification or repealing altogether. In Nigeria, statutory valuation for compensation for damage caused by oils spill pollution is a source of serious contention in terms of adequacy of compensation derived through strict compliance with the existing prescribed statutory methods. Literature is rife with documentation of agitations for adequate compensations in several oil producing communities in the Niger Delta region of Nigeria (Mustapha and Ayodele 2016), (Gogo and Nweke 2018). There is also paucity of international protocols which specifically address onshore oil spill damage to farmlands, or which provide standard methods of assessment to achieve adequate compensation. This creates a lacuna, as weak and non-transparent national laws cannot be held to account when compared with international standards because they are also non-existent. It has been suggested that due to the complex nature of the valuation of contaminated assets, as evidenced by the quantum of papers on this matter, many practicing valuers might still not be discharging the professional duty to an adequate degree (Keeping 2001). In formulating and developing valuation methodology, valuers must be careful to ensure that they are within the confines of statute, however, such statutes need to be credible, just, and fair to form the basis for adequacy. (Keeping 2001) asserts that levels of valuers' competence in this area, as measured against an objective standard, are often extremely low and that many valuers are negligent when acting for clients with an interest in a potentially or contaminated site. The existence of separate codes of practice for this aspect of valuation can make it more mailable and able to respond quicker to changing needs.

Resource Governance

Natural resource governance refers to the norms, institutions and processes that determine how power and responsibilities over natural resources are exercised, how decisions are taken, and how citizens - women, men, indigenous peoples and local communities participate in, and benefit from the management of natural resources (Springer, Campese and Nakangu 2021). While the concept of governance is used in different ways, it generally deals with questions of how, and by whom decisions are made, and within the contested arenas of power, values, and relationships (Campese 2020). How natural resources are governed through statutes and other legislation may affect how much attention is given to issues such as contaminated lands and compensation. Governments are increasingly devolving the governance of natural resources from central administrations to subnational levels. Researchers routinely document the complexity and contradictions of this process, but policy prescriptions and their underlying theoretical models remain overly simplified (Bartley, Andersson and Van Laerhoven 2008). Contextually, this study falls within a natural resource governance framework. Land governance processes associated with oil spill damage assessment and valuation for compensation, can benefit from improved natural resource governance practices. Professional valuers are expected to take cognizance of the effect of environmental factors on the value of land, but the degree to which they mention these factors can be akin to negligence if it is not comprehensive enough to influence the actual value. If valuers fail to gather enough of such relevant information before undertaking a valuation, they may be acting negligently (Keeping 2001) . Governance interventions can be of value in the drive for adequate compensation. Before a valuation of contaminated land or property can be produced, the environmental risk relating to that land or property must be assessed. Considering the power and influence structure of subsistence farmers relative to oil giants and regulatory agencies, the chances that they can afford to engage environmental experts to produce a land

quality statements ahead of the valuation, are quite slim or simply non-existent. Good governance is required to ensure that the interests as well as the handicaps of all parties are properly accounted for in contaminated land valuation and compensation.

Damage Assessment for Compensation

Damage assessment involves taking steps to make a record and a comprehensive account of the actual damage to landed property and the loss sustained by victims of an oil spill. This should be synonymous with the utility and value of the property to the owner or farmer, in this study's context. Where claims are to be made for damage, it should be meticulously scoped as the basis for compensation valuation. One of the challenges with oil spill damage assessment is the identification of what constitutes the 'thing' or 'things' that have been damaged. In legal parlance, damage is also defined as a loss or harm resulting from injury to a person, property, or reputation (Merriam Webster 2023). Unless a party suffers any of the a above, technically they will not be paid damages or monetary compensation. Such an injury may be tangible or intangible. Intangible property includes rights over land and such rights can be affected by oil spills where the land is contaminated. Hunters and gatherers who use the forests have intangible rights to use and enjoy such forests on which their source of livelihood depends. Such intangible rights can be compensated if value can be ascribed to them. Landowners, particularly those with a reversionary interest in land may suffer losses including goodwill of a business due to the presence of contamination in an area due to stigma. Long-term illnesses caused by carcinogens present in the atmosphere because of oil pollution may not be immediately visible. However, oil spill victims can fall ill or develop respiratory illnesses from noxious fumes. Injury to persons may include the seepage of crude oil into groundwater and well-water causing groundwater pollution and food sources may also be contaminated leading to loss of livelihoods and other economic damages that are personal to the claimants. The challenge to the assessment team is to prove that all such real or perceived losses are a direct result of the oil spill and no other known or remote causes. Injury to reputation is an overly complex issue as the object which loses reputation may not be an individual, but lands may become stigmatized because of the presence of pollution and such stigma might remain despite the best efforts at remediation. Claims for reputational injury to the land because of stigma may be entertained. If by reputational injury to the property it becomes stigmatized and the value is impaired, the owner does suffer future financial losses, and this should be recoverable as damage at large. There is the need to identify the full spectrum of damage that can result from oil spills before a value is ascribed to it.

Contaminated Land Valuation

Oil spills may be seen as any other disaster, particularly where the affected persons and community members are unable to cope or recover using their own resources. Valuing contaminated farmlands for compensation is usually challenging as the fundamentals of valuation are sometimes omitted to achieve value when relying solely on statutes that were not well thought out or have limited reach. The required parameters for valuation consider issues such as the date of inspection, basis of valuation, purpose of valuation, full documentation including photo-documentation of the items to be valued, prevailing market rates and all other considerations for a complete and comprehensive valuation. These parameters which form the basis for valuation should be achievable in for a comprehensive valuation. Contamination affects property values through its impact on the real estate bundle of rights. These rights include the right to possess, enjoy, control, and dispose of real property. (Akujuru and Ruddock 2014) discuss the importance of socio-cultural values in the total economic value of contaminated land by examining what constitutes a valuable interest on contaminated land and how socio-cultural factors are valued in the damage assessment process. They conclude that there are socio-cultural interests in contaminated land and recommend that any comprehensive damage assessment requires the incorporation of socio-cultural values in the valuation. They suggest that adopting a

valuation approach that reflects the value of cultural goods like shrines and totems will assuage the feelings of the host communities that they are deprived of their rights when offered any compensation. This will minimize their hostility to the operations of such oil and gas companies and their reluctance to accept any compensation offered because of damage due to contamination. It is also crucial that the responsible agencies are sufficiently knowledgeable on damage scoping and that they engage persons with the right expertise to undertake the assessment particularly as the victims, may not be in any financial position to procure a full-blown scientific assessment of the damage. While it is understood that it is the duty of claimants to provide evidence of damage, in a situation where poverty becomes a hindrance to the engagement of professional valuers, such policies might need to be reviewed in favour of the poor and replaced with pro-poor policies which take into consideration the socioeconomic conditions of oil spill victims.

Compensation

Compensation is a broad word that has different meanings. It is a means to make a suitable and counterbalancing payment to somebody for some sort of loss or detriment which also conveys the etymological meaning of compensation (Wittich 2008). Compensation can include giving goods rather than money and the intent is to "make one whole" (or at least better) after an injury or loss (Hill and Hill 2005). Compensation can also be that which is ordered by a court to be done to relieve a party that has broken a condition and place the opposite party in no worse situation than if the condition had not been broken. To avoid some of the injustices or deliver a more specific interpretation and application of the term compensation, jurists have used specific phrases to express compensation in diverse legal settings and applications. In addition, most of the enactments have qualified compensation using diverse terms which are further examined. The intent of the International Convention on Civil liability for Oil Pollution Damage, 1992, is to ensure that adequate compensation is available to persons who suffer damage caused by pollution resulting from the escape or discharge of oil from ships. Compensation is a relative concept and subjective and open to multiple interpretation. The onus lies on the person(s) who have lost an item of value to show how valuable it was or is to them, and to accurately estimate their losses. This is usually difficult, and the fallback usually rests with the provisions of statutes, conventions, and protocols, which further complicate the subject of adequate compensation. A cursory look at compensation concepts provides a basis for assessing adequacy. The terminology and basic principles often associated with compensation valuation, are spread out in an inconsistent manner across several legislation (Kakulu, Okorji, et al. 2014). These include the principles of equivalence, fairness, equitability, promptness, and other such terms frequently associated with compensation as provided for in relevant enactments. The authors advocate that compensation valuation can operate within statutes, but they must be updated or re-drafted in a manner that enables them deliver adequate compensation.

Compensation Adequacy

The concept of adequate compensation and what principles should be followed when developing standards to regulate compensation is discussed. Adequate compensation refers to reparation or reimbursement which is equal, or proportioned, to the value of that for which it is taken (Black 2019). On the other hand, in consideration of tort, the principle of restitution in integrum dictates that the plaintiff should not be worse off after the taking can be construed to mean adequacy. Current legislation guiding oil spill compensation in Nigeria is obtained from the apex land use regulation, which is the Land Use Act, CAP L5 LFN 2004, the Petroleum Act and the Oil Pipelines Act amongst others. It also includes guidelines such as the compensation rates of the Oil Producers Trade Sector (OPTS) of the Nigerian Chamber of Commerce. By relying on these alone would regularly result in inadequate compensation since they are neither updated regularly in line with valuation practice of income

yielding properties (Mustapha and Ayodele 2016). Adequate compensation has been fronted as a remedy to the longstanding conflict in oil production. In the case of Shell Petroleum Development Company v. Farah (1995) the court ruled that in the event of both physical and environmental damage, compensation should be both in monetary terms to the affected parties and the perpetrator should take steps to restore the polluted environment. (Gogo and Nweke 2018). This is in line with the principle Ubi jus ibi remidium which means that to any legal loss, there must be a remedy. Therefore, adequate compensation, in this case, included orders for the performance of specific action (Gogo and Nweke 2018). Where the action is not taken, or that the action taken is not sufficient to qualify as adequate compensation then the victim is likely to continue agitating. It is essential to ensure that the claimants are not worse off after receiving compensation without the accompanying restoration of the polluted environment. Clear descriptions of what to remediate and the quality of restoration should be such that it satisfies several criteria such as fairness, equivalence, justice, completeness, promptness, and equity. These form the bedrock for the test of adequacy as discussed further below.

Fair Compensation

Compensation is said to be fair when it is in accordance with national and international law and is only applicable in specific circumstances (True Price 2018) human rights principles. Any legitimate attempt to compensate is guided by certain preconditions. There are pre-conditions in farmland valuation and compensation, which, having been met, compensation could be said to have been fair. Also, mischief and obscure laws may promote the propagation of unfair compensation. Obscure laws, faulty interpretation and lack of standards can deprive victims of tort from receiving fair compensation. In Godspower Nweke v. Nigerian Agip Oil Company Ltd. (1976), the presiding court denied the claim of the plaintiff. It relied on section 77 of the defunct Minerals Act to affirm that the parties had agreed to a sum cited in (Adewale 1989). Thus, compensation where there are no standards with which to measure, is subjective and cannot be deemed to be fair. In order to ensure equity in the Nigerian compensation practice (Onyije and Akujuru 2016) recommend that the professional views of valuers should be considered, and the process made more transparent if the process is to be equitable. The legislature/laws should ensure a fair process of determining values for compensation. They (Onyije and Akujuru 2016) also recommend reforms in statutory valuation process in Nigeria and the basis/methodology for determining values should be dictated by the valuers and not the legislation.

Equivalent Compensation

The Food and Agricultural Organization (FAO) of the United Nations provides five principles to guide the application of the concept of equivalence. These are: equivalence, balance of interest, flexibility, application of both de facto and de jure rights in an equitable manner and fairness and transparency, (FAO 2009). However, the application of de facto and de jure rights is a preservation of the court. In the case of United States v. Miller et al, 317 U.S. 369 Supreme court (1943), the Court ruled against the respondents who wanted to review the compensation figure to an amount than what was considered a fair market value prior to the government's approval of the development project, (United States v. Miller et al 1943). Equivalent compensation is also called "commutative" justice or exchange justice and is common in sales transactions or contracts, where each party believes that they have received suitable value or value that is at least equal to what they have lost. The guiding principle in commutative justice is that whatever is given up by one party in an exchange must be equal to what he receives (Robert 2010). With reference to farmland, the concern is about what exactly the farmer gives up when he loses his land because of oil spills. Based on the subjective nature of valuation, concrete guidelines may be required to achieve concrete judgements and reduce disparity in values. Following (Robert 2010), persons with similar plot descriptions should get similar payments but this is not always the case. Equitable compensation considers and balances the interests of both the individual and the

community and the polluter. Remediation costs can far outstrip the value of the land and in such cases, a decision must be made as to what the actual considerations are for the clean-up and remediation besides restoring land value.

Just Compensation

Just compensation implies the principle of restitution in intergrum which means compensation (in the case of the tort of negligence) should aim to restore the complainant to a position like where he or she was before he or she suffered a loss. This kind of justice was called "rectificatory," by Aristotle. The implication was that a just exchange rectifies or makes things right between the parties to the exchange, ibid (Robert 2010). It is difficult to determine the just compensation amount in the absence of consistent guiding principles and laws. However, the principles of fair market value may apply. In the case of destroyed farmlands, there are difficulties associated with ascertaining fair market value because of the difficulty in establishing the evidence on which to base such valuation. In the absence of evidence therefore, just compensation becomes elusive, and valuers would need to rely on suitable comparable farmlands to use as a substitute in their valuation.

Full Compensation

The term full compensation in tort law seeks to restore the victim to the position he was in before the tort. The position is, at least implicitly, considered to be the situation where the injured do not suffer any harm at all. However, it is only a negligent injurer who should compensate damages he inflicts on the injured, a non-negligent injurer is not liable for the damage suffered by a victim, (Wijck and Winters 2001). This aptly describes incidences of sabotage and oil spills where a nonnegligent injurer (in this case the oil company), is absolved from making monetary compensation payments because of the cause of spill. The question the study set out to answer therefore is who should be responsible for those farmers who suffer damage because of sabotage due to no direct fault of theirs? Should sabotage spills be classified as a disaster and dealt with as such? Full compensation implies the application of remedies for specific actions, injunctions, and restitution in cases of negligence. In this case the injured party is entitled to full compensation for injuries sustained because of the non-performance. This may include both losses incurred, and any gains deprived or foregone by the aggrieved party because of the harm. The question this unearths is whether the gains deprived or foregone because of the damage to farmlands include future farm productivity outputs until the land recovers following remediation or from natural recovery. In the case of irreparable damage to farmland because of oil spills, the principles of (Friedman 1982) may be worth considering for more appropriate levels of compensation. "Full compensation" also requires a negligent injurer to pay damages which bring the (potential) victim ex ante in the same position as the victim was in the case where the (potential) injurer takes due care, (Wijck and Winters 2001). According to (Friedman 1982), although the obvious principle for determining fair compensation in injury suits is that the injuror must 'make good' the damage to the injuree, there are some injuries for which the application of that principle seems difficult or impossible. (Friedman 1982) argues that there may be no payment large enough to make a blinded man as well off as if the injury had not occurred and that 'full compensation' in this sense, would in fact be overcompensation, in terms both of justice and of economic efficiency, and that there is another criterion which leads to more appropriate levels of compensation and is better able to deal with the 'impossible' problem of fairly compensating the victim of death or serious injury.

Prompt Settlement of Compensation Claims

According to (White 2002) prompt settlement of claims for compensation following oil spills from tankers is in everyone's interest, especially those who have incurred clean-up costs, had their property contaminated or suffered economic losses. (White 2002) also asserts that claimants can facilitate the

settlement of their claims by following four basic principles: (1) adhere to published international guidelines on the admissibility of various classes of claims; (2) keep good records, and follow international advice on claims presentation and the provision of supporting evidence; (3) do not submit claims that are speculative in nature or are inflated beyond their true value; and (4) co-operate and share information with those who will pay the compensation. This presents a perfect scenario as far as compensation is concerned but information regarding compensation is often shrouded with secrecy such that claimants are not sufficiently aware of their rights to enable them to understand how to proceed. Some of the shortcomings of tort as identified by (Markesinis 2019), is that it remains expensive, capricious, and dilatory. Delays can also produce injustice, especially since it tends to benefit wealthy defendants, ibid (Markesinis 2019). In some instances, overly protracted processes and procedures could be a deliberate attempt to frustrate plaintiffs in the hope of wearing them down so that they can accept a lower compensation figure. Also, when there is a time delay in payment of compensation, inflation will reduce the effective value of the compensation. Therefore, it is vital that rulings about compensation adopt the principle of promptness and define the time scope within which compensation should be executed or interest is due and how much. Ibid (True Price 2018). Prompt," compensation anticipates immediate recovery irrespective of the value of the loss or expropriation. Previously, in Tanzania, the State would expropriate land from an individual and compensate only for the unexhausted improvements and not the loss of value attributable to the land itself. However, reforms in the Land Act No. 4 of 1999, saw the country adopt progressive description of compensation legislation. The 1999 Act requires takers "to pay full, fair and prompt compensation to any person whose right of occupancy or recognized long-standing occupation or customary use of land is revoked or otherwise interfered with to their detriment by the State under this Act or is acquired under the Land Acquisition Act..", (Komu 2014)

Achieving Adequate Compensation

Article 1 of the Civil liabilities Convention (CLC) clearly defines who can bring a claim, and the nature of the claim as follows: "Person" means any individual or partnership or any public or private body, whether corporate or not, including a State or any of its constituent subdivisions. (a) if compensation for impairment of the environment shall be limited to costs of reasonable measures of reinstatement undertaken or to be undertaken. The CLC provides for compensation for impairment of the environment to be limited to costs of reasonable measures of reinstatement undertaken or to be undertaken and the costs of preventive measures and to prevent reoccurrence. Includes loss of profit from impairment to the environment and further losses or damage caused by preventive measures conducted if any. The Sustainable Development Goals (SDG's) are a bold commitment by the United Nations (UN), to, amongst other goals, end poverty in all forms and dimensions by 2030. This involves targeting the most vulnerable, increasing basic resources and services, and supporting communities affected by conflict and climate-related disasters, (UNDP, n.d.). Conflict situations in oil producing communities in the Niger Delta region of Nigeria are often linked to oil spill related disaster and issues of inadequate compensation for land and farmlands contaminated with hydrocarbons (I. I. Kakulu 2014). Furthermore, Goal 1 of the SDG's aspires by 2030, to ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance (UNDP, n.d.). To actualize the UN aspirations in Goal 1 particularly the control over landed property by the poor and vulnerable, there is the need to further examine those enactments and policy regulations that are not pro-poor (in favour of the poor). The issue of oil spills and compensation in oil production is one of such issues militating against the actualization of SDG 1 by the year 2030 and this study seeks to address it. Nigeria is in urgent need of guidelines that enables parties to a compensation claim,

understand what their entitlements are in a way that enables them to manage their expectations. Unfortunately, in the case of onshore oil spill pollution, only country level regulations continue to apply, and this makes it difficult to have a global perspective and one of the issues this study highlights.

Methodology

The study proposition is that 'adequate compensation can be achieved using appropriate valuation methodologies which comply with statute, and statutes that should be designed to fulfil the requirements for adequacy as described in this framework. Currently, there is no harmonized document which contains the procedures and methodologies for undertaking contaminated land valuation (CLV) in Nigeria. If adequacy can be achieved by satisfying compensation criteria in relevant laws, then valuation methodology, as recommended by regulatory agencies, should be consistent with the intentions of the law. The study was conducted as participatory and policyoriented research, with a grounded theory strategy. Data collection methods consistent with participatory action research (PAR) such as focus group discussions and facilitated sessions, formed the main instrument of data collection. The PAR design was considered appropriate for this type of study because the focus is not to simply expand the frontiers of knowledge but to bring about lasting change based on emerging theory and through recommendations for policy reforms. The multi-method study was conducted within an underlying pragmatist philosophical framework combined with phenomenology which informed the participant selection. Typically, pragmatist research uses whatever combination of research methods it considers necessary to find answers to research questions provided that the rigour required of each independent method is fully complied with (Dudovskiy 2021). Pragmatist research also recognizes that there are many ways of interpreting the world and undertaking research, and as such no single point of view can ever give the entire picture. There are also and that there may be multiple realities (Sauders, Lewis and Thornhill 2019).

The study proceeded with a pragmatist philosophy, a pragmatist strategy (what works), phenomenologist ontologies and epistemology as well as axiological considerations. These informed the methodological choices resulting in a mixed methods strategy which combined dialogues with quantitative experiments, field surveys, participatory action, and grounded theory to answer the general and more specific research questions. Pragmatist research combines both, positivist, and interpretivist positions within the scope of a single research according to the nature of the research question (Dudovskiy 2021). Although these are two extreme mutually exclusive paradigms about the nature and sources of knowledge (Dudovskiy 2021), there is the occasional need for seasoned researchers to modify their philosophical assumptions over time and move to a new position on the continuum (Collins and Hussey 2014). Such a position enables them adopt methodologies that best address various aspects of a research problem even if they must combine mutually exclusive paradigms and ignore or override the quantitative versus qualitative paradigm wars as the study alluded to. Positivist research relies on a deductive reasoning approach, based on objectivist ontologies and value-free axiology. In positivism, quantitative methods may be employed in social research while interpretivism integrates human interests into a study. Interpretivist research which is on the opposite end of the spectrum relies on inductive reasoning in its approach, based on subjectivist ontologies and a biased axiology. Applied research in this context refers to solution-based research targeted at addressing a particular issue which the study identifies as the absence of a dedicated valuation code for valuing contaminated lands in Nigeria, and the need to develop one. Pure research methodologies on the other hand were deployed for explanatory purposes building on the findings from the qualitative dialogue sessions. Certain aspects of the data collection and analytical strategies were qualitative with heavy reliance on secondary data sources, facilitated sessions and questionnaires. Also, the interpretivist paradigm has a worldview in which meaning is given by induction to the subjective

(personal) experiences of the participants in a study. In this context, less attention was given to measurements and more to making sense out of the lived experience in a subjective relationship between the researcher and respondents and participants.

Experiments were undertaken also, and the findings were used to validate and, in some cases, or contradict the findings from the qualitative dialogue sessions thus leading to more credible conclusions. The experiment investigated the impact of crude oil contamination on crop productivity and land value as part of the larger study. Data collection methods and analytical techniques consistent with these strategies were utilized. Facilitated sessions formed the main tool used in data collection for the larger part of the study which included research seminars, strategic brainstorming, focus group and expert review meetings. These were used to collect diverse types of data for the study commencing with exploratory facilitated sessions and other investigative and explanatory sessions. The use of focus groups was to ensure that all participants were given equal opportunity to have equal voice and thereby ensure that all contributions made by every participant was given a chance to influencing the direction of the study as well as the outcome of the study in some way. Several formal and informal facilitated sessions were held over the entire duration of the study. Strategic brainstorms were held at the initial commencement of the study in 2017, several others were held in 2021 at the end of the second round of field work activities.

Participant/Stakeholder Recruitment

Phenomenology underpins participatory action research (PAR) because it recognizes the importance of contributions made by those who have experienced a phenomenon firsthand. Those whose lived experiences of a phenomenon can throw more light into the phenomena can collectively contribute ideas to find solutions to it. Also, group dynamics can lead to the formation of innovative ideas, and it was therefore critical to ensure that at each session, there was a fair spread of stakeholders. Participant selection for the strategic brainstorm was done using a combination of randomized sampling and purposive sampling. Invitation to participate was circulated widely, with a pre-registration requirement which included a field where registrants were required to indicate the industry with which they were associated. The approval process used this criterion to grant access and regrets were sent to those registrants who were not granted access. Aiming for 20 to 30 participants per brainstorming session, including members of the research team, an average number of about eighty-five people were approved for participation with an expectation that about 30 to 40 percent of this number would log in. Participants were not incentivized for some of these sessions but participated to learn and to make contributions to the dialogue. Participants were recruited via invitation letters, SMS, email invitations, study tour contacts and telephone invitations. Other participants were recruited via snowballing as they were recommended and invited by participants of previous sessions. The sessions lasted a minimum of ninety minutes and a maximum of 2 hours. All sessions ended when data saturation was perceived to have been reached. In addition, all moderators were experienced in facilitation and were able to keep the participants engaged in a lively discussion without digressing from the subject. Participants for both focus group and facilitated sessions were chosen based on their having specialized knowledge about land governance, contaminated farmlands, valuation and compensation matters, site remediation, environmental law, and other aspects of environmental awareness. These included academic researchers, industry players, NGO's and others interested in the subject who wanted to learn more. Other participants were chosen based on work or real-life experiences as they could make meaningful contributions to the discussions in a group setting. The selection of the people was crucial to the quality of the discussion and interpretation of the outcome. The focus groups and facilitated sessions were designed such that they included enough participants to yield diversity in the information provided. Although desirable in such discussions, consensus building was not the main thrust of focus groups nor

facilitated sessions. With a choice to randomly select participants or purposefully perform the selection, purposive sampling techniques were applied. A multistage purposeful sampling technic was adopted in which rather than maintain the same set of participants attending multiple meetings, some participants were dropped, and other participants added to a reasonable proportion of participants from previous sessions to infuse the discussion in subsequent sessions with innovative ideas and perspectives. The methodology was exploratory leading to the production of new forms of knowledge through the process of interaction and dialogue.

Study participants consisted of key representatives of the Nigerian Institution of Estate Surveyors and Valuers (NIESV) and the Estate Surveyors and Valuers Registration Board of Nigeria (ESVARBON). The Nigerian Institution of Estate Surveyors and Valuers (NIESV) is the apex body involved with the valuation of landed property in Nigeria while ESVARBON is the Regulatory Board. Participants were also purposively selected from the high-level decisionmaking personnel from the Nigerian National Petroleum Company (NNPC) along with Directors from the Federal Ministry of Lands and Housing; the National Oil Spill Detection and Response Agency (NOSDRA) and the Department of Petroleum Resources (DPR). Contributions made by participants during the discourse were utilized for understanding the depth, breadth and explaining the data. The sessions typically had twenty participants including two session facilitators. The role of policy, legal, and regulatory framework in the assessment and valuation of hydrocarbon contaminated farmlands for compensation was reviewed via secondary data by examining compensation related enactments such as the NNPC Act, The Petroleum Act, The Oil Pipelines Act and the Minerals and Mining Act all part of the Laws of the Federal Republic of Nigeria (LFN). Stakeholders from several regulatory agencies responsible for various aspects governance of oil spill damage assessment and compensation in Nigeria were engaged in focus group meetings and online facilitated sessions. A semi-systematic literature review was used to validate the empirical data obtained from a high-level policy dialogue in a facilitated session/Focus group discussion conducted on the 17th of May 2017 at the Rockview Hotel Royale, Abuja, Nigeria. This type of review, sometimes referred to as a systematic literature review or meta-analysis, is a critical survey of literature that attempts to "evaluate and interpret all available research evidence relevant to a particular question" (Glasziou, 2001). Rather than focus on the symptoms in the form of inadequate compensation, the study seeks to provide explanation to the consequences of inadequate compensation for the purpose of seeking precise and more definite conclusions about this issue. Knowledge is produced by inductive reasoning.

Data Generation and Collection

Data was generated and collected primarily through dialogue as is consistent with participatory research. Sixteen different interactive sessions were conducted over the period of the study from the commencement of the study in 2017 to the final validation workshop in 2021 with an almost 18-month of limited activity occasioned by the Covid-19 pandemic and massive national and global lockdowns. These are grouped into six (6) Single Focus Group sessions; three (3) Multiple Focus Group Sessions; two (2) Single Facilitated Sessions; four (4) Multiple Facilitated Sessions and One (1) Peer review validation Workshop held in 2021. In between these meetings other forms of observational and experimental data sources including field surveys were undertaken which fed into various parts of the larger study. The strategic brainstorms and facilitated sessions generated all three forms of data. Data was obtained from the questionnaires which were filled by individual participants during the face-to-face sessions held in Minna and Abuja, Nigeria contributed to the study. A total of sixteen (16) separate interactive sessions were held beginning Following the initial strategic brainstorms, two Single Focus group meetings were held with research team members and invited representation. One of such

meetings was held with farmers participating in the 'adopta-farm' work package of the study in line with Objective 3 of the wider study. A second one was held with a research team and representatives from the United Nations Environment Programme (UNEP) and the Hydrocarbon Pollution Remediation Project (HYPREP) in remediation of contaminated soils as part of compensation. Participants were selected based on their level of expertise and perceived ability to contribute their expert opinions towards the development and refinement of the study propositions and hypotheses. The strategic brainstorming also generated ideas some of which required in-depth analysis and follow-up discussions. Multiple focus groups and facilitated sessions are useful for dealing with emergent (exploratory) data as well as systematic (validation) data for data saturation. Participants to the Multiple Focus Group meetings were purposefully selected based on their expertise in terms of previous academic research participation and output, professional and field experience, and ability to contribute to further develop the emerging themes and theories. The expert review Focus group held three separate facilitated meetings during which emergent issues were further developed. Saturation occurred by the third meeting, which was the last meeting prior to the writing up of the research report. The strategic brainstorm identified key people who volunteered to grant key informant interviews to the team where they could freely share their lived experiences of the phenomena. Such people were later interviewed, and analysis done on the audio recording. The methodology was exploratory leading to the production of new forms of knowledge through the process of interaction and dialogue. In the facilitated sessions which had several participants, by recognizing that some participants might feel uncomfortable with sharing their thoughts, opinions, beliefs, and experiences publicly, polls were launched intermittently on key issues and identity of the responses were protected. This also served as an internal validation mechanism. To ensure also that a reasonable number of persons participated in the each facilitated session, participants were overrecruited by almost fifty percent (Wilkinson 2004), because of the possibility that some participants might not be available on the day of the focus group. (Morgan 1997) has suggested overrecruiting of the total number of participants required as a way of assuring reasonable attendance.

The video conferencing facilitated sessions generated individual, group and group interaction data which were captured by audio and video recording, meeting notes, comments in the chat box feature and responses to polls launched intermittently during the sessions. Polls were launched for the sole purpose of building consensus and identifying not only emergent themes in the study but also the degree of consensus or dissenting and alternate opinions which generated quantitative data that was later used as a consensus building tool and a validation instrument. Data generated through the interactive process of discussions, arguments and counter arguments was collected using a combination of note taking, video and audio recording of the sessions. The underlying philosophical ontology of the study made it imperative that all contributions had equal chances of being heard and as such polls were introduced which provided anonymity in the selection of answers. Participants were encouraged to send chat messages to the facilitators where they felt constrained and declined to chat freely on the open chat box visible to everyone. Poll results were subjected to quantitative analysis. Using the total number of participants as the population, the reposes to the polls represent a sample from the total population. (Krueger 1994) and (Morgan 1997) suggested that three to six different focus groups are adequate to reach data saturation and/or theoretical saturation, with each group meeting once or multiple times, which was the methodology adopted in this study. Also, in previous works cited by (Onwuegbuzie, et al. 2009) multiple meetings using multiple focus groups makes it possible to assess the extent to which saturation has been reached. Multiple focus groups and facilitated sessions are useful for dealing with emergent (exploratory) data as well as systematic (validation) data for data saturation. If at subsequent sessions nothing new emerges then it was safe to assume that data saturation had occurred. In the study, data saturation began to occur at the fifth facilitated session and

data saturation was achieved after the seventh session when information became repetitive, and it became possible to anticipate what could be said by discussants. At this point, whereby the collection of more data appeared to have no additional interpretive worth ((Sandelowski 2008); (Given and Saumure 2008) (Onwuegbuzie and Collins 2007) no further interactive sessions were organized. By the seventh facilitated session, there was no new knowledge or theories emerging as participants began repeating what had been captured at earlier sessions. This signaled the end of the data generation, collection and saturation phase of the study and the commencement of the data transcription and organization for data analysis.

Data Analysis and Interpretation

The data collection and analytical methods were a mix of qualitative and quantitative. There is a great deal of skepticism about the value of focus groups and other facilitated sessions which arises from the perception that focus group data are subjective and difficult to interpret. However, the analysis and interpretation of focus group data can be as rigorous as that generated by any other research method. It can be quantified and submitted to sophisticated mathematical analyses, even though the purposes of focus group interviews seldom require this type of analysis (Stewart and Shamdasani 2014). The data obtained from the Focus Group and Facilitated sessions were analyzed individually within the context and the objective behind the research questions driving each session. The findings from each session were documented and formed the basis for further analysis. There are several options available for analyzing data from focus groups and facilitated sessions (Onwuegbuzie, et al. 2009) which are ranked from the most rigorous one which is the transcript-based analysis, through the tape-based analysis, note-based analysis and memory-based analysis being the least rigorous. The memory-based analysis is the least rigorous particularly as it involves the moderator recalling the events of the focus group and presenting these to the stakeholders. Transcript-based analysis was utilized for the multiple focus groups while a combination of note-based and tape-based analysis was used for the single focus groups. Memorybased analysis was used in a few strategic brainstorms at the exploratory stages of the study, but the notes were circulated to discussants for their inputs. Audio and Video recordings were transcribed and subjected to qualitative analysis.

Thematic Analysis

Thematic analysis and grouping of responses were done for both verbal and written responses that were obtained using questionnaires at the end of the session. Twelve persons completed questionnaires out of the twenty that participated in the dialogue session held at Abuja. This provided further insight into some of the issues raised. The questionnaires improved participation, particularly for people who had been quiet during the preceding two-hour dialogue session but expressed their views more succinctly in writing. The transcript of the sessions and the unstructured questionnaire responses were analyzed thus capturing 'real' thoughts, feelings as represented in their contributions. Data was synthesized, and the findings show evidence of the key issues on a meta-level. Gaps and areas in which more research is needed were uncovered and this was a critical component of creating theoretical frameworks and building conceptual models for this study. A semi-systematic review was considered suitable because of the broad and multidisciplinary nature of oil spill compensation issues that have been conceptualized differently and studied within diverse disciplines. Different theoretical approaches and/or themes were mapped, and knowledge gaps identified within the literature. In addition, an integrative review approach was considered useful and facilitated the combination of perspectives to create new theoretical models presented later in this paper.

Group Data Generation

Data analysis was done for each separate facilitated session which included strategic brainstorming,

focus groups and expert review meetings. Data was analyzed at the individual, group and group interaction level using a combination of content analysis, conversation analysis and constant comparison analysis (CCA) tools. Individual comments in the chat box or substantive statements made by participants when making oral contributions were analyzed and through data reduction methods such as affinity grouping, themes were grouped together to form group data. The grouping of emergent themes into categories formed the basis of the group data which was compared with group data from other groups. Interaction data was obtained by paying particular attention to new threads of thought outside of the original research questions which developed during the interaction and informed the concluding sections of each of the facilitated sessions. Each unit of analysis, individual, group and group interaction were analyzed. Individual data were analyzed using methods consistent with individual interviews. Everyone who made a substantial contribution was treated as an individual interviewee. Responses from such individuals were clustered together to capture the overall perspective of the individual. The analysis also sought to uncover argumentative interactions that enhance the richness of the data. (Kitzinger 1994)

Transcript-Based Analysis

Transcript-based analysis is a rigorous and time-intensive mode of data analysis (Krueger 1994). Video and audio tapes were transcribed at the end of each session. Transcripts were produced containing the text of the meeting which ranged from 16 to 27 pages for the strategic brainstorm sessions and 15 to 23 pages for the expert focus group sessions. The typing was in Times New Roman, 12pt font size and double spaced on A4 size paper. During the transcript analysis, the focus was on the research question and responses that addressed it and provided better understanding of the phenomena. The researchers also analyzed emerging concepts and themes which were carried over into subsequent sessions and elaborated further upon. Tape based analysis was used in the analysis of the session with farmers and the research team. The video was played, and an abridged transcript prepared and used simultaneously along with the meeting notes produced by the assistant moderator. This approach was considered suitable because of the nature of interactions and the limited ability of some of the farmers to express themselves in more formal ways. Portions transcribed included those that had to do with the specific subject as there were digressions and, in some cases, sentiment laden contributions. Memory-based analysis was also useful for capturing some of the discussions held in other less formal sessions such as the Focus group session on Remediation which addressed a simple but very key question.

The Bow-tie-Butterfly (BB) Analytical Tool

The BB Model (I. I. Kakulu 2014) is a thematic mixed analysis tool that organizes data from facilitated sessions and focus groups, into a form that fosters easy analysis. The method initially expands transcript data into substantive statements paying particular attention to keywords-incontext and thereafter commences the data reduction using affinity definitions and thematic categories leaning towards the original research questions. The model re-orders the data by deductive analysis and presents it in a thematic format for inductive analysis and drawing of inferences. It analyzes not only the substantive statements made but where necessary, enumerates them, notes the frequencies associated with them to establish proportions and validate inferences. The disaggregation data obtained from facilitated sessions further enhances use of the methods whose underlying paradigms and philosophical assumptions treat all participants as equal. These are further reduced until they answer the original research questions. Current trends of thought and new insights are subject to theoretical sampling or additional focus groups are conducted until data saturation is achieved. The BB method, by grouping substantive statements, identifies the emergent themes and the proportion of statements which contribute to these themes. This reveals where emphasis lies in the group contributions in terms of the consensus views and dissenting views of participants (Onwuegbuzie, et

al. 2009). Micro-interlocutor analysis (Onwuegbuzie, et al. 2009) was also used by delineating which participants responded to each question, the order of responses and the nature of the responses where it assessed for non-sequitur, rambling, or focused responses. Non-verbal communication used by participants during online facilitated sessions such as the thumbs-up emoji or the applaud were also analyzed by replaying the video of the session and identifying these actions.

Unit of Analysis and Data Transcription

Analyzing focus group data can be done on a few levels such as on an individual basis, group basis or based on the outcome of the interaction where contributions no longer remain polarized to individual convictions, but a certain degree of consensus has been reached through dialogue. Analyzing individual data is also important because it enables the documentation of focus group members who did not contribute to the category or theme. It also identifies their voices, or lack thereof on topics discussed. According to (Onwuegbuzie, et al. 2009) the individual members might include those who are relatively silent as they are either too shy to speak about the issue or do not want to reveal that they have a different opinion, attitude, experience, level of knowledge. Some may not deem the issue to be worth discussing, less articulate and for several other reasons. By doing the analysis on all three levels it was possible to study the data collected and present emergent themes. In addition, the degree of consensus and dissent revealed by the analysis increases the richness of the data. Analyzing and interpreting information about dissenters helped in determining the extent to which the data that contributed to the theme, reached saturation or within-group data saturation. Thus, documenting information about dissenters (Maxwell 2005), increases the descriptive validity, interpretive validity, and theoretical validity associated with the emergent themes, which, in turn, increased Verstehen (i.e., understanding) of the study area and key issues. Verstehen refers to a situation where the researchers are in a position where they can understand the phenomenon from the actors, in this case the study participants' point-of-view. It refers to understanding the meaning of actions from the actor's point of view. It is like entering into their shoes and feeling what they feel about the subject and adding their opinions and convictions to the overall findings. The inclusion of frequency data into the substantive statements by the launching of polls helped in no small measure to disaggregate the focus group data that was generated. This way, each focus group member was recognized and treated as a unique and important study participant. Notwithstanding the rigour required in transcript-based analysis, each facilitated session was recorded, and transcription of the recordings was the first step in the data analysis process. This was done to have a permanent written record of the group discussions and make it available to any other interested parties or researchers. To capture the essence of the session, minimal editing was done so that the thought processes and speech of each respondent was preserved as much as possible. The transcription process documented incomplete sentences, half-finished thoughts, parts of words, odd phrases, and other types of spoken words that are characteristic of group discussions. During the transcription, attention was paid specifically to the entire character of the discussion such as the way participants use words and the tone. No attempt was made to code these as it could affect the interpretation of a particular statement. Non-verbal communication, gestures, behavioral responses, and other observational data were not captured and are not reflected in the transcription. For internal validation, multiple analysts were used which provided an opportunity to assess the reliability of the categorizations made. Poll results were also used to validate various positions for consensus building and to capture divergent views.

Content Analysis

(Krippendorff 2013) defines content analysis as a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use. Content analysis methods include unitizing, sampling, and recording. In a phenomenological and grounded theory study

however, the underlying philosophical connotation presupposes that every piece of information has equal chance of being documented and heard, as such, the pre-coding is usually set aside for coding derived from the data itself as is consistent with grounded theory studies. This process was facilitated using the BB-analytical model (I. I. Kakulu 2014). Themes emerging during the content review were further developed and categorized into sub-themes through a twin process of data expansion followed by data reduction. This is in tandem with (Strauss & Corbin, 1998), open coding, which can be used during constant comparison analysis, where the data are chunked into small units that are referred to as substantive statements usually made by the respondents as documented in the transcripts, a process known as data expansion. Following the data expansion, a descriptor, or code, is attached to each of the units which are further grouped into categories based on similarity in terms of content and context. In a process of selective coding, themes are then developed that express the content of each of the groups.

Authors (Onwuegbuzie, et al. 2009) also conceptualize how conversation analysis offers much potential for analyzing focus group data and contend that their framework represents a more rigorous method of both collecting and analyzing focus group data in social sciences research. They propose micro-interlocutor analysis as a method of conversation analysis which incorporates and analyses information from the focus group by delineating which participants respond to each question, the order of responses and the nature of the responses judging whether they are non sequitur, rambling, or focused giving an assessment of the knowledge level of the respondents. Although this method might have proven to be suitable if utilized in this study, the careful selection of participants ahead of each session limited it is use as there were hardly any cases of rambling or non sequitur contributions during these sessions due to the caliber or participants. The microinterlocutor analysis was, however, used in analyzing how focused the responses were to the questions asked and the degree to which respondent went off course to get their opinions heard or remained on track.

Findings

Conclusions are drawn which according to (Keeping 2001) suggest that many valuers still have some way to go in attempting to discharge their professional obligations satisfactorily when valuing contaminated land and other sites affected by environmental harm. The key question put across to the participants was on how professional valuers can ensure that the fundamental principles of compensation are adhered to while undertaking the valuation of contaminated of damaged land? Four issues were addressed emanating from extant regulations. The corresponding legislation are presented as follows:

Suitability of the Land Use Act

The Land Use Act (LUA) Cap L5 LFN 2004 first promulgated in Nigeria in 1978, was for the purpose of compensation in compulsory acquisition of landed property. In this Act, no compensation value is prescribed for bare land, but it makes provision for the assessment of compensation for rent, if any, paid by the occupier during the year in which the right of occupancy was revoked. The holder and occupier are entitled to compensation for the value of their unexhausted improvements. It makes an implicit assumption that bare land/agricultural land has no value. Participants responses and their perceptions on the suitability of this Act for use in the valuation of contaminated lands for compensation, were analyzed and categorized as follows:

Participants stated as follows:

1. The assumption that land has no value as stipulated by the LUA is baseless considering that there are other ancillary costs associated with land ownership besides the cost of the land per se, that are not provided for in compensation under the Act.
2. In practice, plantations and economic trees are usually recognized as major value

improvements which represent long-term economic expectations based of farmers.

3. That within the context of valuation of oil contaminated lands, the LUA is not applicable.
4. That the LUA is not applicable in the valuation of contaminated or damaged lands as it provides for compulsory acquisition and does not address contaminated land valuation.
5. The LUA faces an acceptability challenge in Nigeria as some States still practice different land tenure laws.
6. That the concepts 'fair and adequate' are relative considering that the LUA does not give room for market value.

Some participants also made recommendations in favour of retention of the LUA including the possibility of adaptability to make it suitable and fit-for-purpose, to be used as the main legislation for contaminated farmland valuation. Some of the responses are as follows:

1. Participants felt that there is the need for a switch to a fair value basis rather than statutory valuation as this will increase the flexibility in the application of appropriate compensation methods by professional valuers.
2. Others advocated for retention of the LUA with provision for valuation of the worth of the loss in terms of the number of years when the claimant (farmer) will not have value from the land to achieve adequacy.
3. Participants also felt that the LUA needs to be amended to enable it to provide adequately for contaminated land valuation as in its current form, it is unable to.
4. They were also of the opinion that the provisions of the LUA do not sufficiently provide for compensation for damage to land and as such, a more scientific approach is needed which would provide for damage assessment.

Other participants felt that the LUA is in order because by its provisions, the value of bare land belongs to the State Government, who is the 'owner' and not the occupier of the Land based on the LUA.

Fair and Just Compensation

Section 20(2) of the Oil Pipelines Act Cap 07, LFN 2004 recommends just compensation as a result of damage suffered by any person (other than on account of his own default or on account of the malicious act of a third person), as a consequence of any breakage of or leakage from the pipeline or an ancillary installation, and loss (if any) in value of the land. It provides for assessment to be according to the provisions of the Land Use Act. Logically therefore, all the observations in section 5.1 above apply to the inability of the Oil Pipelines Act to deliver just compensation. Participants provided further insight on just compensation as follows:

1. Participants observed that there is a conflict between the Oil Pipelines Act and the LUA which are moving in opposite directions.
2. They believed based on the dependence of the Oil Pipelines Act on the LUA, there is no value added in one depending on the other.
3. They also suggested that since the LUA did not envisage the oil pipelines act 07 LFN 2004, there is no convergence between the two.
4. It was also considered that since the provisions of the LUA prevent it from executing powers over oil sector operations in one breadth, it technically should have no relationship with oil-related compensation and as such it cannot be relied upon to provide the method of assessment for contaminated land valuation.
5. That just compensation is subjective and linked to the individuals and community's understanding and views on justice and entitlement, and that compensation standards and estimates should be objective

Participants also made recommendations in their responses on the issue of fairness and adequacy of the oil pipelines Act, as follows:

1. That just compensation requires a basis of valuation which is not provided for in the Act. They recommend that in the absence of one, fair value would suffice as the basis.
2. That a fair value basis of valuation of contaminated land will restitute or restore the claimants to their original condition.
3. They also gave some indication as to what would constitutes fair value stating that it should include resettlement, financial compensation, relocation which have psychological, spiritual and otherwise implications.

Full, Prompt and Adequate Compensation

The Nigerian Constitution the NNPC Act (2004) for instance, provides for the payment of compensation in respect of any loss or damage that may have been suffered in consequence of the operation of the provisions of the Act. These operations include oil exploration and production. The amount of compensation should be as prescribed under the Land Use Act. The NNPC Act gives no further description of the characteristics of compensation as it pertains to loss nor to damage and is therefore silent on compensation adequacy or otherwise. The Petroleum Act provides for the holder of an oil exploration or prospecting license, or oil mining lease, to be liable to pay fair and adequate compensation for the disturbance of surface rights to any person who owns or is in lawful occupation of the licensed or leased lands. It however fails to further qualify what is meant by fair or adequate compensation by way of performance of a specific task or full description of the heads of claim that can deliver adequacy.

Conclusion

Recognizing that the LUA remains the reference for compensation in Nigeria, the study reviewed the suitability of the LUA to deliver adequate compensation for compulsory purchase in the first place and thereby making it able to deliver adequacy in contaminated land valuation. The study reveals the conflict and the challenges faced by farmers when it comes to the subject of contaminated farmlands and compensation. Whereas one agency is vested with the responsibility of assessing ecological damage, the polluter is vested with the responsibility of assessing losses and making payments for unexhausted improvements on the land, as per the land use Act, which includes unharvested crops. The question then is clear, what does a farmer lose? If he loses access to fertile soils which is like a colossal loss of natural capital, who gets paid? Does the farmer get compensated for the ecological damage or does the payment for ecological damage go to the State? The validity of emerging themes focused on assessing the descriptive validity, interpretive validity, and the theoretical validity. The purpose of validity according to (Maxwell 2005) is to increase the Verstehen - understanding of the issues of inadequate compensation. The methodology has combined several methods of qualitative data collection to address the research objectives leading to different layers of triangulation and improving the overall validity of the data collected. This paper has described the overarching methodology of the main study on Land resource governance in oil spill compensation. It has contributed to further shaping an experimental study on the adequacy of the current compensation regime, in soil remediation which the findings agree is a major component of oil spill compensation. It has specifically contributed, through the voice of study participants and stakeholders, the need for a review in the intervention values and closeout values for soil remediation post oil spill. Participants agree that if soil remediation is a part of compensation, then the values of contaminants remaining in the soil as residue after a clean-up and remediation exercise, should be such that it does not interfere with farming and crop production. It also alluded to the fact that the findings from a study of this nature are essential to further challenge the adequacy of the existing remediation interventions and an essential component of the contaminated land valuation tool.

The study concludes also that a dedicated contaminated land valuation (CLV) code will not necessarily override existing policies on compensation but seek to integrate existing practices with research informed modifications, the ownership of the process and contributions by relevant stakeholders was essential. The findings obtained from the data gathered through the multi-method approach will be utilized in the development of the CLV code. key. The findings from the interactions with research participants also further justified the need to map the traditional farming patterns in local communities and develop baseline data for use during crop enumeration activities associated with compensation for loss of economic crops. The dialogue processes refined and better shaped the objectives of this additional study. The anticipated outcomes of these three additional studies which are rooted in findings from strategic brainstorms, facilitated sessions and online webinars, have influenced these spin-off research objectives in a way that will make them more holistic. the against the valuation practice to decide if the existing practice should be retained or modified in the development of the contaminated land valuation code. The refinement of the objectives of that additional study will enable the development of a more refined valuation code. The cumulative findings of the main research study will no doubt be influenced by the underlying pragmatist philosophical approach coupled with the use of a participatory action research (PAR) strategy, qualitative research data generation and collection methods. This approach has ensured that the voices of key stakeholders were captured during the research from inception to validation.

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Theme A:
Real Estate Development, Environmental Standards and Evaluation and National Development

Exploring Public Sector Assets Maintenance Policy as a Pivotal Catalyst for Economic Growth and Development

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Abstract

The maintenance of public sector assets is crucial for driving economic development in Nigeria. The study is aimed at examining the various strategic means of boosting states internally generated revenue by adopting Public Sector Assets Maintenance Policies using the Sharks Stadium Port Harcourt as a case study. The main source of primary data the researcher used to collect data was through a structured questionnaire and interview. The purposive sampling technique was adopted in the selection of the sample size for the study. Frequency Distribution Tables and Inferential Statistics were used in the analysis for the study, while the hypothesis was tested using the linear regression analysis. The result revealed that there is significant relationship between maintenance management and Gross Domestic Product. The study recommended that There should be in place an effective implementation of maintenance policy of public sector assets.

Keywords: Public Sector, Assets, Maintenance, Economic Development

Introduction

Maintenance of public sector assets in Nigeria leaves much to be desired. This is because the public sector assets which are capital intensive to construct are left to rot away due to lack of inadequate maintenance effort. The value derivable from the assets optimum performance or full capacity utilization declines. Public sector assets are provided by government to serve social needs of the people; they also have revenue earning potentials when properly harnessed. Examples of such public assets relevant to this study are the sporting and cultural facilities such as football stadium, civic centres, museums, libraries etc. These public assets need proper maintenance if the objectives for their initiation and construction must be realized. Maintenance, as posited by Bamgboye (2006) is "the art of bringing back the life span of an item". Physical assets require regular maintenance to sustain its usefulness. Maintenance encapsulates efforts, actions and activities aimed at ensuring sustainability of the life span of an infrastructure.

Unfortunately, governments in developing countries such as Nigeria are faced with immense challenge of maintaining infrastructure to deliver and sustain basic services to the citizens and to foster economic growth, World Bank Group (2016) in Ambakederemo & Ekenta, (2023). Furthermore, Abumere (2012) and Bubou (2015) remarked that the poor state of infrastructure arising from poor maintenance poses serious challenge to economic developmental efforts. According to Alani (2012), the lack of maintenance of public sector assets in the country is the bane for infrastructure - driven national development". Sani (2012) opined that maintenance is very essential to ensure that infrastructural facilities or public sector assets are functioning at optimum level, at minimum cost of repairs and providing a safe environment for all users. It is true that as public assets are maintained, the desired lifespan are maintained and the potentials to add value to economic development is assured.

Study Aim and Objectives

This paper aims at examining strategic means of boosting Rivers State internally generated revenue by adopting Public Sector Assets Maintenance Policies using the Sharks Stadium Port Harcourt as a case study.

To achieve the aim, the objectives are to:

i. Identify the different types of Public Sector Assets.
ii. Identify the benefits of maintenance policies. iii. Identify the major challenges to overcome for effective & efficient maintenance of the public sector assets on states' economy.

Research Hypothesis

Ho1: There is no significant relationship between maintenance management and Gross Domestic Product in Nigeria.

Review of Related Literature

Concept of Maintenance

Maintenance deals with assuring that all of the elements of the infrastructure are serviced so they operate efficiently and are reliable and safe IFMA (2014) as cited by Ambakederemo & Ekenta, (2023). Maintenance includes scheduling and conducting regular, periodic predictive, preventive and corrective maintenance activities. A Facility Manager is expected to operate and maintain the facility in a manner that supports the goals of the entire organization and balancing competing requirements. The following areas of focus are relevant for all facility maintenance programmes:

1. Providing safe, healthy and productive environments.
2. Develop lowest component/system failure with optimum reliability at cost effective rates.
3. Anticipate change and make plans ahead for necessary adaptation.
4. Ensure compliance with relevant international, national and local codes and regulations.

Objectives of Maintenance

According to Oyefeko (1999) in Adenuga et al (2010), the objectives of maintenance of assets are to ensure that the functional requirements of the asset are attained at all times; to enhance the quality of the built structure to meet modern day requirement; to prolong the life span of the built structure and to guarantee the economic and financial returns from the utilization of the facility. Other objectives are to ensure that safety of the users / occupants and to preserve reasonable standard for the asset at minimum cost.

Benefits of Good Public Sector Assets Maintenance Management

i. Effective maintenance policy contributes to the sustainable and cost-effective maintenance of an organization.
ii. Maintenance management and its effective implementation encourages the productivity of stadium facilities operations. iii. Continual quality improvements in keeping the pace of the organizations to remain competitive and relevant.
iv. Enhancing the workplace and facilities safety, security and comfort to the stakeholders.

Challenges to Overcome for Effective and Efficient Public Sector Assets Maintenance Management

The following are the major challenges (among others) to overcome for better results from public sector assets maintenance management.

i. Poor institutional framework for Public Sector Assets Maintenance
ii. Corruption

iii. Inappropriate Maintenance Management Procedures
iv. Inadequate funding for the creation of access to, upgrading and maintenance of public assets.
v. Non-engagement of Public-Private Partnership arrangements.
vi. Lackadaisical attitude of Governments to explore maintenance management as a strategy to boost her internally generated revenue.

Assets

An asset is an item of economic value owned or controlled by an individual or organization with the expectation of future benefits. It increases a firm's value and income, or helps in its overall operations. Assets are either tangible or intangible. Tangible assets are physical assets and are not consumed in the course of operations. Examples include buildings, equipment, Plant & Machinery or vehicles such as cars, trucks etc. Intangible assets are non-physical, such as goodwill, brand name or domain name. They usually add to an organization future worth. Some notable examples of intangible assets are software, website, and patented technology.

There are also current assets, which are easily converted into cash within a year. Cash at bank or in hand, trade debtors and prepayments are examples of current assets. A fixed asset is something owned by the organization and will be used for at least one year. They are also tangible in nature and include land, buildings, motor vehicles, plant & Machinery etc. There are also financial assets such as stocks and shares. Chowdhury (2019) also listed financial assets to include investments, foreign currency reserves and gold holdings. Chowdhury et al; (2019) listed fixed assets to include Art and Museum Collections while classifying receivables, inventories and prepaid expenses as current assets.

Public Sector Assets

Public sector assets refer to all organizations which are established, run and financed by government on behalf of the public (Adam, 2010). Public Sector Assets are property held by the government in trust for its citizens or masses. They are also referred to as government property and usually capital intensive to acquire. Public Sector Assets include public school buildings, stadium, civic center, teaching hospitals as well as natural resources like oil and minerals, forests, ports, lakes, rivers and oceans. According to Omigbodu (2018), public assets in most parts of the world include, but not limited to;

i. Public Offices
ii. Government Schools
iii. Government Schools
iv. Military & Paramilitary Barracks
v. Museums
vi. Sports & Recreational Facilities
vii. Residential Quarters of Public Servants
viii. Land Reserved for Public Use
ix. Public Roads
x. Airports
xi. Seaports
xii. Water ways
xiii. Rail Tracks

Sharks Stadium

Stadium is a venue for outdoor and indoor sports, concerts, or other events. Stadiums are notable public sector assets as they provide recreational value to the society which translates to good health condition. Stadium has the potential to impact on the economy of the host state and community.

Sharks Stadium also known as the Sharks Football Stadium, which is a multi-purpose stadium located

in Port Harcourt, Nigeria. It was built in 1998 and has a seating capacity of approximately 10,000 spectators. Apart from the stadium itself, there are ancillary economic units that have emerged in the vicinity of the Sharks' stadium. For example, restaurants, lodging accommodation, sports shops, etc. have sprung up and these various units provide jobs for the community. Revenues are collected for the state by way of income, value - added and withholding taxes from parties who transact with the stadium authority.

Front view of the Sharks Stadium
Source: Researchers' Field Survey, 2023

Public Sector Policy

Public Sector Policy is a course of action created and/or enacted, typically by a government, in response to public, real world problems. Public policy generally consists of the set of actions - plans, laws, and behaviours adopted by a government. It is part and parcel of public sector policy to provide facilities for the people, enact policies for their maintenance and ensure that the objectives of maintenance are achieved by way of low cost, asset efficiency and elongation of asset useful life. For the avoidance of ambiguity, the public sector of an economy is the sector that provides a range of governmental services, including infrastructure, public transportation, public education, sports, health care, police and military services. The public sector policies focus on formulating the framework for providing services that can benefit the entire society rather than just those who are using the service.

Asset Maintenance Policy

A study by Oluwatoyin and Olotuah (2015) as cited by Ambakederemo & Ekenta, (2023) defines maintenance policy as the ground rules for the allocation of resources (men, materials and money) between alternative types of maintenance action that are available to management. It opined that in order to make a rational allocation of resources, the benefit of maintenance to the organization should be identified vis-à-vis the costs involved. Consideration must be given to issues such as objectives, benefits and policies. It is also required that a maintenance policy be clear, written documents that consider assets life cycle, desired standard of maintenance and length of time that maintenance is required. In formulating maintenance policy, the factors to consider are compliance with statutory requirements, cost, method of financing and method of execution, i.e. if by contracting or by direct labour option, Oluwatoyin & Olotuah, (2015).

Economic Development

According to Agarwal (2020), Economic Development elevates people from low standards of living into proper employment with suitable shelter, and guarantees sustainability which means meeting the needs of the present without compromising future needs. Economic Development is a policy intervention that aims at improving the well - being of people. Economic growth is an aspect of development which is measured by the increase in a country's total output or real Gross Domestic Product (GDP) or Gross National Product (GNP). The Gross Domestic Product of a country is the total value of all final goods and services produced within a country over a period of time. Economic development includes measurable index such as Human Development Index (HDI), Human Poverty Index (HPI), Infant Mortality, Literacy rate etc, (Ambakederemo, 2023).

While assessing the fundamental determinants of economic development, Bloch & Tang, 2004; Acemoglu & Robinson, 2008, affirmed that institutions are key and still identifying conventional factors of human capital, physical capital, technology etc as proximate causes of economic development in Nigeria.

Important as infrastructures are to economic development, they are usually ignored in developing countries at a time that global efforts and attention are focused on the prospect of stimulating development through infrastructure funding or capital budgeting. For economic development to be attained in third world Countries, there must be sustained level of economic growth stimulated by government spending, hence Muritala & Taiwo (2011) submits that government expenditure and economic development has a positive relationship i.e. between GAP and recurrent and Capital expenditure. Economic Development is therefore relevant in the measurement of progress and quality of life in developing nations.

Material and Methods

Data Analysis

The study employed the quantitative research technique using a cross sectional survey design. The main source of primary data the researcher used to collect data was through a structured questionnaire and interview. The purposive sampling technique was adopted in the selection of the sample size for the study. Frequency Distribution Tables and Inferential Statistics were used in the analysis for the study, while the hypothesis was tested using the linear regression analysis.

Result and Discussion

Table 1: Ho1: There is no significant relationship between maintenance management and Gross Domestic Product in Nigeria.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.540[a]	.292	.290	2.488

a. Predictors: (Constant), Maintenance Management.

For the hypothesis, we realized a coefficient of determinant (r square) of 0.292 which implies that 29.2% of the outcome of GDP is accounted for by maintenance management alongside a regression coefficient of 0.540 which is positive. With this we proceed to our test for ANOVA.

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	858.840	1	858.840	138.766	.000[b]
	Residual	2085.732	152	6.189		
	Total	2944.572	153			

a. Dependent Variable: GDP
b. Predictors: (Constant), Maintenance Mgt.
c. **. Correlation is significant at $P < 0.05$

From our ANOVA table, we realized an F value of 138.776 which is within the acceptable range alongside a p-value of 0.000 which is less than alpha of 0.05. The result is a strong affirmation of the acceptance of the hypothesis.

Conclusion

If a nation must develop, it is imperative that installation as well as maintenance of its existing facilities be given priority. This is more so for developing nations like Nigeria where there is a huge gap between the supply and demand for such facilities due to high rate of population growth and other factors (Dabara et al., 2015). Governments (Federal, State and Local), private organizations and individuals need to have a strategy on how to maintain their infrastructural facilities to ensure sustainability of same. This can be achieved through maintenance culture which is said to have a correlation with national development.

Recommendations

The following recommendations are proffered on the way forward:

i. There should be in place an effective implementation of maintenance policy by ways of regular inspection of public stadiums to prevent dilapidation and ensure their good condition for sporting events that would earn revenue and add to the desired economic development.
ii. Good governance should be the only antidote to reduce the level of corruption and minimize loss of internally generated revenue.

iii. The maintenance and management of public sector assets should be left to the Estate Surveyors & Valuers, the professionals endowed with the appropriate training and skills and rightly recommended by law for such function.

iv. States economy should be diversified to discourage overdependence on monthly allocation from Abuja with a view to boost their internally generated revenue.

v. There is need to amend and enact new policies that will stimulate maintenance of Public Assets.

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National Development and Infrastructure in Nigeria: The Impact of Internal and External Financing of Budget Deficit

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Abstract

A consensus of opinions from the scholarly literature reiterates that the major cause for the buildup of external and domestic debt, by Low Developed Countries (LDCs), is the financing burden arising from public expenditure, which is associated with fiscal deficit. In Nigeria, the provision of infrastructure such as in the area of transportation via road construction, airways and waterways, is what deficit financing seeks to achieve. This study focuses on the concept of deficit financing in Nigeria and empirically investigates its impact on economic development, using selected macroeconomic variables as proxies. Following a quasiexperimental research design, this study adopted the Keynesian theory as a theoretical framework to guide the study. Several statistical tests including correlation analysis, co-integration bound tests and regression modelling were carried out to generate two models. External debt and internal debt were the dependent variables, while the explanatory variables were exchange rate, real gross domestic product and balance of payment. The generated models were further subjected to heteroscedasticity and stability tests. The findings show that current year external debt, lag one real gross domestic product and lag two balance of payment have a positive significant relationship while, current year exchange rate, lag two and three of real gross domestic product and current year balance of payment have negative significant relationship with the external debt in Nigeria. In the same vein current year, lag one, two, three and four of exchange rate and real gross domestic product have a positive relationship with internal debt. While, current year, lag one, two, and lag one real gross domestic product have a negative relationship with internal debt this implied that internal debt has a negative impact on gross domestic impact while external debt has a positive impact on exchange rate, and balance of payment respectively. The study outcome provides empirical evidence about deficit financing, which can constitute a basis for the government and policymakers to curtail its negative impact on the macroeconomic landscape of Nigeria.

Keywords: Budget Deficit, Debt Financing, Infrastructure, Macroeconomics, National Development

Introduction

Over the years, Nigeria has been classified as an underdeveloped economy. Some schools of thought attributed the economic backwardness of Nigeria to the mismanagement of human and material resources. In this instance, it is presupposed that funds planned for development programmes and policies are sub-optimally utilized or embezzled. Consequently, the purpose for which the budget is designed is not achieved. Because the budget is an estimated fund for policy implementation, whereby the funds are not used for the purpose for which it is designed, the resultant effects are deficits. Therefore, a budget deficit is a situation whereby budgeted funds are not adequate to achieve the estimated development programmes (Olaoye, 2016). This has been the bane of Nigeria over the years. Nigeria is blessed with material resources, yet borrows externally and internally to finance her economic plans and policies. This is why in most cases money planned for certain policies that would bring about development is been mismanaged, with the notion that funds could be borrowed to finance the budget. Borrowed funds further require proper utilization, to achieve set goals. Pioneer studies, such as Cold (1984) and Keynes (1936) proposed that appropriate borrowing and management to

finance fiscal deficit is necessary for government in LDCs to achieve their set goal. This implies that although borrowing is a bad idea in the first place, the proper utilization of the funds borrowed is mandatory. A lack of proper utilization of borrowed funds is another dimension of the problem, which further compounds the economic situation in LDCs (Akinmulegun, 2014).

The financing of public debt is, however, very costly. This is because the government pays much more interest for the money borrowed, and the resultant effect is that funds that would have been used for the development of various sectors of the economy, will be channeled to debt payment (Monogbe et al., 2015). The fall in the agricultural sector which was a major source of foreign earnings has resulted in an over-dependence on the oil sector. This has led to a situation whereby, if there is a fall in oil price, this will result in borrowing to finance the budget. This borrowing has been affecting economic growth in Nigeria because of the interest paid on borrowed funds. This is a cardinal problem in LDCs including Nigeria that have mostly resorted to financing of fiscal deficit through borrowing (Adeosun, 2017). The Nigerian government has been adopting external and internal sources of financing fiscal deficit. External and internal borrowing thus constitute the primary avenue for debt financing. The implication of borrowing to finance a deficit budget is that there will be a lack of infrastructure and socio-economic amenities, necessary to promote economic growth (Ayadi & Ayadi, 2008).

Considering the importance of deficit financing in developing different sectors of the economy, the consequences have generated diverse views by scholars, policymakers and economists (Adenikinju & Olofin, 2000; Ele et al., 2021). It is believed that the tendency to engage in deficit financing is often carried out with the notion of increasing the government's role in the provision as well as achieving modern economies. Most LDCs are faced with the problem of low capital formation, low level of technological advancement as well as low private investment due to inadequate infrastructure to promote and encourage investment in the economy. Based on the resource constraints, the best option for the government has been financing of fiscal deficit in Nigeria. This is quite often seen in Nigeria as a primary source for providing socio-economic facilities and infrastructure in the areas of transportation, education, health, water, power etc. These infrastructures are what deficit financing could achieve, if the government is deliberate, as a strategy for promoting economic growth and development. Yet, there is glaring evidence of a weak massive deficiency of infrastructure.

Against this backdrop, this study seeks to empirically investigate whether financing fiscal deficit has macroeconomic implications in Nigeria. The specific objectives are to examine the impact of internal and external financing of fiscal deficit on Real Gross Domestic Product in Nigeria, exchange rate and Balance of payment.

Conceptual Clarifications, Theoretical Framework and Empirical Literature Review

Conceptual Clarification

External Debt: Borrowing could be domestic or external. Thus, a situation where money borrowed from a foreign financial institution like the World Bank, International Monetary Fund (IMF) etc. one not paid back, forms a basis for external debt. In comparing the debt to GDP ratio in Nigeria is noted to have worsened in recent years. In this case the debt to GDP ratio amounted to 16.3% in 2016 to 23.3% in 2020. External debt burden increased in recent times as a result of deficit financing. The resultant effect has been that the less purchasing power of local currency becomes debt servicing through foreign exchange which increases the unit of domestic currency that will be exchanged for foreign currency. This situation led to unfavorable exchange conditions. However, the fiscal deficit increased by 13.7% from N2.36 trillion in 2017 to N5.60 trillion in 2021 and debt service rose by 17% from N2.687.81trillion in 2020 to N3.124.38 trillion in 2021 (CBN 2021).

Internal Debt: In the course of borrowing to finance the fiscal deficit, Nigeria may consider internal sources of finance. Thus, borrowing within the country without repayment brings about domestic or internal debt. Thus, internal debt is a result of too much borrowing without repayment. Internal debt as of 2022 is N5.782 trillion (CBN 2023). The rise in internal debt is a result of the fact external borrowing has posed some level of danger in the Nigerian economy, especially in the areas of foreign exchange that cause a reduction in domestic currency purchasing power. The fact remains that internal debt as a result of domestic borrowing to finance the budget deficit has the consequences of reducing the economic growth in Nigeria. Therefore, Nigeria should consider the implication debt burden irrespective of been local or international and manage the available human and material resources (Adofu & Abula, 2009). Thus, the external debt burden on macroeconomic variables will be determined through the econometric analysis.

Real Gross Domestic Product (RGDP): This is the Gross domestic product after deduction based on the value of the inflation rate. This means that the monetary value is ascertained based on the inflation rate, and what the available money can purchase is the real gross domestic product. This is why it is used to measure the level of economic performance in an economy. However, external and internal financing effects on real gross domestic product will be examined and revealed based on the study that will be conducted by applying econometric tools.

Exchange Rate (Excr): This is the rate for which domestic currency is exchanged for foreign currency. The exchange rate is determined based on the level of international transactions between two countries (Egwaikhide, 1992). This implies that if foreign transactions are more beneficial to the foreign country, there is a tendency that there will be a high exchange rate with the domestic currency. For instance, external borrowing can affect the exchange rate because a high-interest rate is paid on the repayment. Thus, since the domestic currency is used for repayment, there will be more funds going to the foreign country in exchange for the domestic currency. Hence, there is a tendency for local currency purchasing power will reduce. In any the level of effect of external financing of fiscal deficit on the exchange rate will be determined through an analysis conducted (Ajayi, 2013).

Balance of Payment (BOP)

This is the monetary transaction record made between two countries that are in international trade. In this record of transactions, countries will ascertain if the transactions are favourable or not. Thus, a country may have a deficit or balance of payments, it all depends on the type of goods and services exchanged for the transaction. Technology and other valuable transactions lead to a balance of payment for such a country. Most LDCs have problems with the balance of payment because they transact agricultural produce that has less monetary value. However, the natural effect of external and internal financing on the balance of payment will be determined based on an econometric study.

Theoretical Frame Work

This section outlines the various theories that support or oppose the need for external and domestic borrowing to finance the fiscal deficit in Nigeria.

Keynesian Theory: John Maynord Keynes is a great British Economist whose theories and policies have developed LCDs over the years. Keynes is of the view that borrowing to finance fiscal deficit is necessary because it enables the government to provide necessities that one needs in the country, such as good roads, good health services, portable water etc. Therefore, financing of fiscal deficit promotes economic growth as well as full employment according to Keynes

Classical Theory: Contrarily to Keynes, the classical theory which is made up of the works of Adam Smith, David Ricardo, and John Staut Mill, has advocated policies that also support the development of the LDCs since 1800 - 1850. They believed that external or domestic borrowing reduces the level of economic development, which means the people of the country will bear the consequences as regards to increase in inflationary situation, foreign exchange problem, and increase in interest rate that is capable of reducing private investment. This implies that government should be discouraged from borrowing considering its inherent tendencies.

Dual GAP Theory: Like this theory, it is of the view that investment solely depends on the level of savings and in a situation where there is a low level of savings private individuals and government can borrow to augment the available resources. It is on this premise that this study is supported by this theory.

Empirical Literature Review

Peterson (2021), examined the link between budget deficit financing and its impact on selected macroeconomic fundamentals; interest rate broad money supply, and inflation rate in Nigeria. The time series of 1980 to 1990 was used applied and the econometric tool adopted was Autoregressive distributed lag. The result revealed that deficit financing through borrowing either domestic or external influenced the broad money supply and inflation rate negatively in the long run while, the interest rate was influenced positively in the long run. The study recommended that the Nigerian government should be discouraged from borrowing considering its impact on economic growth.

Akanmobi and Unachukwu (2021) investigated the impact of domestic financing of fiscal deficit and some macroeconomic variables, Gross Domestic Product, inflation rate, exchange rate and interest rate in Nigeria. Ordinary Least Square (OLS) was adopted for the analysis, the study revealed that fiscal deficit financing has a negative impact on Gross Domestic Product, and exchange rate in the short and long run while, inflation rate and interest rate were impacted positively in the long run. Therefore, the study suggested that the Nigerian government should maximize the use of material resources to generate revenue to avoid borrowing to finance the budget deficit in Nigeria.

Chukwu and Okere (2020) carried out a study on the relationship between fiscal deficit financing through external borrowing and economic growth in Nigeria. GDP was a proxy for economic growth, the data for the study was from 1980 to 2000, the study adopted a unit root test and based on the order of integration, the study employed Auto-regressive distributed lag, the study shows that there is a negative impact on Gross Domestic Product in Nigeria since the interest on loan repayment would have been used for the sectorial development. Hence, the study recommended more investment in infrastructural development that could aid investment in different sectors of the economy.

Momodu and Monogbe (2017), evaluated the influence of domestic and external financing on fiscal deficit and macroeconomic variables in Nigeria from 1987 to 2010. In the analysis, the Vector Auto-regressive (VAR) technique was employed. The macroeconomic variables were; interest rate, inflation rate, production price index and exchange rate. The study indicated that external and domestic financing through loans affected all the macroeconomic variables analyzed negatively as a result of repayment of debt. Hence, the Nigerian government should ensure proper management of money borrowed to avoid constant borrowing of funds.

Wuyah and Amwe (2015), analyzed the impact of external financing on fiscal deficit and some macroeconomic variables in Nigeria, these variables are production price, index, exchange rate, interest rate and real gross domestic product. Data used for the study was from 1990 to 2013 and the

Granger causality test was adopted for the study, the study shows that external sources of finance that brought about external debt impacted negatively on the underlined macroeconomic variables. Thus, the study recommended that the Nigerian government should seek other sources of generating funds rather than borrowing because of the consequences attributed to borrowing.

Methodology

The type of research design that will be adopted for this study is a quasi-experimental design which is commonly used in social science. The importance of this type of design is that it gives room for the examination of two or more dependent and independent variables. This study adopted the work of Keynes who believed that there is a need for external or domestic borrowing with the notion that it promotes economic growth based on -the provision of infrastructures. However, the framework adopted in this study is similar to that of Johnson, 2018 whose work is limited to 1985 to 2016 with some variables: production price index, exchange rate and inflation, though with modification. However, this study included the unemployment rate, balance of payment, and real gross domestic product, this study also extended its study from 1987 to 2021. This study has two models: External debt and internal debt which are from the dependent variable (a proxy for external and internal borrowing) while the explanatory variables are exchange rate, real gross domestic product and balance of payment.

Where:
Extd = f(excr, rgdp, bop)
Intd = f(excr, rgdp, bop)
Given the functional relationship, the econometric model is specified below:

$$Extd = a_0 + a_1\, excr + a_2\, rgdp + a_3\, bop - \varepsilon i$$

$$Intd = a_0 + a_1\, excr + a_2\, rgdp + a_3\, bop - \varepsilon i$$

Where:
Extd = external debt
Intd = internal debt
Excr = exchange rate
Rgdp = real gross domestic product
εi = Error term
a_0 = constant
$a_1 a_2 a_3$ are co-efficient of the variables

Data Analysis and Discussion of Findings

Trend Analysis

Trend analysis of all the variables will be conducted to show how the data fluctuated over time graphically. Figures 1a and b are the trend analysis of external and internal debt over the years.

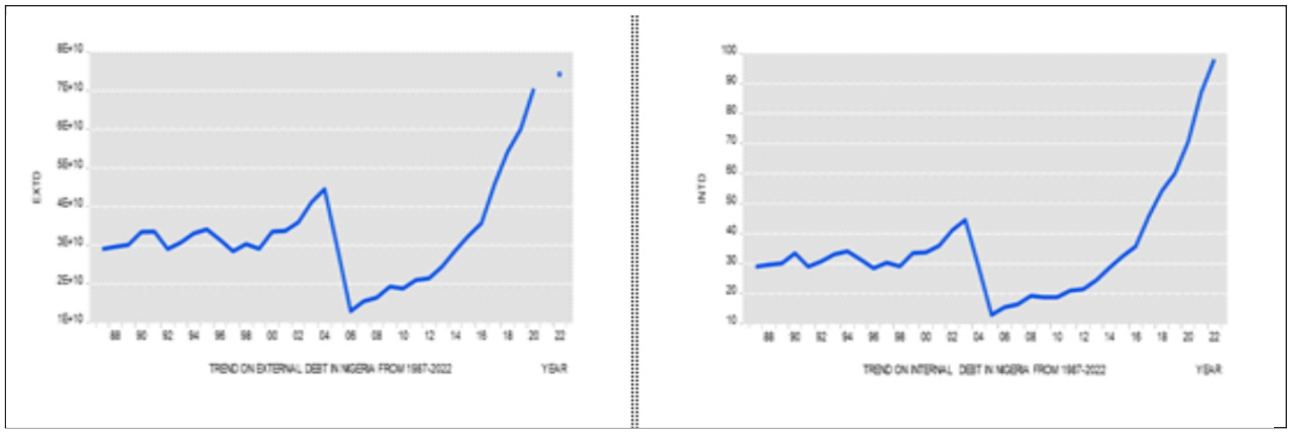
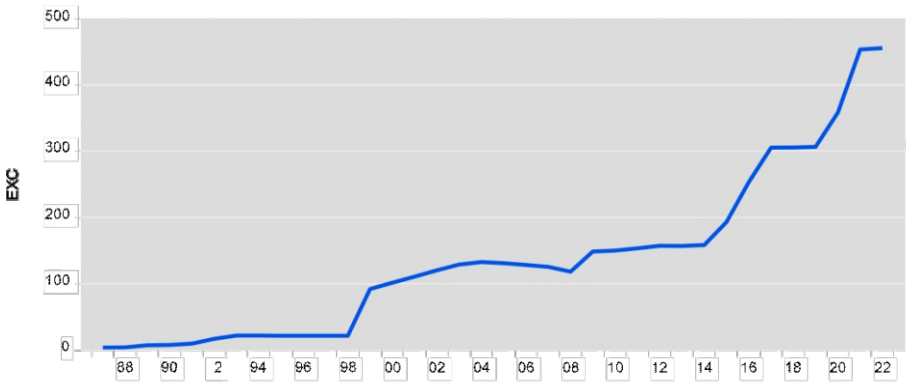


Figure 1a and b: Trend Analysis of External and Internal Debt

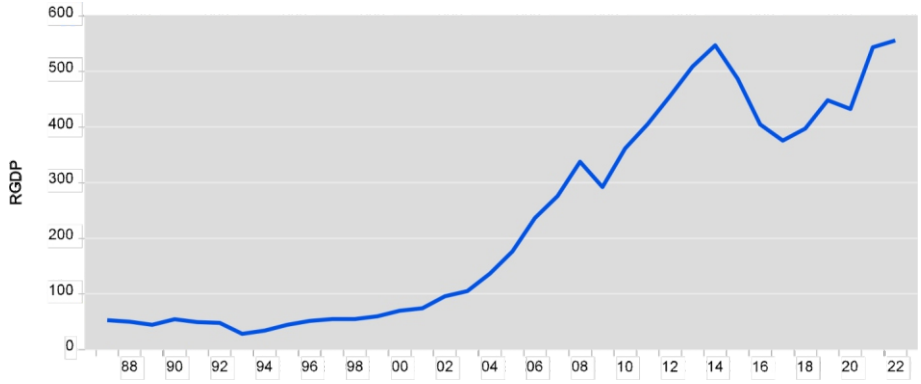
As Figure 1 shows, the trend in external and internal debt profiles has similar peaks and dips at various times over the period.



TREND ON EXCHANGE RATE IN NIGERIA FROM 1987-2022 YEAR

Figure 2: Trend on Exchange Rate

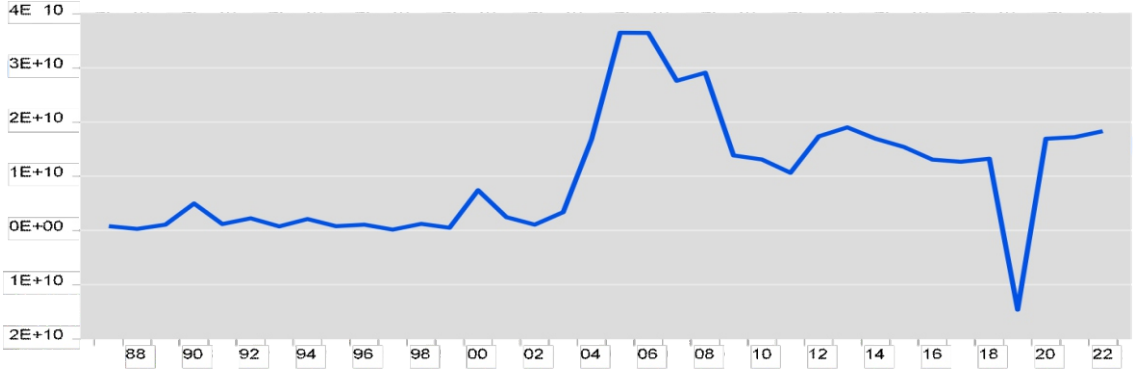
Figure 2 shows the trend in the exchange rate, which shows that the exchange rate has not been stable over time within the period of study. However, there was a high rise in the exchange rate in 2020. This could be attributed to institutional instability in Nigeria.



TREND ON REAL GROSS DOMESTIC PRODUCT IN NIGERIA FROM 1987-2022 YEAR

Figure 3: Trend on Real Gross Domestic Product

The trend in Figure 3 shows that the Real Gross Domestic Product is characterized by rising fluctuation with a slow rise from 1987 to 2008. It fell a little bit in 2009 and rose again from 2010 to 2014 until 2020. The instability in the Real Gross Domestic Product is a result of fluctuations in different sectors of the economy in Nigeria.



TREND ON BALANCE OF PAYMENT IN NIGERIA FROM 1987-2022 YEAR

Figure 4: Trend on Balance of Payment

Figure 4 shows a rise in the balance of payment from 1987 and started fluctuation from 1922 though there was an improvement in the balance of payment in 2019. This could be attributed to improvements in oil prices and other functional sectors.

Descriptive Statistics

The descriptive statistics of the time series shared in Table 1 show that between1987 and 2022, domestic (internal) debt, external debt, exchange rate, real gross domestic product, and balance of payment averaged, 3,427753, 24.15950, 4.632198, 4.960852, 22.30459 respectively.

Table 1: Descriptive Statistics for External and Internal Debt Model

	LOG(DOMD)	LOG(EXTD)	LOG(EXC)	LOG(RGDP)	LOG(BOP)
Mean	3.427753	24.15950	4.632198	4.960852	22.30459
Median	3.411478	24.14750	4.857251	4.915592	23.09055
Maximum	4.584967	25.02885	10.32902	6.319941	24.32137
Minimum	2.561868	23.28528	1.391282	3.323236	18.94090
Std. Dev.	0.417607	0.388220	1.973370	1.020903	1.526106
Skewness	0.435468	0.092563	0.883740	-0.021466	-0.483628
Kurtosis	3.745144	3.327888	4.532148	1.330964	1.948750
Jarque-Bera	1.915914	0.206766	7.979220	4.065139	2.976036
Probability	0.383676	0.901782	0.018507	0.130998	0.225820
Sum	119.9714	845.5825	162.1269	173.6298	780.6605
Sum Sq. Dev.	5.929462	5.124309	132.4025	35.43629	79.18597
Observations	35	35	35	35	35

The range of variables throughout the study is 2.561868 to 4.584967, 23.28528 to 25.02885, 1.391282 to 10.32902, 3.323236 to 6.319941, 18.94090 to 24.32137. However, the exchange rate is normally distributed, and the result of the descriptive statistics analysis revealed instability in both external and domestic debt and some macroeconomic variables in Nigeria within the period of study. This is evidenced in the standard deviation in the minimum and maximum. Hence, this calls for a probe of the feature of the data.

Inferential Data Analysis

This section of the data analysis reports the results of the different inferential data analyses carried out on the collated data.

Table 2: Correlation Matrix for External Debt Model

	DOMD	EXC	RGDP	BOP
LOG(DOMD)	1			
LOG(EXC)	0.241	1		
LOG(RGDP)	0.018	0.630	1	
LOG(BOP)	-0.089	0.577	0.837	1

Table 2 which is the result of the correlation matrix for the external debt model shows that the explanatory variables have a weak relationship among the variable which call for further investigation in the study.

Table 3: Correlation Matrix for Internal Debt Model

	DOMD	EXC	RGDP	BOP
LOG(DOMD)	1			
LOG(EXC)	0.270	1		
LOG(RGDP)	0.119	0.636	1	
LOG(BOP)	-0.086	0.583	0.839	1

Table 3 indicates that the selected macroeconomic variables (independent) have a weak correlation with each other. There absence of a strong correlation among the dependent variables. Hence all the variables will be included in the model for further analysis.

Table 4: Unit Root Test for the Two Models Adopting Augmented Dickey-Fuller Test

Variables	Variable at level	Variable at first difference	Order of integration
Extd	-0.565732	-3.075894	1(1)
Intd	-0.453035	-3.142535	1(1)
Excr	1.648149	-3.915821	1(1)
Rgdp	-	-3.399248	1(1)
Bop	-2.478938	-627.2207	1(1)

Table 4 indicates that external debt (extd), internal debt (intd), exchange rate (Excr) and balance of payment (bop) attained stationarity at 5% at first difference 1(1) while real gross domestic product (rgdp) attained stationarity at 5% at levels 1(0).

Table 5: Correlation Bound Test for External Debt Model

F-Bounds Test		Null Hypot hesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	4.444554	10%	2.2	3.09
K	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37
Actual Sample Size	30		Finite Sample: n=30	
		10%	2.525	3.56
		5%	3.058	4.223

Table 5 shows the bound test result for the external debt model. The result revealed that there is a long-run relationship between explanatory and dependent variables within the period of study, as shown in the f-statistics and critical value. Hence, there is a need for further investigation to determine the extent of the relationship.

Table 6: Long-run Co-integration for External Debt Model

Levels Equation				
C ase 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(EXTD)	1.036291	0.180977	5.726100	0.0001
LOG(EXC)	-0.009080	0.022370	-0.405926	0.6926
LOG(RGDP)	-0.523973	0.670481	-0.781488	0.4510
LOG(BOP)	0.307598	0.423969	0.725521	0.4833
C	-26.00791	9.981929	-2.605499	0.0245

Table 6 shows the long-run result of the external debt model. It revealed that the exchange rate has a positive significant influence by external debt at a 5% level. While external debt has a negative significant influence on real gross domestic product in Nigeria.

Table 7: ECM Regression for External Debt Model

ARDL Error Correction Regression				
Dependent Variable: DLOG(DOMD)				
Selected Model: ARDL(2, 4, 0, 4, 4)				
Case 2: Restricted Constant and No Trend				
Date: 05/15/24 Time: 01:23				
Sample: 1987 2022				
Included observations: 30				
ECM R egression				

C ase 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(DOMD(-1))	-1.283956	0.474080	-2.708311	0.0204
DLOG(EXTD)	0.035052	0.490283	0.071493	0.9443
DLOG(EXTD(-1))	-0.387013	0.156411	-2.474332	0.0309
DLOG(EXTD(-2))	-0.424641	0.154721	-2.744557	0.0191
DLOG(EXTD(-3))	-0.347881	0.147479	-2.358852	0.0379
DLOG(RGDP)	0.029835	0.146875	0.203133	0.8427
DLOG(RGDP(-1))	-0.669361	0.173491	-3.858188	0.0027
DLOG(RGDP(-2))	-0.448763	0.170826	-2.627010	0.0235
DLOG(RGDP(-3))	-0.603558	0.168996	-3.571424	0.0044
DLOG(BOP)	-0.141787	0.031093	-4.560094	0.0008
DLOG(BOP(-1))	0.109143	0.044062	2.477060	0.0307
DLOG(BOP(-2))	0.131488	0.035793	3.673568	0.0037
DLOG(BOP(-3))	0.130701	0.030384	4.301599	0.0013
CointEq(-1)*	1.084518	0.197802	5.482842	0.0002
R-squared	0.818894	Mean dependent var		0.024852
Adjusted R-squared	0.671746	S.D. dependent v ar		0.202072
S.E. of regression	0.115774	Akaike info crite rion		-1.169626
Sum squared resid	0.214458	Schwarz criterio n		-0.515734

Table 7 revealed that current year external debt, lag one real gross domestic product, and lag two balance of payment. have positive significant relationships while, current year exchange rate, lag two and three of real gross domestic product and current year balance of payment have negative significant relationship with the external debt in Nigeria with R-square (0.92) and adjusted square (0.86).

Table 8: Post Estimation for External Debt Model

Diagnostic Test	F-Statistics	Probability
Jarque-bere Test Normality	0.015556	0.992252
Breush-Godfrey Serial Correlation LM Test	0.614752	0.5584
Breuch-Pagam Godfrey Heteroscedasticity	1.220067	0.3631
Ramsery Rest Test for Specification Error	6.263003	0.0278

Table 8, which is the post estimation, revealed that residual is normally distributed around the mean. There is no evidence of auto-correlation as shown by serial correlation LM test probability value of 0.5584. in the same vein, the Heteroscedasticity result shows that there is the presence of constant variance. The Remsey Reset Test shows that no variable is missing in the model, as indicated in the probability value of 0.0278. This shows that the model is properly specified which implies that the model is good for prediction and forecast.

Table 9: Post Estimation for Internal Debt Model

Diagnostic Test	F-Statistics	Probability
Jarque-bere Test Normality	0.319032	0.852556
Breush-Godfrey Serial Correlation LM Test	2.298466	0.1277
Breuch-Pagam Godfrey Heteroscedasticity	1.002617	0.5257
Ramsery Rest Test for Specification Error	1.516994	0.2324

Table 9 revealed that the residual is normally distributed around the mean. This indicates that there is no auto-correlation as revealed by the serial correlation as revealed by the serial correlation LM test of probability value of 0.1277. The result of the heteroscedasticity test shows that there is the presence of constant variance. Remsey test result shows that no variable is missing in the model as indicated in the probability value of 0.2324. This implies that the model is properly specified and that the model is good for forecast and prediction.

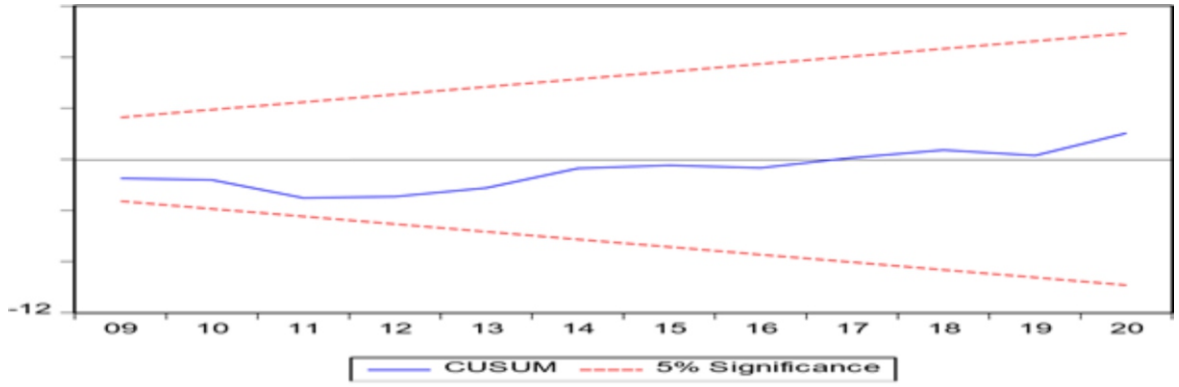


Figure 5: Stability Test for External Debt Model

In conducting the stability test, it is important to incorporate the short dynamics and stability in the long-run parameter of the model. Based on this the study adopted the cumulative sum of regressive residual for the stability for the short-run dynamics and long-run recursive residual. The Gusum value stays within the 5% critical value, bound by two straight lines as indicated in Figure 5. Based on the result one can say that estimated parameters in short and long-run dynamics in the model of external debt were relatively stable within the period of study.

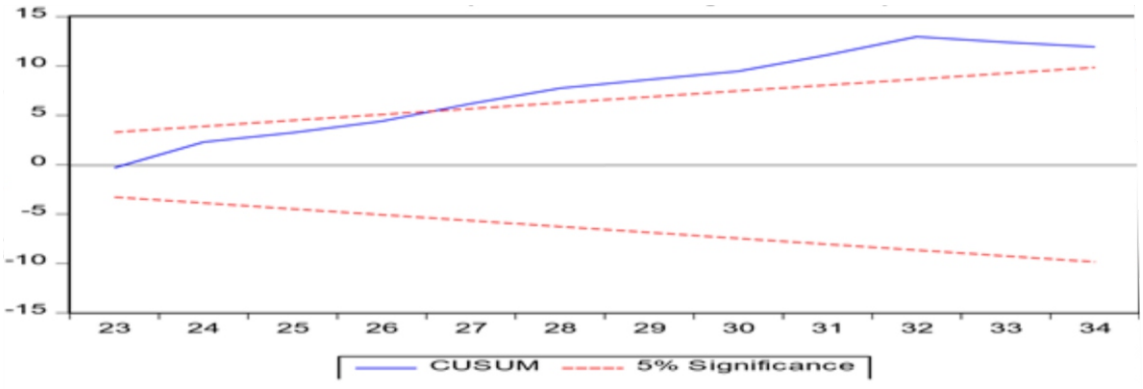


Figure 6: Stability Test Result for Internal Debt Model

The stability test conducted incorporated the short and long-run dynamics, as shown in Figure 6. In this stance, the study adopted the Cumulative sum of recursive residual for the stability of the short-run dynamics and long-run residual. The cusum value stays within the 5% critical bound as indicated in the straight line. One can conclude that the estimated parameters in the short-run and long-run dynamics of the internal debt model were stable over the period of steady.

Conclusion and Recommendations

The external debt model clearly shows that current year external debt, lag one real gross domestic product and lag two balance of payment have a positive significant relationship while, current year exchange rate, lag two and three of real gross domestic product and current year balance of payment have a negative significant relationship with the external debt in Nigeria. In the same vein current year, lag one, two, three and four of exchange rate and the current year's real gross domestic product have a positive relationship with internal debt. While, current year, lag one, two, and lag one real gross domestic product have a negative relationship with internal debt this implied that internal debt has a negative impact on gross domestic impact while external debt has a positive impact on exchange rate, and balance of payment respectively. Against this backdrop, the following recommendations are proffered.

i. **Stability of exchange rate**

Relevant authorities or policymakers should advocate for the production of goods and services that will promote exportation that will bring about foreign exchange earnings. When more export is carried out there is the tendency or possibility of boosting local currency in Nigeria. The utilization of human and material resources will lead to better productivity that will develop different sectors of the economy.

ii. **Effective production of goods and services**

Considering the impact of external and internal debt on real gross domestic product caused by deficit financing, it becomes imperative for the government or policymakers to embark on various policies that will promote an increase in real gross domestic product. This could be done through the deregulation of interest rates on agriculture. This policy will enable those in the agricultural sector to have interest-free loans and consequently, lead to the expansion of agricultural production that will increase real gross domestic product.

iii. **Proper Management of Fund of Borrowed**

The need to manage money borrowed to finance a deficit budget cannot be overemphasized based on the inherent tendencies from funds borrowed. In a situation where money borrowed is well utilized, there is the tendency or possibility that there will be infrastructural development that could promote sectorial development as well as increase production that will encourage the exportation of locally produced goods. The resultant effect in this instance is an improvement in the balance of payment which is affected by external and internal borrowing.

The study has contributed to the existing literature on the subject matter of internal and external financing of fiscal deficit in Nigeria. In this instance, the study provides empirical evidence about deficit financing and consequently, the knowledge obtained from this, will assist government and policymakers on how to carry out deficit financing so that it will have a negative impact on some macroeconomic forces in Nigeria. However, the study can also be applied as a reference point for those in academics and further studies could be carried out, especially where a gap is created in the study.

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Exploring the Prospects of Public Market Development as a Panacea for National Economic Growth in the Niger-Delta Region, Nigeria

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Abstract

Public market development holds significant potential for national economic growth. The resource-rich but economically challenged Niger-Delta exemplifies how improved infrastructure can drive regional and national progress, where economic disparities had not been addressed contributing to broader development goals. This study employs a mixed-method approach, administering 239 questionnaires with a 76.7% response rate (188 retrieved). Utilizing a pragmatic philosophy and explanatory case study in the NigerDelta, surveys and interviews were conducted in three ultra-modern markets. Data were analyzed using frequency tabulation, percentages, mean, and relative importance index (RII). The study identified significant challenges in public market infrastructure, including governance issues, financial constraints, logistical problems, and health, safety, and environmental concerns, impacting market efficiency and economic contributions. Despite these challenges, developing public markets offers substantial economic and social benefits, such as stimulating local economic activities, generating employment, increasing household income, enhancing market efficiency, boosting government revenue, supporting small enterprises, promoting local production, and fostering innovation. Conclusively, collaborative efforts between government, private investors, and local communities are essential for sustainable development. This research offers a blueprint for using public markets to drive inclusive growth and stability in resourcerich, underdeveloped regions like the Niger-Delta.

Keywords: Infrastructure, Economic Growth, Public Markets, Sustainable Development, Niger Delta

Introduction

The Niger-Delta region of Nigeria, known for its abundant natural resources, particularly crude oil, is paradoxically characterized by significant economic challenges and underdevelopment. Despite its wealth in resources, the region struggles with high levels of poverty, unemployment, and environmental degradation, leading to a complex socio-economic landscape (UNDP, 2006). These issues necessitate a strategic approach to fostering sustainable development, and one potential avenue is the development of public markets. According to (Nkpite, Ihuah and Ogbonda, 2024a), public markets, traditionally seen as centers for economic activities, trade, and social interaction, play a critical role in local and national economies. They serve as hubs for small and medium-sized enterprises (SMEs), providing a platform for local entrepreneurs to access wider markets and for consumers to obtain diverse goods and services. This function is particularly relevant in the Niger-Delta, where many communities rely on informal trade and agriculture as primary sources of livelihood (Akinola, 2018). Economic theories and empirical studies suggest that the development of public markets can stimulate economic growth by enhancing trade, generating employment, and fostering entrepreneurship (Fafchamps, 2004). By improving infrastructure, market accessibility, and regulatory frameworks, public markets can facilitate more efficient distribution of goods, reduce transaction costs, and increase market participation. This can lead to higher productivity and income levels, thereby contributing to overall economic growth (World Bank, 2019).

In the context of the Niger-Delta, the prospects of public market development as a panacea for economic growth are particularly convincing. The region's strategic location, coupled with its rich agricultural potential, offers a unique opportunity to develop robust market systems that can drive regional and national economic progress. However, the current state of public markets in the NigerDelta is underdeveloped, characterized by poor infrastructure, inadequate regulation, and limited access to financial services. The underutilization of public markets faces significant barriers for local producers and traders accessing wider markets, resulting in suboptimal economic outcomes (Oyedele, 2012). As the traditional economic interventions have often fallen short of addressing the multi-faceted challenges of the Niger-Delta. Public markets, which serve as hubs for local trade and entrepreneurship, present a promising avenue for such strategies. Moreover, the lack of organized markets limits the ability to generate employment and stimulate local economies, exacerbating poverty and economic disenfranchisement (Adetayo, 2018). There is a critical need for innovative and sustainable economic strategies that can harness the region's intrinsic strengths by developing public markets.

Furthermore, the establishment of well-organized public markets can help mitigate some of the socio-economic issues in the region by providing stable employment opportunities and fostering community cohesion (Ekpo, 2004). The Nigerian government and various development agencies have recognized the potential of market development in their policy frameworks. Initiatives aimed at improving market infrastructure, providing financial support to traders, and enhancing market governance have been proposed as part of broader economic development strategies (Nigerian Ministry of Budget and National Planning, 2017). However, the success of these initiatives depends on comprehensive planning, effective implementation, and the active participation of local communities. Therefore, exploring the prospects of public market development in the NigerDelta Region is not only timely but also critical for devising sustainable economic strategies that can uplift the region and contribute to Nigeria's overall economic growth.

Statement of the Problem

The Niger-Delta region of Nigeria, despite its vast natural resources and significant contributions to the national economy; there remains plagued by severe socio-economic challenges. High levels of poverty, unemployment, and environmental degradation are pervasive, undermining the region's potential for sustainable development (UNDP, 2006). The reliance on crude oil as the primary economic driver has not translated into broad-based economic prosperity for the region's inhabitants, leading to widespread disenchantment and socio-political unrest. It is observed that the current state of public markets in the Niger-Delta is underdeveloped, characterized by poor infrastructure, inadequate regulation, and limited access to financial services. Yet, the traditional economic interventions have often fallen short of addressing the multi-faceted challenges of the Niger-Delta. There is a critical need for innovative and sustainable economic strategies that can harness the region's intrinsic strengths. Public markets, which serve as hubs for local trade and entrepreneurship, present a promising avenue for such strategies. (Akinola, 2018).

The underutilization of public markets in the Niger-Delta impedes their potential to drive economic growth. Without robust public markets, local producers and traders face significant barriers in accessing wider markets, resulting in suboptimal economic outcomes. Moreover, the lack of organized markets limits the ability to generate employment and stimulate local economies, exacerbating poverty and economic disenfranchisement (Rebelo, Santos and Silva, 2016). Given the strategic importance of public markets in fostering economic development, there is a pressing need to explore their potential in the Niger-Delta context. The underutilization of public markets in the Niger-Delta may be traceable to

inadequate infrastructure hindering efficient trade and commerce, due to poor market governance and lack of regulatory frameworks contributing to inefficiencies and market distortions with limited financial services for traders and market participants that restrict economic activities and growth potential, and challenges reduce market accessibility, affecting both traders and consumers. With the above assertion, this study therefore investigates the prospects of public market development as a panacea for national economic growth in the Niger-Delta, Nigeria.

Aim and Objectives of the Study

This study aims to critically investigate the prospects as a solution for national economic advancement in the Niger-Delta Region, Nigeria. The following specific objectives are to:

i. Assess the primary challenges hindering the effective functioning of public markets for economic growth in the study area.
ii. Identify potential benefits of public market development driving sustainable economic growth in the study area.
iii. Provide evidence-based recommendations for policymakers and stakeholders on the strategic development of public markets to drive sustainable economic growth.

Research Questions

The study had two objectives, which were addressed through the following research questions:

i. What are the primary challenges hindering the effective functioning of public markets for economic growth in the study area?
ii. What are the potential benefits of public market development that drive sustainable economic growth in the study area?

Significance of the Study

This study on exploring the prospects of public market development as a panacea for national economic growth in the Niger-Delta Region, Nigeria, holds significant implications for various stakeholders, policy makers, and researchers. The study on national economic growth is poised to generate valuable insights that can inform policies, empower communities, advance academic knowledge, and contribute to achieving sustainable development goals. By addressing the significance of market infrastructure and governance in fostering economic prosperity and community well-being, this study aims to make a meaningful impact on regional development efforts in Nigeria. The findings of this study will address issues that are essential for unlocking the potential of national economic growth in the Niger-Delta. Understanding the potential of public market development as a catalyst for economic growth is crucial for policymakers and government agencies. By identifying key factors that hinder or promote market efficiency and economic productivity, this study can inform strategic interventions to stimulate local economies, create employment opportunities, and enhance income generation within the Niger-Delta Region. Furthermore, the findings of this study can contribute to evidence-based policy formulation and implementation at local, regional, and national levels. Recommendations derived from the study can guide policymakers in developing effective regulatory frameworks, infrastructure investments, and economic strategies aimed at maximizing the socio-economic benefits of public market development while addressing existing challenges. This statement emphasizes the broader implications and contributions of the study on public market development in the Niger-Delta Region, Nigeria, highlighting its relevance to economic development, community empowerment, policy formulation, academic discourse, and sustainable development goals.

Scope of the Study

This study focuses on purpose-built public markets in Rivers, Bayelsa, and Delta States within the

Niger-Delta Region. It includes markets built, owned, or operated by State or Local Governments. The selected markets are New Town Ultra-Modern Market in Port Harcourt, Rivers State; Swali Ultra-Modern Market in Yenegoa, Bayelsa State; and Uvwie Ultra-Modern Market in Effurum Warri, Delta State. The research involves 1,964 respondents: 1,882 end-users of lockup shops, 40 market administrators, 30 visitors/community members, and 12 government officials, identified during a pilot study. The focus on ultra-modern public market infrastructure addresses a gap in existing studies, which predominantly examine office environments. While ideally, the study would cover all public markets in the Niger-Delta Region, it is limited to the specified ultra-modern markets. New Town Market is located at Latitude 4.7578 and Longitude 7.03079, along Creek Road/Harold Wilson Drive and Bishop Johnson Street and King Jaja Street in Port Harcourt, Rivers State. Swali Market is at coordinates 4°55'29"N and 6°15'45.6"E, situated at 853 Melford Okilo

Road, Opolo, Yenegoa in Bayelsa State. Uvwie Market is at 5°33'0"N and 5°46'0"E, along Alegbo/Ugbolokposo Road, Effurum Warri in Delta State. Public market development supports local economies, livelihoods, and trade activities. Understanding its operational challenges and benefits is crucial for sustaining economic growth and prosperity in the region.

Literature Review

Public Market Development and National Economic Growth

According to Nkpite, Ihuah and Ogbonda (2024a), public markets play a crucial role in the economic development of nations, serving as hubs for trade, entrepreneurship, and community interaction. As the investments in market infrastructure and governance can contribute to broader economic outcomes. This review studies explore the relationship between public market development and national economic growth as detailed below.

Economic Contribution of Public Markets: Public markets contribute significantly to national economies by fostering economic activities and generating employment (Nkpite, et.al., 2024b). Akinola (2018) emphasizes that well-developed public markets provide opportunities for smallscale entrepreneurs to access markets, promote local production, and stimulate economic diversification. These markets serve as platforms for income generation and poverty reduction, particularly in developing regions where informal economies thrive. Fafchamps (2004) underscores that efficient market systems reduce transaction costs, improve market accessibility, and enhance the efficiency of goods distribution. These improvements contribute to increased productivity and competitiveness, thereby bolstering economic growth at the national level (Nkpite and Ekenta, 2021). The economic benefits of public markets extend beyond direct market activities to include multiplier effects in related sectors such as transportation, agriculture, and services.

Infrastructure Investment and Market Efficiency: Investments in market infrastructure are critical for enhancing market efficiency and stimulating economic growth (Rebelo, Santos and Silva, 2016). Ekpo (2004) discusses how improvements in market facilities, such as sanitation, security, and transportation infrastructure, can attract more traders and customers. Enhanced market infrastructure not only improves the trading environment but also supports local businesses by reducing operational costs and increasing profitability. The World Bank (2019) highlights that strategic investments in market infrastructure can lead to significant improvements in market functionality and economic performance. These investments include upgrading physical facilities, implementing technology solutions for market management, and ensuring sustainable environmental practices (Nkpite & Ekenta, 2021). Such initiatives not only enhance market operations but also contribute to broader economic goals, including job creation and income generation.

Governance and Regulatory Frameworks: Effective governance and regulatory frameworks are essential for the sustainable development of public markets and their contribution to national economic growth (Nkpite, et.al., 2024b). Akinola (2018) argues that transparent and accountable market governance systems promote fair competition, reduce market distortions, and improve investor confidence. Clear regulations and enforcement mechanisms ensure market stability and protect the rights of traders and consumers alike. According to the Nigerian Ministry of Budget and National Planning (2017), enhancing market governance is a key component of national economic strategies. The Economic Recovery and Growth Plan (ERGP) emphasizes the importance of regulatory reforms to streamline market operations, remove barriers to market entry, and foster a conducive business environment. These reforms are crucial for unlocking the full economic potential of public markets and integrating informal economies into formal economic structures.

Social and Environmental Impacts: Public market development not only contributes to economic growth but also has significant social and environmental impacts (Nkpite, et.al., 2024a). Akinola (2018) notes that vibrant public markets promote social cohesion by providing spaces for cultural exchange, community interaction, and collective identity formation. These markets serve as social hubs where diverse groups converge, fostering social integration and mutual understanding. However, Ekpo (2004) warns that rapid market development can also lead to environmental challenges such as increased waste generation and resource depletion. Sustainable market development strategies, including waste management initiatives and green infrastructure investments (Nkpite & Ekenta, 2021), are essential to mitigate these environmental impacts and promote eco-friendly market practices.

Operational Challenges and Opportunities for Public Market Development

Public markets in the Nigeria face a myriad of challenges that hinder their development potential, they also present significant opportunities for economic growth and community development (Nkpite et.al., 2024b). The specific challenges and opportunities associated with public market development are here highlighted with key insights and recommendations for policymakers and stakeholders.

Challenges in Public Market Development

Infrastructure Deficiencies: Odozi and Akinola (2018) states that one of the primary challenges facing public market development in the Nigeria is inadequate infrastructure. Nnodim (2018); Holodny (2015) underscores that many markets lack basic amenities such as proper sanitation facilities, electricity, storage facilities, and reliable transportation infrastructure. These deficiencies not only affect market operations but also deter traders and customers, leading to reduced economic activities and potential revenue loss (Nkpite *et.al*., 2024a). Ekpo (2004) further elaborates on the impact of poor infrastructure on market efficiency, noting that inadequate facilities increase transaction costs, limit market accessibility, and hinder the growth of marketbased enterprises. Addressing infrastructure gaps is crucial for enhancing market functionality and attracting investments that can drive economic growth in the region.

Governance and Regulatory Issues: Effective governance and regulatory frameworks are essential for the sustainable development of public markets (Nkpite *et.al.,* 2024b). However, Akinola (2018) highlights that governance in many Nigerian markets is characterized by weak enforcement of regulations, corruption, and lack of transparency. These issues create uncertainties for market participants, undermine investor confidence, and contribute to market inefficiencies. Ekpo (2004) emphasizes the need for strengthened regulatory oversight to ensure fair competition, protect consumer rights, and promote market integrity. Clear and consistent regulatory frameworks are

necessary to streamline market operations, remove barriers to entry, and foster a conducive business environment that supports market growth and development.

Opportunities for Public Market Development

Economic Stimulus and Employment Generation: Despite the challenges, public market development in the Nigeria presents significant opportunities for economic stimulus and employment generation (Nkpite et.al., 2024a). Akinola (2018) argues that well-planned market development initiatives can create numerous job opportunities for local residents, particularly in sectors such as retail, logistics, and services. These markets serve as platforms for small-scale entrepreneurs to access markets, promote local production, and stimulate economic diversification. Fafchamps (2004) underscores that efficient market systems reduce transaction costs, improve market accessibility, and enhance the efficiency of goods distribution. These improvements contribute to increased productivity and competitiveness, thereby bolstering economic growth at the local and national levels.

Social Cohesion and Community Development: Public markets are not only economic hubs but also social spaces that foster community interaction, cultural exchange, and collective identity formation (Nkpite, et.al., 2024b). Akinola (2018) highlights that vibrant markets promote social cohesion by providing opportunities for diverse groups to converge, interact, and build relationships. These interactions strengthen community bonds, enhance social capital, and contribute to overall community well-being (Nkpite & Ekenta, 2021). Moreover, public markets can serve as platforms for promoting inclusive growth and empowerment, particularly for women and marginalized groups. Investments in market infrastructure and support services can empower these groups economically, improve their livelihoods, and promote gender equality within market communities (Nnodim, 2018; Holodny, 2015).

Public Market Development as a Panacea for Economic Growth

Public markets are pivotal to economic growth in both developing and developed economies, serving as critical nodes for trade, entrepreneurship, and community development (Odozi and Akinola, 2018). It is important to explore key insights into its impacts, challenges, and policy implications on the role of public market development as a catalyst for economic growth.

Economic Contributions of Public Markets: Public markets play a significant role in stimulating economic activities and fostering local economic development (Nkpite et.al., 2024a). Akinola (2018) emphasizes that vibrant public markets create employment opportunities, support smallscale enterprises, and promote local production. These markets serve as platforms for economic transactions, generating income for traders, service providers, and suppliers within the market ecosystem. Fafchamps (2004) underscores that efficient market systems reduce transaction costs, improve market accessibility, and enhance the efficiency of goods distribution. By facilitating trade and commerce, public markets contribute to increased productivity, competitiveness, and overall economic output (Holodny, 2015). This economic multiplier effect extends beyond market boundaries, benefiting related sectors such as transportation, agriculture, and tourism.

Infrastructure and Market Efficiency: Investments in market infrastructure are crucial for enhancing market efficiency and supporting economic growth (Nkpite et.al., 2024a). Ekpo (2004) considers how improvements in market facilities, including sanitation, security, and transportation infrastructure, can attract more traders and customers. Enhanced infrastructure not only improves the trading environment but also reduces operational costs, increases market participation, and boosts local economic activities. The World Bank (2019) pointed out that strategic investments in market infrastructure can lead to significant improvements in market functionality and economic performance. These investments

include upgrading physical facilities, implementing technology solutions for market management, and ensuring sustainable environmental practices. Such initiatives are essential for maximizing the economic benefits of public markets and integrating informal economies into formal economic structures.

Governance and Regulatory Frameworks: Odozi and Akinola (2018) opined that effective governance and regulatory frameworks are critical for the sustainable development of public markets and their contribution to economic growth. Akinola (2018) argues that transparent and accountable market governance systems promote fair competition, reduce market distortions, and improve investor confidence. Clear regulations and enforcement mechanisms ensure market stability and protect the rights of traders and consumers, fostering a conducive business environment (Nkpite et.al., 2024a). The Nigerian Ministry of Budget and National Planning (2017) emphasizes the importance of regulatory reforms in enhancing market governance and promoting economic growth. The Economic Recovery and Growth Plan (ERGP) outlines strategies to streamline market operations, remove barriers to market entry, and foster a competitive market environment. These reforms are essential for unlocking the full economic potential of public markets and driving sustainable economic growth.

Social and Environmental Impacts: Public markets contribute not only to economic growth but also to social cohesion and environmental sustainability (Odozi & Akinola, 2018). Akinola (2018) notes that markets serve as social hubs where community members interact, exchange cultural knowledge, and build social networks. These interactions strengthen community bonds, enhance social capital, and contribute to overall community well-being. However, rapid market development can also pose environmental challenges such as increased waste generation and resource depletion (Nnodim, 2018; Holodny, 2015). Sustainable market development strategies, including waste management initiatives and green infrastructure investments, are essential to mitigate these impacts and promote eco-friendly market practices (Nkpite et.al., 2024b).

Comparative studies offer valuable insights into how improvements in market infrastructure can transform economic outcomes. For example, a study by the World Bank (2019) on market infrastructure in Sub-Saharan Africa demonstrates that investments in basic amenities such as sanitation, electricity, and secure trading spaces can lead to significant improvements in market efficiency and economic performance. Applying these lessons to the Niger-Delta context, targeted infrastructure development could similarly enhance the functionality and economic contributions of public markets in the region. In the Niger-Delta context, little or none of these studies have been conducted on public market development's role in economic growth. Ekpo (2004) Nkpite and Ekenta (2021) addresses broad economic development and policy challenges in Nigeria but does not consider public market development in regional growth. Fafchamps (2004) discovers market institutions and economic performance, yet overlooks public market development in Nigeria's socio-economic context. The UNDP (2006) report focuses on human development indicators and broader issues, missing microeconomic aspects of public market development in the Niger-Delta. The Nigerian Ministry of Budget and National Planning (2017) details a national economic recovery plan without exploring public market impacts on the Niger-Delta. Odozi and Akinola (2018) and Akinola (2018) analyze regional policies but do not specifically address public markets' role in economic growth. World Bank (2019) reports provide a macro perspective, ignoring public market development. This study aims to fill these gaps by analyzing public market development's role in economic growth, examining socio-economic impacts on local communities, and offering policy recommendations for the Niger-Delta, enhancing regional economic strategies and providing actionable insights for policymakers.

Methodology

This study focuses on three selected public markets in the Niger-Delta Region: New Town Ultra Modern Market in Port Harcourt, Rivers State; Swali Ultra-Modern Market in Yenegoa, Bayelsa State; and Uvwie Ultra-Modern Market in Effurum Warri, Delta State. These urban markets were chosen for their economic significance and representativeness. Employing a mixed-methods case study approach, the research integrates both qualitative and quantitative data through questionnaire surveys and personal interviews, as advocated by Creswell and Plano Clark (2018). The target population includes market administrators, vendors, government officials, and community leaders from the selected states, providing diverse insights into market development. A pilot survey identified a total population of 239 respondents, who were randomly selected for data collection. This comprehensive data gathering achieved a representative response rate of 76.7%. Quantitative data were analyzed using frequency tabulation, percentages, mean, and the relative importance index (RII), while qualitative data underwent content and thematic analysis. The integration of quantitative and qualitative data will facilitate evidence-based policy recommendations and strategies to enhance market infrastructure, governance frameworks, and socio-economic benefits for local communities. This robust mixed-method approach ensures a detailed investigation of the operational challenges and benefits associated with public market development, ultimately driving sustainable economic growth in the Niger-Delta Region, Nigeria.

Results and Discussion

Condition of Components of Public Market Infrastructure

Table 1 shows the condition of components of public market infrastructure hindering national economic growth in the Niger-Delta Region. The majority of responses were less than average with <3.00 mean score reflecting the very poor state of market infrastructure components: sanitary facilities, waste management systems, electricity and water supply, drainage systems, storage and cold chain facilities, parking and transportation, and poor premises cleanliness. Also, the components of lockup shops &stalls and security and safety measures were rated (>3.00) fair, which is the average mean score. This implies that all the components of public market infrastructures as listed in Table 1 is not greater than average (>3.00) and are dilapidated and little or no attention been paid to maintenance management, except in situations where deliberate force was applied to rectify defects by the Market Traders Association.

During interview; more than 50% of the respondents agree that infrastructure deficiencies in many public markets in the Niger-Delta suffer from inadequate infrastructure, hindering efficient trade and commerce. As the components of existing public market infrastructure lacks the potentials of driving sustainable economic growth due to infrastructure deficiencies, governance issues, and financial barriers.

Table 1: Condition of Components of Public Market Infrastructure

Condition of Components	Weigh: N= 188					∑fx	∑fx/∑f	Decision
	VG	G	F	P	VP			
Lockup shops &stalls	42	40	36	37	35	587	3.122	Fair
Sanitary Facilities	36	36	36	38	42	550	2.925	Poor
Waste management systems	34	34	37	39	44	539	2.867	Poor
Security and safety measures	40	39	37	36	36	575	3.060	Fair
Electricity and water Supply	30	36	38	38	46	530	2.819	Poor
Drainage systems	36	35	37	40	40	511	2.718	Poor

Condition of Components	Weigh: N= 188					∑fx	∑fx/∑f	
	VG	G	F	P	VP			
Storage and Cold Chain Facilities	36	35	37	38	42	549	2.920	Poor
Parking and Transportation	35	32	36	46	39	537	2.856	Poor
Premises cleanliness	34	34	37	43	40	543	2.888	Poor

Legend: <2.00= Very Poor, >2.00= Poor, <3.00= Fair, >3.00= Good, & <4.50 =Very Good. Note: ∑f = Number of values; ∑fx = Sum of Values; ∑fx/∑f = Sum of Values divided by Number of values (mean).

Source: Authors' Field Survey, 2024

Current State of Public Market Infrastructure

Figure 1 shows that 40% of the rated public market infrastructure conditions are very poor, 22% agree to be poor, 16% indicated that the infrastructure conditions are fair, while 12% as good. However, 10% rated the conditions of the public market infrastructure as excellent. This infers that the general conditions of public market infrastructure are poor. Consistent with earlier studies of Akinola (2018); Ekpo (2004); the findings provided a comprehensive overview of the dilapidated condition of many market facilities, including inadequate stalls, poor sanitation, lack of waste management systems, and insufficient security measures. These conditions not only deter traders and customers but also pose significant health risks, impacting the overall functionality and attractiveness of these markets. This study has demonstrated that the impact of poor infrastructure on market efficiency and trader profitability is high. The findings discovered that many markets lack basic amenities such as clean water, electricity, and proper drainage systems. These deficiencies result in unfavorable trading conditions, reduce market hours, and increase the cost of doing business, thereby limiting the economic potential of these markets. It also indicated that the absence of reliable infrastructure in markets increases transaction costs and reduces the overall efficiency of goods distribution. This inefficiency translates to higher prices for consumers and lower profit margins for traders, undermining the economic viability of market activities.

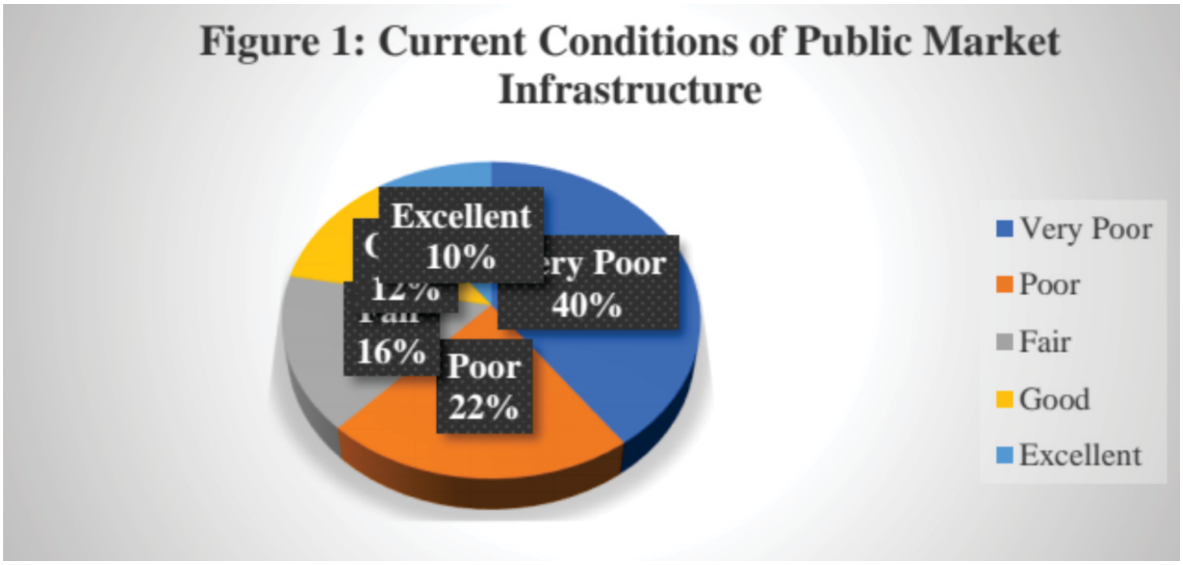

Figure 1: Current State of Public Market Infrastructure

Operational Challenges of Developing Public Markets

Table 2 shows the operational challenges of developing public market infrastructure hindering national economic growth in the Niger-Delta Region. The response rate of >3.00 mean score/RII>0.60 in Table 2 reveals the operational challenges at which public market development are hindered from national economic growth that are most important. Table 2 shows the respondents' responses with their rating/ranking. However, most of the respondents agreed upon all of the items presented under the variable, meaning that all the items listed under as the operational challenges of developing public market infrastructure hindering national economic growth were indicated as being used and the highly-rated once since the mean or RII of every item range from >3.00 mean scores or RII>0.60. This shows the consensus that the respondents hold towards governance issues, financial constraints, logistical problems, health and safety concerns, and environmental concerns as operational challenges affecting public markets efficiency and economic contributions. This study finding aligned with earlier studies of Fafchamps (2004); Ekpo (2004); Akinola (2018); Odozi and Akinola (2018) suggests that enhancing access to finance through microcredit schemes and financial literacy programmes can empower traders and stimulate market growth. Additionally, improving transportation and storage infrastructure can mitigate logistical inefficiencies, while robust waste management systems can address health and environmental concerns. Therefore, effective implementation of new strategies is essential for overcoming the operational hurdles faced by public markets.

This study has identified also the pervasive situation in the public markets are logistical challenges such as poor transportation infrastructure, inadequate storage facilities, and inefficient supply chains that significantly impede market operations. Many markets lack proper roads, making it difficult for traders to transport goods efficiently. Many markets lack proper roads, making it difficult for traders to transport goods efficiently. Moreover, inadequate storage facilities lead to high levels of waste, particularly for perishable goods. These logistical problems result in increased transaction costs and delays, reducing the competitiveness of market traders. Similar issue has occurred due to poor sanitation and waste management are common problems, creating unhygienic conditions that deter customers and pose health risks to traders and consumers alike. These health and environmental issues have also significantly posed operational challenges in Niger-Delta public markets. The absence of proper sanitation facilities and ineffective waste disposal systems are major concerns that need urgent attention to improve market conditions. The study has shown that beyond infrastructure, public markets in the Niger-Delta also face significant operational challenges that affect their efficiency and economic contributions. Key among these are governance issues, financial constraints, logistical problems, and health and environmental concerns. Addressing these infrastructural and operational challenges requires a multifaceted approach involving infrastructure investment, regulatory reforms, and financial inclusion initiatives.

Table 2: Operational Challenges of Developing Public Markets

OperationalChallenges	**Weigh: N= 188**					**∑fx**	**∑fx/∑f**	**RII**	**Rank**
	5	**4**	**3**	**2**	**1**				
Governance issues	40	39	38	37	34	578	3.07	0.614	2nd
Financial constraints	37	37	40	37	37	564	3.00	0.600	4th
Logistical problems	43	38	36	36	35	582	3.09	0.618	1st
Health and safety concerns	37	37	40	37	37	564	3.00	0.600	4th
Environmental concerns	38	38	38	38	36	568	3.02	0.604	3rd

Legend: <3.00= Disagree, >3.00= Agree. Note: ∑f = Number of values; ∑fx = Sum of Values; ∑fx/∑f = Values divided by Number of values (mean). and RII = relative importance index

Source: Authors' Field Investigation, 2024

During interview, more than 50% of the respondents agree that investments in market infrastructure and market-oriented policies stimulate economic activities within and around the markets, fostering local entrepreneurship and job creation. These economic activities contribute to poverty reduction and economic empowerment, especially among women and youth who constitute a significant portion of market participants. Moreso, improved market infrastructure enhances market efficiency, reduces transaction costs, and increases market participation, thereby boosting economic productivity and competitiveness at the local level. One of the key informants stated that:

> *'Market activities also contribute to the preservation and promotion of local cultures and traditions: it serves as social hubs where community members converge, interact, and engage in cultural exchange'.*

It suggests that public markets foster social cohesion by providing spaces for social interaction, networking, and community solidarity. These interactions strengthen social bonds, build trust among community members, and promote collective identity formation. Public markets often showcase diverse cultural practices through food, crafts, music, and other cultural expressions, enhancing cultural diversity and mutual understanding among different ethnic groups within the Niger-Delta Region.

Prospects of Developing Public Markets

Figure 2 indicates that 45% of the respondents agree of economic benefit being one the prospects of developing public markets, 37% agree to view that the prospects of developing public markets is for social benefits, 18% being of environmental benefits. neutral, 15% being high and !0% being very high. From the Figure it can be seen that the prospects of developing public markets include economic, social and environmental benefits. It implies that these potential benefits, Nigeria can leverage public market development as a key driver of sustainable economic growth, fostering a more resilient, inclusive, and prosperous economy.

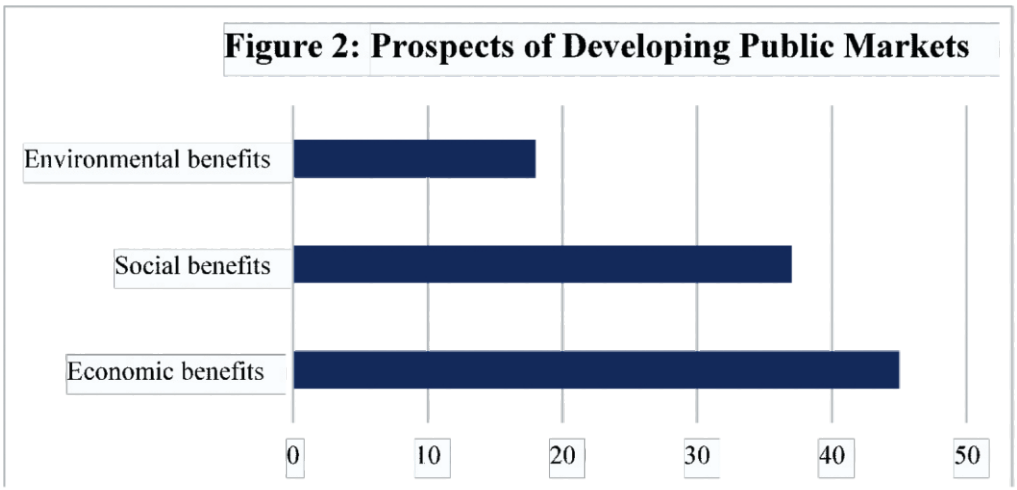

Figure 2: Prospects of Developing Public Markets

Potential Economic and Social Benefits of Developing Public Markets

Table 3 shows the potential of economic and social benefits of developing public markets in Niger Delta Region. As shown in Table 3; more than half of the respondents with RII>0.60 identified stimulate stable and localized economic activities, generate employment, generate employment, increase household income, enhance local economic development, improve market efficiency, enhanced government revenue, increased productivity and competitiveness, support small-scale enterprises, promote local production, and support innovation as the economic benefits of public market development. Similarly, as shown in Table 3; more than half of the respondents with RII>0.60 identified social benefits of public market development include to foster community interaction, preserve cultural heritage, promote inclusive economic participation, enhance civic engagement, improve consumer choice, affordability, and overall welfare, and provide spaces for urban growth. This study finding affirmed the studies of Fafchamps (2004); (Ekpo (2004) Akinola (2018); and World Bank (2019) which emphasizes that efficient market systems reduce transaction costs, improve market accessibility, and enhance the efficiency of goods distribution. By facilitating trade and commerce, public markets contribute to increased productivity, competitiveness, and overall economic output. This economic multiplier effect extends beyond market boundaries, benefiting related sectors such as transportation, agriculture, and tourism.

The study has demonstrated that public markets play a significant role in stimulating economic activities and fostering local economic development. And any vibrant public markets create employment opportunities, support small-scale enterprises, and promote local production. These markets serve as platforms for economic transactions, generating income for traders, service providers, and suppliers within the market ecosystem. Still, the study identified public markets as not only contributing to economic growth, but also to social cohesion and environmental sustainability. It should be noted that markets serve as social hubs where community members interact, exchange cultural knowledge, and build social networks. These interactions strengthen community bonds, enhance social capital, and contribute to overall community well-being. Nevertheless, rapid market development can also pose environmental challenges such as increased waste generation and resource depletion. Sustainable market development strategies, including waste management initiatives and green infrastructure investments, are essential to mitigate these impacts and promote eco-friendly market practices. Evidence in this study explained the transformative potential of public market development as a panacea for economic growth. By stimulating economic activities, creating employment opportunities, enhancing market efficiency, and fostering social cohesion, public markets contribute significantly to local and national economic development. Strategic investments in market infrastructure, coupled with effective governance and regulatory frameworks, are essential for harnessing the full economic and social benefits of public markets. Policymakers and stakeholders must prioritize sustainable market development practices to ensure inclusive growth, environmental sustainability, and long-term economic prosperity.

Table 3: Potential Economic and Social Benefits of Developing Public Markets

Potential Economic and Social Benefits	Weigh: N= 188					∑fx	∑fx/	RII	Rank
	5	4	3	2	1				
Economic Benefits									
Stimulate stable and localized economic activities	50	38	35	35	30	607	3.23	0.646	1st
Generate employment	38	42	38	37	35	581	3.09	0.618	6th
Generate household income	47	38	35	35	33	595	3.16	0.633	2nd

Table 3: Potential Economic and Social Benefits of Developing Public Markets

Potential Economic and Social Benefits	Weigh: N= 188					∑fx	∑fx/	RII	Rank
	5	4	3	2	1				
Enhance local economic development	44	39	37	34	34	589	3.13	0.626	4th
Improve market efficiency	44	37	37	36	34	585	3.11	0.622	5th
Enhanced Government Revenue	46	39	35	33	35	593	3.15	0.630	3rd
Increased productivity and competitiveness	38	37	42	36	35	571	3.04	0.608	7th
Support small-scale enterprises	40	37	40	35	36	576	3.06	0.613	8th
Promote local production	40	40	35	36	37	574	3.05	0.610	9th
Support innovation.	38	37	42	36	35	571	3.04	0.608	10th
Social Benefits									
Foster community interaction,	50	38	35	35	30	607	3.23	0.646	1st
Preserve cultural heritage	47	38	35	35	33	595	3.16	0.633	2nd
Promote inclusive economic participation	46	39	35	33	35	593	3.15	0.630	3rd
Support healthy lifestyles	44	39	37	34	34	589	3.13	0.626	4th
Enhance civic engagement.	44	37	37	36	34	585	3.11	0.622	5th
Provide spaces for urban growth	43	38	36	36	35	582	3.09	0.618	6th
Improve consumer choice, affordability, and overall welfare	40	39	38	37	34	578	3.07	0.614	7th

Legend: <3.00= Disagree, >3.00= Agree. Note: ∑f = Number of values; ∑fx = Sum of Values; ∑fx/∑f = Sum of Values divided by Number of values (mean). and RII = relative importance index.

Source: Authors' Field Survey, 2024

Conclusion

The study established that there are several challenges hampering effective functioning of public market development, pivotal for stimulating economic growth. These recurrent operational challenges stemmed from infrastructure deficiency, regulatory and bureaucratic hurdles, security concerns, access to finance, technological gaps, market information asymmetry, and political instability. Moreover, sustainable market development practices can ensure that economic gains are balanced with social inclusiveness and environmental stewardship, contributing to long-term economic resilience and prosperity. Addressing infrastructure deficiencies, strengthening governance frameworks, and leveraging market opportunities are essential for unlocking the full economic and social potential of public markets in the region. Still, prioritizing infrastructure investment, strengthening governance frameworks, supporting economic empowerment initiatives, integrating technology, promoting sustainability, and implementing robust monitoring mechanisms, public markets in the Niger-Delta Region can realize their potential as engines of economic growth, cultural preservation, and community development.

Furthermore, the study underscores the dual benefits associated with public market development in the Niger-Delta. These opportunities driving sustainable economic growth include enhanced market accessibility and trade, employment generation, economic diversification, increased agricultural productivity. boost to small and medium-sized enterprises (SMEs), technology integration and innovation, enhanced revenue generation for government, improved food security, promotion of regional and international trade, community development and social cohesion. The study accentuates

the transformative potential of public market development as a panacea for economic growth. The study findings align with criticism that by capitalizing on these opportunities, Nigeria can create a more vibrant and sustainable economy, leveraging public market development as a catalyst for broad-based economic growth and development. As these transformative potentials of public market development stimulates economic activities by creating employment opportunities, with enhanced market efficiency through fostering social cohesion; public markets contribute significantly to local and national economic development. Strategic investments in market infrastructure, coupled with supportive policies and governance frameworks, are essential for harnessing these benefits and ensuring sustainable economic growth and development in communities where public markets operate. However, realizing these benefits requires addressing the governance, financial, and logistical challenges that currently impede market efficiency. Targeted interventions and effective policy implementation are essential for leveraging the full potential of public markets to drive sustainable economic and social development in the Niger-Delta.

Recommendations

The effective functioning and potential benefits of public market development in Nigeria, pivotal for stimulating economic growth. It is imperative to ensure that public market operations are unhindered to smoothened the potential benefits of public market development in order to drive sustainable economic growth. The following suggestions are meant to drive sustainable economic growth through public market development. These suggestions include:

i. Investment in infrastructure is crucial to enhance the functionality and attractiveness of public markets: by improving sanitation facilities, water supply, and waste management systems to meet hygiene standards, upgrade market facilities for operational efficiency facilitate easy access for vendors and customers, thereby increasing market footfall and economic activity
ii. Effective governance and regulatory frameworks are essential to foster transparency, accountability, and market efficiency: with clear policies and guidelines for market administration, ensure equitable distribution of market benefits, and protect the rights of market stakeholders.
iii. Supporting economic empowerment initiatives will strengthen market resilience and contribute to local economic growth: access to credit facilities for market vendors empower vendors with essential skills for market competitiveness and sustainability.
iv. Harnessing technology can enhance market efficiency, customer engagement, and operational management; leveraging on technology for business growth and customer service enhancement
v. Promote sustainable practices to mitigate environmental impact and ensure long-term market viability through effective waste management and energy-efficiency
vi. Establish a robust monitoring and evaluation framework to track progress, measure impact, and guide future interventions: to address concerns, and continuously improve market management and service delivery.

Institutionalizing these recommendations can significantly enhance sustainable economic growth through public market development requiring the commitment of all public market stakeholders. As implementing these recommendations will require collaborative efforts from government agencies, market associations, private sector partners, and community stakeholders in Niger-DeltaRegion, Nigeria.

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Urbanization and Its Environmental Implications on Yenagoa City of the Niger Delta, Nigeria

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Abstract

The Niger Delta region, particularly Yenagoa City, has witnessed substantial urbanization driven by population growth, rural-to-urban migration, and economic development. This mixed-method study investigates the environmental implications of rapid urbanization in Yenagoa through a comprehensive household survey and engagement with key stakeholders, including local government officials, urban planners, community leaders, and representatives from relevant organizations. Three primary objectives guided the research: firstly, to uncover the multifaceted environmental implications of rapid urban growth in Yenagoa; secondly, to identify challenges associated with these implications; and thirdly, to recommend strategies for promoting sustainable urban development practices in Yenagoa. The study revealed that rapid urbanization in Yenagoa has significant environmental impacts across various themes, including deforestation and loss of green spaces, wetland conversion and degradation, air and water pollution, loss of biodiversity, increased waste generation, infrastructure strain, land degradation, slum and squatter settlement formation, flooding, and the urban heat island effect. It identified 39 significant challenges such as environmental damage, higher energy demand, exacerbated air pollution, respiratory and cardiovascular diseases, environmental pollution, health hazards, resource depletion, waterborne diseases, ecosystem damage, water scarcity, ecosystem imbalance, economic losses, cultural impacts, climate change, soil erosion, habitat loss, service disruptions, and reduced quality of life. These findings underscore the urgent need for sustainable urban development strategies. The study proposes strategies for promoting sustainability, including integrated planning, green infrastructure development, community engagement, environmental conservation, and economic sustainability. Tailored urban planning strategies are recommended, focusing on ecosystem-based planning, floodplain and coastal zone management, integrated water management, climate-responsive design, community involvement, sustainable transportation, and the development of green infrastructure. These strategies aim to address the complex environmental challenges posed by rapid urban growth in Yenagoa, ensuring that future development is sustainable and resilient to environmental pressures.

Keyword: Urbanization, Environmental Implications, Niger Delta, Sustainable Development, Urban Planning, Policy Recommendations

Introduction

Rapid urbanization is a global trend, especially in developing economies across Asia and Africa (United Nations (UN), 2014). This phenomenon, characterized by the movement of people from rural to urban areas, drives socio-economic development by creating opportunities for improved living standards, access to better services, and economic growth. However, it also presents significant challenges for sustainable development, including the strain on infrastructure, environmental degradation, and social inequalities (UN, 2018).

Nigeria is a prime example of this urbanization trend. Today, the country is rapidly urbanizing, with more people living in urban areas than in rural communities. According to the revised 2018 UN report, 53% of Nigeria's 213 million people now reside in urban areas, a figure projected to rise above 70% by

2050. This shift is driven by various factors, including population growth, ruralurban migration, and the concentration of economic activities in urban centers.

Rural-urban migration in Nigeria is propelled by the allure of better education, healthcare, and employment prospects found in cities. Urban areas promise a higher quality of life and more opportunities, drawing individuals from rural communities. However, this rapid influx of people into cities leads to overcrowded urban spaces and immense pressure on existing infrastructure. Housing, in particular, becomes a critical issue, as the demand far exceeds the supply, resulting in inadequate and often substandard living conditions (Ajanlekoko, 2002). The situation in Yenagoa, the capital city of Bayelsa State, mirrors these national trends.

Problem Statement

The urbanization of Yenagoa, the capital of Bayelsa State, Nigeria, commenced with its designation as the state capital in 1996. This pivotal event triggered a substantial influx of people into the city, attracted by the promise of employment opportunities within the state. Formerly one of the least developed local government headquarters in the former Rivers State, Yenagoa experienced an uncontrolled surge in rural-urban migration following its elevation to capital status. This influx, predominantly comprising youths aged 18-30 and recent school leavers seeking better prospects, quickly outpaced the city's planned development.

This rapid urbanization has precipitated a myriad of interrelated challenges. Yenagoa has witnessed the unchecked growth of unplanned structures, contributing to chaotic urban sprawl. Inadequate waste management practices, including the indiscriminate disposal of refuse, coupled with insufficient drainage systems, have significantly degraded the city's environmental quality. The sudden population surge exacerbated housing shortages, intensifying accommodation problems. Existing infrastructural capacities were overwhelmed by the influx of migrants, resulting in inadequate provision of essential social services and utilities.

Moreover, the limited job market in Yenagoa failed to absorb the growing workforce, resulting in widespread unemployment. Frustrated by the dearth of opportunities, the idle youth population turned to criminal activities, such as vandalizing oil installations and kidnapping expatriate workers for ransom. The concentration of governmental functions, employment opportunities, and social infrastructure in Yenagoa continues to fuel rural-urban migration, placing further strain on the city's already burdened infrastructure and services.

In addition to these challenges, Yenagoa faces environmental issues such as wetland conversion, deforestation, and urban heat island effects. Wetland conversion and deforestation threaten biodiversity and reduce the city's resilience to climate change impacts. Urban heat island effects, exacerbated by the rapid expansion of concrete and asphalt surfaces, contribute to elevated temperatures, affecting public health and increasing energy demands for cooling.

These multifaceted challenges underscore the urgent need for comprehensive research and intervention. Understanding the impacts of urbanization on Yenagoa's environment is crucial for developing sustainable development strategies that mitigate these issues, enhance environmental resilience, and improve the quality of life for its residents.

Aim and Objectives of the Study

The aim of this study is to investigate the impacts of urbanization on Yenagoa, the capital city of Bayelsa State, Nigeria.

The specific objectives of the study are as follows:

i. Uncover the multifaceted environmental implications of rapid urban growth in Yenagoa.
ii. Identify the challenges associated with the environmental implications of rapid urban growth in Yenagoa City.
iii. Recommend strategies for promoting sustainable urban development practices in Yenagoa.

Based on the above research objectives, this research seeks to address the following key questions:

i. What are the multifaceted environmental implications of rapid urban growth in Yenagoa?
ii. What challenges are associated with the environmental implications of rapid urban growth in Yenagoa City? iii. What strategies can be recommended for promoting sustainable urban development practices in Yenagoa?

Study Area

Yenagoa Local Government Area is situated in the northeastern part of Bayelsa State, at the confluence of the Epie and Ekole creeks, with Ekole being a major tributary of the Nun River. It shares boundaries with Kolokuma/Opokuma to the north, Southern Ijaw to the south, Sagbama to the northwest, and Ogbia to the east (Fig 1). Geographically, Yenagoa lies within the Equatorial climatic belt, characterized by high temperatures, humidity, and heavy rainfall, with coordinates between latitudes 4°49'N and 5°23'N, and longitudes 6°10'E and 6°33'E (Oladimeji & Ohwo, 2022; Elemuwa, Hart & Promise, 2021).

The area experiences consistent Northeast trade winds and uniform temperatures throughout the year, ranging between 26°C to 28°C. It has heavy annual rainfall averaging between 3,000mm to 3,500mm, with a brief dry season from December to February. Rainfall is accompanied by thunderstorms and torrential showers. Relative humidity remains high year-round, ranging from 80% to 85%, due to abundant water sources and constant high temperatures (Iyorakpo, 2015).

According to the 2006 National Census, Yenagoa had a population of 353,344 people, growing annually at a rate of 2.9% (NPC, 2006). The urban area encompasses several proximate settlements from Kolokuma-Opokuma, Yenagoa, Ogbia, and Southern-Ijaw, totaling 29 communities. These settlements stretch along both sides of the Mbiama-Yenagoa primary road, covering approximately 61 hectares of built-up residential areas and 140 hectares dedicated to governmental functions, education, health, and religious uses (Eyenghe & Owei, 2020).

Yenagoa's landscape includes private farms, forests, and marshlands, particularly in the northern and southwestern parts of the area. The region is crisscrossed by rivers and creeks like the Nun River, Ekole, and Epie creeks, resulting in floodplains and back swamps that support diverse flora and fauna (Oladimeji & Ohwo, 2022). Notably, depositional actions along the Ekole creek have formed geographical features such as an 'Ox-bow Lake' near Swali in the southern area.

Vegetation in Yenagoa is characterized by freshwater swamp forests rich in timber, oil-palm, and various forest products. The area's dense forest cover thrives due to favorable conditions of high temperatures and abundant precipitation, supporting year-round vegetation growth. Floating vegetation like water hyacinths can be found along the creeks and rivers, adding to the ecological diversity of region.

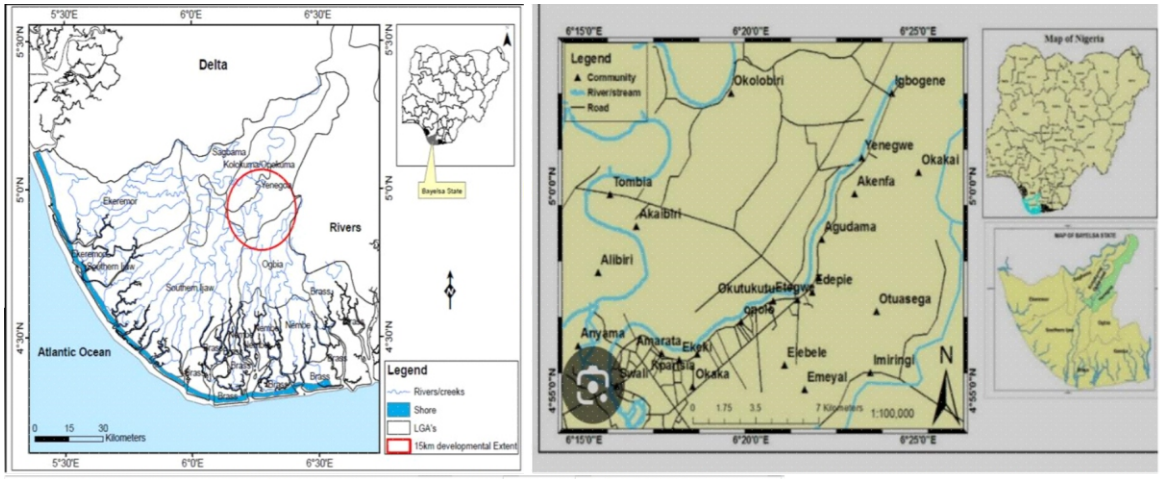

Fig. 1: Bayelsa State showing Yenagoa City (the Study Area)
Source: Author's Adaptation from Administrative Map of Bayelsa State from Office of the Surveyor General, 2015 and Yenagoa Master Plan, 2004.

Literature Review

This section considered a conceptual review of the key terms and an empirical review of related literature on the above subject matter by other scholars.

The Concept of Urbanization

The world is currently witnessing a notable surge in urbanization, with an increasing number of individuals relocating to cities. Urbanization is characterized by the growing concentration of people in urban areas, a trend historically intertwined with specialization, industrialization, and overall economic advancement (Sharma, 2003; Hussain & Imitiyaz, 2018). While scholars may debate the precise mechanisms underlying this connection, a fundamental aspect of urbanization involves a shift in employment patterns, notably transitioning from agricultural to non-agricultural sectors, thus fostering a more intricate and diversified economy.

Urbanized areas exhibit distinct characteristics setting them apart from rural regions. According to Weeks (2010), there are six of these characteristics. Firstly, there exists a pronounced division of labor, where individuals specialize in various occupations, spanning manufacturing, healthcare, and education, among others, thereby weaving a complex economic fabric. Secondly, production within urban settings often hinges upon technological advancements, enhancing efficiency in the manufacturing process. Thirdly, urban locales serve as hubs for the exchange of a diverse array of goods and services. Moreover, urban areas typically boast high population densities, fostering a blend of cultures and backgrounds. Finally, as urban areas expand, they encounter challenges such as congestion, pollution, inadequate housing, and strains on public services. Understanding the concept of urbanization is crucial for assessing its impacts on societies, economies, and the environment, and for developing strategies to manage its effects sustainably.

The Concept of Sustainable Development

Sustainable development has been defined in various ways, but the most frequently quoted definition comes from the Brundtland Report, also known as Our Common Future. It defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (The International Institute for Sustainable Development (IISD, 2024).

Sustainable development refers to the pursuit of economic growth, social equity, and environmental protection while ensuring the needs of present and future generations are met. It involves balancing economic progress with social well-being and environmental stewardship to create a more equitable and resilient society. Sustainable development aims to address the interconnected challenges of poverty, inequality, and environmental degradation by promoting inclusive growth, resource efficiency, and conservation. Key principles of sustainable development according to Mensah (2019) include integrating economic, social, and environmental considerations into decision-making processes, promoting equity and social justice, and fostering collaboration among governments, businesses, and civil society. By embracing sustainable development principles, communities can strive for long-term prosperity while safeguarding natural resources and enhancing quality of life for all.

Empirical Review

Iyorakpo (2015) conducted a comprehensive study on the impact of rapid urbanization on environmental quality in Yenagoa metropolis, Bayelsa State, Nigeria. The study aimed to investigate how rapid urbanization has affected the local environment, focusing on various aspects such as unplanned urban expansion, waste management issues, drainage deficiencies, and inadequate housing. Methodologically, Iyorakpo adopted a mixed-methods approach to gather and analyze data. Secondary data sources included demographic statistics and environmental reports, providing a foundation for understanding historical trends and existing challenges. Primary data collection involved fieldwork and interviews conducted in five selected zones: traditional Yenagoa, Onopa, Kpansia, Biogbolo, and Agudama-Epie. The findings of his study highlighted several critical environmental challenges exacerbated by rapid urbanization. One key issue was the proliferation of unplanned structures, contributing to urban sprawl and land use conflicts. Inadequate waste disposal practices were prevalent, leading to environmental pollution and health risks within the community. Furthermore, deficiencies in drainage infrastructure exacerbated flooding and waterlogging during rainy seasons, posing significant challenges to both infrastructure integrity and public health. Additionally, the rapid influx of migrants into Yenagoa resulted in severe housing shortages, further straining urban development efforts.

Eludoyin, Obafemi and Hardy (2017) investigated the impact of urbanization on land use change in Yenagoa Metropolis, Bayelsa State, Nigeria, spanning the years 1986 to 2013. Using Landsat imagery and advanced classification algorithms, the study analyzed the expansion of built-up areas and its implications for other land uses. They found significant growth in built-up areas, increasing from 36.09 km^2 in 1986 to 102.25 km^2 in 2013, reflecting a 66.16 km^2 overall increase. Predictive modeling indicated a rising probability of sparse vegetation converting into urban areas. The study recommended interventions to mitigate land use changes, emphasizing awareness campaigns and sustainable land management practices.

Ekpenyong's (2020) study investigated the impact of urbanization on environmental degradation in Yenagoa Metropolis, Bayelsa State, Nigeria. Using the concentric zone model, the study employed a correlational design and sampled 339 respondents through structured questionnaires using both probability and non-probability sampling techniques. Data analysis involved statistical tools such as percentages, frequency distributions, pie charts, means, binary logistic regression, and Pearson correlation using SPSS version 23.0. The study found that rapid urbanization in Yenagoa Metropolis contributed significantly to housing shortages, increased instances of flooding, and worsening sanitary conditions. These outcomes highlighted the detrimental environmental effects of urban growth in the area. To mitigate these issues, the study recommended improvements in housing infrastructure,

enhanced environmental sanitation practices, and effective urban planning by the Yenagoa Capital City Development Authority.

Imaitor-Uku, Owei, Hart, and Ayotamuno (2021) conducted a study on the impact of settlement growth on the urban environment in Yenagoa Metropolis using Landsat imagery from 1988 to 2020. Through supervised image classification, they assessed changes in land use and cover, focusing on built-up areas, water bodies, and vegetation. The research documented significant expansion of built-up areas over the years, highlighting a pressing need for improved urban planning and sustainable land use management in Yenagoa. Recommendations included empowering urban planning agencies and educating the public on environmental conservation to support sustainable urban development.

Elemuwa, Hart, and Promise (2021) conducted a study on spatial change detections and wetland inventory in Yenagoa and their study revealed rapid and largely unregulated urban development. Their study employed GIS and remote sensing to analyze land use/land cover changes using satellite imagery from 1990, 2000, 2010, and 2020. They found a significant increase in built-up areas and a corresponding decline in wetlands, indicating the severe impact of urban expansion on the environment. Their analysis showed a continuous increase in built-up areas from 1990 to 2020, with a total percentage change of 273.31% (4,178.7 hectares). Vegetation cover increased by 38.55% (974.34 hectares), while wetland cover decreased by 61.96% (5,144.99 hectares). Specific wetland losses were observed at Yenegwe (29.918%, 197.95 hectares) and Igbogene (36.028%, 358.7 hectares). Additionally, wetlands in Anyama, Swali, Kpansia, and Opolo towns were completely lost by 2010 due to persistent reclamation activities. They engaged the Markov Chain model and predicted further wetland losses of 32.47%, 30.68%, and 28.99% by 2030, 2040, and 2050, respectively, if current trends continue. The study highlighted the importance of using remote sensing and GIS for environmental monitoring and recommended integrating wetland policies into urban planning to mitigate further losses (Elemuwa, Hart & Promise, 2021).

Research Gap

This study on "Urbanization and Its Environmental Implications on Yenegoa City of the Niger Delta, Nigeria" addresses key gaps identified in previous research efforts focused on Yenagoa's urbanization and its environmental impacts. Previous studies by Iyorakpo (2015), Eludoyin et al., (2017), Ekpenyong (2020), Imaitor-Uku et al., (2021), and Elemuwa et al., (2021) predominantly utilized remote sensing, GIS, and statistical analyses to quantify physical changes such as land use conversion and wetland loss. Their studies provided valuable insights into the spatial extent and magnitude of urban growth and its ecological consequences. However, these earlier studies overlooked the social dimensions of urbanization impacts and community perspectives. They primarily focused on physical changes, such as the expansion of built-up areas and the decline of natural habitats like wetlands. While informative, these studies did not extensively engage with local stakeholders or incorporate community perceptions and experiences of urbanization's environmental effects.

In contrast, this present study adopts a mixed-method approach, incorporating a household survey, engagement of key stakeholders and documents review. By including perspectives from local residents, government officials, urban planners, and community leaders, the study provides a holistic understanding of urbanization's multifaceted environmental implications. This methodology not only quantifies physical changes but also explores residents' awareness of environmental impacts, perceived challenges, and proposed solutions. This study therefore fills a crucial gap by bridging quantitative assessments with qualitative insights into community perspectives and solutions for sustainable urban development.

Methodology

The convergence variant in triangulation design of mixed-methods research was used. The purpose of this design was to collect, analyze, and integrate both qualitative and quantitative data to provide a comprehensive understanding of the impacts of urbanization on Yenagoa, the capital city of Bayelsa State, Nigeria. This approach allows for the strengths of both qualitative and quantitative methods to be utilized, ensuring a more robust and corroborated set of findings (Creswell & Plano Clark, 2023). By converging data from multiple sources, the research aimed to cross-validate findings, uncover the multifaceted environmental implications of rapid urban growth, identify associated challenges, and recommend strategies for promoting sustainable urban development practices in Yenagoa (Tashakkori & Teddlie, 2010). Data collection for the study involved head of household survey, key informant interviews and a literature review. The research employed a yes-or-no head of household questionnaire, drawing on the methodologies of Smyth, Dillman, Christian and Stern (2006); and Smyth, Christian and Dillman (2008). This approach enabled a straightforward assessment of respondents' perceptions and experiences related to urbanization and its environmental implications, providing clear and actionable data to inform urban planning strategies and policy interventions. The questionnaire was designed to gather data on various environmental issues resulting from rapid urban growth. It included questions on deforestation, wetland conversion, air and water pollution, biodiversity loss, waste generation, infrastructure strain, land degradation, slum formation, flooding, and temperature increases. The study's population included all residents of Yenagoa City in Bayelsa State. Since the 2006 national population data did not break down the populations to individual communities, the 1991 population data was used and projected. According to the National Population Commission (NPC) data from 1991, the city's population was 72,173. Using an exponential growth model with a 6.5% annual growth rate, the population for 2022 was estimated at 420,841 (NPC, 2021). The target population for this study comprised the residents of sampled communities, totaling 172,411 individuals as of 2023. An assumption of five persons per household, based on National Bureau of Statistics (NBS) data from 2016, resulted in an estimated 34,482 households. The Taro Yamane Formula was applied to determine the sample size with a 5% level of precision, yielding approximately 395 respondents. The sampling process focused on residents of the Yenagoa Local Government Area. The 29 communities within the study area were selected using a simple random sampling technique. Twenty percent of these communities were then chosen for sampling, resulting in six communities- Agudama, Amarata, Swali, Ovom, Akada, and Okutukutu (See Table 1). A total of 395 questionnaires were administered to heads of households, with 386 questionnaires returned for analysis. In addition, 12 key informants were interviewed.

Table 1: Sample Distribution of Communities

S/No.	Communities	Population (1991)	Projected Population (2023) at 6.5% Growth Rate	Number of Households (Projected)	No. of Questionnaires to be Administered
1	Agudama	3,002	28,924	5,784	66
2	Amarata	3,556	34,542	6,908	79
3	Swali	2,520	24,253	4,851	56
4	Ovom	6,320	60,856	12,171	139
5	Akaba	806	7,753	1,551	18
6	Okutukutu	1,670	16,083	3,217	37
	Total	**17874**	**172,411**	**34,482**	**395**

Source: Researcher's Computation (2024) Using NPC, 1991 Figures

Key informant interviewed were local government representatives, urban planners, community leaders, and NGO representatives who provided qualitative insights into environmental impacts and sustainable development strategies. Additionally, a literature review examined existing academic papers, government reports, and policy documents to contextualize challenges and identify strategies for sustainable urban development. In data analysis, qualitative data underwent thematic analysis to identify recurring patterns, while quantitative data was subjected to descriptive statistical analysis.

Results of Findings
Environmental Implications of Urbanization in Yenagoa City

Key informant interview identified 11 themes: Deforestation and Loss of Green Spaces, Wetland Conversion and Degradation, Air Pollution, Water Pollution, Loss of Biodiversity, Increased

Waste Generation, Infrastructure Strain, Land Degradation, Slum and Squatter Settlement Formation, Flooding, and Urban Heat Island Effect. These themes formed the basis for questionnaire design for heads of households survey. The household survey conducted revealed widespread concern among residents about the environmental consequences of rapid urbanization in Yenagoa. Table 2 shows the percentage distribution of these implications as a result of the household survey. The findings from the household survey, encompassing 386 respondents, reveal the profound environmental implications of rapid urban growth. These implications are dissected across various themes, highlighting the community's perception of these issues.
Deforestation emerges as a prominent concern, with 295 respondents (76.4%) acknowledging it as a significant environmental implication of urban expansion. The majority agree that the unchecked growth of urban areas leads to the loss of forests, which are crucial for maintaining ecological balance and providing habitat for diverse species. However, 91 respondents (23.6%) did not perceive deforestation as a major issue, suggesting a possible lack of awareness or differing priorities.

Similarly, wetland conversion is recognized by 275 respondents (71.2%) as a critical environmental concern due to urbanization. Wetlands play a vital role in water purification, flood control, and supporting biodiversity. The conversion of these areas for urban development disrupts these functions, exacerbating environmental degradation. Nevertheless, 111 respondents (28.8%) disagreed, indicating varying levels of understanding or concern about the importance of wetlands.

Air pollution is overwhelmingly viewed as a significant consequence of rapid urbanization, with 320 respondents (82.9%) in agreement. Urban areas, with their dense population and industrial activities, contribute substantially to air quality deterioration, impacting public health and the environment. On the other hand, 66 respondents (17.1%) did not consider it a major issue, possibly reflecting differences in exposure or awareness levels.

Water pollution is another critical environmental impact identified by 310 respondents (80.3%). The increase in urban runoff, industrial discharge, and inadequate waste management systems lead to the contamination of water bodies, posing serious health risks and affecting aquatic life. Conversely, 76 respondents (19.7%) did not see water pollution as a significant concern, highlighting a disparity in perception.

The loss of biodiversity is acknowledged by 305 respondents (79.0%) as a significant issue linked to urban growth. The expansion of urban areas encroaches on natural habitats, leading to the decline of various species. However, 81 respondents (21.0%) did not view this loss as a major concern, suggesting differing views on the value of biodiversity.

Increased waste generation is perceived by 315 respondents (81.6%) as a major environmental implication of urban growth. The rise in population density leads to more waste production, challenging waste management systems and contributing to pollution. Nonetheless, 71 respondents (18.4%) disagreed, indicating a potential lack of awareness about waste management issues.

Infrastructure strain is highlighted by 290 respondents (75.1%) as a significant consequence of rapid urbanization. The growing population puts pressure on existing infrastructure, leading to overburdened transportation systems, utilities, and public services. In contrast, 96 respondents (24.9%) did not consider it a major issue, reflecting varying experiences with infrastructure capacity.

Land degradation is identified by 280 respondents (72.5%) as a significant environmental issue resulting from urban growth. The conversion of land for urban use often leads to soil erosion, reduced agricultural productivity, and loss of natural landscapes. However, 106 respondents (27.5%) did not perceive land degradation as a major concern, indicating differing priorities or awareness levels.

Slum or squatter formation is recognized by 260 respondents (67.4%) as a major issue due to rapid urban growth. The influx of people into urban areas often outpaces the development of adequate housing, leading to the proliferation of informal settlements with poor living conditions. Conversely, 126 respondents (32.6%) did not see this as a significant concern, suggesting differing views on housing issues.

Flooding is seen by 275 respondents (71.2%) as a significant environmental implication of urban growth. The alteration of natural drainage systems and increased impervious surfaces lead to higher flood risks. However, 111 respondents (28.8%) did not view flooding as a major issue, highlighting varying perceptions of flood risk.

Finally, the increase in temperature is acknowledged by 325 respondents (84.2%) as a major environmental impact of rapid urban growth. Urban heat islands, caused by the concentration of buildings and human activities, lead to higher temperatures compared to rural areas. Nonetheless, 61 respondents (15.8%) did not view it as a significant issue, indicating differing experiences with urban heat.

Table 2: Environmental Implications Resulting from the Rapid Urban Growth in Yenagoa City

S/N	Environmental Implications	YE S		NO	
		Frequency	%	Frequency	%
1.	Deforestation	295	76.4	91	23.6
2.	Wetland Conversion	275	71.2	111	28.8
3.	Air Pollution	320	82.9	66	17.1
4.	Water Pollution	310	80.3	76	19.7
5.	Loss of Biodiversity	305	79	81	21
6.	Increased Waste Generation	315	81.6	71	18.4
7.	Infrastructure Strain	290	75.1	96	24.9
8.	Land Degradation	280	72.5	106	27.5
9.	Slum / Squatter Formation	260	67.4	126	32.6
10.	Flooding	275	71.2	111	28.8
11.	Increase in temperature	325	84.2	61	15.8

Source: Field Data, 2024

Challenges Associated with the Environmental Implications of Rapid Urban Growth in Yenagoa city

Key informants identified about 39 significant challenges associated with the environmental implications of rapid urban growth in Yenagoa city. They include:

Environmental damage, higher energy demand, exacerbated air pollution, respiratory illnesses, cardiovascular diseases, environmental pollution, health hazards, resource depletion, waterborne diseases, ecosystem damage, water scarcity, ecosystem imbalance, economic losses, cultural impact, climate change, soil erosion, habitat loss, service disruptions, reduced quality of life, economic impact, pollution of air, land, and water bodies, spread of diseases, reduced availability of clean water, loss of ecosystem services, interruptions in essential services such as water supply, electricity, and transportation, deterioration of living conditions, decreased economic productivity, pollution of soil and water, reduced agricultural productivity, economic impacts on agriculture and livelihoods, increased vulnerability to flooding, loss of wetland ecosystems and biodiversity, degradation of water quality impacting aquatic ecosystems and human health, health risks, poor living conditions, social inequality, marginalization of vulnerable populations, exacerbation of urban poverty, degradation of urban environment, strain on infrastructure and public services, extensive property damage, economic losses, displacement of communities, social and economic disruptions, spread of waterborne diseases, increased health risks.

Table 3 presents the frequency and percentage of various environmental implications along with their associated challenges. A prominent concern is the increase in temperature, reported by 325 respondents (84.2%), which brings challenges such as health impacts from heat-related illnesses and deaths (30.0%), heightened energy demand (25.0%), and exacerbated air pollution (29.2%). Air pollution, with a frequency of 320 (82.9%), is linked to respiratory and cardiovascular diseases (28.5%), environmental damage (27.0%), and economic costs from healthcare and productivity loss (27.4%). Increased waste generation, highlighted by 315 respondents (81.6%), poses challenges including environmental pollution (27.0%), health hazards from pest-spread diseases (26.5%), and resource depletion (28.1%). Water pollution, recorded by 310 respondents (80.3%), leads to health risks from waterborne diseases (28.0%), ecosystem damage (27.5%), and reduced availability of clean water (24.8%). The loss of biodiversity, indicated by 305 respondents (79.0%), results in ecosystem imbalance (26.5%), economic losses in agriculture, forestry, and tourism (27.0%), and cultural implications (25.5%). Deforestation, with a frequency of 295 (76.4%), contributes to climate change (25.0%), soil erosion and reduced fertility (25.5%), and habitat loss (25.9%). Infrastructure strain, reported by 290 respondents (75.1%), presents challenges such as service disruptions (26.0%), reduced quality of life (24.5%), and economic impacts hindering growth and development (24.6%). Land degradation, a concern for 280 respondents (72.5%), is associated with reduced agricultural productivity (24.0%), desertification (24.5%), and loss of ecosystem services (24.0%). Wetland conversion, recorded by 275 respondents (71.2%), brings challenges like increased flood risks (23.5%), biodiversity loss (23.8%), and poorer water quality (23.9%). Flooding, also with a frequency of 275 (71.2%), results in property damage (24.0%), displacement of communities (23.5%), and public health risks such as waterborne diseases and mosquito breeding grounds (23.7%). Lastly, slum or squatter formation, reported by 260 respondents (67.4%), poses health and safety issues (24.5%), social inequality (23.9%), and environmental degradation (19.0%).

Table 3: Environmental Implications and Detailed Associated Challenges of Rapid Urban Growth in Yenagoa City

Environmental Implications	Frequency (Yes)	Percentages (%)	Detailed Associated Challenges	Percentage (%) of Each Challenge
Increase in Temperature	325	84.2	Health impacts: heat -related illnesses and deaths	30.0
			Higher energy demand	25.0
			Exacerbated air pollution	29.2
Air Pollution	320	82.9	Respiratory and cardiovascular diseases	28.5
			Environmental damage	27.0
			Economic costs from healthcare and productivity loss	27.4
Increased Waste Generation	315	81.6	Environmental pollution	27.0
			Health hazards: disease spread by pests	26.5
			Resource depletion	28.1
Water Pollution	310	80.3	Health risks: waterborne diseases	28.0
			Ecosystem damage	27.5
			Reduced availability of clean water	24.8
Loss of Biodiversity	305	79.0	Ecosystem imbalance	26.5
			Economic losses: impact on agriculture, forestry, tourism	27.0
			Cultural impact	25.5
Deforestation	295	76.4	Contribution to climate change	25.0
			Soil erosion and reduced fertility	25.5
			Habitat loss	25.9
Infrastructure Strain	290	75.1	Service disruptions	26.0
			Reduced quality of life	24.5
			Economic impact: hampered growth and development	24.6
Land Degradation	280	72.5	Reduced agricultural productivity	24.0
			Desertification	24.5
			Loss of ecosystem services	24.0
Wetland Conversion	275	71.2	Increased flood risks	23.5
			Biodiversity loss	23.8
			Poorer water quality	23.9

Table 3: Environmental Implications and Detailed Associated Challenges of Rapid Urban Growth in Yenagoa City

Environmental Implications	Frequency (Yes)	Percentages (%)	Detailed Associated Challenges	Percentage (%) of Each Challenge
Flooding	275	71.2	Property damage	24.0
			Displacement of communities	23.5
			Public health risks: waterborne diseases, mosquito	23.7
			breeding grounds	
Slum/Squatter Formation	260	67.4	Health and safety issues	24.5
			Social inequality	23.9
			Environmental degradation	19.0

Source: Field Data, 2024

Discussion of Household Survey Findings

Yenagoa City faces significant environmental challenges due to rapid urbanization and industrialization (Imaitor, Ayotamuno, Owei & Hart, 2020). The findings from the household survey in Yenagoa reveal significant concerns among residents regarding the environmental impacts of rapid urbanization. These insights highlight various areas where urban growth is perceived to be causing substantial environmental degradation and stress on local ecosystems.

Deforestation, viewed as a major issue by 76.4% of respondents, underscores the significant impact of rapid urban expansion on forested areas. This widespread deforestation leads to habitat destruction, loss of biodiversity, and disruption of local climate regulation. The high percentage of concerned respondents reflects the community's awareness of the crucial role forests play and the adverse effects of their removal. Forests are essential for maintaining ecological balance, supporting diverse species, and regulating climate (Lukina, Geraskina, Gornov et al., 2021). The loss of these areas due to urban development not only threatens wildlife but also disrupts vital ecosystem services, emphasizing the need for sustainable urban planning (Obia, Itam & Archibong, 2015).

Wetland conversion, representing a concern for 71.2% of respondents, highlights the critical role wetlands play in maintaining ecological balance, including water filtration and flood control. The significant concern expressed by over 70% of respondents suggests that urban development is encroaching on these essential areas, potentially leading to increased flooding, loss of wildlife habitats, and diminished water quality (Muziri, Banhire & Matamanda, 2019). Wetlands are crucial for sustaining biodiversity, regulating water cycles, and mitigating natural disasters. The encroachment of urban development into these areas not only disrupts these vital functions but also threatens the survival of numerous plant and animal species dependent on wetland ecosystems (Obia et al., 2015; Ibama, Nengi & Tari, 2022).

The concern about air pollution, representing 82.9% of the urbanization challenge, underscores the significant impact of urbanization on air quality. This deterioration can be attributed to increased vehicular emissions, industrial activities, and construction dust, posing significant health risks such as respiratory issues and cardiovascular diseases (Tsiouri, Kakosimos & Kumar, 2015). The rise in urbanization is typically associated with elevated levels of air pollution due to increased vehicular

traffic, industrial activities, and construction. The proliferation of industries releases pollutants into the air and water, compromising air quality and contaminating water bodies. The escalating number of vehicles further contributes to alarming air pollution levels, adversely affecting the health of residents. Inadequate infrastructure exacerbates the issue by leading to improper waste disposal, further polluting the environment and posing health risks (Maji, Ahmed, Kaur-Sidhu, Mor & Ravindra, 2023). Pollutants such as particulate matter, nitrogen oxides, sulfur dioxide, and volatile organic compounds can have deleterious effects on air quality and human health.

With over 80% agreement, water pollution is a critical issue linked to urban growth. The rapid urban expansion in Yenagoa has precipitated this concerning issue of water pollution. As urban areas expand, so does the risk of water contamination through various means such as runoff from urban surfaces, industrial discharges, and improper waste disposal practices. These pollutants not only degrade water quality but also pose significant threats to aquatic ecosystems and public health by contaminating drinking water sources (Madhav, Ahamad, Singh, Kushawaha, et al., 2020). Yenagoa's burgeoning population exacerbates this issue, as the demand for freshwater resources intensifies, potentially leading to scarcity. With no public water supply system in place, residents rely heavily on alternative sources such as boreholes, rainwater, wells, and local river channels for their water needs. However, the purity of these sources remains questionable, yet a staggering high percentage of the population relies on them. Groundwater in Yenagoa is generally unfit for drinking and other household uses and requires treatment for these parameters to make it portable and meet the WHO's standards for household waters (Okoh, Oruabena, Amgbari, & Nelson, 2019). Moreover, the unchecked pollution stemming from both legal and illegal oil and gas activities further compounds the problem, with contaminants from these activities infiltrating water bodies, endangering aquatic ecosystems, and posing health risks to communities dependent on them (Okoh, et al., 2019). Evidence of this pollution is starkly visible, with oil slicks often seen floating on the water surfaces. The lack of concerted efforts towards remediation exacerbates the situation, leaving both the environment and the populace vulnerable to the adverse effects of water pollution.

The high concern percentage (79.0%) for biodiversity loss underscores residents' awareness of the adverse effects of urbanization on local flora and fauna. The reduction in green spaces and natural habitats can precipitate species decline and disrupt ecosystem balance. Urbanization often precipitates habitat destruction and fragmentation, culminating in biodiversity loss. The encroachment of the concrete jungle upon Yenagoa's precious forests is resulting in deforestation, which not only eradicates vital habitats but also disrupts delicate ecological equilibrium. The conversion of natural habitats into urban areas is disrupting the ecological balance and precipitating the decline or extinction of native species. As the city sprawls, wildlife corridors shrink, isolating animal populations and imperiling their survival. Wetlands, pivotal for flood control and water filtration, are being drained and repurposed for development, compromising the city's natural defenses and ecosystem health (Chukwuka & Adeogun, 2020).

Increased waste generation, comprising 81.6% of the urbanization challenge, emphasizes the pressing issues surrounding waste management infrastructure. Urban areas inherently produce more waste, posing concerns related to pollution, pest attraction, and unsanitary conditions if not managed effectively. The rapid urban growth of Yenagoa has exacerbated this issue, leading to a surge in solid waste generation and straining waste management systems. Inadequate infrastructure for waste collection, disposal, and recycling has resulted in littering, pollution, and environmental degradation (Ekpeyong, 2020).

Infrastructure strain, comprising 75.1% of the urbanization challenge, underscores the significant

pressure on essential systems like roads, water supply, and sanitation. Rapid urban growth frequently surpasses infrastructure development, resulting in overcrowding, traffic congestion, and deficient public services (World Bank, 2021). The construction of urban infrastructure, encompassing roads, buildings, and utilities, bears both positive and negative environmental ramifications. While enhancing access to services and fostering socio-economic advancement, infrastructure development also triggers habitat destruction, land fragmentation, and alteration of natural landscapes (United Nations, 2019).

Land degradation, resulting from construction activities, overuse of land, and improper land management practices, can reduce soil fertility, increase erosion, and negatively impact agricultural productivity. Urbanization is steadily transforming agricultural land, forests, and wetlands into urban areas, causing land degradation and the depletion of ecosystem services. This shift results in deforestation, soil erosion, and alterations in land use patterns, ultimately degrading soil quality, diminishing vegetation cover, and heightening the risk of flooding and erosion (United Nations, 2019; FAO, 2020). As urban areas expand, housing and essential amenities such as water, electricity, and waste disposal become increasingly inadequate. In locations like Akenfa, Kpansia, Tombia, and Obele, characterized by substandard living conditions often referred to as slums, millions reside, particularly vulnerable to crime due to unemployment (World Bank, 2021; UNHabitat, 2020).

The formation of slums or squatter settlements, a critical issue reflected by a concern level of 67.4%, highlights the inability of the urban housing market to keep pace with population growth. This leads to poor living conditions, lack of access to basic services, and increased social challenges. Ekpeyong (2020) reports that urban residents in Yenagoa are living in predominantly poor sanitary conditions, with a high mean score of 3.0. Additionally, a mean score of 3.3 indicates that more city dwellers are now living in uncompleted buildings. Moreover, a mean score of 3.4 corroborates that Yenagoa city has experienced rapid growth in population density recently. This is further supported by a mean score of 3.5, showing that residents who cannot afford house rent in the city live in batcher houses. Finally, a mean score of 3.5 reveals that hospitals are overcrowded, indicating strained healthcare infrastructure.
Concerns about flooding, noted by 71.2% of respondents, are linked to the disruption of natural water flows due to urban development and the loss of wetlands. Flooding can cause extensive property damage, displacement, and health risks, underscoring the need for effective urban planning and flood management strategies. The conversion of natural landscapes into urban areas often interferes with natural drainage systems, leading to increased runoff and reduced absorption capacity. This exacerbates the risk of flooding, particularly in areas where wetlands, which naturally mitigate floods, have been drained and developed (Chukwuka & Adeogun, 2020; Ibama, Nengi & Tari, 2022). Effective urban planning must integrate flood management strategies to safeguard communities and maintain ecological balance (Tingsanchali, 2012; Kalogiannidis, Kalfas, Giannarakis & Paschalidou, 2023).

The term urban heat island (UHI) describes the phenomenon in which cities are generally warmer than adjacent rural areas (Heisler & Brazel, 2010). In Yenagoa City, the majority of the respondents (84.2%) reported it as a major challenge. Urban areas tend to experience higher temperatures compared to surrounding rural areas due to the heat island effect, a result of the physical properties of buildings and other structures, as well as the emission of heat by human activities. This effect is most pronounced on clear, calm nights, and its strength depends on background geography and climate. However, there are often cool islands in parks and lessdeveloped areas (Parker, 2010). The proliferation of concrete and asphalt surfaces, coupled with reduced green spaces, has led to elevated temperatures, exacerbating heat-related health risks and increasing energy demand for cooling (Yenneti et al., 2020). Residents of

Yenagoa city have reported suffering from excessive heat and heat rashes (Amadi, Ogbanga, & Agena, 2015). The heat island effect, compounded by climate change, poses a significant threat to the city's resilience.

Strategies for Promoting Sustainable Urban Development Practices in Yenagoa

The contributions from the groups of key informants highlighted several critical areas for action such as Integrated Urban Planning, Green Infrastructure and Climate Adaptation, Community Engagement and Social Equity, Environmental Conservation and Economic Sustainability, Sustainable Urban Planning Strategies.

Integrated Urban Planning

Local government officials emphasized the need for cohesive urban planning that aligns with the city's developmental and sustainability goals. They stressed the importance of policy support, capacity building, and public-private partnerships to drive sustainable initiatives.

Green Infrastructure and Climate Adaptation

Urban planners advocated for the incorporation of green infrastructure, such as parks and sustainable drainage systems, to improve environmental resilience. They also highlighted the importance of adopting mixed-use development patterns and integrating climate change adaptation measures to mitigate risks like flooding and extreme weather events.

Community Engagement and Social Equity

Community leaders prioritized initiatives that address local concerns, such as access to clean water, sanitation, and affordable housing. They emphasized the necessity of community participation and empowerment in decision-making processes to ensure that development efforts are culturally sensitive and responsive to local needs. Ensuring social equity and inclusivity in urban projects was also a key concern to address disparities in resource access and opportunities.

Environmental Conservation and Economic Sustainability

Representatives from environmental NGOs highlighted the potential for eco-friendly initiatives, including tree planting campaigns, waste management programs, and environmental education, to promote sustainability. Academic institutions and development agencies stressed the importance of research, knowledge exchange, and best practices to inform evidence-based policies and provide technical expertise and funding support for sustainable development.

Sustainable Urban Planning Strategies

Urban planners further identified specific sustainable urban planning strategies tailored to address the unique environmental challenges faced by Yenagoa City and the Niger Delta region:

i. **Ecosystem-Based Planning**

Adopt an ecosystem-based approach to urban planning that integrates ecological considerations, preserves natural habitats, and enhances ecosystem services. Designate protected areas, green corridors, and buffer zones to conserve biodiversity, support ecological connectivity, and maintain ecosystem resilience.

ii. **Floodplain Management**

Implement floodplain management strategies to mitigate flood risks, protect communities, safeguard infrastructure, and boost the preparedness and resilience of the population. Incorporate floodplain mapping, zoning regulations, and green infrastructure solutions such as

wetland restoration, mangrove protection, and natural flood defences to reduce vulnerability to flooding and enhance resilience to climate change impacts. Employ, integrate, and deploy psychosocial aid workers and other professionals through both federal and state emergency management agencies. Additionally, training town planners at local government offices (area planning authorities) on disaster emergency response will be crucial for effective community enlightenment programs, data collection, and planning by emergency management agencies. Architects should also be trained to develop vernacular architecture for emergency flood mitigation, ensuring that building designs are adapted to local conditions and can effectively withstand flood events.

iii. **Coastal Zone Management**

Develop coastal zone management plans to address coastal erosion, sea-level rise, and coastal hazards. Implement shoreline stabilization measures, dune restoration projects, and mangrove rehabilitation initiatives to protect coastal communities, infrastructure, and ecosystems from erosion, storm surges, and saltwater intrusion.

iv. **Integrated Water Management**

There is no public water supply in the study locations. There is need to adopt integrated water management strategies that promote sustainable water use, protect water quality, and enhance aquatic ecosystems. Implement watershed management approaches, rainwater harvesting systems, and wastewater recycling programs to conserve water resources, reduce pollution, and improve resilience to water-related challenges.

v. **Climate-Responsive Design**

Incorporate climate-responsive design principles into urban infrastructure and buildings. Design resilient infrastructure, energy-efficient buildings, and green spaces that can withstand extreme weather events, minimize carbon footprints, and enhance urban livability.

vi. **Community-Based Planning**

Engage local communities, indigenous peoples, and marginalized groups in participatory planning processes. Ensure their perspectives, knowledge, and needs are integrated into urban development plans. Foster collaboration, social cohesion, and empowerment through community-driven projects and inclusive decision-making mechanisms.

vii. **Sustainable Transportation**

Promote sustainable transportation options such as public transit and non-motorized transport. The water channels should be utilized as inland water ways. They asked when electric vehicles will be used in Yenagoa Nigeria to reduce traffic congestion, air pollution, and carbon emissions as it is the global trend now. Develop integrated transport systems, pedestrianfriendly streetscapes, and cycling infrastructure to enhance mobility, accessibility, and environmental quality.

viii. **Green Infrastructure Development**

Invest in green infrastructure projects such as parks, green roofs, and urban forests to enhance biodiversity, mitigate urban heat island effects, and improve air quality. The concept of the Hamilton gardens is a good one but there is need to prioritize the preservation and restoration of natural habitats, green spaces, and ecological corridors to create resilient and sustainable urban environments. The Ox-bow lake area can be a unique tourist attraction site.

Extracts from Literature in Support of Sustainable Urban Planning Strategies

i. **Green Infrastructure:** Green infrastructure, encompassing parks, green roofs, urban forests, and wetlands, plays a vital role in enhancing environmental resilience (PamukcuAlbers,Ugolini, La Rosa, Gr?dinaru, Azevedo & Wu, 2021). Integration of green infrastructure into urban planning enhance environmental resilience and thus mitigates flooding, reduces urban heat island effects, improves air and water quality, and preserves biodiversity (Staddon, Ward, De Vito, Zuniga-Teran, Gerlak, Schoeman & Booth, 2018; Varg60as-Hernández & Zdunek-Wielgo?aska, 2021).

ii. **Low-Impact Development**: Low-Impact Development (LID) is an approach to land development and stormwater management that aims to mimic natural hydrological processes to reduce the impact of urbanization on the environment. LID practices focus on managing stormwater runoff at its source through various techniques such as permeable pavements, green roofs, rain gardens, and bioretention basins (Dietz, 2007; Zahmatkesh, Burian, Karamouz, Tavakol-Davani & Goharian, 2015). These strategies enhance environmental resilience by improving stormwater management and reducing the risk of flooding and water pollution (Pour, Abd Wahab, Shahid, Asaduzzaman & Dewan, 2020; Mattos, Oliveira, De Souza Bruno, Oliveira, Vasconcelos & Lucas, 2021).

iii. **Climate-Resilient Design:** Incorporating climate-resilient design principles into urban infrastructure and buildings can enhance their ability to withstand extreme weather events, sea-level rise, and other climate-related hazards. Such designs reduce vulnerability and enhance environmental resilience in the face of climate-related hazards (Henstra, 2012; Adams, Yoon & DeFlorio, 2017).

iv. **Sustainable Transportation:** Promotion of sustainable transportation options, such as public transit, cycling, and walking, offers multiple benefits for environmental resilience (Tumlin, 2012; Gordon, 2023). These options reduce traffic congestion, air pollution, and greenhouse gas emissions while improving air quality, public health, and urban livability (Patil, 2021).

v. **Ecosystem-Based Adaptation:** Ecosystem-based adaptation measures, including mangrove restoration, shoreline stabilization, and coastal protection, contribute to environmental resilience by preserving natural habitats and buffering against storm surges (Chong, 2014). These measures support biodiversity conservation and enhance resilience to coastal hazards (McVittie, Cole, Wreford, Sgobbi & Yordi, 2018; Mustafa Saroar, Mahbubur Rahman, Bahauddin & Abdur Rahaman, 2019). Implementing ecosystembased adaptation measures will enhance environmental resilience by preserving natural habitats, buffering against storm surges, and supporting biodiversity conservation in Yenagoa City.

vi. **Community Engagement and Capacity Building:** Community engagement and capacity building are integral to promoting environmental resilience. Engaging local communities in decision-making processes, raising awareness about environmental issues, and building local capacity for sustainable urban development foster social cohesion, resilience, and ownership of environmental initiatives (Berkes & Ross, 2013; Ruiz-Mallén, Satorras, March & Baró, 2022).

vii. **Green Economy and Innovation:** Promotion of green economy initiatives, such as renewable energy development, eco-tourism, and sustainable agriculture, offers economic opportunities

while enhancing environmental resilience in Yenagoa city. These initiatives stimulate economic growth, create jobs, and contribute to a more sustainable urban environment (Hassanein Muhammad, 2022; ????? & ???????, 2023).

viii. **Policy and Planning Integration:** Integration of environmental considerations into urban planning policies and decision-making processes is essential for mainstreaming sustainability principles (Friend, Jarvie, Reed, Sutarto, Thinphanga & Toan, 2014). Policy and planning integration enhance coordination among stakeholders and promote holistic approaches to sustainable urban development, thereby enhancing environmental resilience (Sharifi & Yamagata, 2018; Davidson, Nguyen, Beilin & Briggs, 2019).

By leveraging and implementing these integrated and participatory strategies to sustainable urban development, Yenagoa City can enhance its environmental resilience, adapt to future challenges, and create a more livable and sustainable urban environment for current and future generations.

Conclusion

This study provides a comprehensive analysis of the environmental implications of rapid urban growth, environmental challenges and recommended strategies associated with rapid urbanization in Yenagoa City. Environmental implications span various themes, including deforestation and loss of green spaces, wetland conversion and degradation, air pollution, water pollution, loss of biodiversity, increased waste generation, infrastructure strain, land degradation, slum and squatter settlement formation, flooding, and urban heat island effect. Key informants identified 39 challenges associated with rapid urbanization, such as environmental damage, higher energy demand, exacerbated air pollution, respiratory illnesses, cardiovascular diseases, environmental pollution, health hazards, resource depletion, waterborne diseases, ecosystem damage, water scarcity, ecosystem imbalance, economic losses, cultural impact, climate change, soil erosion, habitat loss, service disruptions, and reduced quality of life.

However, the study did not only highlight challenges but also outlines a pathway toward a more sustainable future for Yenagoa. Strategies such as integrated planning, green infrastructure development, and community engagement offer a roadmap for balancing urban growth with environmental responsibility. Tailored strategies, including ecosystem-based planning and sustainable urban planning approaches, provide actionable steps specific to Yenagoa's unique challenges.

By leveraging insights from field surveys, interviews with key informants, and existing literature, and fostering collaboration among stakeholders (including government, urban planners, architects, engineers, community leaders, and environmental organizations), Yenagoa can envision a future where urbanization drives sustainable development rather than environmental degradation. Achieving this future requires a commitment to integrated and participatory approaches that ensure growth is harmonized with environmental stewardship and social equity. This study serves as a call to action, encouraging Yenagoa to embrace transformative urban development practices that will benefit current and future generations alike.

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Impact of Oil and Gas Activities on Vegetation Abundance, Growth and Development in Etche, Rivers State

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Abstract

The study evaluated the effects of gas flaring on vegetation abundance, growth and development in Etche, Rivers State. Four communities (Umuebulu, Umuechem, Odagwa and Ndashi) in Etche, Rivers State were purposively selected. Four transects were established in each of the sampling site. The quadrant size was further gridded into 10 m2 to subdivide the sampled area from which the gridded cells were randomly sampled. On each transects, five quadrants were laid at the interval of 50m, 100m, 150m, 200m and 250m on both side of the transect. Data on plant species density were counted on each quadrant and recorded. To ascertain the farmers' perception of gas flaring impacts on crop growth and vegetation, a well-structured questionnaire was distributed to 400 farmers purposively sampled within the flare site. Results revealed that vegetation density were generally higher in the control site than the flare site. Research findings also revealed a statistically significant difference in the vegetation of the flare site and the control site. It was also revealed from the analysis of farmers' perception of gas flaring impacts on crop growth that gas flaring inhibits crop growth and development and was partly responsible for the yellowing of leaves and stems near flare sites. The study recommends the enactment of greenhouse emission regulations that monitor the gas being flared by the oil companies.

Keywords: Oil and Gas Activities, Gas Flaring, Impacts, Vegetation Abundance

Introduction

Oil production deploys the burning of hydrocarbon gases. The flaring off of natural or associated gas is done as a by-product of the drilling of crude oil from reservoirs in which oil and gas are mixed. A higher percent of the gases is being flared, resulting in pollution of the area (Olisemauche & Avwerosuoghene, 2015). The Niger Delta mangrove and rainforest belt (where the study location lies) is one of the most fragile ecosystems in the world. It is among the most oil- impacted and polluted region in the world (Raji & Abejide, 2013). Although, natural gas is an important source of energy to man, its extraction has impacted negatively on the environment. Flaring is adopted during the process of petroleum refining and chemical processing for safe disposal of waste gases, process upsets, plant start-up or shut-down and process emergencies. Flaring is a high-temperature oxidation process used to burn combustible components, mostly hydrocarbons, of waste gases from industrial operations (Adole, 2011).

Gas flaring is a major source of greenhouse gases (GHG) contributing to global warming which could accelerate the problem of climatic change and harsh living conditions on earth, if not checked. Flaring releases carbon dioxide and methane, the two major greenhouse gases. Gas flaring has negative effects on the immediate environment, particularly on vegetation growth and wildlife (Aghalino, 2009). As the majority of the inhabitants in the Niger Delta region are farmers, the impacts of gas flaring are putting livelihood at great risks. Nzeadibe et al. (2011), also argue that the changes in the rainfall patterns as a result of the burning of natural gas have affected agriculture and thereby livelihoods in the region. The gas flared by the oil companies in these communities' during oil and gas production has devastated a substantial part of the vegetation and communal farmlands (Ukala, 2010).

Moreso, previous researches have also revealed that the endpoint of this unchecked emission of gases is the release of millions of tons of carbon dioxide and methane which means that these oilfields

contribute to global warming, threaten biodiversity including vegetation and wildlife species (Audu, 2013). In addition, there is a correlation between gas flaring and vegetation growth (Odjugo & Osemwenkhae, 2009). Scholars like Abdulkareem et al. (2009); Orimoogunje et al. (2010) have attempted to address the perennial problems associated with the causes of gas flaring and oil spills. However, a majority of these studies concentrated on gas flaring impacts on the microclimate, soil physico-chemical properties and biodiversity composition. There is scarcity of literature on gas flaring impacts on vegetation abundance, growth and development. Vegetation loss which is amongst the environmental challenges of gas flaring is not peculiar to the study area alone but remains a global challenge. However, the consequences of environmental pollution have taken a toll on Etche. The study area has witnessed a steady decline in vegetation, biodiversity and ecological resources, which are the main sources of their income and the people's mode of survival (Chiaka & Aiyeloja, 2013). It has therefore become imperative to undertake a study of this nature to investigate fully the effects of gas flaring on vegetation abundance, growth and development in selected parts of Etche, Rivers State.

Materials and Methods

The study area, Etche is located between latitude 4030l-5040lN and longitude 6040l-7020lE (Figure 1).

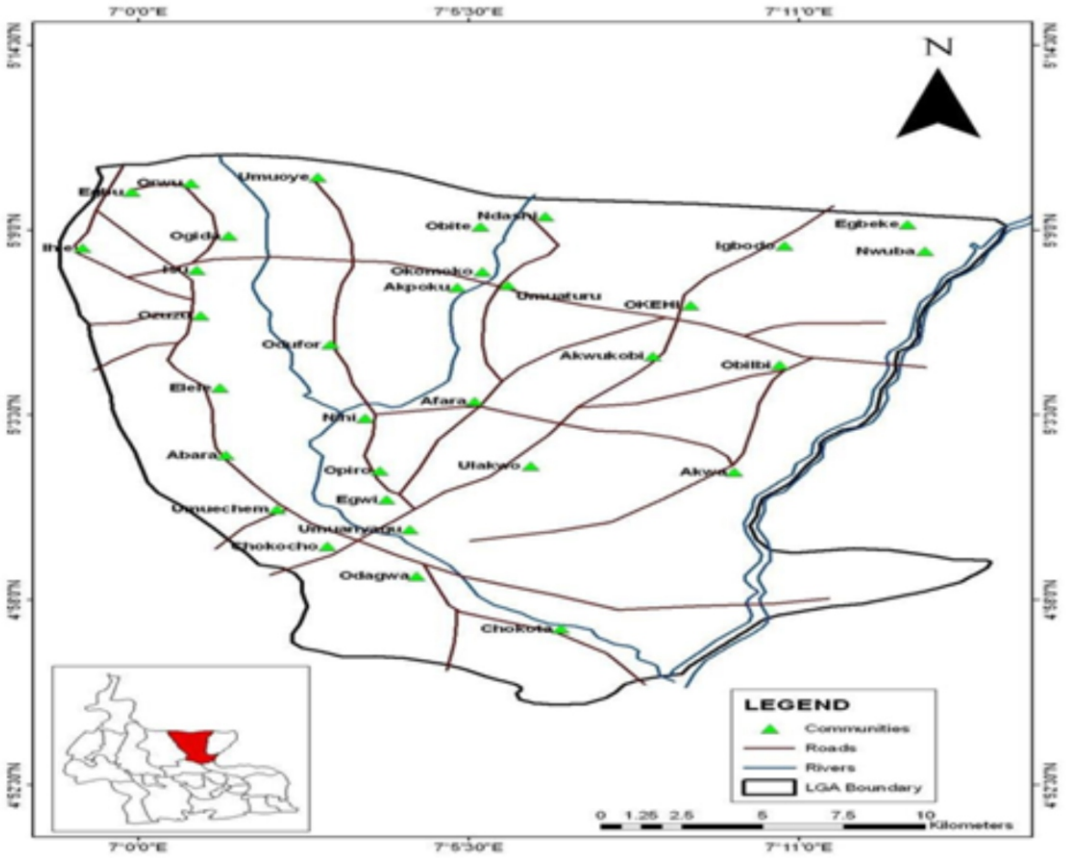

Figure 1: Map of Etche Showing Communities

The target population of interest comprises of communities in close proximity of the selected gas flaring locations in Etche local government area of Rivers State which includes Umuebulu, Umuechem and Odagwa.

Table 1: Population of Selected Communities

S/No	Selected Gas Flare Communities	1991 Census Population	2024 Projected Population
1.	Umuebulu	4,562	14,008
2.	Umuechem	4,593	14,103
3.	Odagwa	6,069	18,636
	Total	**15,224**	**46,747**

Source: National Population Commission, 1991

Due to the large sample size, the research employed the Taro Yamene (Yamene, 1973), formula so as to reduce the sample size to a manageable size of 400 respondents as shown below. The formula is expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

Where

n = sample size required

N = total population

1 = constant

e = $(0.05)^2$ error margin

$$n = \frac{46,747}{1 + 46,747(0.05)^2}$$

n = 396.6 (Aprox. 400).

Therefore, the sample size of this research is 400.

The purposive sampling technique was deployed in selecting the rural farmers within the flare site for administration of the research questionnaire. The data for the study was derived from the secondary and primary sources. Secondary data shall be obtained from related research reports, journals, textbooks and magazines. The primary data was obtained from the field analysis. Ndashi (control site), Umuebulu, Umuechem and Odagwa communities were purposively chosen for this study. A reconnaissance survey was carried out to identify the flare site for easy transect and quadrant laying. A cutlass was used to open up the transect and the tape was used to determine the distance of the quadrant. The quadrants were established at 50m interval along the transect. Purposive sampling technique was adopted in choosing the direction of transect. Four transects were established in each of the sampling site (that is, the flare site and the control site).

The quadrant size was further gridded into 10 m2 by measuring dimensions of 10m x 10m with a measuring tape and pegs to subdivide the sampled area from which the gridded cells were randomly sampled. The procedure was repeated for all the sampled quadrants based on the interval of 50 m while a quadrant of 50m x 50m was gridded into 10 m2. On each transects, five quadrants were laid at the interval of 50m. From the flare site, the first quadrant at the interval of 50 m, the second at 100 m, third at 150 m, and so on to the fifth at 250 m on both side of the transect respectively. Data on vegetation

abundance were counted on each quadrant and recorded. The mean values in each quadrant were obtained. To ascertain the farmers' perception of gas flaring impacts on vegetation abundance, growth and development, a well-structured questionnaire was distributed to 400 farmers purposively sampled within the flare site.

The study employed the use of statistical tools for the data analysis. Various statistical methods used in the Social Sciences for analysis such as tables were deployed. In this research, the paired t' test statistics was employed to analyze the means difference in vegetation abundance between the flare site and the control site.

Presentation of Results

Objective 1: Investigate the Vegetation Abundance in a Selected Flare Site and Control Site in Etche, Rivers State

Table 2 reveals the measurement of vegetation abundance in the selected flare and control site in Etche, Rivers State. Results revealed that the values of species density at 50m were 32 plant species for Umuebulu, 42 for Umuechem, 52 for Odagwa and 122 species density for Ndashi (control site). Plant species density at 100 m were 36 plant species for Umuebulu, 47 for Umuechem, 57 for Odagwa and 127 species density for Ndashi (control site). Plant species density at 150 m were 39 plant species for Umuebulu, 49 for Umuechem, 59 for Odagwa and 134 plant species density for Ndashi. Plant species density at 200 m were 42 plant species for Umuebulu, 52 for Umuechem, 60 for Odagwa and 138 plant species density for Ndashi. Plant species density at 250 m were 48 plant species for Umuebulu, 58 for Umuechem, 68 for Odagwa and 141 plant species density for Ndashi (control site).

Table 2: Vegetation Abundance in the Selected Flare and Control Site in Rivers State

S/No	Distance from Flare sites (m)	Plant Species Density at Umuebulu	Plant Species Density at Umuechem	Plant Species Density at Odagwa	Plant Species Density at Ndashi
1	50	32	42	52	122
2	100	36	47	57	127
3	150	39	49	59	134
4	200	42	52	60	138
5	250	48	58	68	141
	Total	**197**	**248**	**296**	**662**

Objective 2: Examine the Impact of Gas Flaring on Vegetation Abundance in Etche To examine the impact of gas flaring on vegetation abundance, the student t-test was employed to compare if there is a significant difference between the vegetation at a selected flare site and that of the control site. The student t-test is represented by the equation

$$\frac{x_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where S_1= Standard deviation of first set of values S_2= Standard deviation of second set of values n_1= Total number of values in the first set of values n_2= Total number of values in the second set of values x_1= Mean of first set of values x_2= Mean of second set of values
From table 2, Mean of vegetation abundance at Umuebulu = 39.4 Mean of vegetation abundance at Ndashi (Control site) = 132.4.
Standard deviation of Sample 1=5.48
Standard deviation of Sample 2= 7.00

$$t = \frac{39.4-132.4}{\sqrt{\frac{5.48}{5}+\frac{7.00}{5}}}$$

$$t = \frac{93}{1.58} \quad t = 60.4$$

H_0: There is no statistically significant difference in vegetation abundance between the flare site and control site in Etche.
H_1: There is a statistically significant difference in vegetation abundance between the flare site and control site in Etche.

$Df = n_1 + n_2 - 2 = 5+5-2 = 8$.

The table t-value at 95% probability level is 2.31 while the calculated t-value is 60.4. Since the calculated t-value is greater than the table t-value, the alternated hypothesis is accepted. This implies that there is a statistically significant difference in vegetation abundance between the selected flare site and control site in Etche. It can therefore be concluded that gas flaring had significant effect on vegetation of the study area.

Objective 3: Ascertain the Farmers' Perception of Gas Flaring Impacts on Crop Growth and Development This section examines farmers' perception of gas flaring impacts on crop growth in the flare site. This was achieved through administration of structured questionnaire to elicit response from the population of study.

Socio-Economic Characteristics of Respondents

Table 3 shows the socio-demographic characteristics of respondents. The distribution of sampled respondents from the questionnaires analyzed shows that 13.8% were within the ages of 18-28, 24.5% were within the ages of 29-39, 25% were within the ages of 40-50, 19.5% were within the ages of 51-60 and 17.3% were above 60 years. Furthermore, questionnaire analysis revealed that 48.5% of the respondents were males and 51.5% of the respondents were females. In the analysis of the marital status of respondents, it was revealed that 31.5% of the respondents were single and 55.8% were married. The percentages of divorced, widowed and separated respondents were 2.3%, 7.5% and 3% respectively. From the questionnaire analyzed, it shows that 22.8% of the respondents had no formal education. 45.5% had primary school education, 25% had secondary education and 6.8% had tertiary education.

Table 3: Socio-Demographic Characteristics of Respondents

Variables	Frequency(n=400)	Percentage (%)
Age (years)		
18-28	55	13.8
29-39	98	24.5
40-50	100	25
51-60	78	19.5
> 60	69	17.3
Gender		
Male	194	48.5
Female	206	51.5
Marital Status		
Single	126	31.5
Married	223	55.8
Separated	12	3
Divorced	9	2.3
Widowed	30	7.5
Level of education		
No formal education	91	22.8
Primary	182	45.5
Secondary	100	25
Tertiary	27	6.8

Perceived Impacts of Oil and Gas Activities on Vegetation Growth

Figure 2 below reveals that 122 respondents representing 30.5% of the total sample population strongly agreed that gas flaring has increased the incidence of crop diseases and pest, 250 representing 62.5% agreed, 18 respondents representing 4.5% disagreed and 10 respondents representing 2.5% strongly disagreed. This shows that a vast majority of the respondents were in agreement that gas flaring has increased the incidence of crop diseases and pest.

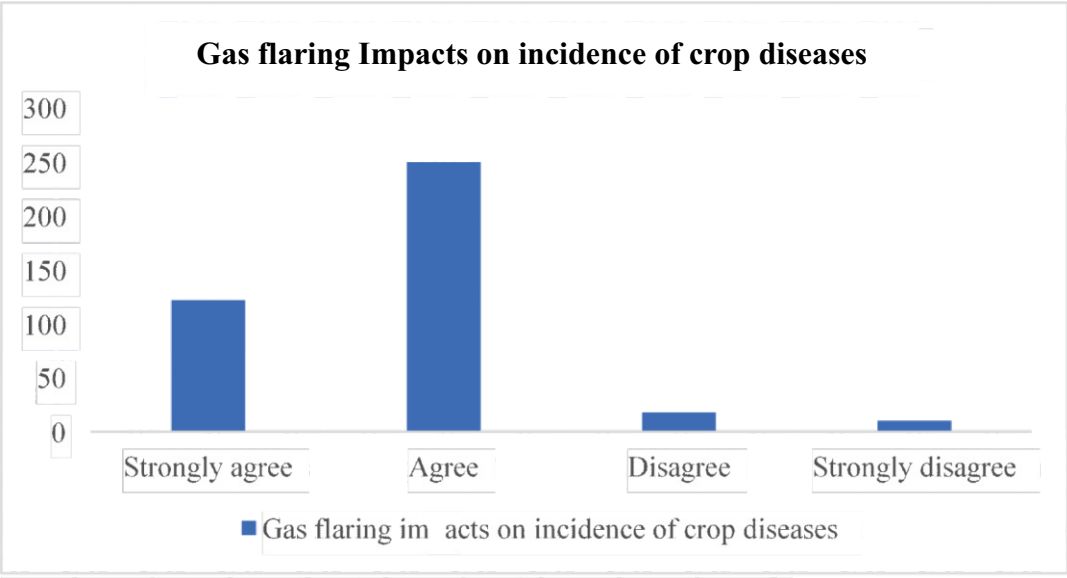

Figure 2: Gas flaring Impacts on Crop Diseases

Figure 3 below reveals that 116 respondents representing 29% of the total sample population strongly agreed that gas flaring produces excessive heat which inhibits vegetation growth and development, 184 representing 46% agreed, 62 respondents representing 15.5% disagreed and 38 respondents representing 9.5% strongly disagreed. This shows that a vast majority of the respondents were in agreement that gas flaring produces excessive heat which inhibits vegetation growth and development.

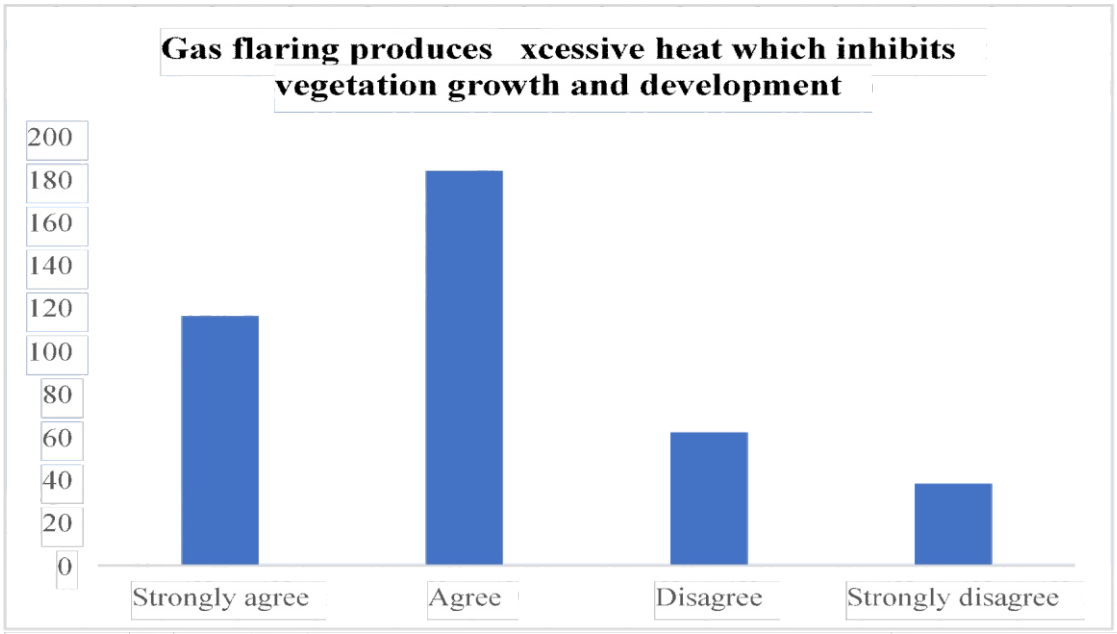

Figure 3: Gas Flaring Produces Excessive Heat Which Inhibits

Vegetation Growth and Development

Figure 4 below reveals that 169 respondents representing 42.3% of the total sample population strongly agreed that gas flaring produces acid rain which damages crops and vegetation, 151 representing 37.8% agreed, 46 respondents representing 11.5% disagreed and 34 respondents representing 8.5% strongly disagreed. This shows that a vast majority of the respondents were in agreement that gas flaring produces acid rain which damages crops and vegetation excessive heat which inhibits vegetation growth and development

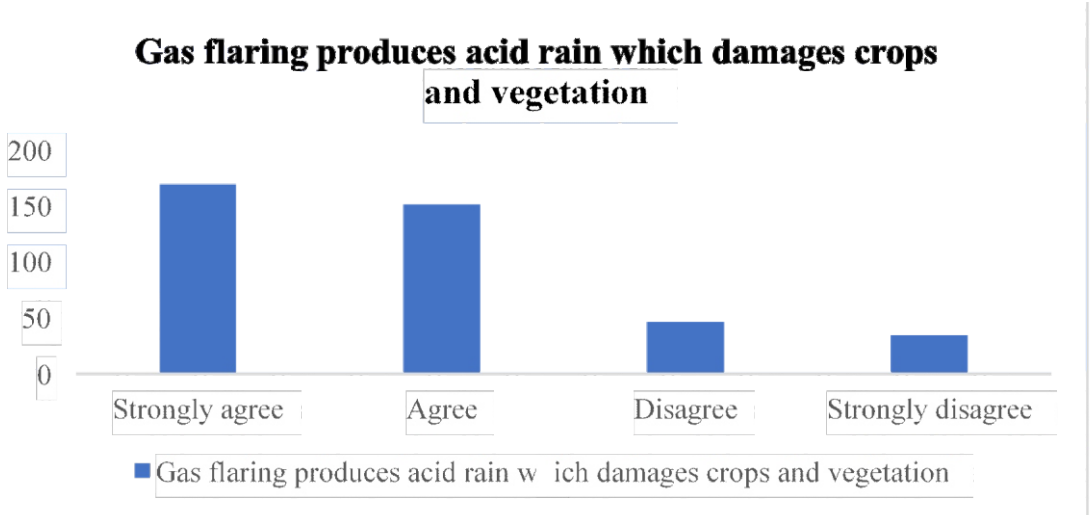

Figure 4: Gas Flaring Produces Acid Rain Which Damages Crops and Vegetation

Figure 5 below reveals that 108 respondents representing 27% of the total sample population strongly agreed that the leaves and stems of plants near flare sites have decreased in dimension, 201 representing 50.3% agreed, 64 respondents representing 16% disagreed and 27 respondents representing 6.8% strongly disagreed. This shows that a vast majority of the respondents were in agreement that the leaves and stems of plants near flare sites have decreased in dimension.

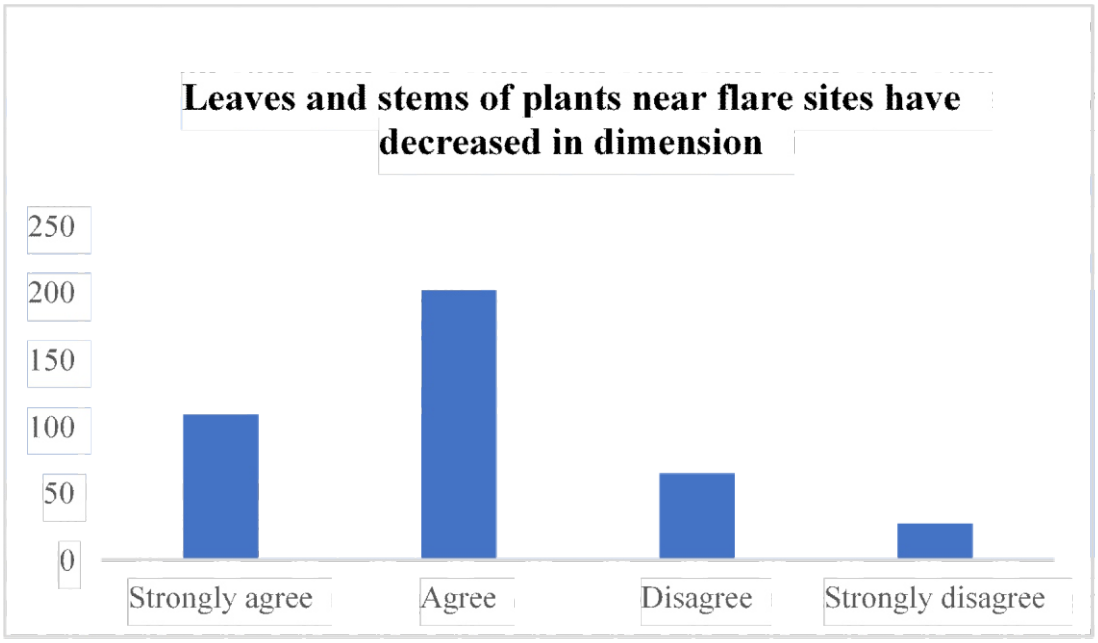

Figure 5: Leaves and Stems of Plants Near Flare Sites Have Decreased in Dimension

Figure 6 below reveals that 96 respondents representing 24% of the total sample population strongly agreed that gas flaring is partially responsible for the yellowing of leaves and stems near flare sites, 197 representing 49.3% agreed, 74 respondents representing 18.5% disagreed and 33 respondents representing 8.3% strongly disagreed. This shows that a vast majority of the respondents were in agreement that gas flaring is partially responsible for the yellowing of leaves and stems near flare sites.

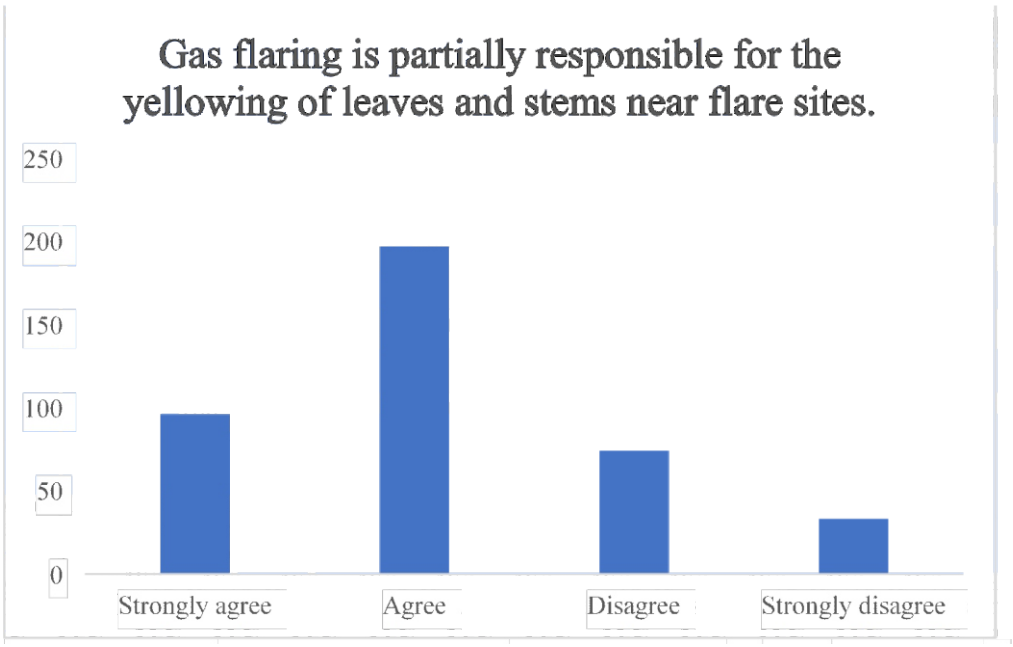

Figure 6: Gas Flaring is partially Responsible for th Yellowing of Leaves and Stems Near Flare Sites

Figure 7 below reveals that 131 respondents representing 32.8% of the total sample population strongly agreed that gas flaring affects biodiversity leading to biodiversity decline, 164 representing 41% agreed, 82 respondents representing 20.5% disagreed and 23 respondents representing 5.8% strongly disagreed. This shows that a vast majority of the respondents were in agreement that gas flaring affects biodiversity leading to biodiversity decline.

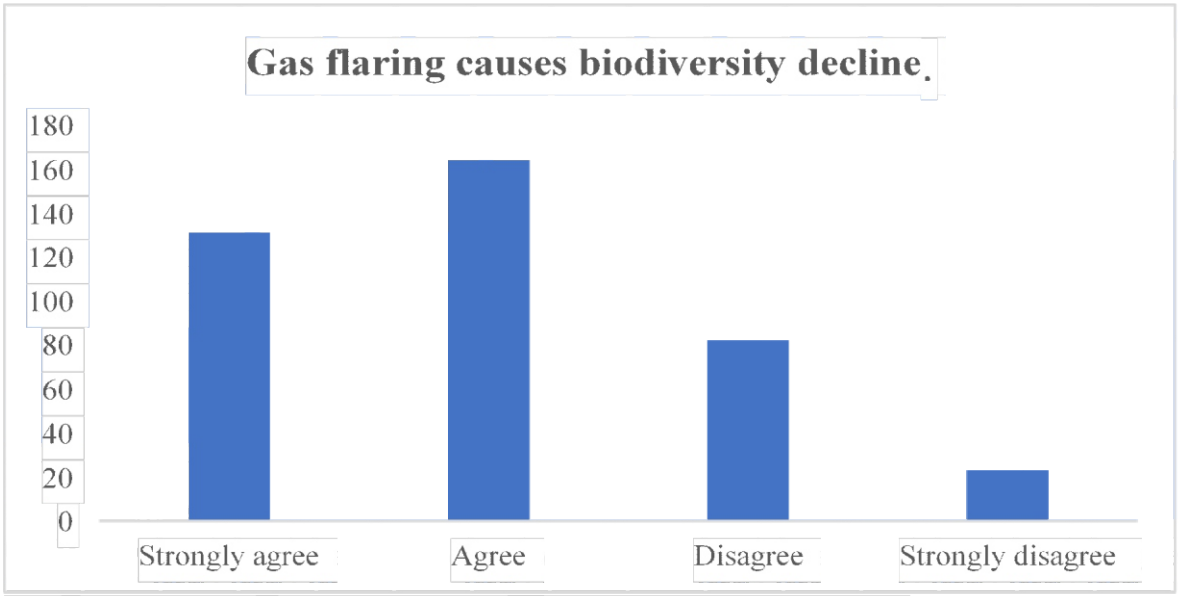

Figure 7: Gas Flaring Cause Biodiversity Decline

Figure 8 below reveals that 142 respondents representing 35.5% of the total sample population strongly agreed that gas flaring causes soil acidification which reduces soil fertility, 167 representing 41.8% agreed, 73 respondents representing 18.3% disagreed and 18 respondents representing 4.5% strongly disagreed. This shows that a vast majority of the respondents were in agreement that gas flaring causes soil acidification which reduces soil fertility.

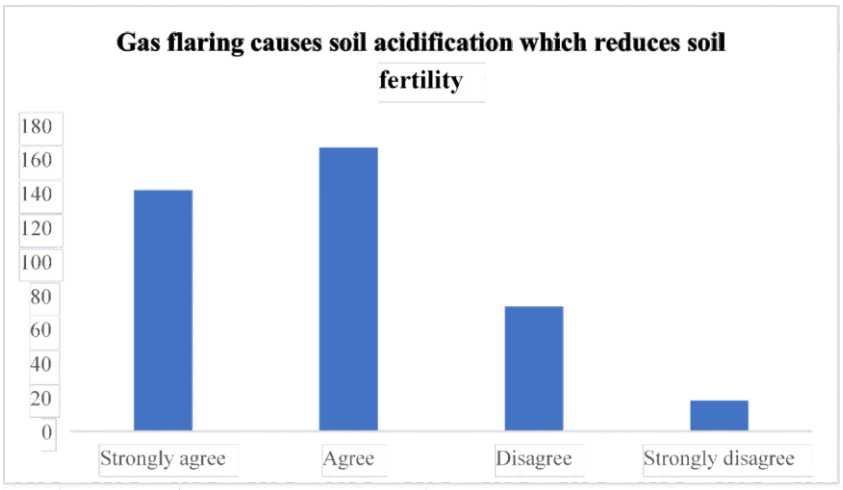

Figure 8: Gas Flaring Causes Soil Acidification Which Reduces Soil Fertility

Discussions on Findings

The finding of this research revealed that vegetation abundance and density was higher in the control site than the flare site. This research finding is in agreement with the findings of Bakpo & Emejuru (2019) who noted that the flare sites had a lesser vegetation density which may be attributed to crop retardation in the flare sites.

The research findings revealed a statistically significant difference in the vegetation of the flare site and the control site. This research finding is in agreement to the findings of Abua & Ashua (2015) who in their separate study revealed a statistically significant difference in vegetation density between the flare site and the control site.

It was also revealed from the analysis of farmers' perception of gas flaring impacts on vegetation growth that gas flaring inhibits vegetation growth and development. This research finding is in tandem to the research findings of Ozabor & Obisesan (2015) who revealed in their separate research that gas flaring significantly affected growth of vegetation and various crops.

Research findings revealed that the leaves and stems of plants near flare sites have decreased in dimension. Research findings also revealed that gas flaring causes soil acidification which reduces soil fertility. It was also revealed that gas flaring was partly responsible for the yellowing of leaves and stems near flare sites in agreement to the finding of Seiyaboh & Izah (2017) who revealed in their study discovered that that chlorosis, abscission and yellowing of leaves, wilting of the leaf tips and accelerated senescence were observed at the flare sites.

Conclusion

The assessment of the effect of gas flaring on vegetation abundance and development revealed that gas flaring has greater impact on plant species closer to the flare site at 50m than at other zones. More plant species were discovered as distance from the flare site increases. The study also revealed that vegetation density was greater in the control site than in the flare site. This implies that gas flaring impacted on the vegetation of the study area. The study recommends the enactment of greenhouse emission regulations that monitor the gas being flared by the oil and gas companies.

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Difficulties of Project Management in Public Property Development Projects in the Niger Delta Region

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Abstract

Public projects have huge differences from other types of projects, which these differences have an implication on the existing methods used in managing these projects. Often times, in the Niger Delta region, the development of public projects are faced with some project management difficulties. At the same time there is evidence of uncompleted projects, abandonment of projects, time overrun, and cost overrun by the government in the Niger Delta. These have become a continuous challenge faced by the developers, populace and government, as stated in previous studies. Therefore, the aim of the study is to examine these difficulties that arise during the development of public projects in the Niger Delta region. However, focus was given to government initiated funded projects in the Niger Delta region. The research has taken an interpretative philosophy with multiple case study approach of explanatory and exploratory case studies in project management of public property development. Quantitative and qualitative data were collected using ten (10Nr) semi-structured interviews, and one hundred and thirty (130Nr) questionnaires. The data was analysed using Statistical Package of Social Science (SPSS) version 2021. Data's were interpreted using descriptive statistics and relative important index (RII), and the result were represented in table. Further, the study highlighted eleven difficulties of project management in public property development. The study further recommends that the identification of nine difficulties of project management would improve the delivery of public projects and sustain the contemporary public property development projects.

Keywords: Difficulties of Public Projects, Project Management, Public Property Development

Introduction

Property Development involves the transformation of land or buildings for specific purposes, such as residential, commercial or industrial uses, for which factors including zoning regulations, environmental impact, and community needs to determine the best use for a piece of land must be considered. Public properties are those properties that are owned by the government or any of her ministries, departments or agencies from any tier (Federal, State, and Local Government) (Amoah, Berbegal and Marmon 2022). The goal of the development of public property development projects is to achieve social benefit because it is a non-profit making status. The activity of public development project involves planning, design, finance, and the assembling of a team to manage the project to completion stage which is the basic function of project management (Folger, 2024). Effective project management plays a crucial role in the successful development of public property development project which Nigeria have made some progress in project management, such as government commitment, increased investment, capacity building, and technology adoption, but still they are faced with several difficulties (GIPM, 2023).

The Niger Delta region of Nigeria is a coastal environment located in the Atlantic coast of southern Nigeria where a river divides it into numerous tributaries (Ike & Emaziye, 2012). The Nigeria's Niger Delta region by this description would have been the fan shaped area covering the three states of Bayelsa, Delta and Rivers alone as the geographic Niger Delta, but for the purpose of revenue sharing,

the region is said to be made up of nine oil producing states upon which ecological funds are raised for public projects (Akujuru, 2014). The population of the region is estimated at 42.65 million people (Osigwe, Okungbowa & Rafiu, 2023).

Figure 1: Map of the Niger Delta Region of Nigeria
Source: Niger Delta Home page, 2013

Statement of the Problem

The Niger Delta region is noted to have had a definitely visible climate change problem amidst its natural equatorial climatic condition dominated by mangroves and tropical swampy rainforest, with heavy rainfall almost throughout the year, having a maximum output of 3785 mm at Brass (Nigerian Met 2007), high monthly temperature of 26.670C, and high relative monthly humidity reaching 90%, (Ituen and Alonge, 2009). There exists myriad of physical geographical problems as identified to include: flooding, siltation, erosion and submergence of developed areas as well as pervasive environmental degradation, which all are capable of impeding the process of infrastructural development and has officially led to the region being tagged 'difficult terrain (Ogele, 2022).

Nevertheless, there has been significant underdevelopment of public property development projects which is blamed on the placement of affairs in the hands of government personnel who are interested in misappropriation and wasteful spending of huge revenue from oil (Isidiho and Sabran, 2015). It is observed that many government projects are prolonged for years, failing to meet the projects objectives, wasting tax payers' money or they are shortly terminated in the midst of the planning or implementation stage (specifically in the Niger Delta region of Nigeria). This is caused by the environments in which the projects are developed, leading to abandonment of projects, delivery of low-quality projects, and sometimes uncompleted projects. This research therefor investigates these reoccurring barriers that are encountered during the development of public project. Therefore, the aim and objective of the study is to identify the difficulties of project management in public property development projects I the Niger Delta Region.

Literature Review

Public Property Development Projects

Project is defined as a set of principles, methods, tools, and techniques for the effective management of work in a specific and unique Organizational environment (Waldt, 2015). Projects consume resources and these resources are in form of Time, Money, Materials and Labour, which the aim is to oversee them

and apply them effectively as possible (Waldt, 2015). Public property development projects are projects funded by government, which is meant is owned and operated by the government (Kassel, 2010). Project management Institute defined public projects as projects that are implemented by the decision of the central level government institution (Gasik, 2022). Public property development projects include: transportation projects, educational projects, recreational projects, residential/accommodation projects, healthcare projects, telecommunication projects, agricultural projects, water resources projects ad electricity projects.

Project Management in Public Development Projects

Project management is a complex job that requires knowledge, skills, and capabilities from many areas which are executed in the environment of its organisation and many of the activities carried out is as a result of the arrangement adopted for all organisation activities (Gasik, 2022). Waldt, (2015) defined project management as the essential for a successful development; also, he mentioned that managing a project is establishing a definable, measurable project outcome that relate to a government department's strategic goal, ensuring that project outputs are attained by utilizing the project team, and managing the interrelationship between all stakeholders and roleplayers. Westland (2022) described project management as a highly complex field and pointed out eight key principles of which are believed to simplify the development process and they include: Definition a project organization structure; Setting clear project goals and objectives; Creating a communication plan; Defining roles and responsibilities; Creating a risk management plan; Setting a project performance baseline; Creating a change management plan and Focus on value delivery.

Barriers of Project Management in Public Property Development Projects

It is seen that Niger Delta Region have no institutional framework or regulatory bodies that can assess, review and control current and future skill requirement for property development project management system (Odusami, Iyagba & Omirim, 2003; Nwachukwu & Emoh 2011; Kissi & Ansah 2013). However, Abbasi, Al-mham and Sukhoo (2004) as cited by Ogunde, Olaolu, Afolabi, Owolabi and Ojelbi, (2017), emphasized that difficulties of project management are shortage of skilled staff, difficult economy and social condition, Weak political institution, deeply rotted cultural and religious beliefs. Also, Caliste (2012) outlined the following as difficulties of project management in public projects and they are poor project definition, misunderstanding between project goals and objective. According to Salau and Salawu (2014) outline eight difficulties encountered in public projects and they include: Bureaucratic bottle neck leading to unnecessary delay, increase in cost of project, granting contract to incompetent persons, nonkeeping of proper account books, and lackadaisical activities of people towards government projects. However, in view of this the difficulties of public project management include the following which was drawn from the literature review.

Bureaucratic bottle neck: Bureaucracy bottleneck is defined as a complicate official system which caused delay in one stage of a development process that makes particular process take longer to accomplish (Reed, 2005).

Poor project definition: project definition is the foundation of any project for all future decisions and it act as a base for all future decisions, changes and work involved in project execution (Eduarado, 2022).

Misunderstanding between project goals and objective: project goals are the end result a developer wishes to achieve as a long-term gain, whereas project objective is a concrete task that need to be executed in order to attain an end results; they are more concrete and specific which cover short to mid-term achievements that usually need to be implemented on a daily basis (Cohen, 2022).

Increase in cost of project: increase in cost of project is an unexpected change in the project budget that ends up increasing the total cost and this happen due to economic factors that occur due to inaccuracies in project budget or scope; technical reasons too is another factor which is due to erroneous estimates or incorrect data gathering and psychological causes which is due to the presence of scope creep or any decrease in project commitment levels (Yvvika, 2022).

Corruptions: Corruption takes the form of public servants taking money or favors in exchange for services or politicians misusing public money or granting public projects to their sponsors, friends and families. Obayeu, (2007) defined corruption as an effort to secure wealth or power through illegal means for private gain at public expenses or a misuse of public power for private benefit.

Granting contract to incompetent persons: an incompetent developer is one that is poor communicator, indecisive and cannot inspire a shared vision, makes poor decisions, lack team building skills, lacks integrity, lacks project management skills, and lacks problem solving skills (Ondiek, 2015).

Non-keeping of proper account books and other records: Record keeping helps property developer efficiently and productive, because without a thorough documentation of records there will be miscommunication and data loss (Hilinski, 2017). Poor recording leads to problems with rippling effect and it can be very serious when records are needed for budgets and pay roll (Hilinski, 2017).

Lackadaisical attitude: it is well known that incoming governments make no effort in keeping any existing projects that was carried out by the previous government rather they abandon the project and embrace on new ones with a view to drain the little resources of the state (Adeyemi an Omotehinshe, 2007).

Economy and social condition: social condition affects development by preventing clearances and the movement of men, materials and equipment (Shabir, Aftab, Nafees, Zubair and Rawal, 2023). Public development is dependent on healthy economy and there are many economic factors that affect the implementation of public projects such as interest rates, taxes, laws and legislation, jobs and political activities.

Weak political institution: Political institutions are the organisations in a government that create, enforce and apply laws (Alistair, 2020). They often mediate conflict, make policy on the economy and social systems and otherwise provide representation for the population which Nigerians political institution is weak because they do not fulfill their purposes.

Deeply rotted cultural and religious beliefs: Culture and religion is a very powerful force and is multidimensional; a person placed in different organisations would act differently because a strong embedded culture creates social ideas that guide individual behavior (Muzinda, 2017); (Suda, 2007).

Methodology

Efforts to identify the difficulties of project management in public property development projects were discussed in the literature review. However, in gathering information the study adopts quantitative and qualitative approach using case study design which allows the use of mixed method approach of data collection sources and analytical techniques. Based on the quantitative approach, a five-point likert scale questionnaire survey design was designed and self-delivered to the participants. This was adopted because it helps to cover a wide geographical targeted population, assures respondent of privacy, it is timing, less expensive, less of interaction and there is no possibility of interviewer bias

(Creswell & Plano Clark, 2011). The questionnaire sample was drawn from the total estimated staff members' such as quantity surveyors, estate surveyors, engineers, project managers, architects from the ministries, departments and agencies associated with public property development projects in each of the nine Niger Delta states. Since the total sample size of the study was largely unknown and the entire domain was large, a stratified simple random sampling was conducted with an assumed population of 200 to calculate the finite population using Taro's Yammane formula (Ihuah, 2015). This was determined and the targeted population size for questionnaire was 132 but 130 questionnaires were retrieved which represents 98.5% of the respondents' rate and 10 interviewees were sampled. Further, the data was analysed using statistical package for the social sciences version 2021, where data were interpreted using descriptive statistics and relative important index (RII), and the result were represented in tables.

Similarly, based on the qualitative approach, data was analysed by transcribing the data's after organising all relevant documents and visual information. However, the reason for transcribing of data is to get meaningful interpretation and to summarize voice records into words (Yin, 2009). Finally, the qualitative data supports the quantitative data; this was done by linking arguments and evidence. According to Seale (1999), questionnaire data fills the gaps in the knowledge which could not have been done with interview alone, hence, helping to provide more explanation to the findings of an interview.

Data Analysis/Findings and Discussion

This section deals with the presentation and analysis of data gathered from the field, where data collected are presented in forms appropriate for interpretation and understanding using the various analytical tools and text discussed in the previous section.

The data presentation involves the use of relative important index, for interpretation of result, the range of figures in Table 1, will be adopted in judging the strengths of the response within the whole research analysis (Pallant, 2013).

Table 1: Decision Rule Table for Judgment of Analysis

Range	Judgment
0.00 - 0.29	Very weak
0.30 - 0.39	Weak
0.40 - 0.59	Moderate
0.60 - 0.79	Strong
0.80 - 1.00	Very strong

Source: Pallant, 2013

Based on the literature review, questionnaire administration and interview conducted the Following theme emerged and discussed below also data for analysis were collected through questionnaire administration and interview, the following theme emerged from the result of the analysis and discussed below:

RII = (n1 + 2n2+3n3+4n4+5n5)/5N Where:
n1 = number of respondents that answers strongly disagree;
n2 = number of respondents that answered disagree;
n3 = number of respondents that answered neutral;
n4 = number of respondents that answered agree;
n5 = number of respondents that answered strongly agree;
N = total number of respondents = 130.

Table 2, outlined the result on the barriers of project management in public property development projects by the respondents. The Table showed that the respondents strongly agree that corruption (ranked 1st), bureaucratic bottleneck (ranked 2nd), economy/social condition (ranked 3rd) are the major barriers of project management in public property development projects. The result also showed that grant of contract to incompetent developer, misunderstanding between project gals and objective, poor project definition, weak political institution scored above 0.80 R.I. I score, the respondents strongly agree that they are barriers of project management n pubic property development project. Also, non-keeping of proper records, lackadaisical attitude and rooted cultural beliefs scored above 0.70 RII score, the respondents agreed that they are also barriers of project management public property development projects, except for increase in cost of project which scored above 0.40 R.I. I score

"…all these barriers of project management in public property development projects you mentioned are encountered during the development of public projects…" (Transcribed interview 2023)

"…the major barriers faced in public property development are corruption, bureaucratic bottle neck and the economy/social condition of the country. There is always an act of nepotism in awarding of contract and this has affected public project delivery, which eliminating this act is difficult as pubic projects is developed in a political environment..."

Table 2: Barriers of Project Management in Public Property Development Rank Based on Relative Importance Index (RII) Value

Barriers of project management in public property development	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	RII values	Ranking
Corruption	2	0	18	120	460	0.923	1st
Bureaucratic bottleneck	2	0	18	184	380	0.899	2nd
Economy/social condition	0	16	54	248	210	0.859	3rd
Grant of contract to incompetent developer	2	12	78	80	380	0.849	4th
Misunderstanding between project goals and objective	0	20	24	256	240	0.831	5th
Poor project definition	0	16	36	256	230	0.828	6th
Weak political institution	4	16	42	248	210	0.800	7th
Non-keeping of proper records	4	12	72	200	230	0.797	8th
Lackadaisical attitude	4	20	36	272	180	0.788	9th
Rooted cultural/religious beliefs	14	20	96	160	170	0.708	10th
Increase on cost of project	2	8	24	136	410	0.477	11th

Source: Field Survey, 2023

The study on the barriers of project management in public property development projects revealed that thier Property developers are faced with several barriers especially in the public sector and that these barriers affect the public property development process in the study area. However, from the analysis and result as shown in Table 2, the respondents agreed that corruption, bureaucratic bottleneck, economy/social condition were the major barriers of project management in public property development projects but that grant of contract to incompetent developer, misunderstanding between project goals and objectives, poor project definition, weak political institution, non-keeping of proper records, lackadaisical attitude, rooted cultural beliefs and increase on cost of project are also barriers of project management in public property development projects. This was in agreement with the study by Ogunde, Olaolu, Afolabi, Owolabi and Ojelbi, (2017); Caliste (2012); Salau and Salawu, (2014), who established that the following are barriers of project management in public property development projects. Therefore, the above eleven (11) barriers of project management encountered during the development of public property development projects are important for every public property developer to be aware of, during the development process.

Conclusion and Recommendations

The literature review on project management in public property development in the Niger Delta region shows that mass public projects are faced with several barriers during the development process, which these barriers tend to create problem of variation, delay in execution, and total abandonment of the project. This paper demonstrates that barriers of project management in public project are encountered during the development process and that they arise due to the political environment that the project is developed.

Subsequently, the research recommends that the eleven barriers of project management in public property development projects are important aspects that every developer should not neglect to watch out for, so as to improve the delivery of public projects and sustain the contemporary public property development projects so as to reduce waste of public fund in the hands of corrupt government and facilitate multiple developments in the region.

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Conceptual Cataloging of Risks in Property Development Process for Sustainable Residential Property Development in Port Harcourt Metropolis

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Abstract

Several records of property development projects failure in Port Harcourt metropolis are observed and this have led to significantly need to underscores the issues behind the recurring disaster in the city. Especially, in the specific context of residential property development processes risks and cataloging the risks into the three sustainability dimensions for better-quality property development. Therefore, the aim of the study is to identify and catalog (classify) the risks in the residential property development processes using the sustainable development dimensions of Environment, Economic and Social, for sustainable residential properties development in Port Harcourt Metropolis. The study adopted both quantitative and qualitative research approach in a case study research design with questionnaire and interview instruments adopted in the collection of information. A total number of eighty (80) questioners were sent to various professionals involved in residential property development while sixty (60) were retrieved representing a response rate of 75% and ten (10) interviewee were sampled to collaborate the quantitative information. Gathered data were analysed using descriptive statistical techniques in the Statistical Package for Social Sciences (SPSS) version 2021, as well as Relative Importance Index (RII) and the results were represented in tabular form. The findings of the study indicated that, there were twenty-six (26) types of risks in residential property development processes. Further, the finding revealed that twelve (12) were classified: under residential property development processes environmental risks; ten (10) under residential property development processes economic risks; and seven (7) under residential property development processes social risks. Again, the findings underscored that financial risks is most crucial as it appeared in all the dimensions whereas, site risks appeared only in Economic and Environmental risks. The study findings reflect that residential property decision makers and developers should consider these classifications early enough, so as to avert residential property development failures in Port Harcourt metropolis and enhance residential property development.

Keywords: Risks; Residential Property Development Processes; Residential Property Development
Processes Environment Risks; Residential Property Development Processes Economic Risks; Residential Property Development Processes Social Risks

Introduction

Risk has both negative and positive impact on residential property development projects but most times when it is mentioned it sends a negative signal to the receiver, although there have been several definitions by researchers on what is risk both in the negative and positive aspects (Wiegelmann, 2012). Risk is defined as a probability of more than one outcome, which when it occurs it has a positive or negative effect in an investment thereby causing development failure or success (Hillson, 2002). Also, risk is an occurrence that is experienced by a property developer, owner of a project which occurs during the development process. Risks do not naturally occur without any factors leading to it and these are the elements of sustainability which are political/social, environmental and economic (Prakash, Ambekar & Vishal, 2017).

The need for residential property development is significant as accommodation is the primary need of humans (Ihuah & Kakulu, 2016). Residential property development risks are negative or positive factors that arise during the execution stage that are likely to result to increase in the final cost, duration and quality of the development (Oladapo, Odeyinka & Akindele, 2006). Thus for residential property development to be sustainable, it must be delivered at the right time, marketed at the right time and with the right price (Gehner, 2008).

Over the years there has been progress in establishing the link between sustainability and property development which environmental, economic and social issues need to be addressed (Isaac, John & Daley, 2010). Sustainable development is defined in terms of Social, Economic and Environmental dimensions which are required in order for residential property development to be constructed successfully. However, these aspects of sustainability will help developers to understand which of those risks that occur during the development of residential properties are environmental, economic and social in nature which these forms the classification of risk.

However, in Port Harcourt metropolis, risk is seen to be a major factor in residential property development processes, which are tackled without the understanding of what these risks are and how they influence the development processes. Every residential property development process is associated with risk and there is need for these risks to be classified into the dimensions of sustainability so as to develop sustainable residential property. Therefore, the aim and objective of the study is to classify risks in residential property development processes in Port Harcourt metropolis into the sustainability dimensions for more understanding, awareness and enhanced quality property development.

Literature Review

Concept of Risk in Residential Property Development

Fisher and Robson, (2006) defined risk as the combination of probabilities of events and its results. The Australian/ New Zealand Standard for Risk Management, (2004) defined risk as the possibility of something happening that impacts on an objective which is to make a gain or a loss and it is measured in terms of likelihood and consequence. Similarly, Dickinson, (2001) also suggested that risk is the extent to which the outcomes from the corporate strategy of an organization may differ from those specified in its corporate objectives, or the extent to which they fail to meet these objectives. Based on the above definitions, it is right to define risk as the probability of an event that occurs during the development of projects and the outcomes have an effect on the development's objects over the stated period of time.

Sustainability Dimensions

Absolute avoidance of risk to occur in residential property development is achievable only when property developer understands what sustainability is and is not (Orlu & Ihuah, 2021). However, in general sustainability is defined as the ability to maintain or sustain its self over a period of time and for the future generation to meet their own need (Orlu & Ihuah, 2021). Sustainability differs from person to person but in a large extent, the definitions include three distinct dimensions: such as environmental, economic and social.

Environmental sustainability: is the ability to preserve and protect the natural environment over time through appropriate practices and policies, meeting present needs without compromising the availability of resources in the future. Factors of environmental sustainability include: air, water and soil pollution; climate change, loss of biodiversity; and economic models (Enel, 2023).

Social sustainability: this aspect of sustainability focuses on the well-being of people and communities, it aims to create inclusive societies, reduce inequality, and ensure long-term wellbeing for all people while preserving social cohesion and justice (Enel, 2023).

Economic sustainability: this approach of sustainability focuses on economic activities and how they are conducted so as to preserve and promote long-term economic well-being. The aim of economic sustainability is to create a balance between economic growth, resource efficiency, social equity and financial stability (Enel, 2023)

Types of Risk in Residential Property Development Processes

Risks in residential property development are threats that occur during the development process which in one way or the other will affect the entire development deliverable (Chen, 2010). Fisher & Robin, (2006) outlined eleven types of risk and they are: policy risk; exchange rate risk; inflation risk; employment rate risk' building materials risk; security risk; tenant's risk; building quality risk; legal risk; economic risk; and interest rate or taxation risk. also, Madhav, (2010) mentioned eleven (11) types of risk and they are: Financial risk; technical risk; Labour risk; conflict risk; social-culture risk; environmental risk; force major risk; economic risk; policy risk; institutional/organizational risk; technological risk; and legal risk. Similarly, Dale et. al., (2005) showed that risks in property development includes: market risk, industry risk; technology risk; economic risk; financial factor risk; government risk; and political influences risk.

Subsequently according to the reviews above the following are the types of risk in residential property development process and they include: Development risk; Interest rate; Time risk; Cost risk; Site risk; Market risk; Financing risk; Purchasing power risk; Business/liquidity risk; Operational risk; External risk; Management risk; Infrastructural risk; Regional risk; Social/cultural risk; Natural risk; Organisational risk; Legal risk; Technological risk; Counterpart risk; Political risk; Decision risk; Contractual risk; Construction risk; Model/design risk; and Labour risk (Orlu & Ihuah, 2021).

Classification of Risk in Residential Property Development Processes into Sustainability Dimensions

Classification of risk in residential property development is critical and should be considered because it can impact on the overall development processes through project schedule, delays, cost overrun and reduced project quality (Khumpaisal et al., 2011). Similarly, risk is classified so as to have an in-depth understanding of risks that occur during development processes and they are used for structuring and placing them on critical path analysis (Gehner, 2008). Doherty, (2000) stated that risks are classified based on operational, output (which is financial) internal /external factors and individual factors. Hargitay and Yu, (1993); Brown and Matysiak, (2000); Baum and Crosby, (2008) all opined that risks are classified as both systematic and unsystematic.

However, in respect to property development processes risks are classified based on social, technological, environmental, economic and political which are concerned by the developer decisions during the feasibility analysis stage and during implementation (Morrison, 2007; Matson, 2000; Millington, 2000). Khumpaisal et al., (2010) argued that the classification of risks into social, technological, environmental, economic and political is pragmatic, simple and very understandable which will help every property developer. Therefore, based on the study risks are classified in three aspect of sustainability which includes: Environmental risk, Economic risk and Social risk.

Residential Property Development Processes Environmental risks: it is risk that is associated with

economic or administrative consequences of slow or catastrophic environmental pollution (Hervey, 2021). Also, environmental risk is the probability or chance of suffering an adverse consequence or the potential threats of negative effects on an investment and the development environment by the introduction of new technology, natural hazards, pollution, and flood etc. arising from activities of the development team members (Faizul, 2021). However, based on the reviews the following were classified under environmental dimension and they include: *Operational risk; financial risk; Site risk; Timing risk; Natural risk; Infrastructural risk; Construction risk; Model/design risk; Labour risk; Organisational risk; Development Risk and External risk*

Residential Property Development Processes Economic risks: economic risk are risk that involve macroeconomic conditions (that is circumstances surrounding the whole economy), and this affects residential property development project negatively or positively (MBN, 2021). Also economic risk is defined as the likelihood that a development output will not have a sale value which can cover its operating cost, maintenance costs and its debts. More so it is important to note that before any development, a developer should look at the general economy if the significant outweighs the likely benefits. However, based on the reviews the following were classified under economic dimension and they include: *Interest rate risk; Financial or credit risk; Market risk; Purchasing; power risk; Business/ L*iquidity risk; Infrastructural risk; Site risk; Cost risk; Labour risk and Contractual risk

Residential Property Development Processes Social risks: social risk is the manifestation of what goes around the environment and it is driven by the influence of the populations perceptions such as beliefs, emotions, mental health, fear and anxieties (Ludke, 2021). Also it represents a combination of some insecure or harmful factors and the development of some social disturbances because of vulnerabilities. Social risk is caused by political transformation, Labour market instability, poverty, health and local industrial accidents (Laura, 2019). However, based on the reviews the following were classified under social dimension and they include: *Counterpart risk; financial risk; Legal risk; Social/cultural risk; Regional risk; Decision risk; Management risk and Political risk*

Research Methodology

The various types of risk were classified in the literature review and they were categorized into environmental, economic and social risk. this study adopted a quantitative and qualitative research approach and used simple random sampling techniques to collect relevant date, the population consist of five professionals (Architects, Property developers, project managers, quantity surveyors and estate surveyors) a total of 80 professionals involved in residential property developers was sampled and 60 professionals participated in the survey and also ten interviewees were sampled. A five-point likert scale questionnaire was developed and distributed evenly to the five professionals. Further, the data was analysed using social science package software version 2021, where data were interpreted in frequency analysis.

Data Analysis, Findings and Discussions

Table 1: Decision Rule Table for Judgment of Analysis

Range	Judgment
0.00 - 0.29	Very weak
0.30 - 0.39	Weak
0.40 - 0.59	Moderate
0.60 - 0.79	Strong
0.80 - 1.00	Very strong

Source: Pallant, 2013

For interpretation of the test results, the range of figures in Table 1 above will be adopted in judging the strengths of the response within the whole research analysis (Pallant, 2013 as cited by Ihuah, 2015). Based on the literature review, questionnaire and interview the following theme emerged from the result of the analysis and discussed below:

Table 2: Classification of Risk Based on Environmental Dimension

Enviromental Risk	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	RII Values	Ranking
Financial risk	0	0	6	80	190	0.69	1st
Timing risk	0	2	15	88	160	0.66	2nd
Site risk	1	0	39	72	140	0.63	3rd
Operational risk	2	6	15	88	140	0.63	4th
Development Risk	2	2	6	136	105	0.63	5th
Infrastructural risk	1	6	39	56	145	0.62	6th
Construction risk	1	8	30	80	125	0.61	7th
Labour risk	2	6	33	76	125	0.61	8th
Natural risk	0	18	30	80	105	0.58	9th
Model/design risk	0	24	27	68	110	0.57	10th
Organisational risk	1	18	42	44	125	0.58	11th

Source: Field Survey, 2021

As shown in Table 2, it shows that there is high ratting score from respondents on strongly agree and agree stating that the following are environmental risk. However, from the qualitative analysis, out of ten interviewees, eight (8) specified that they are all environmental risk and should be classified under environmental dimension of sustainability while two (2) stated otherwise. For instance, an interviewee stated as thus:

"... all this type of risk you mentioned are the types of risk that we can classify as environmental risk and these risks occur during the development of residential properties..." (Transcribed interview 2021).

Therefore, from the qualitative and quantitative analysis it reveals and confirms that the twelve (12) listed type of risk are environmental risks that occur during the development processes of residential properties.

This finding collaborates with Khumpaisal *et al.,* (2011); Hervey, (2021), who ascertained that the following are the type of risk affect residential property development process.

Table 3: Classification of Risk Based on Economic dimension

Economic Risk	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	RII Values	Ranking
Financial risk	0	2	6	80	185	0.683	1st
Interest rate risk	0	0	30	76	155	0.650	2nd
Cost risk	1	6	15	88	145	0.641	3rd
Purchasing power risk	0	2	33	80	140	0.640	4th
Market risk	0	10	18	98	125	0.631	5th
Site risk	1	0	39	72	140	0.630	6th
Infrastructural risk	1	6	39	56	145	0.62	7th
Contractual risk	2	8	33	84	110	0.593	8th
Business/ Liquidity risk	4	12	24	52	145	0.591	9th
Labour risk	4	14	30	76	100	0.560	10th

Source: Field Survey, 2021

From Table 3, it shows that financial risk is the most critical risk with the RII Values 0.683, signifying that 68.3% concord that financial risk is important to look out for in classifying economic risk. Based on the decision rule, other of the risk that ranged from 0.60and 0.59, shows that the respondents concord that they are all types of economic risk which indicates that the ten listed risk above are the types of economic risk.

However, based on the qualitative analysis, ten (10) interviewees, ten (10) stated that they are all the types of economic risk and should be classified into economic dimension of sustainability while none (0) stated otherwise. Therefore, the findings revealed and confirmed that the ten (10) listed type of risk are economic risks that occur during the development processes of residential properties. This finding collaborates with Khumpaisal (2011); MBN(2021); they ascertained that the listed risk above should be classified under economic risk in residential property development.

Table 4: Classification of Risk Based on Social dimension

Social Risk	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	RII Values	Ranking
Financial risk	0	2	6	80	185	0.683	1st
Social/cultural risk	1	10	21	64	155	0.631	2nd
Decision risk	0	10	30	80	125	0.613	3rd
Legal risk	1	18	18	72	130	0.601	4th
Political risk	2	14	30	56	135	0.593	5th
Regional risk	5	12	24	76	110	0.571	6th
Counterpart risk	0	30	18	60	120	0.570	7th
Management risk	1	22	39	64	95	0.553	8th

+

From Table 4, it shows that financial risk is the most critical risk with the RII Values 0.683, signifying that 68.3% concord that financial risk is important to look out for in classifying social risk. Based on the decision rule, other of the risk that ranged from 0.60 and 0.59, shows that the respondents concord that they are all types of social risk which indicates that the eight types of risk classified under social dimension risk are the types of social risk.

However, from the qualitative analysis, out of ten (10) interviewee, out of ten interviewees, nine (9) specified that they are all social risk and should be classified under social dimension of sustainability while one (1) stated otherwise.

Therefore, the findings revealed and confirmed that the eight (8) listed type of risk are social risks that occur during the development processes of residential properties. This finding collaborates with Khumpaisal (2011); Laura, (2019), who established that the following are the type of risk associated to social dimension.

Risk Classification Under Sustainable Dimension in Residential Property Deveoment

Table 5: Summary Classification of Risk in Sustainable Dimension of Residential Property Development

S/No	Environmental Risk in Residential Property Development	Economic Risk in Residential Property Development	Social Risk in Residential Property Development
1	*Operational risk*	*Interest rate risk*	*Counterpart risk*
2	*Financial risk*	*Financial risk*	*Financial risk*
3	*Site risk*	*Market risk*	*Legal risk*
4	*Timing risk*	*Purchasing power risk*	*Social/cultural risk*
5	*Natural risk*	*Business/ Liquidity risk*	*Regional risk*
6	*Infrastructural risk*	*Infrastructural risk*	*Decision risk*
7	*Construction risk*	*Site risk*	*Management risk*
8	*Model/design risk*	*Cost risk*	*Political risk*
9	*Labour risk*	*Labour risk*	
10	*Organisational risk*	*Contractual risk*	
11	*Development Risk*		
12	*External risk*		

Source: Field Survey, 2021

In terms of sustainability, the three dimensions of risks as classified above are fundamental and should be understood at the early stage of residential property development processes in order to make any final decision. Consequently, in the context of the work in residential property development, developers should look out for these risks as identified above at the onset of development and throughout the development processes. However, from the classification it shows that some of the risks are more critical than the other as they appear in all the categories such as financial risk and it must be watched out for by residential property developers. Also, site risk appeared in environmental and economic risk which shows that it is significant.

Therefore, decision makers and developers must consider these classifications earlier, especially in taking any particular action so as to ensure that the full range of risks has been considered because risk can compromise the property development backbone (Khumpaisal *et al.,* 2011). Hence, the Environmental, Economic and Social risk as classified in this research should be considered since they will impact on the overall residential property development processes.

Conclusion and Recommendations

This study sheds light that for sustainability of residential property development process it is important that risks are classified into environmental, economic and social aspects which they were twelve, ten and eight are in each category respectively. Therefore, the study is of the opinion that the above classified risks are known by developers and tackled when it appears during the development processes.

Subsequently, the study recommends that whenever any risk appear during the development process, that it should be understood that it might either be environmental risk or economic risk or social risk because the ability to understand which class it falls will enable developers tackle them appropriately.

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Enhancing Sustainable Real Estate Development through Flood Resilience Strategies

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Abstract

Flood resilience is increasingly critical in real estate development due to the rising frequency and severity of flooding events exacerbated by climate change. This study aims to identify and analyze flood resilience strategies for promoting sustainable development of real estate. The study employs document analysis, focus group discussion and interview with professionals and stakeholders in the real estate sector, including Urban Planners, Architects, Engineers, and Estate Surveyor and Valuers' Consultants. Document analysis of case studies from flood data of various geographic regions provide practical examples and demonstrate the effectiveness of different strategies like the use of elevated foundations, green infrastructure, underground water storage spaces, water garden, upgrade urban spaces and infrastructure using permeable materials, underground tunnel, community-based flood forecasting and warning system, flood control centre with embedded alert systems, integrated community flood response plan in mitigating flood risks in real estate sector. The findings highlight the importance of integrated approaches that combine robust engineering solutions with community engagement and appropriate training. The study recommends the implementation of flood-resistant infrastructure, improving regulatory frameworks, implementation of stringent building codes and standards, enhancing public awareness and education campaigns, using green infrastructure to manage stormwater, expanding urban parks, green roofs, and community gardens, and implementation of floodplain restoration, riparian buffer zones, and coastal resilience strategies. The study concludes that integrating these strategies and fostering stakeholder collaboration into the real estate sector can enhance its resilience to flooding and contribute to more sustainable urban development.

Keywords: Flooding, Flood Resilience, Strategies, Real Estate, Sustainable Development

Introduction

The real estate sector is being frequently impacted by floods, posing significant and growing threat to urban areas worldwide. Studies indicate that the frequency and severity of floods are projected to rise due to climate change (Smith & Jones, 2023). United Nations urbanization forecasts suggest that in 2018, 55% of the global population resided in urban regions, indicating a 24% increase from 1950. Moreover, the pace of urbanization is expected to accelerate, with an estimated 68% of the world's population living in urban areas by 2050 (United Nations, 2018).). The clustering of individuals, structures, and infrastructure is indicative of a society that is more susceptible to climate-induced hydro-hazards (Jahn 2015). Climate change-induced stress on the hydrological cycle has resulted in a rise in the occurrence of natural disasters, such as floods, in recent times (Ghazali et al.). Floods are among the most widespread and frequently experienced natural disasters globally, with significant impacts observed across different cultures and geographical locations. On average, approximately 70 million people are affected by floods each year (UNISDR, 2019). The results of flooding can lead to physical harm to buildings, essential infrastructure, and valuable possessions. Research conducted by Jonkman (2005) in the US evaluated information on international disasters from database of the Centre for Research on the Epidemiology of Disasters in Brussels (CRED) in cooperation with United States Office for Foreign Disaster Assistance (OFDA) on a large number of flood events for flood type on different types of floods and different regions on a global scale found that floods caused 175,000 deaths and impacted more than 2.2 billion individuals from 1975 to 2002. Similarly, in the UK, the effects

have been extensive, with over 5.2 million properties (approximately one in seven homes and businesses) exposed to various flood risks (Environment Agency, 2014). Estimates indicate that more than N49.9 trillion billion worth of property in England and Wales is potentially susceptible to flooding from various sources such as coastal, river, surface water, groundwater, and sewer flooding (Kenney, Pottinger, Plimmer, & Pocock, 2006).

In recent years, Nigeria has experienced a significant increase in flooding, posing a major hazard. In 2012, 2018, and in 2022, Nigeria has faced significant flooding incidents (Umar and Gray, 2022). During the 2012 floods, approximately 600,000 houses were destroyed, over 7.7 million individuals were impacted, and about 636 people lost their lives, demonstrating the severe effects of extreme events. The flooding forced residents of Oke-Ayo and Eleyele in Ibadan to evacuate their homes. Loss of life and property damage occurred in the Olodo and Apete areas of Ibadan (Onifade *et al.,* 2014). Additionally, in Plateau State, 39 individuals perished and roughly 200 houses were demolished due to the floods (Onifade, Adio-Moses, Adigun, Oguntunji & Ogungboye, 2014). The 2022 flooding in Nigeria resulted in the deaths of approximately 603 individuals and the displacement of 2.5 million people from their homes, according to the federal government. The Ministry of Humanitarian Affairs, Disaster Management and Social Development also disclosed that 82,053 houses were completely destroyed, and 332,327 hectares of land were entirely submerged. Additionally, statistics indicate that there have been 2,407 injuries, 121,318 partially destroyed houses, and 108,392 hectares of farmland partially affected.

The 2012 Nigeria floods, for example, resulted in the country incurring total losses exceeding $16.9 billion from property damage, decreased oil production, agricultural losses, and other impacts (Amangabra & Obenade, 2015; Egbenta, Udo & Otegbulu, 2016). The frequent occurrence of floods, combined with the limited capacity to cope and the high vulnerability of the population, continues to endanger numerous lives and properties (Komolafe, Adegboyega & Akinluyi, 2015). The dangers of flooding to public safety and the progress of the country have become a growing concern for stakeholders. Floods are frequent natural disasters that lead to significant financial losses and human suffering (Kuang & Liao, 2020). This emphasizes the importance of implementing strong flood resilience strategies in the real estate industry to reduce risks and promote sustainable development.

In highly populated urban areas, where real estate development is concentrated and often situated in flood-prone regions, floods can have severe economic and social consequences (Brown and Green, 2021). For example, the flooding of residential and commercial properties doesn't just result in immediate financial losses but also causes instability within the community and disrupts infrastructure (Williams, 2020). As a result, it becomes crucial to incorporate effective flood resilience measures not only to safeguard investments but also to support broader sustainability objectives (Robinson & Clark, 2019). The presence of an effective protection system against river flooding can greatly enhance public safety and decrease the social and economic impacts of flooding. To address the challenges posed by flooding in urban areas, the concept of resilience is emerging as a leading approach for evaluating the sustainability of urban systems. It becomes increasingly difficult to reduce and mitigate the factors contributing to flooding. Therefore, adaptation actions are imperative in this context. Adaptation plays a crucial role in minimizing future costs. While traditional approaches focus on combating water through structural measures, the resilience approach emphasizes a "flood friendly" strategy by implementing non-structural measures that are more adaptable to the increasing frequency of floods. Impenetrable surfaces are adding increased pressure to existing urban drainage systems due to a higher percentage of rain events, resulting in runoff that overwhelms the drainage network and leads to inevitable urban flooding. Additionally, urban areas may experience more frequent and severe

flooding due to climate change (IPCC, 2008). The resilience approach assigns responsibility for urban flood risk management to both governmental and community levels while also considering the population's ability to withstand floods over time. Strategies play a crucial role in mitigating flood damage and saving lives.

Urban areas face considerable challenges due to flood risks, impacting not just the real estate sector but also the wider goals of sustainable urban planning and development. Given that climate change is making flooding events more frequent and severe, it is crucial to implement effective strategies that improve the real estate sector's resilience. In light of these challenges and opportunities, this study explores various strategies to mitigate flood risks in real estate sector, aiming to promote sustainable urban planning and development.

Literature Review

The reviews begin with the meaning of flooding, types of flooding in Nigeria and thereafter narrow it down to the impact of flooding on urban infrastructure and real estate. This is followed by flood resilience, its importance in real estate and strategies for enhancing flood resilience in real estate.

Flooding

Flooding is a general temporal condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation of runoff (Jeb and Aggarwal, 2008). The occurrence of flooding is a common and highly destructive environmental hazard, varying in type and severity (Wizor & Week, 2014). Floods are inevitable natural events that frequently impact waterways and natural drainage systems, leading to loss of life, destruction of natural resources and surroundings, health challenges, and economic damage on an annual basis (Bhagavathi et al., 2011; Chiadikobi *et al.,* 2011; Berezi *et al.,* 2015; Nwankwoala and Jibril, 2019a). Annually, flooding affects more than 520 million people worldwide, causing over 25,000 deaths and resulting in global economic losses of approximately $50 billion (Alphen *et al.,* 2011). Flooding in Nigeria manifests as coastal, flash, river, and urban floods (Nwankwoala & Jibril,
2019b).

Types of Flooding

There are four broad flooding types: Coastal flooding, Groundwater flooding, River (or fluvial) flooding, and Pluvial flooding (ActionAid, 2006; Sterna, 2012; Birmah *et al.,* 2021).

Coastal flood: Coastal flooding can occur in low-lying coastal areas, such as estuaries and deltas, when these areas are inundated by brackish or saline water. Brackish-water floods happen when river water overspills embankments in coastal reaches (Birmah, *et al.,* 2021). This overflow can be exacerbated when high-tide levels are elevated above normal by storm-surge conditions or by large freshwater flood volumes flowing down an estuary. Saline water coastal inundation may occur when exceptionally large wind-generated swells are propelled into semi-enclosed bays during severe cyclones (Smith & Ward, 1998; Birmah et al., 2021).

Flash flood: They are often associated with rivers in inland areas, where sudden heavy rainfall can swiftly transform them into destructive torrents. Flash floods are also linked to dam bursts.

River flood: Also known as fluvial flooding in river valleys, it mostly occurs on floodplains along rivers. When the river exceeds its capacity, the banks and the floodplain become flooded. The excess water then spills over onto the floodplain, leading to inundation. Most river floods result directly or

indirectly from climatological influences such as heavy and prolonged rainfall (Smith & Ward, 1998). Areas that are low-lying are highly prone to inundation. The impact of sea level rise can be felt globally, especially along coastal communities. Countries and regions like Tuvalu, the Cook Islands, parts of Myanmar, Vietnam, New Orleans, Rotterdam, China, India, and Thailand in the Pacific Islands and Southeast Asia, as well as the Niger Delta in Nigeria, United Kingdom, Germany, and Serbia, among others, have experienced flooding attributed to sea level rise.

Urban or Pluvial flood: Pluvial flooding typically occurs during short-duration, high-intensity rainfall events, but can also be brought on by lower-intensity prolonged rainfall. An already saturated or impermeable ground, whether due to freezing, paving, or other factors, can worsen the extent of pluvial flooding (Falconer, 2009). This type of flooding is often linked to urban areas where large expanses of impermeable surfaces and inadequate drainage systems make communities vulnerable to water inundation following heavy rainfall (Youssef & Pradhan, 2011). The primary cause of urban flooding is usually a severe thunderstorm or prolonged rainstorm that saturates the soil after a period of moderate rainfall (Andjeikovic, 2001).

Impact of Flooding on Urban Infrastructure and Real Estate

Flooding poses significant challenges to urban infrastructure and real estate, affecting economic stability, public safety, and sustainable development goals. Understanding these impacts is crucial for implementing effective mitigation strategies and enhancing resilience in urban environments.

The impacts of flooding, as highlighted by Apan *et al.* (2010), are largely negative and extreme, affecting the social, economic, and environmental aspects. These include property, crop, and livestock damage, loss of human life, health issues, and destruction of infrastructure such as roads, bridges, and power plants. According to Ajayi (2012), flooding also leads to the disruption of economic activities and the livelihoods of those affected. Furthermore, floods can result in the destruction of public and private property, the incapacitation of utilities, impassable roads and bridges, ruined crops and agricultural lands, disturbances to emergency services, and fatalities. During such events, individuals may find themselves stranded in their homes without power or heat, or unable to access their homes. Potential long-term risks involve the spread of diseases, the loss of livestock, damage to sewer lines or septic systems leading to water contamination, downed power lines, destruction of fuel storage tanks, fires, and the release of hazardous substances.

Floods have a profound and complex impact on urban infrastructure and property. Floodwaters can damage buildings, compromising their structural integrity and requiring expensive repairs (UN-Habitat, 2023). Furthermore, flooding disrupts vital services such as electricity, water supply, and transportation, impacting daily urban life and economic activities (as per Smith and Jones, 2024). Water infiltration can weaken foundations, corrode structural elements, and damage electrical and mechanical systems (Smith and Brown, 2023). Repairing such damage is costly and time-consuming, impacting property values and requiring substantial investment in rehabilitation and restoration efforts (UN-Habitat, 2023). During flood events, urban infrastructure supporting essential services such as electricity, water supply, and transportation networks can be severely disrupted. Power outages, water contamination, and road closures hinder daily activities and emergency response efforts (FEMA, 2023). Beyond immediate damage, repeated flooding can depreciate property values and increase insurance premiums, undermining the economic resilience of affected communities (EPA, 2022). Flooding can cause disruptions in service continuity and economic losses for businesses and productivity decline for residents (EPA, 2022).

The economic consequences of floods go beyond immediate repair expenses and include declines in property value, business disruptions, and higher insurance costs (OECD, 2022). Real estate markets in flood-prone areas may witness decreased demand and lower resale prices, impacting investor trust and potential development opportunities (IPCC, 2021). Additionally, uninsured damages and financial pressure on households can worsen social disparities and economic inequality within communities (UNEP, 2021). Flood occurrences present significant health and safety hazards for urban dwellers, especially vulnerable groups like children, the elderly, and individuals with limited mobility (Smith and Jones, 2024). During flood events, there is an increased risk of waterborne diseases, injuries from debris, and exposure to hazardous materials, highlighting the importance of effective emergency response and public health interventions (UNDRR, 2021).

Among the various natural hazards in Nigeria, flooding has consistently resulted in the most extensive damage to private property and public infrastructure. Urban infrastructure and real estate are significantly affected by flooding, emphasizing the need for proactive measures to improve resilience and reduce risks. Thus, incorporating resilience measures into urban planning and real estate development is critical for enhancing long-term sustainability. By integrating sustainable practices, investing in resilient infrastructure, and fostering community engagement, cities can build safer, more sustainable urban environments capable of withstanding and recovering from flood events.

Flood Resilience

The concept of resilience has been described in various ways. Fisher (2015) mentioned that there are over 70 definitions of resilience. Generally, resilience is the capacity to anticipate, prepare for, respond to, and recover from significant multihazard threats with minimal damage to social wellbeing, the economy, and the environment (National Research Council, NRC, 2010). In a broad sense, resilience is defined as the ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events (National Research Council, 2012). The capability to mitigate significant all-hazards risks and incidents and to quickly recover and rebuild critical services with minimal damage to public safety and health, the economy, and national security is known as resilience according to the ASCE Committee on Critical Infrastructure (ASCE, 2013). Resilience recognizes the existence of interconnected and interdependent social, economic, natural, and manmade systems that support communities (Rubin, 2013). This study focuses on floods as a natural threat to the real estate sector, specifically on resilience to flooding, which includes a community's ability to plan for, respond to, and recover from floods.

Importance of Flood Resilience in Real Estate

The urban development and economic stability are significantly influenced by the real estate sector, which is becoming more susceptible to flooding impacts. With urbanization on the rise and climate change worsening weather patterns, it is anticipated that the frequency and severity of floods will increase (Johnson et al., 2022). These occurrences present significant dangers to real estate investments, infrastructure, and community welfare (Brown & Green, 2021).).

Resilience to floods is incredibly important in the real estate sector for a variety of reasons. To begin with, it helps protect the value of properties and reduces financial losses caused by flood damage. Properties with resilient design elements, like raised foundations, flood barriers, and stormwater management systems, are more capable of enduring flooding and lowering repair expenses (Smith & Jones, 2023). Furthermore, resilient buildings and infrastructure contribute to the stability of real estate markets by maintaining investor confidence and decreasing insurance costs (Lee & Smith, 2018). Additionally, flood resilience supports environmental sustainability by lessening the ecological

repercussions of floods. Through the incorporation of green infrastructure and sustainable drainage systems, real estate developments can efficiently handle stormwater runoff, relieve strain on local water systems, and preserve natural habitats (Robinson and Clark, 2019). The implementation of these strategies not only strengthens the ability of individual properties to withstand challenges but also plays a part in wider initiatives aimed at improving urban resilience and adapting to climate change (Brown & Miller, 2017).

In conclusion, flood resilience supports community resilience by safeguarding at-risk populations and crucial infrastructure. Those involved in real estate development and urban planning have an obligation to include resilience measures that prioritize public safety and fairness, ensuring that all residents have access to secure and resilient housing options (Williams, 2020). By improving community readiness and response capabilities, flood-resistant real estate contributes to the overall resilience of cities and encourages sustainable urban growth (Johnson et al., 2022). Thus, integrating flood resilience into the real estate sector is essential for safeguarding investments, promoting environmental sustainability, and enhancing community resilience in the face of increasing flood risks

Strategies for Enhancing Flood Resilience in Real Estate

Implementing effective flood resilience strategies is essential for mitigating risks and ensuring the sustainability of real estate developments in flood-prone areas. These strategies encompass both structural and non-structural measures tailored to enhance resilience against flood hazards (Robinson & Clark, 2019). Some of these strategies identified from literature are shown below:

Structural Measures: Structural measures significantly enhance flood resilience in the real estate sector by providing physical protection against flood hazards and minimizing potential damage to buildings and infrastructure. (Robinson & Clark, 2019). Types of structural measures include elevated foundations, flood barriers and walls and waterproofing and sealing. Elevating building foundations above flood levels is a crucial strategy for reducing flood damage, as it minimizes floodwater ingress into living and working spaces during inundation events. (Lee & Smith, 2018). Flood barriers and walls, installed along riverbanks and coastal areas, provide physical protection against floodwaters, redirecting or containing them away from developed areas. (Brown and Green, 2021). In waterproofing and Sealing, building envelopes must be waterproofed and sealed to prevent water infiltration and flood damage to internal structures and contents. This involves using waterproof materials and sealants to prevent water penetration through walls, roofs, and foundations. (Smith & Jones, 2023).

Structural flood resilience measures reduce risk by protecting structures from flood damage, reducing repair costs and operational downtime. Properties with robust measures may qualify for lower insurance premiums due to reduced risk exposure. Additionally, building resilience supports long-term sustainability goals by minimizing environmental impacts and promoting resourceefficient construction practices.

Non-Structural Measures: Non-structural measures are crucial in flood resilience strategies in the real estate sector, enhancing planning, preparedness, and community engagement in addition to structural interventions (Robinson & Clark, 2019). non-structural measures include early warning systems, land use planning and zoning, and community engagement and education. Early warning systems uses real-time data from weather forecasts, river gauges, and meteorological sensors in these systems to provide timely alerts and advisories to residents, property owners, and emergency responders, enabling proactive evacuation, asset protection, and emergency plan activation and

enhancing overall community safety (Brown & Green, 2021). Authorities uses land use planning and zoning, to enforce regulations restricting development in flood-prone areas, promoting water body setbacks, and mandating green spaces to absorb excess water during flood events. Integrating flood risk assessments into land use decisions mitigates vulnerability and ensures sustainable urban development (Lee & Smith, 2018). Community engagement and education requires educating residents and property owners about flood risks, emergency preparedness, and resilience measures promotes a proactive community response to flood events (Lee & Smith, 2018). Community engagement initiatives involve stakeholder participation in resilience planning, flood drills, and awareness of local flood risk maps and evacuation routes.

Non-structural measures offer cost-effectiveness, community resilience, and environmental sustainability. They require less initial investment and can reduce flood-related damages and recovery costs. Engaging communities in resilience-building activities strengthens social cohesion and adaptive capacity. Green infrastructure and sustainable land use planning contribute to environmental conservation and enhance ecosystem services in urban areas.

Technological Innovations for flood resilience: Technological innovations significantly enhance flood resilience in the real estate sector by providing advanced solutions for monitoring, predicting, and mitigating flood risks (Robinson & Clark, 2019). These include green infrastructure, smart building technology, and Flood Forecasting and Modeling. Green infrastructure technologies, such as green roofs, permeable pavements, and rain gardens, aid in sustainable stormwater management and flood risk reduction by absorbing and detaining rainwater. (Johnson et al., 2022). Green infrastructure in urban designs improves ecosystem services, water quality, and climate resilience by directing runoff into rain gardens, using pervious concrete, rain barrels, and constructing green roofs. Smart building technologies uses smart sensor systems to monitor flood conditions and environmental parameters in real-time, using sensors in waterways, drainage systems, and buildings to collect data on water levels, precipitation, and soil moisture. (Brown & Green, 2021). Smart sensors provide early warnings and actionable insights, enabling timely decision-making and proactive flood responses, thus enhancing resilience. In flood forecasting and modeling, Advanced flood prediction models utilizes computational algorithms and weather data to improve accuracy and advance warning time for flood events, enabling decision-makers to implement preemptive measures to reduce real estate asset impacts (Smith & Jones, 2023).

Technological innovations enhance flood resilience by improving real-time data collection and analysis, enabling proactive response planning, and reducing costs. They also promote sustainable development by promoting environmentally responsible practices and integrating green infrastructure and Building Information Modeling (BIM) to support urban resilience goals.

Methodology

The research employs qualitative methodology, including a literature review, document analysis of case studies featuring successful flood resilient strategies, focus group discussion and interviews with a flood risk expert. The focus of this review is on the impact of flooding on urban infrastructure and real estate, as well as strategies for improving flood resilience in the real estate sector. The documents which were analysed are flood data from New Orleans (USA), Rotterdam (the Netherlands), Semarang (Indonesia), and Bangkok, (Thailand) as case study subjects. These four cities are diverse culturally, but were chosen because they correlate geographically and share a history of floods comparable to Niger Delta (Nigeria). Despite facing similar vulnerability to coastal floods and the resulting economic effects, these cities vary in their cultural attributes and institutional structures. The economies and

cultural importance of each of these cities make significant contributions to their respective countries. Four areas in Yenagoa, the capital of Bayelsa State, were chosen for interview examination due to the recent construction of residential buildings. Okaka, Akenfa, Biogbolo, and Kpansia were selected as they are situated in high flood risk zones that were severely impacted by the 2012 floods. Additionally, these locations have experienced a greater influx of new residential developments for the middle and upper middle classes over the past six years compared to other areas in Yenagoa. Face to face oral interview were conducted with 21 of the flood risk experts including, (5) Urban Planners, (6) Architects, (6) Engineers, and (4) Estate Surveyors and Valuers of the study area using snowball sampling technique. Due to the exploratory nature of the study, focus group interview was held with 12 flood risk experts in Yenagoa, Bayelsa State purposefully chosen to engage in a guided discussion of a topic and by sharing their experiences of flood events in these areas with one another. This was guided by Babbie's (2005) suggestion that 12 to 15 participants should be brought together in a typical focus group meeting.

Case Studies, Data Presentation, Analysis and Results

This section introduces the case of successful implementation of flood resilient strategies, presents data obtained from the interview, and narratives and quotations obtained from the focus group discussions in the study location.

Case Studies of Successful Implementation of Flood Resilient Strategies

Case 1: Water Garden, New Orleans, USA: New Orleans faced severe flooding due to Hurricane Katrina in 2005, causing 80% of the city to flood. To address this, the city adopted the Mirabeau Garden, a neighborhood-level flood-resilient strategy. The garden redirects excess stormwater from the city's drainage system, creating retention ponds to collect 10 million gallons of stormwater. This method enhances water quality, transforms dirty floodwater into clean water, and increases property values.

Case 2: Waterproof city, Rotterdam: Rotterdam, a port city in the Rhine and Maas River delta, is aiming to become flood-proof by 2025 due to its low-lying geography. To achieve this, the city has implemented innovative flood resilience measures, such as building underground water storage spaces, investing in adaptable infrastructure like flood barriers, floating homes, and green roofs, and engaging residents, businesses, and stakeholders in flood resilience planning. These measures aim to protect real estate and urban infrastructure from flooding and promote sustainable urban development (Oppla, 2022; Lee & Smith, 2018).

Case 3: Community-Based Flood Forecasting and Warning System, Semarang, Indonesia: Semarang, the administrative center of Central Java Province in Indonesia, is prone to tidal and rapid floods due to its flat topography and low-lying coastal areas. To enhance its resilience, the city has developed a municipal resilience plan with an early warning mechanism for tidal floods and a flood prediction system for rapid floods. Satellite data helps coastal communities prepare for tidal fluctuations, while forecasts provide information on flood-prone areas and mitigation strategies (Asian Disaster Preparedness Center (ADPC), 2015). The system provides local communities with flood alerts, enabling them to prepare and evacuate vulnerable areas, ultimately enhancing their flood preparedness efforts.

Case 4: Flood Control Centre, Bangkok, Thailand: Bangkok, Thailand's capital, experienced a devastating flood in 2011 due to high rainfall, river overflow, and poorly designed drainage systems. To manage the situation, the city established a Flood Control Centre (FCC) with 69 remote sites to monitor flood and drainage systems in real-time. The city implemented a decentralization approach, allowing

officials to remotely monitor water gates and pumps, improving information quality and coordination. Institute of Developmental Studies (IDS). 2007. Social media features are equipped with alert systems for enhanced outreach. The FCC also provided evidence-based data for improving planning regulations for green areas retaining flood water.

The case studies emphasize the significance of integrated strategies, stakeholder collaboration, and adaptive management in enhancing flood resilience in urban areas, enabling cities to customize resilience strategies, enhance disaster preparedness, and foster sustainable communities.

Interview Findings

The research findings presented here are derived from interview with professionals and stakeholders in the real estate sector, including, urban planners, architects, engineers, and estate surveyors and valuers and focus group interview. The interview aimed to identify prevalent flood types in the Niger Delta, the coping strategy, the impact of the flood on real estate, successful flood resilience strategies, gather insights on challenges militating against the successful implementation of flood resilient strategies in real estate, and policy recommendations for enhancing flood resilience in real estate projects. The responses from interview were gathered from diverse group of professionals with varying years of experience and occupational setting. The majority of respondents were urban planners (Nr 7) 33.3%, followed by architects 5 (23.8%), engineers 5(23.8%), and estate surveyor and valuer consultants 4(19.0%). Most respondents had significant experience, with (Nr 9) 42.9% having more than 10 years in the field, (Nr 6) 28.6% with 6-10 years, (Nr 4) 19.0% with 1-5 years, and (Nr 2) 09.5% with less than 1 year. This diversity shows a comprehensive understanding of flood resilience practices and their comments were seen as credible and dependable. Out of the 21 respondents, 17 claimed to have a high level of understanding of flood risks and resilience measures, while 3 stated they have a moderate understanding, and only 1 admitted to having a somewhat understanding.

In the study area, respondents identified three types of floods. Many respondents selected multiple options for the types of floods. 90.5% of the respondents indicated that flooding is mostly caused by flash floods, which are often associated with rivers in inland areas. Respondents opined that this type of flooding occurs when sudden heavy rainfall swiftly transforms rivers into destructive torrents. All the respondents attributed the flooding to fluvial flooding from excess water spilling over onto the floodplain, leading to inundation directly or indirectly influenced by climate change, such as heavy and prolonged rainfall. 85.7% of the respondents also mentioned that urban or pluvial flooding typically occurs during rainfall events.

The impact of the flooding on real estate was unanimously acknowledged by all the respondents, who stated that buildings in various communities suffered varied types and levels of damage as a result of the differing extents of inundation. The respondents outlined the diverse direct damages suffered by buildings during the floods, which included: foundations being weakened or failing; ground floors collapsing due to erosion of filling material such as mud or sand from beneath the foundation; destruction of most timber-based building materials, from doors to roof members, depending on the extent of inundation or flood depth and duration of contact with floodwaters; render and paint on walls being damaged due to prolonged contact with floodwater; electrical wiring and fittings being damaged due to the widely used surface wiring technique; and properties being contaminated with sewage, drains, and chemicals from garages. The study highlights three key areas within the real estate industry that require resilient strategies to mitigate the impact of floods. These areas include buildings, transportation networks, and infrastructure facilities. All respondents agree that floodwaters significantly damage buildings, compromising their structural integrity and necessitating costly

repairs. Floods also disrupt transportation networks and urban infrastructure, which are essential for providing services like electricity and water supply, ultimately affecting urban life and economic activities.

When asked about the coping strategy adopted during flooding in Bayelsa State, the majority of respondents (90%) indicated that they use canal building, evacuation to higher or safer places, constructing trenches in gardens or farms to redirect floodwater, and evacuating properties from their houses as coping strategies. However, most respondents also agreed that the affected communities were unprepared to handle a major flood event, which confirms the substantial damage caused by floods each time they occur.

In terms of enhancing flood resilience in real estate, respondents stressed the significance of physical barriers and raising buildings as key structural measures. All 21 respondents, accounting for 100% of the interviewees, highlighted the importance of these measures in protecting properties in flood-prone areas. The survey also aims to determine the importance of non-structural measures in flood resilience strategies in the real estate sector. 90.5% of the respondents emphasized the importance of effective land use planning and the integration of green infrastructure, such as rain gardens and permeable pavements, as critical non-structural measures. Only 09.5% of the respondents were unconcerned about these non-structural measures. These confirm that these strategies can help in the management of stormwater and reduce runoff.

The real estate sector made use of technological innovations as a key strategy for improving flood resilience. According to the interviewees, early warning systems and smart sensors are essential technological innovations for timely flood alerts and preparedness. The respondents also emphasized the importance of advanced predictive modeling tools in assessing flood risks and developing resilience strategies. The interviewees commonly recommended enhancing building codes to incorporate mandatory flood-resistant construction standards.

Focus Group Interviews

The focus group interview with flood specialists was held to discuss key areas within the real estate industry that require resilient strategies to mitigate the impact of floods, and the measures that should be taken to make buildings flood-resistant in Yenagoa, and suggestions they have regarding resilient strategies that work well in the real estate. The number of participants in this group meeting was twelve 12 comprising five 5 Estate Surveyors, two 2 Urban Planners, three 3 Architects and 2 Engineers. Some of the respondents comment reads:

> *"We were stranded at homes without power"*
> *"A lot of people were unable to access their homes for many days"*
> *"The flood water covers everywhere leading to road closures which hinder daily activities. people could not go to farm or market"*

When questioned about the measures that should be taken to make buildings flood-resistant, the participant of the focus group interviewee stated the following: elevating electrical sockets, electrical wiring, and ventilation system controls; raising equipment and machinery on plinths; and using flood-resistant materials for floors and the lower parts of walls and staircases. Incorporating flood resilience in the transportation network involves designing, building, and maintaining ditches and water control structures for roads and trails. It was noted by respondents that most road crossing structures are

currently too small, which puts the transportation infrastructure at risk of damage, hindering emergency services and causing economic disruption. The loss of services during a disaster can be severe, and the unforeseen costs of repairs can be significant. According to one of the participants,

> *"a transportation network with properly sized and placed culverts and ditches is capable of withstanding flooding events".*

The focus group interview survey asked participants to share the primary suggestions they have regarding resilient strategies that work well in the real estate. The feedback highlighted these resilient strategies for their success in enhancing flood resilience in real estate: flood-resistant infrastructure, regulations, frameworks, trees protection measures, building regulations and standards, smart infrastructure technologies, public awareness and education, waste reduction, green infrastructure, urban parks and community gardens, and floodplains restoration. Participants highlighted the key suggestions they wanted to convey regarding flood-resistant strategies in the real estate sector, which are as follows:

> *"Implementing flood-resistant infrastructure, such as levees, flood walls, and drainage systems"*
> *"Improving regulatory frameworks to support flood resilience planning including local management of stormwater to allow the use of green infrastructure techniques"*
>
> *"Adoption of tree protection measures"*
> *Implementing stringent building codes and standards for flood-resistant construction.*
>
> *"Investing in smart infrastructure technologies, digital solutions, and resilient urban systems, such as real-time flood monitoring, early warning systems, and adaptive infrastructure design"*
>
> *"Enhancing public awareness and education campaigns about flood risks and resilience strategies"*
>
> *"Promoting recycling, composting, and waste reduction programs to minimize solid waste generation, alleviate pressure on landfills"*
>
> *"Utilizing green infrastructure, such as wetlands, forests, and natural floodplains, to manage stormwater"*

"Expanding urban parks, green roofs, and community gardens to enhance urban biodiversity, mitigate urban heat island effects"

"Implement floodplain restoration, riparian buffer zones, and coastal resilience strategies to protect natural habitats, restore ecosystem functions"

From the comments provided, it is evident that a strong flood-resistant plan is essential. Those involved in the discussion agree that implementing flood-resistant infrastructure can decrease the chances and extent of flood damage to roads, bridges, utilities, and public buildings, thereby reducing repair and replacement costs. They believe that enforcing strict zoning regulations can prevent construction in high-risk areas and encourage resilient urban planning. Additionally, utilizing smart infrastructure

technologies can improve disaster preparedness and response capabilities. In terms of public awareness and education initiatives, respondents emphasize that these efforts can improve skills, knowledge, and expertise in sustainable urban planning, flood risk management, and climate adaptation strategies. The plan aims to enhance the community's ability to deal with disruptions in waste collection and disposal services caused by floods through recycling and composting. People also pointed out that urban parks, green roofs, and community gardens are able to soak up floodwaters, decrease runoff, and improve the management of stormwater, which in turn reduces the risk of flooding. Lastly, their remarks on restoring floodplains and constructing riparian buffer zones confirm that it can improve the quality of the environment and offer natural flood defenses for communities at risk of coastal and riverine flooding.

The survey participants specifically mention that green infrastructure, also known as Low Impact Development (LID), uses vegetation and soil to manage rainwater at its source, helping to retain and reuse stormwater. It can be a more cost-effective and environmentally friendly alternative to traditional stormwater treatment, especially when integrated into development plans from the outset. On the use of trees, survey confirm that mature trees have the capacity to absorb substantial amounts of rainwater and decrease stormwater flow. To safeguard trees, respondents note that communities could begin by conserving existing undeveloped forested areas. Communities could also mandate the preservation of larger trees, such as those with a diameter exceeding 8 inches, as much as possible at development sites. An important finding of this research is the emphasis on resilience strategy, highlighting the need for local communities to be adequately prepared for flood emergencies. The survey confirms that being well-prepared greatly reduces the impact on loss of life and property damage during disasters. They agreed that the government should ensure that emergency personnel are equipped with appropriate training and equipment for developing and updating local emergency operations plans, as well as evacuation procedures for disasters.

Discussion of Findings

The essential of this study for real estate flood resilience is to promote sustainable urban planning and development, enhance environmental sustainability, foster inclusive, and equitable communities. From the interview and focus group discussion, this study confirms that by integrating climate adaptation measures, green infrastructure, and stakeholder engagement into urban planning processes, cities can mitigate flood risks, improve urban resilience, and create livable, resilient cities that thrive in the face of climate change and natural disasters. The successful implementation of flood resilience strategies in various cities analysed in case studies from two upper income and middle-income countries has provided valuable lessons for enhancing preparedness, mitigating risks, and building sustainable communities. The case study shows that effective collaboration among developers, local authorities, and community groups is crucial for the successful planning and implementation of resilience measures. Successful flood resilience implementation requires an integrated approach that combines engineering solutions with community engagement and regulatory support. The of the case study in Rotterdam for example,

Water squares, also known as underground water storage spaces, are built in cities to store rainwater temporarily during heavy rainfall, thereby decreasing pressure on drainage systems and lowering flood risks.

The interview findings try to find out the understanding of Flood Risks and Resilience Measures in Bayelsa and confirm that majority of respondents (100%) lack understanding of flood risks and resilience measures, thus, majority of affected communities are not prepared to handle major flood events. The research findings from the interview conducted identifies three key areas where the real

estate sector needs to implement resilient strategies for flood resilience. These areas are building infrastructure, transportation networks, and infrastructural facilities. The results show that resilient strategies for buildings involve elevating structures, raising equipment, and using floodresistant materials for surfaces. When it comes to transportation networks, it is crucial to design, construct, and maintain roads with appropriate culverts and ditches.

The study while revealing Flood Resilience strategy suitable for Real Estate confirm that physical barriers and building raising are key structural measures, and that effective land use planning and integration of green infrastructure are critical non-structural measures. Similar findings were documented in Johnson et al., (2022) that green roofs, permeable pavements, and rain gardens, which absorb and detain rainwater, reducing runoff and alleviating pressure on drainage systems during heavy rainfall events. While Lee and Smith, (2018) confirm that constructing buildings on elevated platforms or stilts reduces the risk of floodwater ingress into living and working spaces during inundation events.

In the realm of technological advancements in the real estate sector's flood resilience, it is widely acknowledged by the participants of focus group discussion that early warning systems and intelligent sensors play a pivotal role in providing timely flood alerts and readiness. Additionally, the use of advanced predictive modeling tools is deemed essential for evaluating flood risks and formulating resilience strategies, while building codes should include compulsory flood-resistant construction standards. Research has validated the effectiveness of early warning systems in leveraging real-time data from weather forecasts, river gauges, and meteorological sensors to deliver timely alerts and guidance to residents, property owners, and emergency responders (Brown and Green, 2021). In Semarang, Indonesia, a municipal resilience plan was developed, incorporating an early warning mechanism for tidal floods and a flood prediction system for rapid floods. The prediction provides information on areas at risk of flooding, including roads and suggests measures to reduce the impact of high-water levels. It notifies local residents and provides at-risk areas with advanced notice to prepare and evacuate, ultimately helping communities improve their readiness for flooding. (Asian Disaster Preparedness Center (ADPC), 2015).

Respondents have suggested that flood-resistant infrastructure, regulations, frameworks, tree protection measures, building standards, smart infrastructure technologies, public awareness and education, waste reduction, green infrastructure, urban parks, and floodplains restoration are effective strategies for building resilience in real estate. These strategies reduce flood damage to roads, bridges, utilities, and public buildings. The focus group discussion study found that Strict zoning regulations prevent construction in high-risk areas and promote resilient urban planning; Smart infrastructure technologies enhance disaster preparedness and response; Public awareness and education contribute to sustainable urban planning, flood risk management, and climate adaptation strategies; Urban parks, green roofs, and community gardens absorb floodwaters, reduce runoff, and enhance stormwater management; Restoring floodplains and riparian buffer zones improves environmental quality and provides natural flood defenses; while Green infrastructure, also known as Low Impact Development (LID), uses vegetation and soil to manage rainwater, offering a cost-effective and environmentally friendly alternative to traditional stormwater treatment. A case study in New Orleans and Rotterdam demonstrated successful implementation of elevated foundations, green infrastructure, underground water storage spaces, water gardens, and integrated community flood response plans, resulting in minimal flood damage during flooding events. The study identified strong community involvement and adherence to updated building codes as key success factors for this project. The results of the study underscore the importance of local communities being ready for flood emergencies and the

responsibility of the government in ensuring that emergency personnel have the necessary training and equipment to create and update local emergency operations plans and evacuation procedures.

Conclusion and Recommendations

The study explores the impact of flooding on real estate and suggests flood resilient strategies to mitigate risks. Flooding causes damage to buildings, transportation networks, and infrastructure, leading to displacement and property destruction. The study found that flooding has significantly impacted real estate, causing varying levels of damage to buildings across different communities.

These damages include weakened foundations, collapsed ground floors, destruction of timberbased materials, damage to render and paint, electrical wiring, and contamination with sewage, drains, and chemicals from garages. Resilient strategies are needed for areas like buildings, transportation networks, and infrastructural facilities. Successful implementation requires a combination of structural and non-structural measures, technological innovations, and robust policy frameworks. Measures like flood-resistant infrastructure, regulations, and smart infrastructure technologies can reduce flood damage and lower repair costs. The study also suggests integrating flood-resistant infrastructure, improving regulatory frameworks, implementing strict building codes, raising public awareness, and implementing green infrastructure for stormwater management. By combining these approaches and promoting stakeholder collaboration, the real estate sector can enhance its resilience to flooding and contribute to sustainable urban development.

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Identifying Critical Property-Based Taxes to Enhancing Local Government Revenue in Niger Delta, Nigeria

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Abstract

It has been observed that Niger Delta local governments are struggling about poor revenue generation and lack of adequate revenue collection. The local governments continue to receive insufficient revenues, resulting in major gaps in service delivery and unable to fulfil the demands of the rapidly increasing population. As a strategic means of bridging the gap, it is essential that local governments enhance the locally generated income. This study aims at providing solution to the local government poor revenue generation with a view to ensuring the discharge of their primary responsibilities to the citizens. To achieve these, the study enumerated sources of revenue to the local government and critical property-based taxes for enhancing local government finances, examined the factors affecting property tax compliance behaviour and thereafter developed sustainable strategies for revenue generation for local government from propertybased taxes in the Niger Delta region of Nigeria. Mixed method, Case Study design and Multi-stage random and census sampling to determine the sample size were adopted. Questionnaire survey was administered to Estate Surveyors and Valuers, local government officers and property owners, and triangulated with data from semi-structured expert interviews. Findings revealed that the property-based taxes formed a greater bulk of the total revenues accruing to the local governments and are considered necessary for enhancing local government finances if tapped. Study further showed that the incorporation of sustainable strategies like revenue mobilization action, organizational capacity enhancement and best practices on local revenue mobilization strategies in the current revenue generation practice will enhance revenue generation. The study recommends the use of technology driven mode of Internally Generated Revenue (IGR) collection to reduce cost of collection and improve remittance rate; a system that generates and records accurate information on property transactions; mobilization of taxpayer support through enhanced taxpayer education program; effective cost control and monitoring to ensure avoidable expenses; use of efficient and educated tax collectors. It concludes that the incorporation of these sustainable strategies in the current revenue generation practice is indispensable and highly relevant, if the local government finances are to be enhanced.

Keywords: Property-Based Taxes, Local Government Revenue, Niger Delta

Introduction

When it comes to urban development, taxation is an important source to generate revenue and also a tool to redistribute wealth. The objectives of taxation are many, including alleviating poverty and sharing societal benefits with low-income and disadvantaged groups. Property-based taxes are widely regarded to be an important source of funding for local governments. Despite the paucity of comparable data, property taxes represent "between 40% and 80% of local government revenue, between 2% and 4% of total government taxes, and between 0.5% and 3% of GDP" (Gboyega, 2003). Property-based taxes were identified by Pandey, Chletri, and Baskota (2012) as a crucial avenue of income for the Nepali Government, accruing up to 71% of the total local taxes the local government received in the 2011-2012 fiscal year. It contributed 33% to Internally Generated Revenue (IGR) and 7% to total local government income.

Land and property taxation are the practice of creating and receiving national and/or local revenues

from land and improvements over land. It is key to managing local and central governments affairs. The way in which land-based taxation is used can stimulate land market development, particularly land market transactions (UN-Habitat, 2010). Urban expansion, population growth, economic development and investments in infrastructure and services are factors that contribute to an increased demand for urban land. It is argued that national and mainly local governments should put in place mechanisms to tax land and property to 'recoup' land revenue to sustain urban development. This is particularly important in the context of rapid urbanisation and changing land use such as conversion of rural land to urban land, residential to commercial uses and vice-verse.

Nigeria runs a federal system of government that consists of three tiers, that is: Federal, State and Local governments. Each of these tiers of government has constitutionally assigned responsibilities to be discharged (Uhunmwuongho & Epelle 2008). Universally, local governments are becoming more and more important in the provision of fundamental public services (Sharma, 2021). Local authorities, however, also face significant challenges as a result of rapid and chaotic urbanisation, increasing services, challenges due to rising demand and insider threats to facilities. Most local governments in developing countries are faced with mounting challenges. These issues have been made worse by recent financial and economic turbulence throughout the world. UN-
Habitat (2005) asserts that the primary issue confronting the majority of "local authorities", particularly "those in charge of cities in developing countries, is the widening gap between financial resources and municipal expenditure demands". Due to rising labour and debt service expenses and a municipal income gap, many local governments are experiencing financial difficulties.

Akindele, Olaopa and Obiyan, (2002) asserts that the Local Government Reform of 1976, brought local government into the mainstream of the nation's intergovernmental fiscal relations, with a defined share of the federation account, among other statutory provisions and administrative arrangements. In order to guarantee that good governance and development are brought closer to the people, the local government, which is the third tier of government, is situated administratively closer to the populace. Local government is viewed as a third-tier government and a public sector organisation with statutory duties, financial management, and administrative structures for maintaining itself and providing services to its constituents (Uguru, 2011).

Under this fiscal arrangement, local governments are mostly relying on the federal and state governments for funding and grants. This form of income might be erratic and unpredictable at times, partly as a result of many of the state governments failing to allocate local governments 10% of their internally generated revenue as stipulated. Additionally, some state governments change the amounts that must be given to local governments under the law. To address this, the proponents of the 1976 Local Government Reform made significant efforts to provide financial support for the local government system. In 1976, the Federal Military Administration stated:

"Lack of enough funding and proper institutions has continued to render local government inefficient and incompetent." "In initiating the changes, the Federal Military Government was primarily motivated by the need to stabilise and rationalise local government. This involves the decentralisation of important state government responsibilities to the local level in order to leverage local resources for rapid growth".

This gave raise to provision of different sources of internal revenue generation for Nigerian local governments in subsequent legislations. Also, various measures were initiated to take care of the financial problems of the local system including the enactment of State Edict by states in favour of

other sources of revenue for the local government system. The aim for provision of internal sources of revenue generation to local government is to compliment the statutory allocations from both federal and state governments. It is assumed that if local government can satisfactorily generate a large proportion of its revenue internally, it will cease relying heavily on the statutory allocations. Despite these constitutional provisions for sources of internal revenue, local governments in Nigeria are still unable to tap all these internal sources. Hence, the problem of poor internal generated revenue in most local governments in Niger Delta and Nigeria as whole.

Akujuru, (2015) asserts that there are two fundamental revenue allocation methods under the federal form of government. The first is sharing between several levels of government and the federal or inclusive government. This mechanism for sharing money focuses on revenue that is earned by the federal government, such as taxes, export and import charges, mining rates, and value added tax.

Despite this, local governments in Niger Delta continue to struggle to satisfy the requirements of their constantly expanding urban populations. The provision of essential community infrastructure and services, ranging from enhanced public transportation and clean water to appropriate and secure housing and safe neighbourhoods is the responsibility of local governments. As the world's population continues to urbanise, it will become increasingly difficult to provide basic services without enhancing revenue generation. This instantly prompts the question, "where will the funds for the necessary service enhancements and expansions come from?" This calls for a sustainable strategy that can help unlock the revenue potential in order to meet its statutory functions.

Some of the areas where land and property taxation often face challenges include tax burden, compliance, evasion and enforcement. Demonstrating how property-based taxation is used at local level is often a good incentive to address such challenges. It is worth stressing the fact that no single local community can exist nowadays without having access to the vital public infrastructure. However, we are very often confronted with a serious problem when it comes to funding such an investment. There are many cases in which the tax revenues, collected by the local governments are simply not sufficient to foot the bill for constructing and providing public infrastructure and services. That is why a due consideration was given to the possibility of making the property owners pay their share of the burden for the development of public infrastructure and services. Embarking on land and property taxation requires that governments (central and local) work on improving and addressing collection efficiency. This will need the development of a sustainable strategy to enhance returns from local government revenue sources like property-based taxes.

Aim and Objectives of the Study

The aim of this study is to develop sustainable strategies for enhancing revenue generation through property-based taxes for local governments in the Niger Delta region of Nigeria.

The objectives of the study are to:

i. Identify sources of revenue to the local government; and
ii. Identify critical property-based taxes for enhancing local government finances in the study area.

Scope of the Study

This study on local government property-based taxes is so extensive and intricate. This study focuses on enhancing local governance revenue through property-based taxes. The study will used data from practising Estate Surveyors and Valuers, staff of selected local government and other stakeholders. The

scope is limited to the sources of funding for local governments, property-based taxes financial performance, and capacity to generate funds through property-based taxes.

Study Area

For this study, Niger Delta Region was used. The region is a geo-political entity located in the south-south region of Nigeria, where River Niger empties into the Atlantic Ocean. The Region lies between the estuaries of Benin River to the west and Cross River to the east of River Niger.

Figure 1: Map of Niger Delta Region and Its Confederated States
Source: Survey Department, Rivers State Ministry of Lands and Survey, Port Harcourt, 2020

According to Udoudoh, (2022), the region is rated as the second largest delta in the world spanning over 70,000km2 and described as the largest wetlands in Africa and the third largest in the world. Delta communities are identified with sandy deltaic washed plain of the Guinea Coast, and lowlying flat landscape predominated with coastal plain sediment which are marine, deltaic estuarine, lagoon and fluvial lacustrine materials. The region contains the most treacherous terrain which is made up of vast areas of waste ridge barriers, brackish or saline mangroves, marshy, freshwater, and swamp forest. It is on record that about 8,600km2 of the area is covered by stagnant swamp; while about one-third of the land area is made of fragile mangrove forest, the second largest in the world (World Bank, 1995). Generally, the region is richly endowed with abundant natural resources particularly crude oil, gas and limestone deposits. This incredibly well-endowed ecosystem contains one of the highest concentrations of biodiversity on earth. As reflected in the large expanse of tropical rain forest, the biodiversity is blessed with diverse, exotic and endemic plant, animal and bird species.

Literature Review

This is an overview of the previously published works on the study. The purpose here is to gain an understanding of the existing research relevant to the study and to present that knowledge in the form of a written report.

Local Government

Many scholars have distinct definitions of local governance. This is due to varying opinions on the actual role of local government, which vary depending on the context. There exists broad conceptualization of local government, it is often termed as the government closer to the grassroots (Essien, 2010), also a linking institution between the local populace and the central government

(Robson, 1978). Local government, on the other hand, can be described as government carried out by representative councils constituted by law to exercise certain authorities within defined boundaries (Local Government Reform Handbook, 1992). The United Nations Office for Public Administration in Ola and Tonwe, (2009) defines local government as "a political subdivision of a nation or (in a federal system) state, which is constituted by law and has substantial control of local affairs, including the powers to impose taxes or to exert labor for prescribed purpose.

Local government, according to the International Union of Local Government Authorities (IULA), is defined as a level of government with legally specified powers and responsibilities to control and administer public affairs in the sole interest of the local community (Abe and Omotosho, 2014). Ikelegbe, (2005) conceives it as a segment of a constituent state or region of a nation-state established by law to provide public service and regulate public affairs within its area of jurisdiction. The above presupposes that it is the closest level to the people with powers to perform functions and mandates over its finances and manpower. On the strength of this, the local government is a government under the responsibility of the local people and in the interest of the local population by local representative bodies (Ikelegbe, 2005).

The 1976 local government reform defines local government as "government at local level exercised through representative council established by law to exercise specific powers within defined areas". These powers should give the council substantial control over local affairs as well as the staff and institutional and financial powers to initiate and direct the provision of services and to determine and implement projects so as to complement the activities of the state and federal governments in their areas, and to ensure, through devolution of these functions to these councils and through the active participation of the people and their traditional institutions, that local initiative and response to local needs and conditions are maximized (Murana, 2015).

Accordingly, local governments were established in Nigeria as a third-tier administrative structure to decentralize governance, bring government closer to the people at the grassroots, and make social services vital to national development. They are strategically positioned and in charge of almost 70% of Nigeria's estimated 200 million inhabitants. As a result, they are in a unique position to gather and voice the demands of the majority of Nigerians, as well as to support rural development by deploying the necessary financial and human resources in their operations (Agba, Ocheni and Nnamani, 2014)

Deriving strength from the above definitions, local government can be seen as government in which popular participation both in the choice of decision makers and in the decision-making process is conducted by local bodies. Looking at the concepts from another lens, local government is defined as a unit of government charged with the responsibility of complimenting other levels of government in the provision of essential service to people in the local area. In all emergent states, local government administration has been adopted as the main fundamental instrument for the acceleration and sustenance of rural development. Therefore, various arms of government must aim at stimulating and motivating rural people to take an active part in the development of their communities.

Sources of Revenue for Local Governments in Nigeria

Source of local government finance implies the various means through which local governments generate financial resources to meet their financial obligations in the course of discharging their constitutional functions and duties. Local governments are constitutionally empowered to control and regulate certain activities in their jurisdiction, and in so doing; they impose some levies and rates on these economic activities as a way of generating funds for their operations. The revenue that accrues to

local governments in Nigeria according to Olaoye, (2008) and Alo, (2012) is derived from two broad sources, namely, internally generated revenue (which is revenue generated within the local government area of administration and it entails local tax or community tax, poll tax, or tenement rates, user fees and loans); and externally generated revenue which refers to the local government funds generated outside the local government area of administration. The external sources of local government revenue/finance include:

i. Statutory allocation from federation account in accordance with Section 162(3) of the 1999 Constitution of the Federal Republic of Nigeria (as amended).
ii. Statutory allocation from State Government to the local governments in its area of jurisdiction.
iii. Federal grants -in -aid.
iv. State grants-in -aid
v. Borrowing from state government and financial institutions.
vi. Local government share of value added tax (VAT).

Internally generated revenue is a strategic source of financing local governments operation and which can be explored given the enabling environment and political will. The internally government revenue of local government includes the following:

i. Local rates and commission paid to local government for assisting in the collection of some taxes or dues on behalf of the state government.
ii. Market rates and levies excluding any market where state finance is involved.
iii. Local government business investment
iv. Bicycle, truck, canoe, wheel-barrow and cart fees, other than mechanically propelled truck.
v. Permits and fines charged by customary courts;
vi. On and off liquor license fees.
vii. Slaughter slab fees.
viii. Tenement rates ix. Fees from schools established by the local government.
x. Shops and kiosk rates.
xi. Marriage, birth and death registration fees.
xii. Radio and television license fees (other than radio and television transmitter)
xiii. Right of occupancy fees on lands in the rural areas, excluding those collected by the federal and state governments.
xiv. Cattle tax payable by cattle farmer only.
xv. Naming of street registration fee, excluding any street in the state capital.
xvi. Merriment and road closure levy.
xvii. Religion places establishment permit fee.
xviii. Public convenience sewage and refuse disposal fees.
xix. Signboard and advertisement permit fees.
xx. Vehicle radio license fees (to be imposed by the local government).
xxi. Wrong packing charges.
xxii. Customary burial permit fees.
xxiii. Fees collected from amusement centre established and operated by the local authorities and that of tourist centre and tourist attraction.
xxiv. Rents, fees on private institutions
xxv. Motor Park levies.
xxvi. Domestic and license fees, etc. (Aibieyi, 2005).

As already mentioned above, internally generated revenue formed a greater bulk of the total revenues accruing to the local governments before 1976. With the 1976 Local Government Reforms, these

sources were further widened to enable the local governments to collect enough funds to discharge their development responsibilities. Consequently, the various local government edicts of the various states in the federation included the following as their major sources of revenue to all the local governments in the country:

I) Community Tax/Community Rates
ii) Property (Tenement) Rates
iii) General/Development/Capitation Rates
iv) Licenses, Fees and Charges
v) Advertisement fees
vi) Baker houses licenses
vii) Beggar minstrel fees
viii) Bicycle licenses/hire permits
ix) Births and deaths registration fees
x) Brick making and block industry licenses
xi) Cigarette sales licenses
xii) Burial fees and charges (on local government burial grounds)
xiii) Cart/truck licenses
xiv) Cattle dealers/Butchers? licenses
xv) Contractors? registration fees
xvi) Dane guns? control licenses
xvii) Dried fish and dried meat licenses
xviii) Dog licenses
xix) Marine Fishing/hunting fees
xx) Forestry and fuel/fire wood exploitation fees
xxi) Goldsmith?s licenses
xxii) Hawkers? permits/licenses
xxiii) Hunting licenses
xxiv) Local liquor brewing/sales licenses
xxv) Marriage registration fees
xxvi) Minor/small/cottage industries licenses
xxvii) Control of noise licenses
xxviii) Palm wine fees
xxix) Pit sew licenses
xxx) Produce (palm oil/kernel) buying/sales licenses
xxxi) Rents and plot fees (from Landlords)
xxxii) Retail trade licenses
xxxiii) Slaughter fees
e) Interest on Revenues
i) Interest on state deposits ii) Interests on investments iii) Profits from sale of investments/stocks, shares, etc.
f) Departmental Recurrent Revenues
I) Survey fees - from the Department of Works & Planning
ii) Repayment of personal advances
iii) Refund of salaries and/or allowances
iv) Refund of subsistence of students in training
v) Re-imbursement of state witnesses expenses
vi) Sales of library books and literature
vii) Nursery school and day-care centres fees

viii) Conservancy or compost charge
ix) Sale of produce e.g. palm oil/kernel
x) Profit on local government farm accounts
xi) Tractor/grader/caterpillar hire fees
xii) Irrigation fees
xiii) Sale of firewood
xiv) Sale of timber
xv) Sale of produce
xvi) Cattle/goat/sheep/poultry treatment charges
xvii) Fodder
xviii) Stray animal poundage fees
xix) Workshop repairs receipts
xx) Sale on stores
xxi) Sale of unserviceable stores/vehicles, and equipment fees
xxii) Rents on local government quarters
xxiii) Guest/rent house fees/charges
xxiv) Vehicles, plant and equipment charges
xxv) Profit vehicles advances account
xxvi) Canoe/ferry/mass transit fees
xxvii) Contribution for maintenance of produce evaluation road usage fees
xxviii) Fees and charges in local government-maintained markets
xxix) Fees and charges in local government motor parks
xxx) Registration of business premises
xxxi) Sale of corn
xxxii) Sale of scrap metal, (Aibieyi, 2005).

From the list, it is clear that many of the various sources of internally generated revenues to local governments are either untapped or under-tapped in local governments in Niger Delta. Some, like death registration fees, due to the culture and customs of local people can never be tapped; while others like tenement rates by individual and corporate persons can be potentially lucrative sources of local government revenue, if properly administered and strictly enforced. With courage, honesty, and fair-play local governments may not even bother to look for new sources of internal revenue if the above list is appropriately and adequately tapped and properly accounted for.

Despite the numerous sources of revenue there seems to be lack of adequate and efficient method of collecting the revenue and not sufficiently identifying and adopting appropriate strategies for expanding their revenue bases internally.

Land/Property Based Taxes

Land-based taxes are the charges, levies, rates and rents paid on land, (either developed or undeveloped) to governments for income generation and wealth redistribution (Orekan,2021). It also served as a form of government control over land. It is the responsibility of land-owners to pay taxes on them and it is the duty of a responsible government to collect taxes on land and its appurtenances as at when due. Traditional land and property taxation - commonly referred to as property taxation - is based on the "combined assessed value of land, buildings and improvements thereon" (Owen, 2004).

The Food and Agriculture Organisation (FAO), (2002) defines property tax as an annual tax imposed on real property usually by reference to an ad valorem tax base (i.e., the tax is calculated according to

the value of the property). Such taxes have been in existence for millennia and their benefits are well known. They are transparent, cheap to administer, efficient to collect and well understood by the taxpaying public. They are administratively feasible in virtually any circumstances and, being locationally fixed, are particularly suitable as a source of locally generated revenue for local governments. It is a known fact that property taxation has rightly been identified as a major tool in the strengthening of domestic resource mobilization and consequently, the search for ways and means of expanding the tax base and also strengthening tax administration. According to Ajayi, (2000), Olowu, (2002) and Adedokun, (2012), it is considered a veritable source of revenue for financing development as well as people-oriented programs in virtually all countries, irrespective of whether they are classified as developed or developing economies. (Ezemma, 2013) affirmed that property taxes are beneficial when they are used to finance services that provide corresponding benefits.

Property-based taxes and fees are often considered to be "benefit taxes", meaning those who own or control land that receives greater benefits from public actions and urban services will also pay more in taxes and fees (if the charge is based on land value). Some authors argue that land-based revenues can be progressive in nature as ownership is generally concentrated in upper income groups (Farvacque-Vitkovic and Kopanyi, 2014)
When services are not provided, the taxes become onerous. It is therefore agreed that a welldefined property tax laws alone cannot guarantee the success of tax collection effort.

Methodology
The study adopted Mixed-method research approach employing sequential explanatory design for the study (Creswell, 2003; Creswell, 2014). The study used purposive sample technique for selection of respondents for questionnaire administration and interview schedule with closedended and open-ended questionnaires. A total of three (3) states were selected for the study namely; Akwa Ibom, Rivers and Edo states from the Niger Delta region as case study. Furthermore, three (3) LGAs in each of the selected states were selected for sampling making a total of nine (9) LGAs that were sampled. A total of three hundred and seventeen (317) respondents were interviewed comprises property owners and Estate Surveying and Valuation firms which one hundred and sixty-three (163) questionnaires were returned for collection and analysis (see Table 1). Direct observation and documentation techniques were also employed to categorise, investigate, interpret and identify to understand the issues of property-based taxes of the LGAs to enhance their IGR base for economic development which were used for analysis of data collected during survey (Benge, Onwuegbuzie, Burgess & Mallette, 2010).

Table 1: Summary of Samples for the Three States and Questionnaire Administered and Returned

S/No.	State/Local Government	Respondent Per State/ Local Government	Number Retrieved	Percentage Return
Property Owners	Akwa Ibom			
	1. Uyo	15	9	5.5% (2.8%)
	2. Eket	15	7	4.3% (2.2%)
	3. Ikot Ekpene	15	8	4.9% (2.5%)
	Rivers			
	1.Port Harcourt	15	8	4.9% (2.5%)
	2.Bonny	15	8	4.9% (2.5%)
	3.Eleme	15	7	4.3 % (2.2%)

Table 1: Summary of Samples for the Three States and Questionnaire Administered and Returned

	Edo 1. Egor (Uselu) 2.Ikpoba/Okha (Idogbo) 3.Oriedo (Benin	 15 15 15	 8 7 7	 4.9% (2.5%) 4.3% (2.2%) 4.3% (2.2%)
Estate Surveying and Valuation Firm	Akwa Ibom	22	11	6.7% (3.5%)
	Rivers	123	64	39.3% (20.2%)
	Edo	37	19	11.7% (6.0%)
	Total	**317**	**163**	**100% (51.4%)**

Source: Field Survey, 2023

Results and Discussions

Objective 1: Identify Sources of Revenue to the Local Government

This section's objective is to gather data on respondents' perceptions and understanding of the sources of local government revenue. Local governments are constitutionally empowered to control and regulate certain activities in their jurisdiction, and in so doing; they impose some taxes and rates on these economic activities as a way of generating funds for their operations. Nonetheless, literature has shown that many of the various sources of internally generated revenues to local governments are either untapped or under-tapped in most local governments in Niger Delta.

It was therefore necessary to investigate the sources of revenue to local government in the Niger Delta and subsequently find the most tapped or untapped. The presentation of results of both the descriptive statistics was done in the form of tables and bar graphs. The descriptive statistics shows the varying percentage figures of the variables analysed in bar graphs. From the result, the weighted Mean score, Standard Deviation (SD) and Relative Importance Index (RII) was displayed in a tabular form showing the variables assessed.

Most Tapped Sources of Revenue to the Local Government were identified from literature; a 26 items scale was developed to identify the most tapped revenue source to the local government in the Niger Delta. This is descriptively illustrated in Table 2.

Table 2: Most Tapped Sources of Revenue to the Local Government

Sources of Revenue	Always	Often	Sometimes	Rarely	Never	Scores	RII	Ranking
PlanRate	0	28	39	50	46	375	0.46	18th
RoadTax	8	15	48	53	39	389	0.48	17th
LandValTax	7	5	33	79	39	351	0.43	19th
LandUseCha	15	16	36	68	27	410	0.50	16th
BurFee/Cha	28	28	51	41	15	502	0.62	**7th**
Tene Rate	28	38	54	32	11	529	0.65	**6th**
Shop KioRate	30	36	54	33	10	532	0.65	6th
SlauSlabFee	36	34	49	28	16	535	0.66	**5th**
NamStreeReg	14	43	43	42	21	476	0.58	10th
RighOccuFee	16	30	45	46	26	453	0.56	12th
CatTaxFee	15	14	57	47	30	426	0.52	14th

Table 2: Most Tapped Sources of Revenue to the Local Government

Sources of Revenue	Always	Often	Sometimes	Rarely	Never	Scores	RII	Ranking
MerrRoadClos	18	25	30	62	28	432	0.53	13th
RelPlaceEstPerm	7	21	41	56	38	392	0.48	17th
SignBoaAdver	26	22	13	60	42	419	0.51	15th
WrongPackChar	41	42	35	25	20	548	0.67	**4th**
RentLocGovPro	22	27	18	42	54	410	0.50	16th
InterestInvest	17	20	35	45	46	406	0.50	16th
StatAllocation	66	24	26	27	20	578	0.71	**2nd**
InterGenStateRev	31	27	44	39	22	495	0.61	**8th**
SpeciaGran	12	20	52	52	27	427	0.52	14th
FeeLocGovMotPark	61	43	38	15	6	627	0.77	**1st**
ProfLocGovFarm	11	26	38	51	35	410	0.50	16th
GuestRentFee	25	37	35	43	23	487	0.60	**9th**
FeeLocGovMarket	47	48	19	35	14	568	0.70	**3rd**
RentLocGovQuar	16	39	34	51	22	462	0.57	11th
RegBusPremises	20	31	16	44	52	412	0.52	14th

Source: Authors' Field Survey, 2023

Note: 5 = Always, 4 = Often, 3 = Sometimes, 2 = Rarely, 1 = Never

The variables were assessed using nominal scale a-5-point likert scale ranging from 1-5 where 5 = Always, 4 = Often, 3 = Sometimes, 2 = Rarely, 1 = Never. Consequently, fees and charges in local government automobile parks get a Relative Important Index (RII) of 0.77 and placed top among variables examined for most tapped local government income streams in Niger Delta. It was followed by statutory allocation with RII score of 0.71 and ranked 2nd among the most tapped local government income streams, fees and charges in local government-maintained markets, score a RII of 0.70 and ranked 3rd; followed by improper packing charges with RII score of 0.67 and ranked 4th. The table further shows slaughter slab fees score of 0.67 and ranked 5th among the measured variables, tenement rate and shops and kiosks rates score RII of 0.65 and ranked 6th, burial fees and charges (on local government burial grounds) with RII score of 0.62 and ranked 7th, 10% of internally generated state revenue with RII score of 0.61 and ranked 8th, Guest/rent house fees/charges with RII score of 0.60 was also identified as part of the most tapped revenue sources to local government in the Niger Delta and ranked 9th, while Naming of street registration fee excluding any street in the state capital with RII score of 0.58 and ranked10th, Rents on local government quarters with RII score of 0.57 and ranked 11th, Right of occupancy with RII score of 0.56 and ranked 12th, merriment and road closure levy with RII score of 0.53 and ranked 13th, Cattle tax payable by cattle farmers only; Special grants; and Registration of business premises with RII score of 0.52 and ranked 14th, sign board and advertisement fees with RII score of 0.51 and ranked 15th, land use charge rent on local government properties, interests on investments, profit on local government farm accounts with RII score of 0.50 and ranked 16th, road tax, religious places establishment permit fees with RII score of 0.48 and ranked 17th, planning rates with RII score of 0.46 and ranked 18th, land value tax with RII score of 0.43 and ranked 19th scored less was identified as part of the most tapped revenue sources to local government in the Niger Delta.

Figure 2 below shows the quantitatively analysed data on the most tapped revenue source to the local government in the Niger Delta as indicated by the respondents' responses. It can be deduced from the

findings that the internally generated revenues to local governments formed a greater bulk of the total revenues accruing to the local governments, but are either untapped or under-tapped in most local governments in the study area. Figure 2 below further illustrate the most tapped sources of revenue to the Local Government.

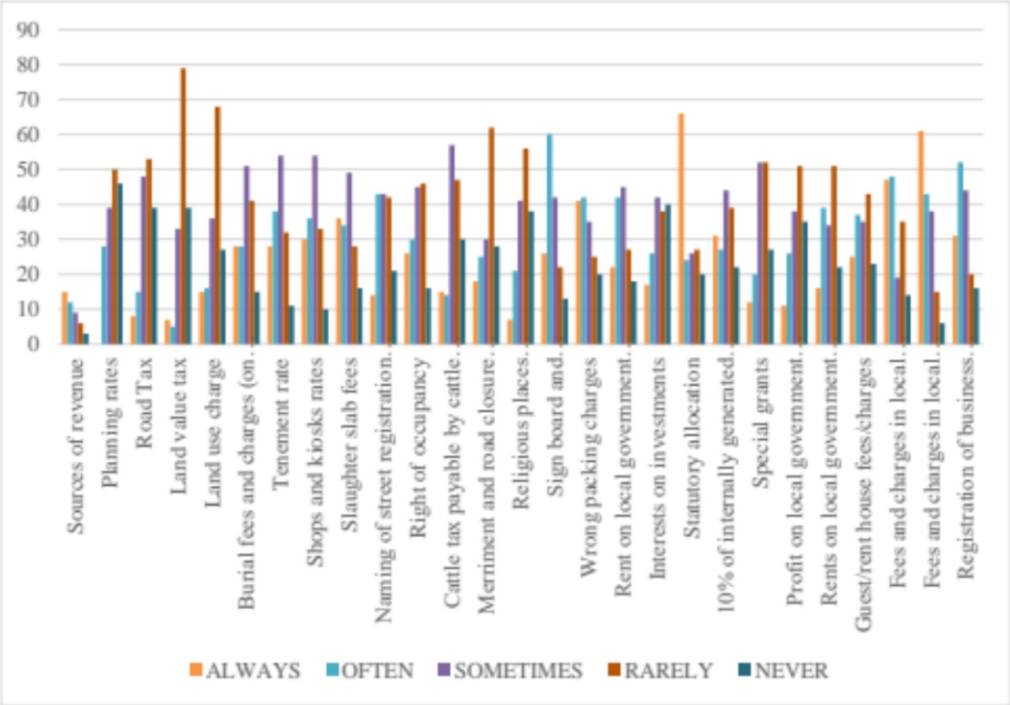

Figure 2: Most Tapped Sources of Revenue to the Local Government.

Source: Authors' Field Survey, 2023

LEGEND	
Planrate	Planning rates
RoadTax	Road Tax
LandValTax	Land value tax
LandUseCha	Land use charge
BurFeeCha	Burial fees and charges on local government burial grounds
TeneRate	Tenement rate
ShopKioRate	Shops and kiosks rates
SlauSlabFee	Slaughter slab fees
NamStreeReg	Naming of street registration fee excluding any street in the state capital
RighOccuFee	Right of occupancy
CatTaxFee	Cattle tax payable by cattle farmers only
MerrRoadClos	Merriment and road closure levy
RelPlaceEstPerm	Religious places establishment permit fees

LEGEND	
SignBoaAdver fees	Sign board and advertisement
WrongPackChar	Wrong packing charges
RentLocGovPro properties	Rent on local government
InterestInvest	Interests on investments
InterGenStateRev	10% of internally generated state revenue
StatAllocation	Statutory allocation
SpeciaGran	Special grants
FeeLocGovMotPark	Fees and charges in local government motor parks
ProfLocGovFarm	Profit on local government farm accounts
GuestRentFee	Guest/rent house fees/charges
FeeLocGovMarket	Fees and charges in local government-maintained markets
RentLocGovQuar	Rents on local government quarters
RegBusPremises	Registration of business premises

Property-Based Sources for Improving Local Government Finances

Having identified the various types of property-based revenue sources for local government, it was necessary to find out which of the property-based sources are critical or necessary for improving local government finances in the Niger Delta states. In order to achieve these respondents were asked to state their opinion on the various property-based revenue sources. For this question, the weights used are 5 = Very Necessary, 4= Necessary, 3= Moderately Necessary, 2 = Rarely Necessary, and 1 = Not Necessary. On a five-point Likert scale, the findings in the table below were used to rank the relative importance of each variable. This ranking was meant to demonstrate the significance and preferences of respondents for the various property-based taxes in order to substantiate how they view the revenue source. Table 3 below shows the quantitatively analysed data.

Table 3: Property-Based Sources for Improving Local Government Finances

Sources of Revenue	Very Necessary…Not Necessary					Total	Me an	SD	Decision
	5	4	3	2	1				
PlanRate	48	59	31	17	8	163	3.75	3.40	Necessary
RoadTax	34	55	36	24	14	163	3.44	3.14	Necessary
LandValTax	39	60	23	22	19	163	3.48	3.21	Necessary
LandUseCha	42	56	43	17	5	163	3.69	3.33	Necessary
BurFee/Cha	35	45	44	25	14	163	3.38	3.09	Necessary
TeneRate	64	35	36	22	6	163	3.79	3.47	Necessary
ShopKioRate	61	41	26	31	4	163	3.76	3.44	Necessary
SlauSlabFee	38	65	28	23	9	163	3.61	3.28	Necessary
NamStreeReg	39	61	29	22	12	163	3.57	3.26	Necessary
RighOccuFee	53	45	37	17	11	163	3.69	3.37	Necessary
CatTaxFee	41	43	37	25	17	163	3.40	3.14	Necessary
MerrRoadClos	32	40	38	20	33	163	3.11	2.92	Not Necessary
RelPlaceEstPerm	25	32	32	34	40	163	2.80	2.65	Not Necessary
SignBoaAdver	48	39	31	21	24	163	3.40	3.19	Necessary
WrongPackChar	48	56	34	14	11	163	3.71	3.38	Necessary
RentLocGovPro	43	58	37	15	10	163	3.67	3.33	Necessary
FeeLocGovMotPark	30	60	25	25	23	163	3.30	3.05	Necessary
ProfLocGovFarm	33	62	35	25	8	163	3.53	3.20	Necessary
GuestRentFee	32	46	40	33	12	163	3.33	3.03	Necessary
FeeLocGovMarket	30	60	25	25	23	163	3.30	3.05	Necessary
RentLocGovQuar	41	65	30	23	4	163	3.71	3.35	Necessary
RegBusPremises	54	61	30	15	3	163	3.91	3.52	Necessary

Source: Authors' Field Survey, 2023

Table 3 above shows the results of respondents' responses on the twenty-two discovered revenue sources from the property-based sources that are necessary or critical to improving the local government finances if tapped. Based on the table, twenty property-based revenue sources scored with a mean rating of more than 3.0 and were therefore considered necessary for improving the local government finances if tapped. The outcome indicated that registration of business premises with a mean score of 3.91 and standard deviation of 3.52 is the most critical revenue source for improving local government revenue generation. This is followed by Tenement rate with a mean score of 3.79 ± 3.47; then Shops and kiosks rates that has a mean score of 3.76 ± 3.44. Planning rate has mean score of 3.75 ± 3.40. This is followed by Land use charge with mean score of 3,69 ± 3.33, similar to Right of Occupancy. This reason was closely followed in order of ranking by Rent on local government properties 3.67 ± 3.33, Rents on local government quarters 3.66 ± 3.33; Naming of street registration fee (excluding any street in the state capital) 3.57 ± 3.26; Land value tax 3.48 ± 3.21, Road tax 3.44 ± 3.14; Sign board and advertisement fees 3.40 ± 3.19; Burial fees and charges (on local government burial grounds) 3.38 ± 3.09; Guest/rent house charges 3.33 ± 3.03; Merriment and road closure levy 3.11 ± 2.92 and Religious places establishment permit fees 2.80 ± 2.65.

Interview Findings

The results of the questionnaire survey were compared with the interview responses in order to find out whether their views were the same or not. Findings indicate that there were similarities in their opinion on the sources of revenue, most tapped revenue sources and property-based taxes necessary to enhance local government finances. The interview responses show that 100% (21) of the respondent agree that tenement rates, shops and kiosks rate, planning rate, sign boards, advertisements, etc. were the internal sources of revenue to the local government. When asked the sources of revenue from which your local government raises revenue, an interviewee said:

> *"We have so many sources of revenue in my local government, like shop owners paying for their shops, tenement rate and others. There are also sources from market women and traders paying. That is the major sources of revenue for now" (Interviewee 1)*

Another interviewee respondent said:

> *"The sources of revenue I always see that they do every month, every year is to collect levies from shops and kiosks. That is, the local government have an organized team that go to shops to collect Levies and remit to the local government and this will serve as a means of generating income for the local government" (Interviewee 2)*

When their opinion was sort on whether the property-based sources of revenue generation can improve their local government finances if tapped, the interview respondents all agree that property-based sources can improve the local government finances when it is been managed effectively. They also opine that it can boost the financial stance of the local government since it brings additional money to the local government. One of the interviewees said: "We need to improve on the system, we have not done very well. So, the system needs to be improved so that our revenue in the local government will improve. The system now is not in order; the government needs to do something to improve the standard" (Interviewee 4)

When asked to state the important reasons property-based sources are necessary or critical to

improving the local government finances, another interviewee respondent said:

> *"the main reason I support property-based tax is because we have so many properties all over the local governments of Nigeria. In fact, if it is properly looked into, it will be the major source of revenue for local councils. Let the owners of properties, pay. Once they pay, it will go a long way in improving the revenues of local government areas. And also, it will help in development. It will go a long way in provision of water supplies. So many will benefit when local governments tap property-based taxes" (Interviewee 6)*

Conclusion

In conclusion, the study has identified many of the various sources of internally generated revenues to local governments which formed a greater bulk of the total revenues accruing to the local governments. The study confirmed that many of these sources are either untapped or under-tapped in most local governments in the study area. The study found that majority of this internal sources are the property-based taxes which are often considered to be "benefit taxes", meaning those who own or control property that receives greater benefits from public actions and urban services and will also pay more in taxes and fees (if the charge is based on land value). The results of the survey of nine local government selected from the three Niger Delta States studied showed that twentyone out of the twenty-two property-based revenue sources for the survey with a mean rating of more than 3.0 are necessary for improving the local government finances if tapped. The study confirmed that property-based revenue instruments tend to be highly visible, and will promote transparency and accountability in local governments and that taxpayers are more attentive and engaged when the tax bill is more visible and transparent. The study thus concludes that the incorporation of sustainable strategies in the current revenue generation practice is indispensable and highly relevant, if the local government finances is to be sustainable. The study finds that a Sustainable Strategy which provides a strategic points and components necessary for the achievement of overall goal of the study. The four-points Sustainable Strategy-ROIS relates to revenue mobilization actions strategy; organizational capabilities enhancement of the local government; incorporation of best practices in local revenue mobilization and generation, and social mobilisation and technical support to the local government.

Recommendations

Based on the results of this study, the following recommendations are suggested in order to enhance the revenue potential of local governments.

i. All property-based taxes should be made known to the entire public to avoid corruption and fraud of any kind from local government officials;
ii. Appropriate sanctions like meaningful additional fees should be put in place and adequately publicized for late payment of property-based taxes. Citizens should know their liabilities and expectations at the beginning of every year;
iii. Local governments should employ technology driven mode of IGR collection as this would reduce cost of collection and improve remittance rate;
iv. The government should develop a system that generates and records accurate information on property transactions. Such information is essential to developing the value map that underlies a good assessment practice;
v. There should be the need to instil discipline, financial probity and accountability within the local government in order to improve and increase development at the grass roots level; and
vi. Carefully observing and adopting the four-points sustainable strategy - ROIS suggested by this study in order to unlock local government revenue potentials.

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Theme B:
Environmental Sciences Education, Decision Support and Urban Space Management

Evaluating the Spatial Placement and Circulation Flow in the Architectural Design of Postgraduate Housing in Rivers State University, Nigeria

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Abstract

The importance of Postgraduate housing to Rivers State University in particular and other universities in general must be recognized. The students immediate need after a day's lecture is a place to eat, relax and sleep therefore his housing must be convenient like classroom and library and must be clean, warm, functional in terms of space arrangement and positioning and well furnished. The primary aim of this study is to carry out detailed study on spatial placement of facilities/spaces (interior and exterior) and circulation flow and subsequently design of students' hostel and reduction on the dependence of active energy (Mechanical) that is, the design will be energy efficient. The researcher has gone through great lengths in examining the history of halls of residence in the world and in Nigerian universities. Various case studies were taken to find out their strengths and prevailing problems especially in terms of placement of spaces, functionality and circulation flow. General principles of students housing were examined and applied according to their particular situation. The result reveals that majority of university lack of attention to postgraduate housing, availability of facilities, the spatial arrangement and circulation pattern had resulted to student's loss of interest in residing in the campus. The study therefore, recommends a state of the art, functional, easy flow, comfortable and sustainable postgraduate housing, that will foster social interaction, communal living amongst student and energy conservation.

Keyword: Spatial Placement, Circulation Flow, Architectural Design, Postgraduate Housing

Introduction

The importance of the social environment in students' life cannot be over emphasized. One of the major facilities students tend to be concerned about when enrolling in a university is the quality and availability of students' housing. In the face of the global growth in the enrolment of students in tertiary education, students' housing has become one of the teething problems faced by higher institutions, especially in developing countries (Center for Global Education, 2002). Patrick., 2003 reveal that students' housing forms part of the facilities that students take into consideration before making a choice of the school they intend to attend among other considerations. As a unit of the environment, housing has great influence on the health, efficiency and social welfare of the community and a major area of interest to policy makers (Adeniyi, 2022). It is, therefore, necessary that students' housing, among other contemporaries, be given a top priority in universities and other tertiary institutions.

Housing of postgraduate students in universities is of no less importance than that of undergraduate students. A postgraduate student is a student who has obtained a degree from a university, etc, and is pursuing studies for a more advanced qualification, such as masters degree, MPhil, and a PhD. (Collins English Dictionary - completed and unabridged, 12th Edition 2014).

The provision of quality housing for postgraduate students in higher institutions is highly justified. Many postgraduate programs involve very high academic work loads, with a significant proportion of self-study / research. This can have the negative effect of making the students feel disconnected from the hustle and bustle of campus life, thus, living introverted and focused lives throughout the duration

of their programme. Many mature students (most of which are postgraduate students), find the university experience very stressful, suffer disorientation and social exclusion. This can be attributed to the fact that these students struggle with their personal challenges and commitments, alongside their studies (Nweke, 2011).

Thomas (2002), examining factors contributing to students' retention, notes the importance of friendship and social networks among the students, these varied demands and challenges, therefore, result in differences in the students' preferences, choices and levels of socialization. Therefore, the students neither have the time nor energy to build a supportive community and network with fellow students. The concept of creating and supporting intentional communities and investment in enhancing postgraduate experience by developing and implementing a good housing initiative that could bridge the gap between postgraduates' student, the family, the university, the educators, and the community through the design of housing has been architecturally explored for many years (Eckersley et al, 2016). From the mass housing of the modernist movement through the contemporary cohousing, varying degrees of success have been achieved. Therefore, the stressful experience of postgraduate students can be made considerably less, using sustainable architectural design and community concept as a tool to enhanced the social interaction. (Kramp, 2010).

Definition of Terminologies

a) Mature students are defined as any student aged 21 or above at the start of their studies (Mature Students' Guide, Universities and Colleges Admissions Service (UCAS)

b) Retention is staying in school until completion of a degree or program (Hagedorn, 2003).

c) A dropout is a student, who enters a college or university with the intention of graduating, and, due to personal or institutional shortcomings, leaves the school and, for an extended period of time, does not return to the original or any other school (Kaufman, 2004).

Aim of the Study

The study aims at evaluating the spatial placement and circulation flow in postgraduate housing design of universities hostel in Nigeria, the case of Rivers State University, and to provide an architectural and sustainable design solution that will support the development of a strong and supportive community among the various generations of postgraduate students.

Objective of the Study

To achieve the above aim, below are the specific objectives of the project.

a) Elaborate provision of communal spaces that would encourage socialization, networking and relationship building among students.

b) Provision of ancillary facilities that will enhance living, aid academic research and create and sustain the spirit of community- such as free internet, library, shopping facilities, canteens, gymnasia, to mention a few.

c) Provision of adequate facilities with good spatial arrangement and circulation that will for co-ed the and a high level of communal living, comfort and convenience.

Research Questions

a) How to create an intentional community in an inclusive postgraduate students' residence, using appropriate design techniques?

b) What technology / innovative approach will be used to meet the peculiar demands of the different categories of postgraduate students?

c) How can facilities with good spatial arrangement and circulation provide a high level of communal living, comfort and convenience in postgraduate housing?

Literature Review

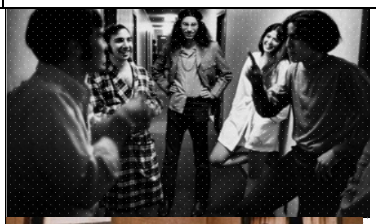
Housing is described as more than just a roof, it provides the opportunity for better lives and a better future (United Nations Human Settlements Programme (UN-Habitat, 2022). Housing provided for students is often referred to as 'hostel' or 'dormitory'. In the United States, 'dormitory' is the most common term, which comes originally from the Latin word dormitorium6; in the United Kingdom, the term 'hall' is more usual; while in Nigeria, the term 'hostel' is mostly used, especially in a university context. (Carla, 2019).

Student housing has played a major role in integrating the living and learning experiences of students in higher education. During the early centuries of the Common Era (CE), and even before the Common Era (BCH), adults (usually young men) traveled long distances by foot, donkey, or oxcart to "sit at the feet of the masters" or learn from Confucius, Plato, Socrates, and other great philosophers, scientists, artists, clergy, and educational leaders of their time (Lucas, 2006).

Table 1: Evolution of Student Housing Over the Centuries

S/N	University	Date of Establishment	Image of housing	Description	Source
1	Bologna in Europe	1088		The first official universities developed in Europe	Scholnick (2013)
2.	Oxford University Paegagogies	**1452**		University developed domus pauperums for poorer students	Scholnick (2013)
3.	German Universities	**1500**		Universities established a system of halls called busen, organized and run by monks	Scholnick (2013)
4	Harvard University	**18th Century**		The concept of the 'Ivory Tower' was	
				developed in students' housing	
5	Massachusetts Hall,	1718 and 1720		It sits on Harvard Yard, and was home to many famous American leaders during the Colonial age. This dormitory was designed to give students privacy and motivation to take their studies serious	TwinXL.com Blog, Oct 15, 2012

6	Harvard University dormitories	19th Century		The majority of dormitories housed only male residents, and they were forced to report to dormitory mothers who watched over them and ensured that they obeyed the strict rules and regulations	Scholnick (2013)
7.	American residence halls housed	**Early 20th Century**		The dormitories in the United States within the period were exclusively for men, the dormitories were more like a house of fraternity. the average dormitory room included a bed, a chai r or a futon and a small desk for each roommate; but most of the living furniture was reserved for the lounge areas. the spaces were not limited to only	
				sleeping but allowed for other social activities	
8.	University of Michigan	1960s and 1970s	 	This period marks the beginning of woman admission into the university and concept of dormitory was forced to change to accommodate women. Universities started building dormitories specifically for them. the University of Michigan opened the Martha Cook Building, which was designed at first to hold 115 women. It was a sign of the university's commitment to attracting women students and giving women the opportunity for an education that was equal to that of a man	Scholnick (2013) TwinXL.c om Blog, 2012

9.	General	1960		During this period, there was a remarkable changes in the political and civil rights, and massive state and federal spending. Disabled and minorities began attending college.	
10	University of Stanford, Brown University and University of Pennsylvania	**1972**	 	Following the geometric in increase the number of both gender, gradually, colleges began to allow co-ed dormitories.	
11	General	**1980**		The dormitories of the 1950s became illequipped to hand le the computer revolution. Rewiring buildings became an expensive and drawn out task.	
	General	**1990**		State and federal funding decreased and the demand for college dormitories increased.	
12	Modern Day Dormitories	2000		There was a new rise of sustainability not only in deploying environmentally friendly materials, but also the way in which the residents used resources. Dormitory rooms now contain many luxuries, making it feel more like a tiny apartment. At Michigan State University, dormitories have been built in recent years that allow students to live and take class	Scholnick (2013)

				all in same building. Most of the dormitories have several different cafeterias that resemble five-star restaurant rather than college dining halls	TwinXL.com Blog, Oct 15, 2021

As dormitory rooms began popping up left and right at college dormitories, the buildings were less architecturally elegant and more functional. There were bathrooms included in some of the rooms themselves, and cafeterias were often located right in the building. Study lounges accompanied were getting bigger in size and including more comfortable furniture and longer beds. The evolution of the university dormitory design and from the common era, through the centuries, and up to the modern day, is aptly illustrated in the figure below.

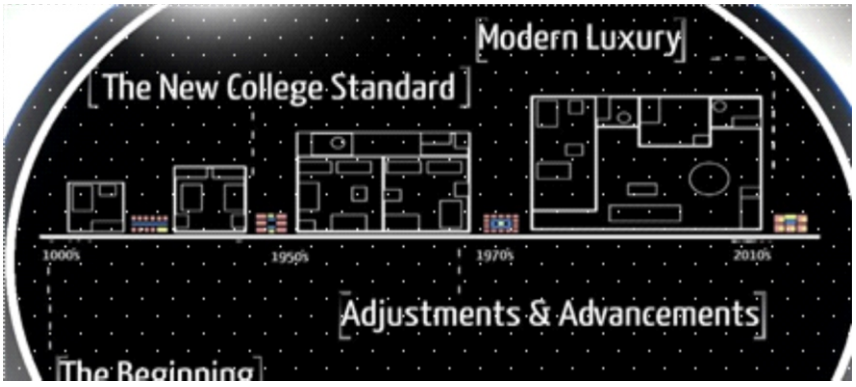


Fig. 1: Evolution of the University Dormitory
Source: Scholnick, 2013

The Concept of Cohousing and Community

Cohousing is a consciously designed of private homes clustered around shared space. Each attached or single-family home has traditional amenities, including a private kitchen. Shared spaces typically feature a common house, which may include a large kitchen and dining area, laundry, and recreational spaces. Shared outdoor space may include parking, walkways, open space, and gardens. (ScottHanson and ScottHanson, 2005).

Students have independent incomes and private lives, but collaboratively plan and manage community and academic activities and shared spaces. Community activities feature regularlyscheduled shared games rooms, meetings, and lecture days. Students gather for parties, games, movies, or other events. Cohousing facilitates interaction among students for social and practical benefits, economic and environmental benefits (McCamant, Durrett and Hertzman, 1994, Sanguinetti, 2014,).

The general structure of a cohousing community is based on the following five principles (ScottHanson, and ScottHanson, 2005)

i. Participatory Process
ii. Residents are active participants in all aspects of the community from the design phase and beyond.

iii. Intentional neighborhood design iv. The neighborhood is designed around the model of a cohousing community, not a typical suburban type neighborhood.
v. Private homes, common facilities
vi. All residents retain their own private homes and autonomy within the community, but share common spaces.
vii. Resident management
Non-hierarchical structure and decision making
A unique aspect of the cohousing model is the relationship between the private and collective spaces.

Students' Residence
It is imperative for student housing to provide the basic infrastructural amenities needed by the student. Such facilities include, toilets, running water, electricity, readily room, canteen, buttery, kitchenette and a recreation area. Provision of these facilities in good working order is something that is not always readily available in Nigerian universities. It is a fairly common occurrence for these facilities to either be unavailable, under-provided or in a state of disrepair (Adebisi, 2017, Utile 2024). Reviewing into the past, many authors have given various ideas about the origin of mass housing for the public and the students in higher institutions, as regard their importance and problems Carla (2019). The works of the above-mentioned researchers express that the importance of well managed and administered student accommodation cannot be overemphasized as data provides conclusive proof that the throughput of students in residences is far better than those that reside off-campus and commute to universities.

Methodology
The deductive method of research involving the collection of data from both primary and secondary sources was adopted. Primary sources of information include personal interviews, on general planning principles, questionnaire (since students are the best source of information regarding their needs and problems). Case studies of existing postgraduate hostel of study area with emphasis on their planning, the internet was also visited for foreign case studies and data collection.

Case Study and Selection Criteria
After a comprehensive study and observation, a purposed built university hostel for postgraduate study was adopted with the following conditions for practical study.
a) University post graduate student hostel/housing that captures the study requirements
b) University post graduate student housing/hostel that adopted and captures the variables under study: basic infrastructural amenities, cohousing community and housing/environment that provide social interration.

Smith College Campus Center, Northampton, Massachusetts, United States
Project Name: **Smith College Campus Center**
Architect: **Weiss Manfredi**
Location: **Northampton, Massachusetts, United States**
Year of Completion: **2003**

Design principle: Students at Smith College-the largest liberal arts institution for women in the country-are assigned to houses, many of them Victorian-era structures complete with living rooms with standard facilities and well layout environment. Meant to foster a collegial environment, while successful, they also create isolated communities. Broadening the opportunity for social interaction, the Smith College Campus Center serves as a mediating body, the only building at Smith available to all students, faculty, and staff

Fig. 2: Smith College Campus Center The Atrium Gallery

Source: www.google.com

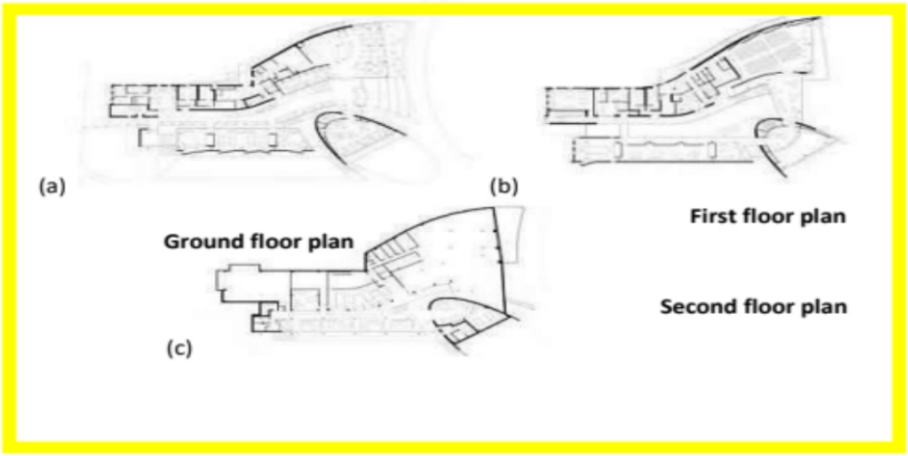


Fig 3: Floor Plans of the Smith College Campus Centre
Source: www.google.com

Design principle: Students at Smith College-the largest liberal arts institution for women in the country-are assigned to houses, many of them Victorian-era structures complete with living rooms. Meant to foster a collegial environment, while successful, they also create isolated communities. Broadening the opportunity for social interaction, the Smith College Campus Center serves as a mediating body, the only building at Smith available to all students, faculty, and staff.

Findings and Benefit from the Base Study

Availability of modern amenities and well laid out spaces that allowed for social interaction amongst student. The furniture encourages occupants to inhabit and take ownership of the building. With its welcoming furniture and pathway orientation, the campus center closes the physical and social gap between residential and institutional buildings, creating a communal living room for the college. The layout of the community is in the form of a central open area with housing and communal building perimeter.

Babcock University Postgraduate Hostel, Ogun State, Nigeria

Project Name: **Babcock University postgraduate hostel**
Location: Babcock University, Ilisan-Remo, Ogun state, Nigeria. Year of construction: 1999

Findings and Benefit from the Case Study

All rooms are en-suite. A 2-man room is provided on the ground floor to accommodate disabled persons. In accordance with Babcock University's tradition of enhanced student's welfare, a Hall

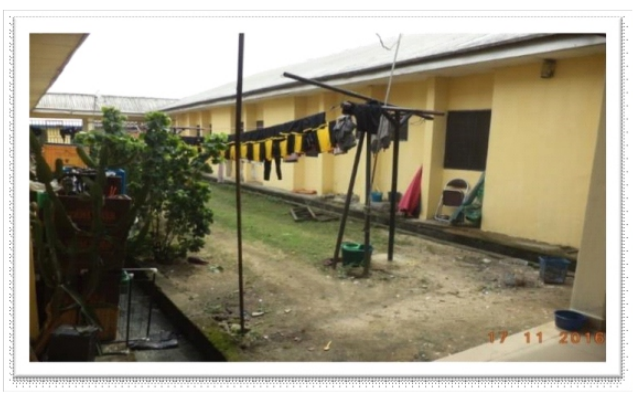
Master's residence (3-bedroom apartment) is provided. While this apartment is joined to the hostel block with a separate entrance. A 650-seater Activity hall is equally connected to the Hostel Block. This is a multi-purpose hall for students use. Other Facilities provided includes: Multi-purpose hall for students use, Hall Master's residence, Study room, Bedrooms of floor area 20m2, 2 Nos laundry rooms are provided on each floor.

Fig. 4: Site Layout and Perspective View of Babcock University Postgraduate Hostel
Source: http//:www.goggle .com, 2024.

Fig. 5: Showing the Floor Plans
Source: http//:www.goggle .com, 2024

Rivers State University Hallow Chamber Hall and PGSA Relaxation Park Postgraduate Hostels
In the campus of the Rivers State University where this study was carried out, there are only two postgraduate hostel buildings: the Hallow Chamber Hall and the PGSA relaxation park hostel constructed by David Nelson-Ordu led administration in 2022/2023, they are reserved for both male and female postgraduate students, Hallow Chamber Hall is a 2-winged building made up of one floor been the ground floor design to containing twenty (22) room spaces while the PGSA relaxation park hostel which is three floor level building containing forty-five (45) rooms, giving a total of 67 rooms which can only house 134 students if paired as against a total of three thousand (3000) postgraduate students in the university.

Fig 6: Pictoral View of Hallow Chamber Hall, RSU.
Source: Authors', 2024



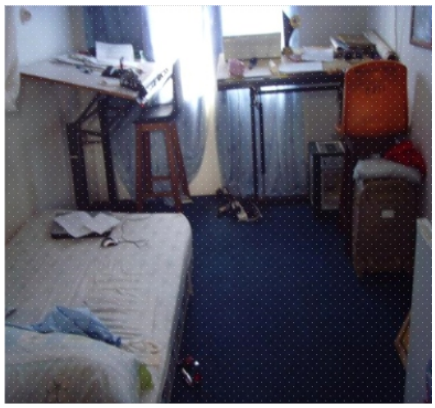


Fig 7: Courtyard View of Hallow Chamber Hall, RSU. The Room Space
Source: Authors', 2024

It was observed that there was shortage of accommodation spaces and basic facilities requirements in Rivers State University as against other foreign and local universities necessary to support the postgraduate students, in the hallow chamber hall postgraduate hostel students of RSU, the absence of refectory and laundry services, had resulted to the students converting the corridors to pantries, kitchens and clotheslines, due to the absence of spaces for cooking and laundry in the design of the hostel; thus, leaving narrow spaces for circulation and traffic and does not incorporate facilities that support older students and students with families. Similarly, the PGSA Relaxation Park Hostel, that was newly constructed with the aim of solving the problem of housing shortage and lack of facilities and recreation space, was observed to be still inadequately, with poor circulation, room spaces not standardize and lack of communal spaces.

Fig 8: Pictoral View of PGSA Relaxation Park Hostel, RSU .
Source: Authors', 2024

Fig 8: Pictoral showing the TV Room of PGSA Relaxation Park Hostel, RSU .
View Showing the Courtyard
Source: Authors', 2024

Data from Questionnaire

Questionnaires were distributed to a two hundred (200) of Post graduate students on the need for a standard and modern post graduate hostel that will enhanced learning and social cohesion between postgraduate students in the Rivers State University. Some other information was gotten from the students that will help in the study. The following paragraphs will give detailed analysis of the data gotten from the questionnaire distributed.

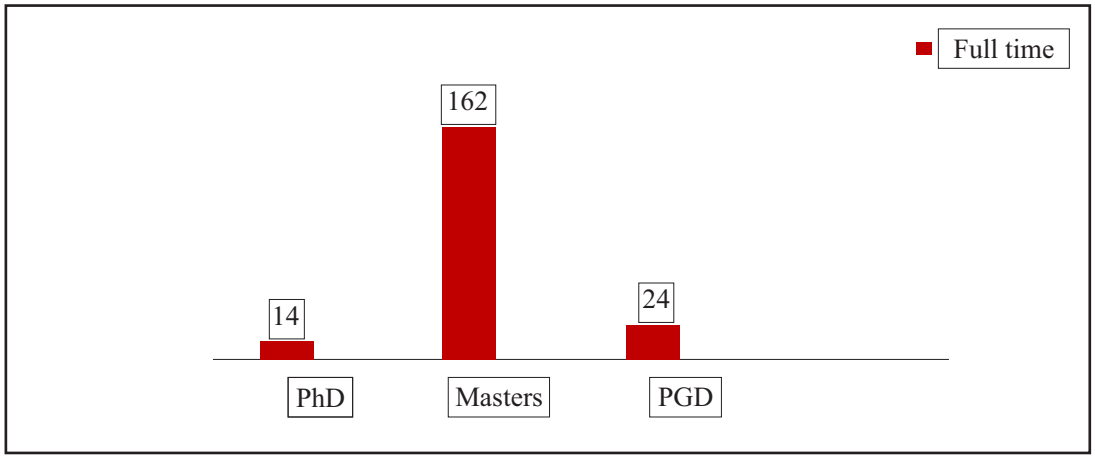


Fig 10. Percentage of Respondents according to their programmes,
Drawn by the Authors

From the Bar Chart above, it is noticed that;

I. A larger part of the Post graduate students enrolled in the Masters' Degree Programme.

ii. There are more Full-time students as compared to the Part-time students.

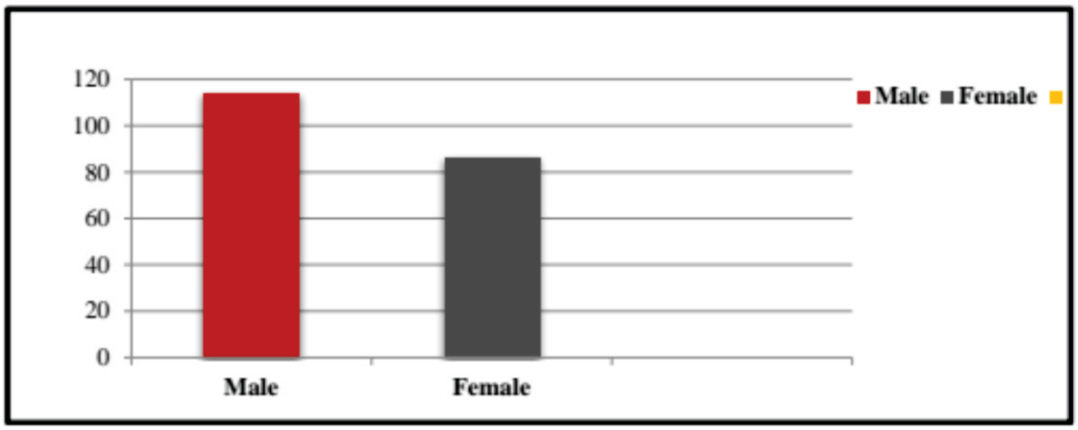


Fig 11. Percentage of Respondents according to their Sex

Drawn by the Authors

From the Bar Chart above, it is noticed that the number of males that are enrolled in the Post graduate programme in the Rivers State University exceeds the number of females.

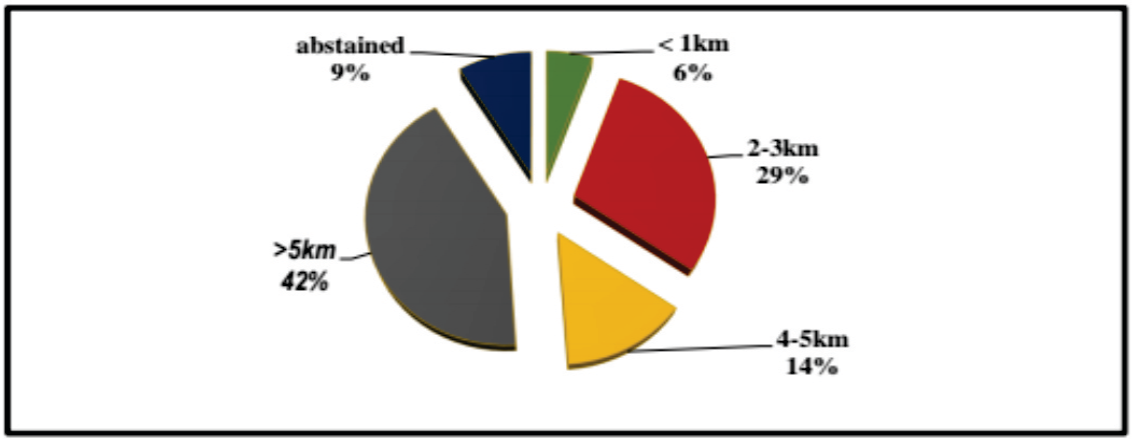


Fig. 12 Percentage of Respondents According to their Distance from School

Drawn by the Authors

Showing that a greater number of postgraduate student comes and leave far from the university

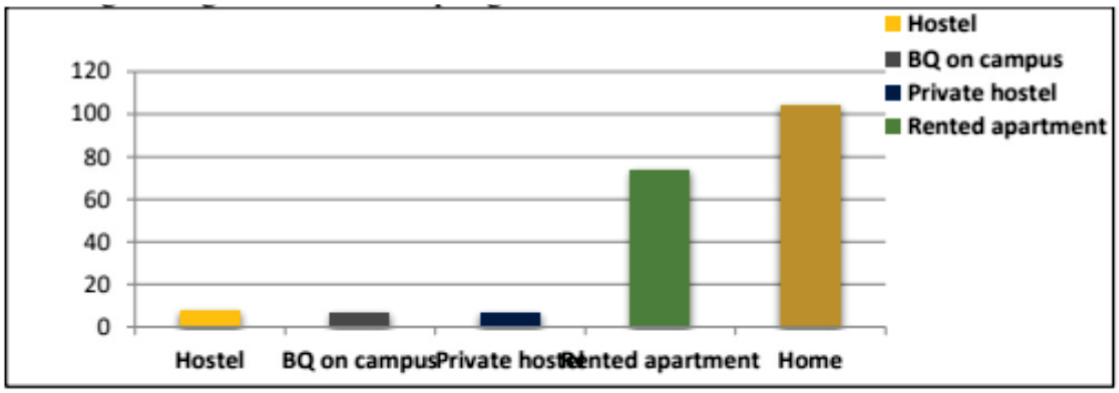


Fig. 13 Percentage of Respondents According to their Accommodation type

Drawn by the Authors

The bar indicates that due to shortage and unavailability of hostel accommodation, majority of the students comes from home while sick for private accommodation around the university environment

Fig. 12 Percentage of Respondents According to their willingness to stay in the hostel
Drawn by the Authors

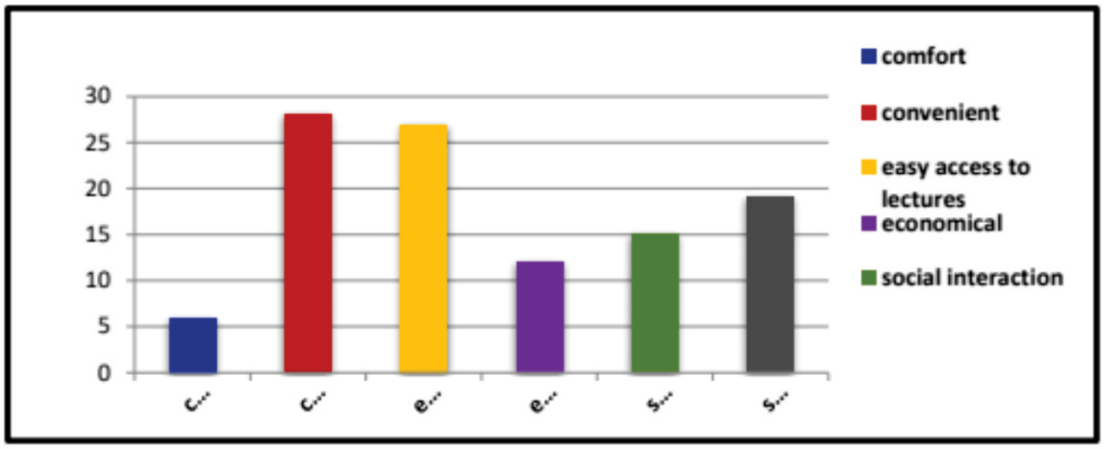


Figure 15: No of Respondents according to their reasons to stay in the hostel
Drawn by the Authors

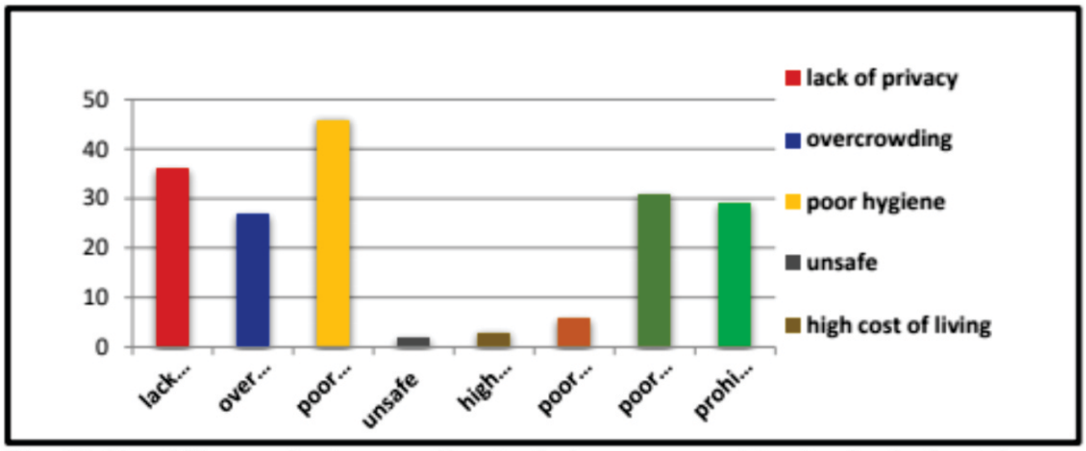


Fig. 16: No of Respondents according to their reasons not to stay in the hostel
Drawn by the Authors

From the pie chart and bar above, majority of students prefer to stay in the university hostel because of the convenient, easy access to lectures and social interaction but due to poor facility, environment and lack of facilities that encourage social and community living and overcrowding, poor hygiene condition.

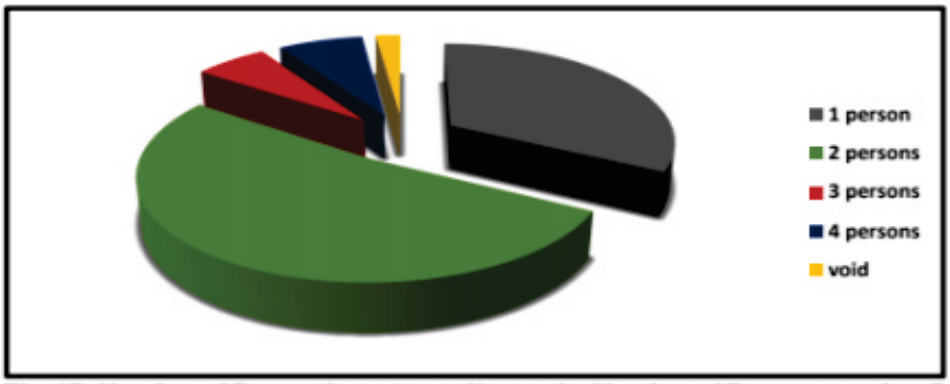


Fig. 17: Number of Respondents According to the Number of Roommates they Prefer
Drawn by the Authors

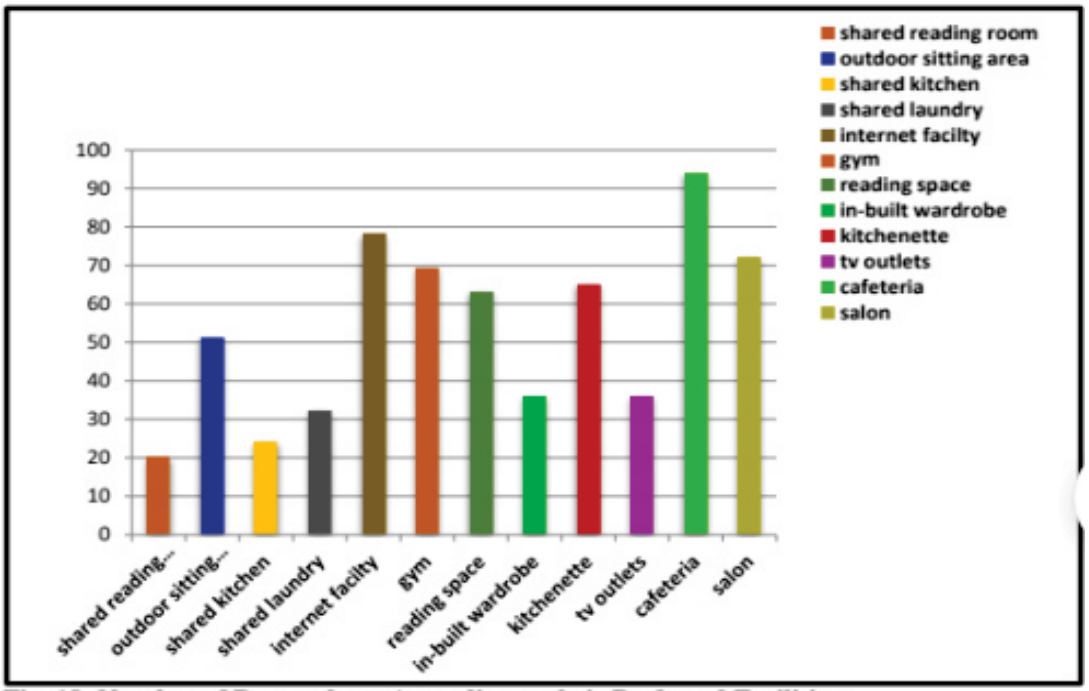


Fig. 18: Number of Respondents According to their Preferred Facilities
Drawn by the Authors

The students however admitted that staying in the hostel would have being the best option if they are provided with the above facilities as listed in the bar chart in figure 18.

Conclusion

All universities should recognize that students' needs and demands have changed and are continuing to change. The need for an improved students' accommodation is evident especially in the area of spatial arrangement of spaces, functions and overall site layouts. This increases efficiency in the design especially in the area of circulation flow. These further increases security, personal space control and comfort of the users.

Recommendations

The University should see the need to improve on the existing condition of postgraduate hostels and also provide a novel hostel for Post graduate students and embark on this project as it will provide proper and standard accommodation for this class of students.
The study further recommended that:

i. The individual sleeping rooms should be designed to allow for proper circulation flow. This means that opening such as doors and doorways should be spatially placed to direct proper movement. For example, sleeping corners for beds and reading tables should not be interrupted by any circulation element so as to allow for maximum utilization and reduce the psychology of overcrowding.
ii. The rooms should be designed to be self-contained, one bedroom and two bedrooms in order to improve sanitary condition and reduce the pressure on facilities. This will also improve circulation flow, help the student/occupant gain control of its space.
iii. The design of common space should allow and support social and communal living.
iv. The design of postgraduate housing should in cooperate facilities and space such as laundry, spaces for the physically challenge, mini-library, canteen, recreation spaces and facilities and a community setting and environment

Conclusively, this study will serve as a design solution to researchers, architects and other professionals in the built environment on the spatial arrangement and circulation flow of postgraduate housing,

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A Test Facility for Verification of Length Measurement using Electromagnetic Distance Measurement in MINNA, Nigeria

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Abstract

A Test line is usually a calibration baseline designed and configured on the earth surface with a set of pillars, ranging from few to more than ten, at distance varying from ten of meters to one kilometer. The baseline is a reference line for conducting surveys, for the triangulation network, calibration of Electronic Distance Measuring (EDM) Instruments detecting the errors, performance, and the correction of the instruments. This paper describes the establishment procedure and use of the facility for verification of electro- optical distance meters in Federal University of Technology, Minna (FUTMINNA). The design and establishment of the baseline consists of 5 concrete pillars with forced centering arrangements that enabled the determination of all instrument errors to an appropriate level of precision. The reference points were set up and the absolute distances between the points were determined with a standard deviation of 0.03mm using the Leica Absolute Tracker AT401. The baseline was also used for testing the distance meters of three total stations, by comparing the actual lengths between the pillars ("true values") with the measured lengths. The points are placed on 0m, 30.5, 86.5, 158, and the last point placed on 195m from the initial point. After establishment of the test line, three (3) different instruments (Sokkia 530R3, Sokkia 630R, and Wild DI 10) were calibrated on three different dates, ensuring similar metrological conditions, to have precise distance measurements. The results obtained from the calibration shows that the readings acquired on these instruments were accurate and approximately containing error of 0.55 millimeters.

Keywords: EDM, Test Line Facility, Calibration Baseline, Triangulation, Concrete Pillars

Introduction

A calibration baseline is a set of pillars, ranging from few to more than ten, at distance varying from ten of meters to one kilometer. The test field calibration baseline is a reference line for conducting surveys, for triangulation network, trilateration and for calibration of Electronic Distance Measuring (EDMI) Instruments. The design and formation of geodetic baseline will aid in correction and standardization of Electronic Distance Measuring (EDM) Instruments with an appropriate level of precision and accuracy (Braun, et al., 2014; Zakari and Aliyu, 2014). As more surveyors acquired EDMI, the surveying profession became concerned about the accuracy of their measurements. It has been shown that whereas accuracies attributed by the manufacturers to the instruments are reliable, errors in the observations, which are often systematic, can result from normal usage due to a reduction in the efficiency of electronic and mechanical components (EDM Calibration Handbook, Edition 17; 2020). Therefore, periodic maintenance, preferably by the manufacturer or a designated representative, is required to minimize such errors. It is equally important to verify the instrument constant and evaluate the measuring accuracy at more frequent intervals in conformity with International Standard Organization (Rüeger, 1990; ISO 17123-4 -Optics and optical instruments, 2012).

With the development of surveying, mapping and development of Geographic information System

(GIS) databases in public and private sector organization, institutions of higher learnings, the establishment of a five point's base pillars placed outdoor at 0m, 30.5, 86.5, 158, and 195m is immensely important in FUTMINNA. Moreover, it will be a constant learning resource for researchers working with various surveying equipment and techniques.

The lack of Test facility for calibration of EDMI in FUTMINNA campus posed a challenge to provide traceability of length for electro-optical equipment with; total stations, reflectorless total stations, laser scanners (Arabatzi et al., 2017; Japhet et al., 2021; Pagounis et al., 2022; Florian et al., 2023). Hence, the aim of this research work is to describe the processes involved in the design and establishment of a geodetic calibration baseline in FUTMINNA.

Literature Review

Electro-optical Distance Meter (EDM) calibration is the determination of instrument correction by comparing the value indicated by the measuring equipment with the known or true value. Due to the aging of the instrument, after repairs and services, jolts of the instrument would inculcate a lot of errors (Janssen, 2015; Arabatzi et al., 2017; Japhet et al., 2022; Kinga et al., 2022; Florian et al., 2023).

One important perquisite for SI traceability is the correct estimate of the associated measurement uncertainty. To determine the magnitude of the errors and their statistical properties of distance measurements of EDM equipment, baselines (outdoor or laboratory based) are commonly used (Janssen, 2015; Florian et al., 2023; Japhet et al., 2022; Kinga et al., 2022; Pagounis et al., 2022). However, establishing a direct link to the SI definition with low measurement uncertainty is laborious and hence, the need for calibration baseline for verification of distance meters on a regular check bases (following standards),to serve as a legal metrological control of measurement or for error detection and more accurate results (Vsevolod et al., 2022). Furthermore, Daniel and Hart (2019), established an EDM calibration baseline in a straight line configuration at the Rivers State University for Electromagnetic Distance Measurement Calibration to determine the performance of the instrument and its standardization. The measurement of the baseline was performed using Leica TC407 one second (1") Total station. The calibration baseline was divided into four bays and a total number of two hundred (200) observations were done in combinations. The analysis of the obtained 200 sample data set yielded the most probable value for the four bays as; and an instrument constant K= -0.0047m. The standard error of the unknown parameter was determined as;? = ?0.000. It was concluded that the result obtained can reliably be used for the calibration of Electromagnetic Distance Measuring Equipment in RUST, Portharcourt, Nigeria. This paper aims to describe a test field facility for distance measurements verification that has been established to cover the educational and research activities of the Federal University of Technology, Minna, Gidan-Kwano Campus.

Methodology

The establishment of a calibration baseline requires first site selection and the clearance of all the wild bushes and scrubs so that the site can be easily accessible. This followed by the location where the base pillars would be formed is selected with the help of surveying by total station and special prism reflector (construction of the calibration pillars bays). On completion of calibration bays, three different EDM instrument (SOKKIA 530R3, SOKKIA 630R, and Wild DI 10) is set up at a particular point which is known as the first point and considered to be as "0m? point for verification of total stations. The sequence of the field procedures for establishment of the baseline in FUTMINNA is as follows:

Establishment of a Control Baseline for Length Measurements

For the establishment of the baseline the first important step was site selection and its clearance of all the wild bushes and scrubs so that the site can be easily accessible. After the site is being cleared up, the location where the base pillars would be formed is selected with the help of surveying by total station (Leica Absolute Tracker AT401) and special prism reflector. For this purpose, Figure 1, depicts the location of geodetic baseline, at Federal University of Technology, Minna on 09^0 32' 30.46" N, 06^0 26'14.37" E at the top left, 09^0 31'15.84" N, 06^0 27' 20."67E at the bottom of the longitude and latitude respectively.

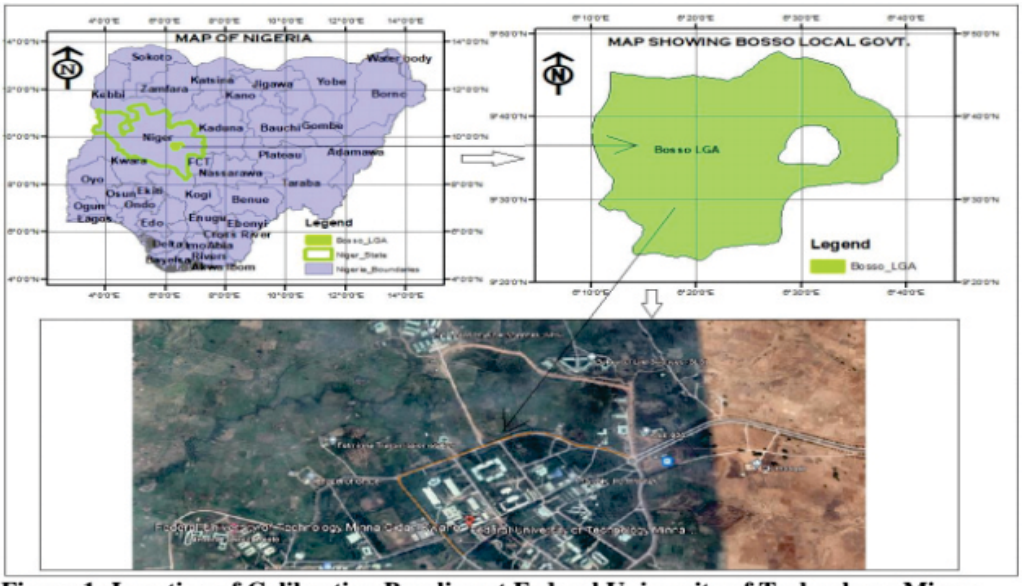

Figure 1: Location of Calibration Baseline at Federal University of Technology, Minna (Gidan Kwanu- Campus)

The instrument is set up at a particular point which is known as the first point and considered to be on chainage 0 .000m? point. For the selection of the points, firstly, instrument is placed on the initial point (point of survey). Then the rest of the points are acquired through this initial point. A total of five points are established on a straight line configuration. The points are placed on 0m, 30.5, 86.5, 158, and the last point placed on 195m from the initial point. To ensure the authenticity of the points taken, a back and forth readings are acquired (Buga et al., 2011).

Construction of the calibration Pillars (Bays)

After the selection of the site the construction process takes place. It is a requisite to dig up the 2 by 2 feet hole. Once the hole is dug then the second stage is to place the steel rods into the exact position of the points observed at the earlier stage. There are two different length of the steel rods attained on is 1 m long and the other is 2m long. In the beginning the 1m long is positioned exactly where the point was placed which was then verified by the total station. After verifying the location then the 2 m long rod is tied up in such a way that the combined length of the rods is 4.5 feet above the ground.

Once it ensured that the steel rods are placed on a right place then the crushed brick are grinded by pressing and squeezing in the base to make the foundation of the pillars. After the foundation was prepared, smoothened and levelled, the cement pipe is placed carefully on the location before the concrete filling gets dry and confirming that the steel plates are not displaced.

Subsequently the concrete is filled after placing the cement pipe so that pipe is fixed into the location. The pillars were constructed keeping in view the standard height of 4.5 feet but to make available the use of pillars for every height, the 6 inches' base is constructed so that the height of the pillar become 4 feet above the ground instead of 4.5 feet.

When the process of placement and filling of the cement pipe is done then came the very important phase of the baseline establishment, which is the placement of the fabricated steel plates. Fabricated steel plates are the plates with forced centering arrangement in order to set up instrument easily (Braun *et al*., 2014). Steel plates are placed very carefully and to confirm that these plates are placed on the right place. The prism reflector is placed onto it and then the reading is acquired.

Verification of total stations using, SOKKIA 530R3, SOKKIA 630R, and Wild DI 10

After the verification that the steel plate is placed on the accurate position, the leveling of the plate is done. The next important stage was the utilization of the geodetic baseline to calibrate modern surveying instruments and minimize their error rate.

The purpose of setting up this control base is mainly to verify precision instruments of a few millimeters such as geodetic total stations and laser scanner instruments for educational and research activities. The total station instruments can be checked for (i) zero error ("instrumentreflector constant"), and (ii) its measured length's standard deviation and its compatibility with the specified one by the manufacturer. In addition, reflectorless total stations and laser scanners can be verified against the manufacturer's specifications and tests regarding their behavior against various materials in order to define correction functions (in relation to material and distance) can be possible. It is emphasized that instruments either of time-of-flight principle or phase difference or using both principles can be tested. The control field was implemented with five specially designed bases made by steel (following ISO 17123-4 specifications). These were embedded in the wall at specified distances in such a way that their heads were on the same horizontal plane (of few mm accuracy). The dedicated design of the bases are designed so that their head carries an integrated 5/8 bolt to be able to attach a tribach in a unique way ("forced centering") to place instruments and accessories (Fig. 2). Figure 2 shows specially designed bases with distances between the bases (baseline reference distances) measured using the three EDM instrument; SOKKIA 530R3, SOKKIA 630R, and Wild DI 10.

Figure 2: Established Pillar Points at Gidan- kwano campus, FUTMINNA.

The verification procedure of the established baseline transpire by mounting the instrument on the base pillar and record the reading by placing the reflector prism on the other base pillars. For all the five pillars the reading process take place by taking one station as base station where instrument is placed whereas the other station act as forward sight and back sight (EDM Calibration Handbook, 2014; EDM Calibration Handbook, Edition 17; 2020).

Considering the station B, the back sight is station A and the forward sight is C, D, and E. For C the back sight stations are A and B whereas the forward sight is D and E. If taking D as base station then back sight is A, B and C and forward sight is E s (Volker & Tony, 2014). But for the station A and E the case is different. In the case of station A there is no back sight, all the four stations act as forward sight. And for the station E there is no forward sight, the four remaining stations act as back sight (Volker & Tony, 2014).

Before the process of acquiring the readings get started the temperature is noted down. This factor is added or set in the instrument before the reading are acquired (Allan et al., 2011). The temperature is measured by using the hand held thermometer (Zakari & Aliyu, 2014).

Results and Analysis

The process of calibration by the method cited earlier is done three times. After that the mean of all the reading is computed to generate the results. The instruments calibrated were SOKKIA 530R3,

SOKKIA 630R, and Wild DI 10 in three different rounds on 26th March 2023, 28th March 2023 and 1st April 2023. It was assured that in all three rounds temperature average temperature was same.

The results obtain from the calibration shows that the reading acquired using these instruments were accurate containing error of approximately 0.6 millimeters. The readings were then analyzed to conform to the algorithm of EDM Calibration Handbook, (2014). It is necessary to reject those reading that are different or in other words are outliers of the set of readings acquired in order to avoid errors or discrepancies. Hence it is essential to refine the readings for the better results (Braun *et al*., 2014).

Considering the distance from A to B the method used for rejection was that first of all the mean of values are taken and then this mean value is subtracted from the individual distance value which computes "R. Then after that the highest value is detected and eliminated from the dataset. The method is repeated until the desired results are obtained. The formula for computing R is as followed: R = | X i - X mean |

After analyzing the readings and rejecting the uncertain values the final accepted measurements for all the stations i.e. from A - B, A - C, A - D, A - E, B - C, B - D, B - E, C - D, C - E and D - E are shown in Table 1. the distance for each station is both ways for example if taking into account the distance from A to B then it's also from B-A (similarly for all the stations). The mean of the three sets of horizontal distances, corrected by atmospheric effects, on March 28th, 2023 and repeated on 1/04/2023 were considered for computations and analysis. Table 1 depicts the field data acquired and its meteorological data on 28/04/2023.

Table 1: Field Data Acquired on 28/04/2023 at the Test Facility of FUTMINNA

Date of Observation	EDM Station Order	X	Temp	Pressure	Relative Humidity
28/04/2023	A- B	30.5201	30.5	1012	56%
28/04/2023	B- C	86.5271	30.5	1012	56%
28/04/2023	C- D	158.0170	30.5	1012	56%
28/04/2023	D- E	195.0250	30.5	1012	56%

Source: Authors´ Fieldwork, 2023

Table 2 depicts the final computed distances of the inter pillar points having an estimated RMS as ± 30 um.

Table 2: Final Accepted Distance for All Stations

S/NO	STATION	DISTANCE(m)
1	A-B	30.5201
2	A-C	86.5271
3	A-D	158.0170
4	A-E	195.0250
5	B-C	56.0094
6	B-D	127.503
7	B-E	164.513
8	C-D	71.4951
9	C-E	108.508
10.	D-E	37.0186

Source: Authors´ Laboratory Work, 2023

The calibration procedure is done only through the electronic distance measurement instruments, therefore it is recommended that the calibration procedures should also be done through the calibrated steel tapes.

Conclusion

A Test facility for calibration of EDMI has been achieved in Federal University of Technology, Minna (Gidan Kwano-campus). This facility would be an asset for the university as it will initiate all the surveying approaches required for construction of the fully functional baseline for the calibration of the EDMs. This baseline will also provide improvements in surveying activities and for calibrating the EDMs (Braun, *et al.* 2014; EDM Calibration Handbook, Edition 17; 2020). The study recommends that another set of measurements be carried out using calibrated Invar Steel Wire or Tape for further verification at a future date. In addition, a future plan to include collimators for horizontal and vertical angular control, as well as two fixed points on the floor, with high precision altimetry, should be placed in the same space so that altimeter systems can be controlled.

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Environmental Adult Education Programmes and Waste Management Disposal in the Public Modern Markets in Port Harcourt, Nigeria

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Abstract

The study examined environmental adult education programmes and waste management disposal in the public modern markets in Port Harcourt, Nigeria. The study adopted the descriptive survey design. The population of the study comprised 50 respondents comprising 23 market women from Sangana market, Afikpo and Rumuwoji ultra modern market in mile 1 and 27 market women from Bishop Okoye, Samwoko and Oroworukwo ultra modern market mile 3. The study adopted total enumeration method in which the entire population was studied without sampling due to the manageable size of the population. Instrument for data collection was a self-structured designed questionnaire titled "Environmental Adult Education Programmes and Waste Management Disposal in the public modern markets in Port Harcourt Questionnaire" (EAEPWMDQ) with a cumulative reliability index of 0.76 obtained showed the instrument was reliable. The questionnaire was structured using the four-point Likert rating scale response of Very High Extent (VHE) = 4points, High Extent (HE)= 3points, Low Extent LE = 2points, and Very Low Extent (VLE) = 1point. Mean and standard deviation statistics were used to answer the research questions, while z-test statistical tool was used to test the null hypothesis at 0.05 level of significance. The study revealed that market women in mile 1 and mile 3 market engaged in keeping the environment clean after their daily sales and the weekly sanitation organized by market chairman equally has been of great help in keeping the market clean at the end of every week. It was therefore recommended that public markets and its environs should be swept and kept clean regularly by these who makes any shop in the market at the close of their daily sales, and market chairmen should ensure markets are kept clean and everyone should keep his/her shade clean on every general market sanitation day.

Keywords: Environmental Adult Education Programmes, Waste Management Disposal, Public, Modern, Markets

Introduction

Cleanliness they say is next to godliness, but will one say same when it comes to the public modern markets in Port Harcourt? Over time in Eheazu (2016) man has advanced to explore his surroundings and use various available resources besides the ground to shape his destiny depending on the magnitude of his capabilities in relation to his experience and level of intellectual and technological development. On the other hand, forces and factors in man's external surroundings, which constitute man's environment, influence his actions and thinking including the type and variety of his intentions, economic activities, as well as his beliefs, attitudes, hopes and visions.

In the course of time, man's utilization of natural resources and his constant interaction with the forces and factors of his environment have yielded not only intended or desirable outcomes, but also harmful circumstances that threaten the survival of plant and animal species (including man) on the planet earth. For instance, the current prevailing twin phenomena of global warming and climate change which have accentuated the incidence of various calamities on earth (improper waste disposal, flooding, tsunamis, crop failure etc.) are largely traceable to unintended outcomes of man's economic and other developmental activities in rural, urban, private and public settings.

In all, man's ignorance of the damage he is doing to earths very delicate ecosystems in his pursuit of unsustainable lifestyles has been stressed as a major cause of environmental degradation (Greenanswers.com, Eheazu 2016).

Environmental adult education as defined by UNESCO Tiblisi in Eheazu (2016) is a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters the attitudes, motivations and commitments to make informed decisions and take responsible action. Environmental education connects us to the world around us, teaching us about both natural and built environments. Environmental education raises awareness of issues impacting the environment upon which we all depend, as well as actions we can take to improve and sustain it. Environmental adult education is recognized as a "hybrid outgrowth of the environmental movement and adult education, combining an ecological orientation with a learning paradigm to provide a vigorous educational approach to environmental concerns (Sumner, 2003).

Eheazu (2004) states that adults constitute the majority in the production process and they are closer to the environment than the children. Therefore, environmental adult education serves as a vital tool for one to maintain environmental quality. Generally, most adults in Nigeria live environmentally incompatible life styles. The quest for wealth and development has blind -folded many to its attendant environmental problems. Resources are produced for survival under ecologically? destructive conditions. Although the extent of damage to humans and environment are not recorded in any statistics, its massive detrimental effects can be seen on valleys, waterways, plants, air, traditionally operated farming, fishing, market places and settlements in Nigeria. Majority of the local population are getting poorer while environmentally related diseases affect urban dwellers. Environmental adult education would encourage people to lead more modest life and more environmentally compatible life style. Environment and development should be unified. The more adults make from the environment today, the less their children would make from it if the environment were not sustainably managed.

Environmental adult education is centered on improving quality of environment through the efforts of individuals, groups and society at large. It aims at liberating adults and by extension young children from the shackles of ignorance, poverty, and poor health resulting from environmental degradation. It focuses on how to develop enquiring minds and creative thinking in adults on waste management both at home and market places without disrupting environmental equilibrium. Environmental adult education programmes is needed to develop the adults' minds, create an ethical awareness of all forms of life, (Adehikun & Ihieghulem, 2015).

Many see environmental adult education as teaching environmental issues and how individuals especially the market women on how they can manage or change their lifestyles of waste disposal at the market place and their personal life as they go about their day to day business in the market. The overarching goal of environmental adult education is to educate her citizens especially those at the market environs on personal hygiene and proper ways of waste management disposal both at home and in the market places.

According to Business Dictionary in Balogun (2011), environmental sanitation concept means the activities aimed at improving or maintaining the standard of basic environmental conditions affecting the well-being of people. These conditions include clean and safe water supply; clean and safe ambient air; efficient and safe animal, human, and industrial waste disposal; protection of food from biological and chemical contaminants; and adequate housing in clean and safe surroundings. It is also called

environmental hygiene. Environmental sanitation is also defined as the art and science of applying sanitary, biological and physical science principles and knowledge to improve and control the environment and factors therein for the protection of the health and welfare of the public.

World Health Organization (WHO) has been at the forefront of environmental sanitation and hygiene action over the past years and developed some key materials intended for policy-makers and technical people dealing with these issues. For a sanitation system to provide the greatest health protection to the individual, the community, and society at large it must anchor on the following assumptions: isolate the user from their own excreta; prevent nuisance animals (e.g. flies) from contacting the excreta and subsequently transmitting disease to humans; and inactivate the pathogens before they enter the environment or prevent the excreta from entering the environment. (Carr and Strauss, in Balogun 2011).

The limitation of environmental sanitation is not far from the fact that people do not realize the health benefits to the individual, the community and to society from improving sanitation. The high cost of improving sanitation is often cited as a barrier to implementing sanitation projects. However, to decrease the proportion of people lacking basic sanitation and water supply by 50% worldwide by the year 2015, it is estimated that US$ 23 billion per year would be needed - about US$ 7 billion a year more than is currently spent (WHO, 2000; WHO, 2001b).

Vagale as cited in Balogun (2011) classified traditional markets on a functional basis before analyzing them. Market may be grouped in terms of several variables like scale of transactions (whether retail or wholesale); type of commodities sold i.e. food grains, cloth and household goods; periodicity whether daily or occurring at regular intervals; time of operation whether functioning in the day, night or day and night; nature of growth i.e. organic, laid out, planned; and ownership of land buildings i.e. town council, local community, family head and individuals. However, the most valid and useful classification of market in Nigeria town seems to be the one based on the periodicity of markets operations. Operating system of traditional market is daily both night and day while some markets operate at day intervals. The periodic and daily operation of these markets classified them as traditional markets because periodicity is one of the criteria of traditional market.

Omole (2010) expressed that markets are man-made features established for the use of man. The work of scholars, particularly those of Filani & Richard, Nwafor, Sada & Mc Nuity, Eben-Saleh in Balogun (2011), among others agreed with this assertion. They went further to identify two basic classes of market places as daily and periodic markets which were further sub-classified as; morning, full-day, night, periodic, provincial and with kingdom markets. Nwafor as cited in Balogun (2011) held the view that a crawly market requires the existence of many full-time traders and that it is a more convenient type of market in that it provides daily needs to the people on daily basis. Browley in Balogun (2011) saw the market place as a place, which provides opportunities to meet one's friends and kinsmen for the exchange of news and gossip. Market gives room for freedom of speech and high level of socialization because of its nature of buying and selling among different categories of people.

Adewole (2OO9) examined the major effects of waste management on the quality of life in two perspectives such as environmental and health effect. The major environmental effects include air pollution and waste pollution, while the health effects include flies which carry germs, mosquitoes breed in stagnant water in blocked drains, rat's spreads typlius, salmonella, leptospirosis and other diseases. Miller in Balogun (2011) considered the second effects of waste management on the quality of life by saying that a city with a hazardous waste facility is now perceived and an undesirable place to live and to identify that people are leaving there is a social somatization.

Lu Aye & Widjaya (2005) compared the level of environmental impact of waste generated by traditional markets with other sources of wastes generation saying that the attributed reason is that in general the waste generated from traditional markets are more uniform, more concentrated and less hazardous than waste from other sources. Argenti (2000) was of the view that the management of waste from the urban food system, particularly from markets and slaughterhouses, poses one of the greatest challenges to city managers. Slaughterhouse waste is related to a host of hygiene, health and environmental problems thereby requiring safe disposal. Growing quantities of waste from processing plants, markets and slaughterhouses together with dumping of plastic packing and waste burning boosts health risks and the pollution of water, soil and air.

Research Wikis (2006) expressed that new waste management methods have been continually introduced over time, as the issues become more pressing including source reduction, recycling, composting, energy recovery and landfill. When these methods are combined properly, they can effectively manage solid waste, while protecting human health as well as the environment. Traditional markets in Ibadan need the intervention of the new waste management methods to promote human health and enhance healthy environment. Antonis (2011) asserted that it is clear that new challenges are emerging and the current situation must be seen in a different way. Our waste management systems and our market conditions, even at their best, are incapable of handling the growing amounts of waste globally. Also expressed that unless a new paradigm of global cooperation and governance is adopted, a tsunami of uncontrolled dumpsites will be the prevailing waste management method.

To this effect, Kpeno (2019) was of the view that waste disposal are those materials that individuals seems not to have need for thereby discarding or throwing them away. Most materials regarded as waste for a particular person may equally not be useful to some others especially the perishable materials. This encourages one to have proper place for every item needed to be kept so that waste when it has to be disposed should be kept in a proper place for disposal so that nobody mistakes items to be kept for future use for item to be disposed, thrown away or discarded. The primary goal of this study therefore is to examine the extent of environmental adult education programmes and waste disposal management in the public modern markets of Port Harcourt, Nigeria.

Purpose of the study

The primary objective of this study was to investigate environmental adult education programmes and waste disposal management in the modern markets in Port Harcourt, Nigeria. Specifically, the study sought to:

5. Determine the extent market women are engaged in keeping the environment clean after daily sales in the public modern markets of Port Harcourt, Nigeria.
6. Examine the extent to which weekly sanitation organized by market chairmen helped in keeping the market clean at the end of every week in the public modern markets of Port Harcourt, Nigeria.

Research Questions

The following research questions were formulated in line with the purpose of the study:

1. To what extent are market women engaged in keeping the environment clean after daily sales in the modern markets of Port Harcourt, Nigeria?
2. To what extent has the weekly sanitation organized by market chairman helped in keeping the market clean at the end of every week in the modern markets of Port Harcourt, Nigeria?

Research Hypotheses

The following hypotheses guided the study and were tested at 0.05% level of significance: **Ho_1**. There is no significant difference between the mean opinion score of mile 1 and mile 3 women on the extent they are engaged in keeping the environment clean after daily sales in the modern markets of Port Harcourt, Nigeria.

Ho_2. There is no significant difference between the mean opinion score of mile 1 and mile 3 market women on the extent the weekly sanitation organized by market chairman helped in keeping the market environment clean at the end of every week in the modern markets of Port Harcourt, Nigeria.

Methodology

This research was designed to gather data from market women from Sangana market, Afikpo market and Rumuwoji ultra modern market all in mile 1 market and market women from Bishop Okoye, Samwoko and Oroworukwo ultra modern market all in mile 3 market. These markets are in Port Harcourt City Local Government Area of Rivers State, Nigeria. The research design adopted in this study was descriptive survey design. The population of the study was 50 respondents comprising 23 market women from mile 1 market and 27 market women from mile 3 market. The study adopted total enumeration method in which the entire population was studied without sampling due to the manageable size of the population. Instrument for data collection in this study was a self-structured designed questionnaire titled "Environmental Adult Education Programmes and Waste Management Disposal in the modern markets in Port Harcourt Questionnaire" (EAEPWMDQ). The instrument was validated by two experts in Adult Education and Community Development and Measurement and Evaluation. The internal consistency of the instrument was determined using Cronbach Alpha statistics. A cumulative reliability index of 0.76 was obtained which showed the instrument was reliable. Copies of the instrument were personally administered to the respondents by the researcher and retrieved. The data collected were analyzed using mean and standard deviation statistics, while the hypotheses were tested using the z-test. Decision rule for the research questions were based on the classification of level of extent as shown below:

Classification

Very High Extent (VHE) = 4.
High Extent (HE) = 3
Low Extent (LE) = 2
Very Low Extent (VLE) = 1

Results

Research Question 1

To what extent are market women engaged in keeping the environment clean after daily sales in the modern markets of Port Harcourt, Nigeria?

Table 1: Extent to which market women engaged in keeping the environment clean after daily sales in the modern markets of Port Harcourt, Nigeria.

S/No	Items	Mile 1 Market Women (N =23)			Mile 3 Market Women (N=27)		
		Mean	SD	Remark	Mean	SD	Remark
1	Market women frequently sweep in and outside their shop at the end of their daily sales	3.00	0.96	HE	3.00	0.90	HE
2	We take turn in sweeping our shop	2.09	1,00	LE	2.15	1.01	LE
3	The entire market smells badly as a result of improper waste disposal	2.30	0.99	LE	2.29	1.00	LE
4	Just like me, my next door neighbor always dispose waste at the end of every day	2.78	0.88	HE	2.77	0.90	HE
5	I keep my shop clean always even as I do not sale perishable goods	2.97	1.00	HE	3,00	0.96	HE
	Grand Mean & SD	2.63	0.95	HE	2.64	0.95	HE

The analyzed data in table 1 showed the mean and standard deviation scores on the extent to which market women frequently sweep in and outside their shop at the end of daily sales in modern markets of Port Harcourt. The mean scores in items 1, 4 and 5 of research question 1 fell within the range of high extent showing that majority of the respondents agreed with items in the table. However, items 2 and 3 fell within the range of low extent, implying that majority of the respondents disagreed with the items. With grand mean and standard deviation of 2.63 and 0.95 is to a High Extent.

Research Question 2

To what extent has the weekly sanitation organized by market chairman helped in keeping the market clean at the end of every week in the modern markets of Port Harcourt, Nigeria?

Table 2: extent to which weekly sanitation organized by market chairmen helped in keeping the market clean at the end of every week in the modern markets of Port Harcourt, Nigeria

S/No	Items	Mile 1 Market Women (N =23)			Mile 3 Market Women (N (N=27)		
		Mean	SD	Remark	Mean	SD	Remark
1	Security personnel in the market constantly locks any shop with dirty environment	3.04	0.88	HE	3.03	0.90	HE
2	The weekly sanitation organized by the market chairman has helped in having a clean environment	2.91	0,96	HE	2.96	0.92	HE
3	Market chairman is in constant collaboration with sanitation personnel in ensuring that the market regularly observed	2.87	0.88	HE	2.96	0.96	HE
4	Market chairman is on his own because I will not clean or sweep my shop surrounding	2.13	1.00	LE	2.11	1.00	LE
5	I am very satisfied at the level of cooperation by women on regular environmental sanitation carried out weekly in my zone	3.17	0.98	HE	3.11	0.98	HE
	Grand Mean & SD	2.82	0.94	HE	2.83	0.95	HE

The analyzed data in table 2 showed the extent to which weekly sanitation organized by market chairmen helped in keeping the market environment clean at the end of every week. The mean scores of items 1, 2, 3 and 5 fell within the range of high extent implying that majority of the respondents agreed with these items. However, item 4 fell within the range of low extent, implying that majority of the respondents disagreed with the items. With the grand mean and standard deviation of 2.84 and 0.95, the answer to research question 2 is of a High Extent.

Hypothesis 1

There is no significant difference between the mean opinion score of mile 1 and mile 3 women on the extent they are engaged in keeping the environment clean after daily sales in the modern markets of Port Harcourt, Nigeria.

Table 3: Z-test Analysis of Difference in Mean Responses Extent to which market women engaged in keeping the environment clean after daily sales in the modern markets of Port Harcourt, Nigeria

Respondents	N	X	SD	DF	z-Cal	z-Crit	LS	Decision
Mile 1 Market Women	23	2.63	0.95					
				48	1.81	1.96	0.05	
Accepted								
Mile 3 Market Women	27	2.67	0.95					

The analyzed data in table 3 showed the z-test analysis on the extent to which market women are engaged in keeping the market environment clean after daily sales. The result on the table showed there is no significant difference between the mean score and standard deviation of market women in mile 1 and mile 3 market on the extent to which they daily clean they market environment. The result on the table further showed the z-calculated value of 1.805 which was less than the z-critical value of 1.96 at 0.05 level of significance and with a degree of freedom of 48. Since the zcalculated 1.805 was less than the z-critical 1.96, the null hypothesis was accepted which means that there is no significant difference between the mean opinion score and standard deviation of mile 1 and mile 3 market women on the extent these market women are engaged in keeping the market environment clean after daily sales.

Hypothesis 2

There is no significant difference between the mean opinion score of mile 1 and mile 3 market women on the extent the weekly sanitation organized by market chairman helped in keeping the market environment clean at the end of every week in the modern markets of Port Harcourt, Nigeria.

Table 4: Z-test Analysis of Difference in Mean Responses of Mile 1 Market Women and Mile 3 Market on the Extent the weekly sanitation organized by market chairman helped in keeping the market environment clean at the end of every week Respondents

z-Cal	z-Crit	LS	Decision					
Mile 1 Market Women		**23**	**2.82**	**0.95**				
					48	**0.97385**	**1.96**	**0.05**
Accepted								
Mile 3 Market Women		**27**	**2.83**	**0.95**				

The analyzed data in table 4 showed the z-test analysis on the extent to which weekly sanitation organized by market chairmen helped in keeping the market clean at the end of every week. The result on the table showed there is no significant difference between the mean score and standard deviation of market women in mile 1 and mile 3 market on the extent to which weekly sanitation organized by market chairmen helped in keeping the market clean at the end of every week. The result on the table further showed the z-calculated value of 0.97385 which was less than the zcritical value of 1.96 at 0.05 level of significance and with a degree of freedom of 48. However, since the z-calculated 0.97385 was less than the z-critical 1.96, the null hypothesis was accepted which means that there is no significant difference between the mean opinion score and standard deviation of mile 1 and mile 3 market women on the extent weekly sanitation organized by market chairmen helped in keeping the market clean at the end of every week.

Discussion

The discussion of the findings strictly followed the two research questions raised in the study. The view of market women engaged in keeping the environment clean after daily sales in the modern markets of Port Harcourt, Nigeria showed that market women at mile 1 and mile 3 ultra modern markets participated in the weekly sanitation market women participated in has help improve their personal hygiene and has equally helped in having a clean environment. The findings is in agreement with Lu Aye & Widjaya (2005) as the level of environmental impact of waste generated by traditional markets with other sources of wastes generation saying that the attributed reason is that in general the waste generated from traditional markets are more uniform, more concentrated and less hazardous than waste from other sources. Further more, the findings agrees with Argenti (2000) as he viewed that the management of waste from the urban food system, particularly from markets and slaughterhouses, poses one of the greatest challenges to city managers. Slaughterhouse waste is related to a host of hygiene, health and environmental problems thereby requiring safe disposal. Growing quantities of waste from processing plants, markets and slaughterhouses together with dumping of plastic packing and waste burning boosts health risks and the pollution of water, soil and air. Therefore, weekly sanitation and proper waste management disposal in the public ultra-modern markets will drastically reduce hazards to human life.

The view of market women on weekly sanitation organized by market chairman helped in keeping the market clean at the end of every week in the modern markets of Port Harcourt, Nigeria showed that market women at mile 1 and mile 3 ultra-modern market organized by the market chairman gave these women insight on healthy living both at home and at market places. The findings agrees with Adewole (2OO9) as he examined the major effects of waste management on the quality of life in two perspectives such as environmental and health effect. The major environmental effects include air pollution and waste pollution, while the health effects include flies which carry germs, mosquitoes breed in stagnant water in blocked drains, rat's spreads typlius, salmonella, leptospirosis and other diseases. Also, Miller in Balogun (2011) considered the second effects of waste management on the quality of life by saying that a city with a hazardous waste facility is now perceived and an undesirable place to live and to identify that people are leaving there is a social somatization. Weekly sanitation in market places especially the public ultra modern markets in Port Harcourt is of high essence.

Conclusion

Based on the results and the findings of this research, the researcher therefore noted that educating market women on proper waste disposal using environmental adult education programmes will be of great help as it will serve as a way of enlightening market women in public modern ultra modern market ways to which mile 1 and mile 3 market and its environs on personal hygiene, protecting the environment from man-made disaster like flooding, erosion, loss of lives etc. and how the public markets can be kept clean after their daily businesses.

However, with the continuous the weekly sanitation organized by the various market chairmen every week, public markets in Port Harcourt will not only be neat but it will improve the personal hygiene of market women to a great extent.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Public markets and its environs should be swept and kept clean regularly by these who makes any shop in the market at the close of their daily sales.
2. Market chairman should ensure markets are kept clean and everyone should keep his/her shade clean on every general market sanitation day.

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Physical Planning: A Panacea for Addressing Declining Residential Quality and Quality of Life in Yenagoa City, Nigeria

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Abstract

Residential quality has become a fundamental determinant of quality of life in urban settlements. The aim of the study is to assess the impact of declining residential quality and quality of life of residents in Yenagoa City, Nigeria. The objectives are to identify residential quality indicators of QoL, assess impacts of residential quality indicators on QoL, and identify sustainable physical planning measures to improve residential quality and QoL of residents of the study area. The study adopted quantitative research approach employing descriptive research design. The study employed simple random technique for selection of 6 neighbourhoods. A total of 396 respondents were gotten applying Taro Yamane formula at 5% precision level and proportionately distributed across sampled neighbourhoods. The study found that the declining residential quality affects physical, social and economic domains of life as residents are living more in rooming housing and block of flats with an average of 4-6 households and 2-3 household, with mostly 4-6 persons per household occupying 2-3 rooms and 1 room. More than 60% of the buildings occupied lacked water supply and mostly earthed roads without drainages. The findings further showed that some neighbourhoods lacked secondary school facilities. The study found prevalent of crime and violence which have caused injury, property loss and life in the study area. Consequently, the study found substantial percent of residents are unemployed with average earning of the employed are less than N60,000 monthly. The study revealed that the contributions of the indicators used for assessing demonstrated from residents rating of perceived QoL perceived of the neighbourhoods as "unsatisfactory" and "satisfactory". However, to improve these conditions the following measures are proffered including urban renewal schemes should be carried out in the neighbourhoods, government agencies involved in physical planning and management should strictly enforce existing physical planning policies, regulations and standards, develop Participatory Planning Approach (PPA) framework were members of the neighbourhoods and the city development agencies will collaborate in the decision making process and halt urban sprawl and leapfrog development in the city to prevent informal settlements formation.

Keywords: Physical Planning, Residential Quality, Quality of Life

Introduction

The transformation of settlements from rural to urban areas has become a contemporary trend in recent decades. The transition of Yenagoa from rural to urban settlement in the mid 1990's from the pronouncement as capital of Bayelsa State resulted to increase in population and investments leading to the development of urban infrastructure and services. This action changed the morphology of the neighbourhoods in the city through the attraction of physical development and human activities affecting the residential quality and quality of life (QoL) of the neighbourhoods. Residential quality encompasses attribute that give sense of well-being in a living environment including food, housing and its accompanying elements and safety and security (WHO-IASSID, 2000). Wokekoro (2015) also supported the description of residential quality as elements that makes residential neighbourhood ideal for habitation for the residents that live in that neighbourhood.

However, poor physical planning and management triggers distortion in neighbourhoods which affect the residential quality and the perceived QoL lived in the environment as this may led to sprawl development and informal settlement formation in urban environment (Fellmann, Getis, and Getis, 2005). Poorly serviced neighbourhood without essential neighbourhood infrastructure and services spur the questions about the residential quality and how people feel about their QoL in the environment they live. In assessing residential quality to achieve improve QoL, indicators are employed to analyse issues of the neighbourhood which help in decision making in housing and neighbourhood preference (Aliu, 2024). Some indicators to assess residential quality as proffered by Zhu, Jin, Zhang & Zhang (2023) include ecology, facilities, security, quality of peripheral facilities, kitchen and bathroom facilities, children-friendly, entertainment, room quality, engineering quality, building performance, and maintenance which was used to assess residential quality in Beijing, China. These indicators can be used to evaluate residential quality of a neighbourhood and will translate to the perceived QoL of the residents. Residential quality evaluation of urban residence is a fundamental part of urban residents' health and social well-being that contribute to urban sustainable development (Zhu et al., 2023). This requirement is crucial to QoL as it cut across physical, social and economic aspects of urban life.

The city of Yenagoa is witnessing increase in population size and densification, and incrementally multiplying in the development of neighbourhoods is facing inadequacy in provision of infrastructure and services likewise the quality of housing provision to her teaming population. The opportunities provided by the city master plan of 2004 to coordinating physical planning and provision of essential infrastructure and services have not been met by government and its agencies. This condition threatens the residential quality of the neighbourhoods thereby jeopardising QoL of residents and the entirety of the urban environment. The defacing environment of the neighbourhoods present declining attributes that affects residential quality, QoL and well-being of residents in several ramifications. This study is to assess the declining of residential quality and QoL of residents of neighbourhoods in Yenagoa City which will help to understand the dynamics of neighbourhoods as to promote sustainable urban environment.

Statement of the Problem

Residential areas are places for community bond and social integration which propels socioeconomic growth and development and QoL of residents that inhabits the area. Observations indicates that residential quality of neighbourhoods is declining in Yenagoa City, Bayelsa State. The decline is resulting deteriorating physical, social and economic aspects of residential quality affecting residents QoL. This condition is accentuated by poor housing condition, inadequate provision of neighbourhood facilities and services, and increasing poverty rate in the neighbourhoods. Furthermore, poor urban planning and management of neighbourhood also highlight these conditions. The non-attendant to these conditions will further increased the impacts of physical, social and economic aspects of the neighbourhoods and reduce the residential quality and overall QoL of the residents in Yenagoa City. Against this drawback, the study is assessing the residential quality decline affecting QoL of residents of Yenagoa City and provide sustainable measures to halt residential quality decline and improve QoL of residents of these neighbourhoods.

Aim and Objectives of the Study

The aim of the study is to assess the impact of declining residential quality and quality of life of residents in Yenagoa City, Nigeria.

Objectives of the study is as follows:

I. Identify residential quality indicators of QoL in Yenagoa City; ii. Assess impacts of

residential quality indicators on QoL in the study area; and iii. Identify sustainable physical planning measures to improve residential quality and QoL of residents of the study area.

Scope of the Study

The Geographical scope of the study covers Yenagoa City LGA in Bayelsa State, Nigeria (see Figure 1). The content scope covers identifying residential quality indicators of QoL in Yenagoa City; assessing impacts of residential quality indicators on QoL in the study area; and identifying sustainable physical planning measures to improve residential quality indicators and QoL of residents of the study area.

Figure 1: Yenagoa City LGA showing Studied Neighbourhoods
Source: Surveyor General's Office, Bayelsa State, 2023

Literature Review

Residential Quality and Neighbourhoods

Keeble (1969) defined urban and regional planning as the art and science of ordering the use of land and the character and siting of buildings and communication routes so as to secure the maximum practicable degree of economy, convenience, beauty and safety. From consensus definitions, urban and regional planning is the process of arrangement of various landuses and human activities in an environment in order to achieve maximum degree of aesthetics, economy, convenience and health. From these descriptions the scholars have displayed the organisation of human settlements irrespective of the hierarchy to a functional one that the inhabitants can reside, work and recreate. The arrangement

of the land uses; residential, commercial, industrial, recreational, transportation, institutional and other human activities should be in such a manner that the living condition and well-being of people residing in the environment are improved.

One fundamental concern urban and regional planning activities does is to provide living environment such as neighbourhoods that is ideal for liveability and sustainability for today's people and that of the future. This can be achieved through the provision of all necessary infrastructure and services that will make living condition worthwhile and improve QoL of the people that reside in the neighbourhoods. Neighbourhoods and its character play pivotal role in shaping the urban form and structure of cities and towns. Ideally, neighbourhoods are to complement one another in order to benefit and contribute to the physical development of the urban environment likewise promoting human existence (Republic of South Africa (RSA), 2019). Neighbourhoods are basically defined as geographical units which serves as residential areas for human habitation (City of Lancaster Comprehensive Plan, 2002). The neighbourhoods go beyond the provision of homes for human accommodation but other elements such as infrastructure, facilities and services that accompanied them for social interactions and community bonds, sense of community, improved local economy and QoL. Therefore, well-designed and developed neighbourhoods provide a setting for residents to develop a strong sense of belonging, which is promoted by their interactions with one another and create special identities that project the images and uniqueness that are visible in character. Some of the characteristics of neighbourhoods as specified by City of Lancaster Comprehensive Plan of 2002 include:

i. Physical condition of housing units;
ii. Opportunities for social interaction;
iii. Careful and strategic placement of retail uses and other appropriate non-residential uses within the neighbourhood area;
iv. Continued investment in public and private property to stabilise property values;
v. High level of owner-occupancy of dwelling units;
vi. Condition of public facilities and infrastructure serving the area;
vii. A sense of community and belonging among residents; and
viii. Access to public open space areas.

These characteristics cut across physical, social and economic domains of human lives and further indicate the level of satisfactions individuals and the community perceive the residential quality of the neighbourhoods. These character presents the visual image in term of forms and psychology of residents including visitors to the neighbourhoods.

Residential Quality and Quality of Life

There are various domains of human life that is used to assess and determine the QoL in urban are especially in neighbourhoods whether in developed or developing countries (Gandelman, Piani and Ferre, 2012; Martinez-Martin, Prieto-Flores, Forjaz, Fernandez-Mayoralas, Rojo-Perez, Rojo and Ayala, 2012). The domains are used to determine individuals' satisfactions and well-being based on the circumstances of life taking cognizance of subjective and objective ratings that are predetermined by internal and external factors within their environment (Gandelman et al., 2012). The domains are used to generate indicators to serves as framework and guideline for assessing and rating QOL of individuals and households in a particular living area to have a general rating subjectively (individuals) and objectively (experts) opinions (Eurostat, 2015). These domains and indicators are used to build the residential quality of a neighbourhood and also characterise QoL perceived by residents of these neighbourhoods they are living.

Residential quality and QoL are concepts that interwove which if not considered in urban planning and management affairs transient into urban degradation as the neighbourhoods will be perceived not good enough for living. This condition may affect physical, social and economic spheres of life in the urban environment relating to the "Broken Window" theory. Physical elements such as housing condition, access roads, drainage systems and water supply often fall into disrepair, leading to increased risks of flooding, waterborne diseases and environmental pollution which breeds informality (Mumford, 1961). Furthermore, social challenges such as increase in crime rates, reduced social cohesion and well-being, and limited access to essential services such as healthcare and education become eminent (Harvey, 2010). Also, decreased property values and disinvestment, discouraging property owners from maintaining or improving their properties. This decline in property values further limits access to affordable housing and exacerbates economic inequalities within neighbourhoods as a result of unemployment and poverty caused deteriorating local economy (Florida, 2008). These conditions impede urban growth and development that threatens sustainable urban development and jeopardises the residential quality and QoL of neighbourhoods in urban area.

Methodology

The study adopted quantitative research approach employing descriptive research design. The study employed simple random technique for the study. Primary data were collected from residents of neighbourhoods of the study area through questionnaire administration (closed and open-ended questionnaires) and physical observations to assess impact of residential quality decline on QoL of residents of neighbourhoods of Yenagoa City. The study identified 29 communities in the study area and 6 communities (neighbourhoods) representing 20% were randomly selected for sampling in the study specifically; Famgbe, Yenagoa, Ovom, Yenizue-Gene, Yenegwe and Igbogene communities. More so, to determine the sample size, 5 persons per household was used to determine the sample population to select respondents (household heads) that participate in the study (National Bureau of Statistics (NBS), 2016). A total 396 respondents were achieved and selected for the study applying Taro Yamane formula which was proportionately spread across sampled neighbourhoods selected for the study. The study used simple random sampling technique to select respondents that was interviewed in the study (see Table 1).

Table 1: Determination of Sample Size for the Study

Sampled Neighbourhoods	1991 Population	2023 Population (Projected Using 6.5% Growth Rate)	No. of Households (HH) (5 Persons per HH)	No. of Households Sampled in the Neighbourhoods
Famgbe	5,229	39,218	7,844	81
Yenagoa	8,723	65,423	13,085	136
Ovom	6,320	40,400	8,080	84
Yenizue-Gene	2,086 473	15,645 3,548	3,129 710	33 7
Yenegwe	3,536	26,520	5,304	55
Igbogene				
Total	**26,367**	**190,754**	**38,152**	**396**

Source: NPC, 1991; NPC, 2018; NBS, 2016; Researchers' Computation, 2023

Results and Discussions

Identified Residential Quality Indicators of QOL in Yenagoa City

There several indicators that are used to determine residential quality of neighbourhoods that impact

on QoL of the residents. These indicators cut across physical, social and economic domains of life which other authors have used to determine the perceived QoL in living environment including Gandelman et al. (2012) and Martinez-Martin et al. (2012). The study has identified indicators according to physical, social and economic domains including the followings:

Physical Indicators

The physical indicators identified and used for assessing the residential quality of the neighbourhoods include building type, building ownership, number of household in building, water supply, electricity supply and access road condition. The data in Table 2 indicated that more than 78.3% of building types are rooming housing and block of flats as revealed in the neighbourhoods of the study area. However, there are also bungalow (standalone), bungalow (semi-detached), storey building (detached) and storey building (semi-detached) buildings found in the neighbourhoods. The study from data presented further revealed that 63.9% of building occupants are renters while 32.3% of occupants of buildings are owner occupiers. The remaining respondents were squatters occupying the buildings in the neighbourhoods. Consequently, most of these buildings were occupied by an average of 4-6 households and 2-3 households accounting for 33.3% and 29.8% of the responses respectively while many buildings are occupied by 7-9 and 10+ households reflecting high densification per hectare in the study area. The average number of persons per household indicated in the neighbourhoods is 4-6 persons per household is equally prevailing in many urban areas in Nigeria. Habitable spaces occupied in buildings by households as revealed in the study in communities are mostly 2-3 rooms and 1 room which is very low for a household of 6 persons and above (see Tables 3, 4, 5 & 6).

Table 2: Building Type

Building Type	**No.**	**%**
Rooming house	190	48
Block of flats	120	30.3
Bungalow (standalone)	42	10.6
Bungalow (semi-detached)	10	2.5
Storey building (detached)	6	1.5
Storey building (semi-detached)	4	1
Others (specify)	4	1
NA	20	5.1
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 3: Ownership of Building

Building Ownership	**No.**	**%**
Owner occupier	128	32.3
Renter	253	63.9
Other (specify)	3	0.8
NA	12	3
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 4: Number of Household in Building

Number of Household in Building	No.	%
1 44	11.1	
2-3	118	29.8
4-6	123	33.3
7-9	53	12.6
10+	37	9.3
NA	21	5.3
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 5: Number of Persons in Household

Number of Persons in Household	No.	%
1 person	22	5.5
2-3 persons	89	22.6
4-6 persons	198	50.1
7-9 persons	55	13.8
10+ persons	21	5.3
NA	11	2.8
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 6: Habitable Spaces (Rooms) Occupied by Household in Building

Habitable Space (Room) Occupied	No.	%
1 room	114	28.8
2-3 rooms	203	51.4
3-4 rooms	33	8.3
5-6 rooms	12	3
7+ rooms	13	3.3
NA	21	5.3
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Thus, Table 7 displays physical domain indicator such as water supply used for determinant of residential quality in the study area. The table showed that 72% of the respondents indicated that there is no water supply in the building they are occupying while 22.9% affirmed they do not have water supply in their building. This data significantly showed that water supply is a lacking amenity in the neighbourhoods studied and affects the residential quality of the neighbourhoods in Yenagoa City. Another vital indicator electricity supply used for the assessment showed that large number of the households have electricity supply in the buildings they are occupying accounting for 89.6% of the

responses as indicated in Table 8. Though, mere 6.6% of the households attest not to have such service in their building. Accessibility which a crucial indicator in the physical domain revealed from data in Table 9 that the condition of access roads in the neighbourhoods from the modal responses are earth, tarred and concrete roads accounted for 50%, 19.2% and 28.5%, respectively. This condition demonstrates that there more of earth roads which do not have solid surface for motorisation in the studied neighbourhoods. The access roads conditions reflect the availability of drainages in the streets of the neighbourhoods as the data presented in Table 10 showed that more than half of the respondents amounting for 60.1% of the responses indicated there is no drainage in their streets in the neighbourhood since the access roads are not tarred or in concrete form.

Table 7: Water Supply in Building

Water Supply	**No.**	**%**
Yes	91	22.9
No	285	72
NA	20	5.1
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 8: Electricity Supply i n Building

Water Supply	**No.**	**%**
Yes	355	89.6
No	26	6.6
NA	15	3.8
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 9: Access Road Condition

Access Road Condition	**No.**	**%**
Tarred	113	28.5
Concrete	64	16.2
Earth	198	50
Others (speci fy)	0	0
NA	21	5.3
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 10: Availability of Drainage in Street

Availability of Drainage	**No.**	**%**
Yes	138	34.8
No	238	60.1
NA	20	5.1
Total	**396**	**100**

Source: Researc hers' Fieldwork, 2023

Social Indicators

Social indicators for assessing residential quality have major connectivity in measuring liveability of neighbourhoods. Some identified social indicators used for the assessment of residential quality include healthcare service, primary school, secondary school, crime and violent activities. Data in Table 11 indicates where households access healthcare service in the study area. Data showed that 67.9% of the households' interviewed acknowledged that their households access healthcare service within their neighbourhoods they are residing, 27.8% of the respondents affirmed that their households access healthcare service outside the neighbourhoods they are living but within Yenagoa and 0.5% said they access healthcare service outside Yenagoa. The data in Table 12 further showed same trend for household access to primary school in the study area. Data revealed that 64.2% of the households' access primary school within the neighbourhoods sampled in the study area, as 16.5% responded that their households' access primary school outside the neighbourhoods but within Yenagoa while 1.5% of households' access primary school outside Yenagoa. The respondents further indicated that 43.1% of households' access secondary school within the neighbourhoods they live followed by 16.8% that access secondary school outside the neighbourhoods but within Yenagoa while 2.5% of households' access secondary school outside Yenagoa as showed in Table 13. Social issues such as crime and violent activity was considered for assessing residential quality. The data in Table 14 indicates that 35.8% of the respondents affirmed that crime and violent activity often occurred in their neighbourhoods while 32.6% said these activities always occurred in their neighbourhoods, they are residing in the study area. These statistics showed that over 68% of the respondents acknowledged considerate occurrences of such activities in their neighbourhoods. The crime and violent activity occurrences have caused some issues that has effected the perceived residential quality of the neighbourhoods. As indicated in Table 15, the activity has caused loss to injury, property and life accounting for 45.3%, 36.5% and 18.2%, respectively from responses of people interviewed.

Table 11: Household Access to Healthcare Service

Household Access to Healthcare Service	**No.**	**%**
Within the neighbourhood	269	67.9
Outside the neighbourhood but within Yenagoa	110	27.8
Outside Yenagoa	2	0.5
NA	15	3.8
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 12: Household Access to Primary Education

Household Access to Primary Education	**No.**	**%**
Within the neighbourhood	254	64.2
Outside the neighbourhood but within Yenagoa	65	16.5
Outside Yenagoa	6	1.5
NA	71	17.8
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 13: Household Access to Secondary Educa tion

Household Access to Secondary Education	No.	%
Within the neighbourhood	171	43.1
Outside the neighbourhood but within Yenagoa	66	16.8
Outside Yenagoa	10	2.5
NA	149	37.6
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 14: Frequency of Crime and Violent Activity in Neighbourho od

Frequency of Crime and Violent Activity	No.	%
Always	129	32.6
Often	142	35.8
Uncertain	15	3.8
Rarely	63	15.8
Not at all	1	0.3
NA	46	11.8
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 15: Loss from Crime and Violent Activity in Neighbourhoo d

Loss from Crime and Violent Activity	No.	%
Life	126	18.2
Injury	314	45.3
Property	253	36.5
Others (specify)	0	0
Total	**693**	**100**

Source: Researchers' Fieldwork, 2023

Economic Indicators

Economic indicators determine the households' economic value, taste and purchasing power in the society. The economic indicators applied for determining the residential quality in the study area include employment status and income level of respondents. Table 16 showed employment status of respondents in the neighbourhoods as the data revealed that 52.6% of respondents are employed while 38.1% of respondents are unemployed. This showed that large proportion of population are unemployed which significantly will affect their taste and purchasing power to acquire daily needs of households. Furthermore, the employment status of the respondents in the neighbourhoods translate to the incomes of the respondents. The data in Table 17 presented showed that 26.8% of respondents' monthly income is less than N18,000 which is highest closely followed by 22.8% representing those earning between N18,001-N30,000 and 17.3% representing those earning between N30,001-N60,000. The data reflects that about 67% of the respondents earn less than N60,000 monthly.

Table 16: Employment Status of Respondents

Employment Status	No.	%
Employed	208	52.6
Unemployed	151	38.1
Retired	12	3
NA	25	6.3
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 17: Monthly Income of Respondents

Monthly Income (₦)	No.	%
Less than ₦18,000	106	26.8
₦18,001-₦30,000	90	22.8
₦30,001-₦60,000	69	17.3
₦60,001-₦90,000	30	7.5
₦90,001-₦120,000	19	4.8
₦120,001-₦150,000	7	1.8
₦150,001-₦180,000	6	1.5
₦180,001-₦210,000	2	0.5
₦210,001-₦240,000	1	0.3
₦240,001+	1	0.3
NA	65	16.5
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Assessed Impacts of Residential Quality Indicators on QoL in the Study Area

The study revealed that most of the households in the neighbourhoods assessed physical neighbourhood condition of neighbourhoods in the study area to have mix feelings of their rating more of "good" and "bad" (see Table 18). The rating of QoL in the neighbourhoods from the residential quality indicators employed in the study area showed that 34.6% and 33.3% of respondents said unsatisfactory and satisfactory in rating of QoL in the neighbourhoods they are living representing over 67% of the responses. Although, some respondents said uncertain accounting for 12.3% while 11.8% and 8% of the respondents said very unsatisfactory and very satisfactory, respectively with rating of QoL in neighbourhoods they live in the study area (see Table 19). The level satisfaction of a residential quality defines a neighbourhood is beyond the building occupied but other facilities and services that will contribute the QoL of the residents living in the neighbourhood (Republic of South Africa (RSA), 2019).

Table 18: Rating of Neighbourhood Condition

Rating of Neighbourhood Condition	No.	%
Very bad	12	3
Bad	114	28.8
Uncertain	47	11.8
Good	161	40.6
Very good	39	10
NA	23	5.8
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Table 19: Respondents Rating of QOL in Neighbourhood

Rating of QoL	No.	%
Very unsatisfactory	47	11.8
Unsatisfactory	137	34.6
Uncertain	49	12.3
Satisfactory	132	33.3
Very satisfactory	31	8
Total	**396**	**100**

Source: Researchers' Fieldwork, 2023

Conclusion

Declining nature of neighbourhoods in Yenagoa City connote unsustainability in the urban environment. However, the study has assessed declining residential quality and its effects on QoL of residents in Yenagoa City, Nigeria. The study has used indicators to assess the residential quality that are within physical, social and economic domains of human existence. The study revealed that physical indicators indicated rooming housing and block of flats occupied by an average of 4-6 households with 4-6 persons per household occupying 2-3 rooms and 1 room averagely. More than 50% of the buildings do not have water supply but having the presence of electricity supply. The roads conditions were mostly earth surface while some are tarred and concrete surface without drainages. The social indicators reflect that facilities such as healthcare service and primary schools are accessed within most neighbourhoods studied but there is a deviation in access to secondary schools which are accessed in other neighbourhoods by households. The study revealed that crime and violent activity frequently occur in the neighbourhoods causing injury, property loss and life. The economic indicators revealed from the study findings that over 50% of the respondents are employed though substantial percent are unemployed (38.1%). These residents earned averagely less than N60,000 monthly. The study revealed that the contributions of the indicators used for assessing the neighbourhood condition in the neighbourhoods from ratings reflect mix feelings of "good" and "bad" from the residents. This is also demonstrated in their rating of QoL perceived in the neighbourhoods as "unsatisfactory" and "satisfactory". These ratings indicated perceived residential quality in a declining direction and affecting QoL of residents in the study area. From the investigation, there is need to enhance the

assessed indicators that are perceived inefficient and inadequate to halt the declining residential quality and QoL in the neighbourhoods to propel sustainability and liveability in the study area. Hence, the study suggests sustainable urban planning and management measures to improve residential quality and residents QoL in the study area.

Recommendations

i. As a priority urban renewal schemes should be carried out in the neighbourhoods to enhance residential quality domains and indicators by providing and upgrading existing infrastructure and services to improve QOL in neighbourhoods;

ii. Government agencies involved in physical planning and management should strictly enforce existing physical planning policies, regulations and standards to enhance physical, social and economic conditions of the neighbourhoods to improve QOL of residents;

iii. Develop a Participatory Planning Approach (PPA) framework were members of the neighbourhoods and the city development agencies will collaborate in the decision making process to plan and re-plan neighbourhoods in the study area; and

iv. Urban sprawl and leapfrog development should be curtailed with sustainable and efficient physical planning and development control measures to control, guide and manage urban growth and development in the city to prevent informal settlements formation.

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Urban Sprawl and land Use Dynamics Within the Fringes of Port Harcourt, Rivers State, Nigeria

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Abstract

Urban sprawl which is the extension of the built-up area into the suburbs and rural areas has impacts on the livelihood of residents and environment. This paper examined Urban sprawl and land use dynamics within the fringes of Port Harcourt. The study covered six Local Government Areas that surrounds the Port Harcourt metropolis which are Oyigbo, Eleme, Etche, Okirika, Emohua and Ikwerre Local Government Areas of Rivers State. It is a longitudinal study which utilised both primary and secondary sources of data. The primary data were obtained using multispectral Landsat imageries. The imagery of 2000, 2010 and 2021 respectively were acquired using Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 OTI/LIRS respectively at a resolution of 30m. 400 questionnaires were administered to residents of the six (6) LGAs. Findings indicates that from the year 2000 to the year 2021, Eleme LGA lost 41.13% of the natural environment to the built environment, Emohua lost 9.91%, Etche lost 7.75%, Ikwerre lost 13.13%, Okirika lost 21.07% and Oyibo lost 41.13% to the built environment as a result of urbanization. It puts causes of urban sprawl as lower land value, improved infrastructure, rise in standard of living, lack of urban planning, lack of laws to regulate urban planning. It was recommended that social amenities should be provided in the rural areas, agriculture which is the basic occupation of the rural dwellers should be made more lucrative and policies to ensure vertical growth rather than just horizontal growth should be put in place.

Keywords: Built-up; Sprawl; Rural; Urban; Port Harcourt; Urbanisation

Introduction

As the globe make its journey on the path of urbanization albeit rapidly, the rural areas have been encroached upon by development from the urban areas. Urban encroachment into rural areas is sometimes called "urban sprawl". Urban Sprawl is the rapid extension of urban areas, development of built-up into the fringes or suburbs and rural areas (Galster, et al., 2001). Among the causes of urban sprawl is low-density development which uses a lot of land. These lands are used in an uncoordinated way. According to U.S. General Accounting Office (1999) and Staley (1999), any growth in suburban areas may be accused of "sprawling," especially when done in an uncoordinated way.

From inception, Port Harcourt city has witnessed remarkable growth which have caused increased demand and use of land. Before 1918, the municipal area of Port Harcourt was mainly farmland and secondary forest. The urban area was established by the colonial government when in May 1913, Lord Lugard acquired approximately 25 square miles of land from the indigenous Ikwerre and Okrika people (Brown & Wachukwu, 2015). According to Ede, Owei, and Obinna (2010), in terms of its physical size, the city grew from 15.54 square kilometres in 1914 to a metropolis covering an area of 360 square kilometres in the 1980's.

According to Weje and Wachukwu (2022), in order to improve on the city, development plans for Port Harcourt was drawn in 1959 and later replaced by the 1975 Master plan. In 2009, the planning area was

increased with the introduction of Greater Port Harcourt City Development Authority Master plan of 2008 which covered about eight (8) Local Government Areas (LGAs) on approximately 40,000 hectares of land with a projected population of 2 million people which cuts across Port Harcourt City, and parts of Oyigbo, Okrika, Ogu-Bolo, Obio/Akpor, Ikwerre, Etche and Eleme Local Government Areas (Weje & Wachukwu, 2022).

The increasing concern for the management of natural resources in recent times has been necessitated by the increasing demographic pressure and its associated anthropogenic activities which have led to serious environmental stress and ecological instability. The outcome of the natural and socio-economic factors of land use and land cover in Port Harcourt call for an accurate investigation in the causes, processes and rate of land use and land cover change in the city and its fringes.

Aim and Objectives of the Study

This research aims to examine the extent of urban sprawl and land use changes within the rural - urban fringe area of Port Harcourt.

The objectives of the study are:

i. Examine the land use change in the fringes of Port Harcourt for 21 years (2000 - 2021).
ii. Ascertain causes of urban sprawl within the rural-urban fringe areas of Port Harcourt.

Scope of the Study

The focus of this one-time study is to analyse the extent and causes of urban sprawl on land resources decline within the rural - urban fringe areas in selected LGA's in Greater Port Harcourt city. The Greater Port Harcourt City Master Plan is a holistic plan for the development of the Greater Port Harcourt City.

Description of the Study Area

The greater metropolitan area comprises the old city and its immediate hinterland. Greater Port Harcourt is located within latitudes 6058´N to 706´N and Longitude 4040´E to 4055´E (See figure 1). It falls almost entirely within the lowland swamp forest ecological zone and is flanked in the east, west and southern limits by mangrove swamp forest (Braide, Izonfur, Adiukwu, & Obunwo, 2004; & Chindah, 2004). Greater Port Harcourt covers an area of approximately 1,900 square kilometres (40,000 Hectares of land) spanning eight Local Government Areas which includes; Port Harcourt, Oyigbo, Okrika, Ogu-Bolo, Obio-Akpor, Ikwerre, Etche and Eleme, with a projected population of about two (2) Million people.

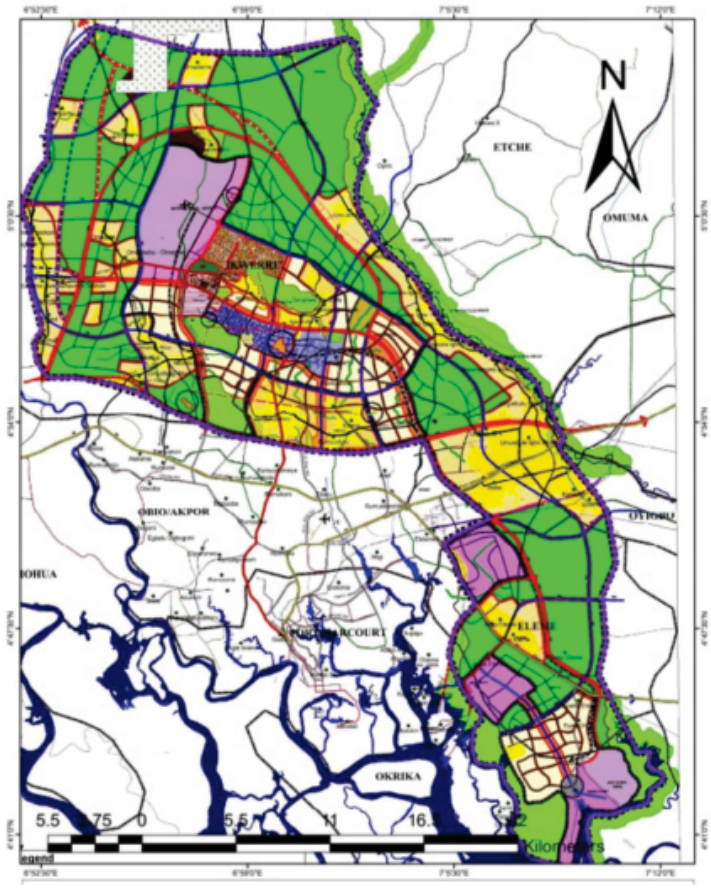

Figure 1: Greater Port Area, in Rivers State.
Source: GPHCDA, Master Plan, 2008

Literature Review

Urban Growth Machine Theory

The founder of urban growth machine theory is Molotch. It was first worked on by Molotch in 1976 (Molotch, 1976), later in that same 1976 by Logan and Molotch. It emerged from Chicago school of urban sociology and Science field of community power studies (Logan & Molotch, 1976). Urban growth machine theory assumes that growth is been controlled by the elite group. Harvey Molotch's work is on how elites and entrepreneurs create the growth of a city. Coalition of actors and organizers share interest in local growth since their actions affect land value, compete with growth machine elsewhere for scarce mobile capacity investment, while simultaneously attempting to gain the tacit support of local publics for such growth (Rodgers, 2009). The elite groups are in Port Harcourt, their land quest for various uses have caused urban sprawl. This quest has caused Port Harcourt to grow from a municipal area to a metropolitan area covering eight (8) local government areas in Rivers State.

The Concept of Urban Sprawl

Urban growth is a critical cause of Sprawl. As cities get bigger, they expand around their Peripheries. But sprawl is more specific in nature, it is an uncoordinated growth, the expansion of a community without a real concern for consequences of poor environmental conditions or environmental impact. Gordon and Richardson (1997), define urban sprawl as leapfrog development. Factors causing urban sprawl differ from region to region. In a nutshell, causes of sprawl include population growth, independence of decision, economic growth, industrialization, speculation, expectations of land

appreciation, land hunger attitude, legal disputes, physical geography, development and property tax, living and property cost, lack of affordable housing, demand of more living space, public regulation, transportation, road width, single-family home, nucleus family, credit and capital market, Government developmental policies, lack of proper planning policies, failure to enforce planning policies, country-living desire, housing investment, large lot size? (Bhatta, 2010).

Empirical Review

Agbora and Weje (2019), carried out a similar work in Bori, Rivers State, Nigeria. the study examined the expansion of Bori to see if land use changes in the area conform to the provisions of Bori Master Plan of 1972. Longitudinal survey design was used for the study, 2003 and 2018 imagery were gotten and analysed. The study discovered that the growth of Bori is at variance with the provision of the master plan as residential land use increased from 1,302.7Ha in 1972 to 5,302.7Ha in 2003 and 7,507.3Ha in 2018 respectively. Commercial land use grew from 144.8Ha in 1972 to 1,117.3Ha in 2018. The natural environment of Bori covered 65.4% of the total land area in 1972 but dropped to 7.3% in 2018. The study recommended a review of Bori master plan and its implementation.

Mairiga et.al (2023), looked at the spatial pattern of urban sprawl in Jos, Plataeu state from 2002 to 2022. The study used GIS mapping and land cover change analysis, neighbourhood statistics, cross change detection techniques and density sprawl to examine the spatial pattern of the sprawl. Findings of the study reveal that settlement area has increased from 125.45sq.km to 208.16sq.km between 2002 to 2022. Water bodies also reduced by 3.33sq.km and open space land use of 127.57sq.km were converted to settlement. The study attributted such growth to urban sprawl.

Alabi (2009), examined urban sprawl pattern and measurement in Lokoja, Nigeria. The study used GIS techniques to obtain local records for the period of 1987-2007 and application of Shannon's entropy theory to measure behaviour of sprawl. The findings showed that there is a correlation between population density and entropy values. Lokoja is experiencing growth along the major highways traversing the city. New development areas are concentrated along the workers' village, tapering along the Kabba-Okene road. The researcher further highlighted that another area of recent expansion was towards the Ganaja-Ajaokuta road where several government estates had sprung up as well as some privately-owned estates.

Aniekwe and Igu (2019), studied urban sprawl in Abuja. The study used 14 variables to represent causes of sprawl and 9 variables to represent effects of sprawl on the environment. Findings of the study indicate that population was the major factor responsible for sprawl; while the effects include loss of biodiversity, high rate of dependency on car, traffic congestion, land degradation, increased crime rate, pollution, etc. The study recommended adherence to guideline on urban development as a way to curb urban sprawl.

Hou et.al (2024), studied urban sprawl of a single urban agglomerations in China. Short term remote data sensing was used to quantify urban sprawl for 2000 to 2020. The study confirmed that China is still experiencing urban sprawl. Findings indicates that urban sprawl was more severe in the western region of China where the Urban Sprawl Index (USI) that was 5.33 during 2020 - 2020 and 89.3% of the cities exceeded the national average sprawl speed. The driving force of transportation on urban sprawl increased tremendously.

In America, Bruegmann (2005) studied sprawl: a compact history. The study justaposes that demand for having a large house detached with garden which is in touch with nature, introverted life styles are

the main reasons of urban sprawl. Nechyba and Walsh (2004) added that racism is also a contributing factor of urban sprawl in America. According to Brody (2013), identified land value, population growth, rising income, decreasing commuting cost, racial strife, age, choice of larger lots as causes of sprawling development in the United States.

Methodology

The research used longitudinal survey research design. It was carried out in-situ at one point in time. The study made use of both primary and secondary sources of data. The primary data are multispectral Landsat imageries, of 2000, 2010 and 2021 respectively. These imageries (Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 OTI/LIRS) were acquired respectively freely online from the site GLCF website with a resolution of 30m. The use of 400 questionnaires which was distributed and retrieved from residents of the urban fringes of Port Harcourt using simple random sampling aided in ascertaining causes of urban sprawl in Port Harcourt.

Results and Discussions

Land Use Changes Due to Urban Sprawl

Eleme local government area has approximately 13,783.24Ha of land. In the year 2000, the built environment covered 3,272.72Ha of land which is just 23.74% while the vegetation covered 76.26%. In the year 2010, the built environment increased by 11.66% thereby covering 4,880.32Ha of land (this represents 35.41% of the total land area). In the year 2021, the built environment further increased by 28.03%. As at 2021, the built environment covered 8,743.69Ha representing
63.44% of the total land, while the vegetation covered 5,039.55Ha representing 36.56% of the total land area (see Table 1).

The loss of vegetation in Emohua local government area is not tremendous. Out of 83,156.56Ha of the total land area, in 2010 the built environment covered only 3.08% while the vegetation covered 96.92%; in the year 2010, the built environment covered 5.74% while the vegetation covered 94.26%; in the year 2021, the built environment covered 12.99% while the vegetation covered 87.009% of the total land area. Emohua local government area has slight change of less than 10% over the years.

Etche has a total of 80,438.37Ha of land. In the year 2000, Etche LGA lost 4.01% of the total area to urban sprawl. In 2010, the local government lost additional 2.93% to the built environment making the vegetation cover to be 74,857.24Ha. In the year 2021, Etche lost an additional 4.821% of its vegetation cover to the built environment, leaving the total vegetation cover at 70,979.91Ha. Ikwerre local government area has a total of 65,666.67Ha of land. In the year 2000, vegetation in Ikwerre LGA covered 96.34% (63,261.69Ha) of the total land area. In the year 2010, the green area of Ikwerre reduced slightly to 61,185.57H and in 2021, the reduction in the vegetation area of Ikwerre became obvious as it dropped to 54,642.97Ha which is 83.21% of the total area as against 96.34% in the year 2000.

Okirika has experienced tremendous loss of natural environment to urban sprawl, especially within 2010 and 2021. The LGA has a total of 22,507.01Ha of land. The natural environment of the LGA covered 89.78% of the total land area in the year 2000; but in 2010, it reduced to 85.41%. While in 2021, natural environment covered just 68.71% of the total land area of the LGA. By implication, from 22,507.01Ha in 2000 to 19,223.24Ha in 2010, then to 15,464.93Ha in 2021.

Oyigbo local government area has a total of 25,184.08Ha of land but lost about half of its vegetation to the built environment. In the year 2000, Oyigbo had the vegetation on 22,139.55Ha (87.91% of the total

land area); in 2010, the vegetation decreased to 20,676.60Ha of land (82.10% of the total land area); then in 2021, the vegetation of Oyigbo further reduced to 11,782.14Ha (46.78% of the total land area). Within the period of 2010 to 2021, Oyigbo lost about 36% of the vegetation to the built environment, this can be tagged as a drastic lost caused by urban sprawl.

Table 1: Land Use Changes Due to Urban Sprawl

LGA	2000	%	2010	%	2021	%
Eleme	3,272.72Ha	23.74	4,880.32Ha	35.41	8,743.69Ha	63.44
Emohua	2,562.25Ha	3.08	4,774.97Ha	5.74	10,802.75Ha	12.99
Etche	3,226.23Ha	4.01	5,581.14Ha	6.93	9,458.46Ha	11.76
Ikwerre	2,404.98Ha	3.66	4,481.10Ha	6.82	11,023.70Ha	16.79
Okrika	2,300.91Ha	10.22	3,283.77Ha	14.59	7,042.08Ha	31.29
Oyigbo	3,044.52Ha	12.09	4,507.47Ha	17.90	13,401.94Ha	53.22

Source: Researchers' Field Survey, 2022

Generally, Oyigbo LGA has lost more of its natural environment to urban sprawl. The LGA lost 5.81% within 2000 to 2010 as indicated in table 2, the surge came within 2010 to 2021 when 35.32% of the natural environment were lost to the built environment thereby making it a total of 10,357.42Ha representing 41.13% of its total land lost to urban sprawl.

Eleme LGA is second to Oyigbo LGA in terms of general loss of natural environment to the built environment. Within 2000 to 2010, Eleme was losing more of the natural environment (11.67%) than other LGAs. Within 2010 to 2021, it lost more 28.03% making it a total of 39.70% (5,470.09Ha) of natural environment lost to urban encroachment.

Okrika is third in the rank of LGAs that have lost rural enclaves to urban form. From 2000 to 2010, the LGA lost 982.86Ha representing 4.37% of its total land area to man-made environment. The LGA further lost 3, 758.31Ha representing more 16.70%, making it a total of 21.07% of its natural environment lost to urban sprawl. Ikwerre, Emohua and Etche LGAs have lost a total of 8,618.72Ha (13.13%), 8,340.75Ha (9.91%) and 6,232.23Ha (7.75%) respectively to man-made environment as a result of urban sprawl.

Table 2: Land Conversion Over the Years Due to Urban Sprawl

LGA	2000 - 2010	%	2010 – 2021	%	Rank
Oyigbo	1,462.95Ha	5.81	8,894.47Ha	35.32	1st
Eleme	1,607.60Ha	11.67	3,863.37Ha	28.03	2nd
Okrika	982.86Ha	4.37	3.758.31Ha	16.70	3rd
Ikwerre	2,076.12Ha	3.16	6,542.60Ha	9.97	4th
Emohua	2,212.72Ha	2.66	6,027.78Ha	7.25	5th
Etche	2,354.91Ha	2.92	3,877.32Ha	4.83	6th

Source: Researchers' Field Survey, 2022

The urban fringes of Port Harcourt have suffered loss of vegetation to urban sprawl. Figure 2 clearly illustrate the land use cover change. It shows there was a rapid expansion of land use cover in all the six (6) Local Government Areas of the State studied. Urban growth and expansion are generally the result of large-scale settlement development that takes place amidst informal governmental land use constraints.

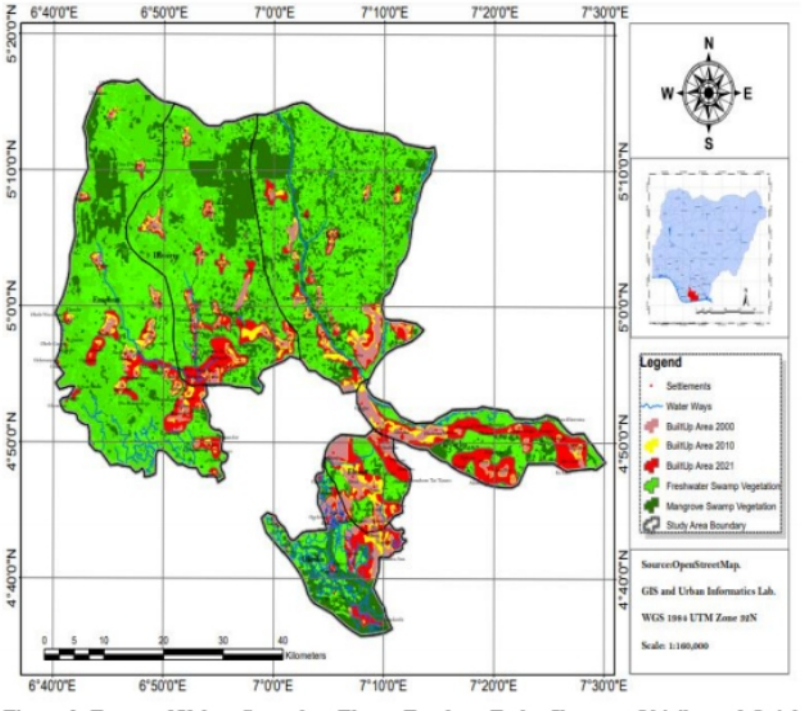

Figure 2: Extent of Urban Sprawl on Eleme, Emohua, Etche, Ikwerre, Okirika and Oyigbo
Source: Researchers' Field Survey, 2022

Major Causes of Urban Sprawl within the Fringes of Port Harcourt

Major causes of urban sprawl are lower land value, improved infrastructure, rise in standard of living, lack of urban planning, lack of laws to regulate urban planning as seen in figures 3 to 6. There are factors which are responsible for population growth and urban sprawl. Such factors are rural-urban migration, increased household income, favourable topography, economy of the region, unbalanced spatial development, regional development, availability of natural resources, planning policies, poverty and focus on horizontal spread rather than high rise growth in a vertical manner. Out of 400 persons who responded, 284 persons which constitutes 71.0% of the respondents agrees that lower land value is the major cause of urban sprawl, 23.0% strongly agree to that. But 0.5% said they disagree and 5.5% said they strongly disagree.

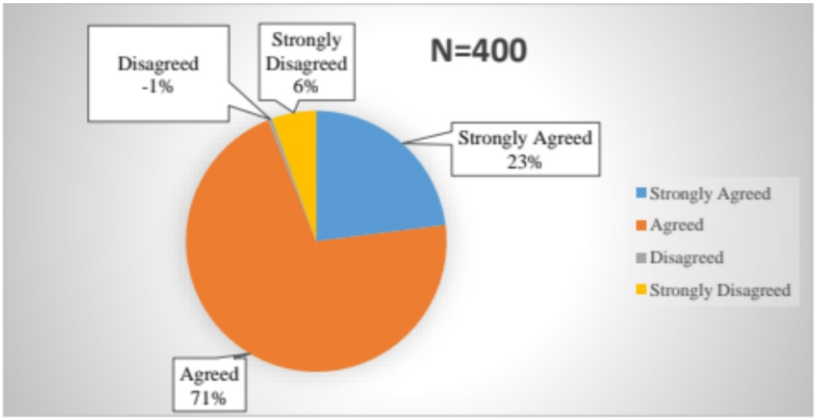

Figure 3: Lower Land Value as a Major Cause of Urban Sprawl
Source: Researchers' Field Survey, 2022

According to Figure 4, most respondents (60.3%) agree that improved infrastructure caused urban sprawl, 3.8% said they strongly agreed that improved infrastructure caused urban sprawl. 0.8% said they disagree and 35.3% said they strongly disagree.

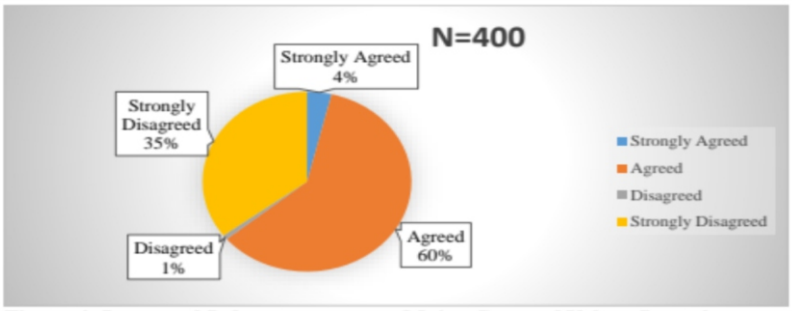

Figure 4: Improved Infrastructure as a Major Cause of Urban Sprawl
Source: Researchers' Field Survey, 2022

Most respondents (260 representing 65.0%) agree that rise in the standard of living caused urban sprawl and 31.3% strongly agrees that rise in the standard of living causes urban sprawl. But, 2.5% disagree and 1.0% strongly disagree that rise in the standard of living caused urban sprawl.

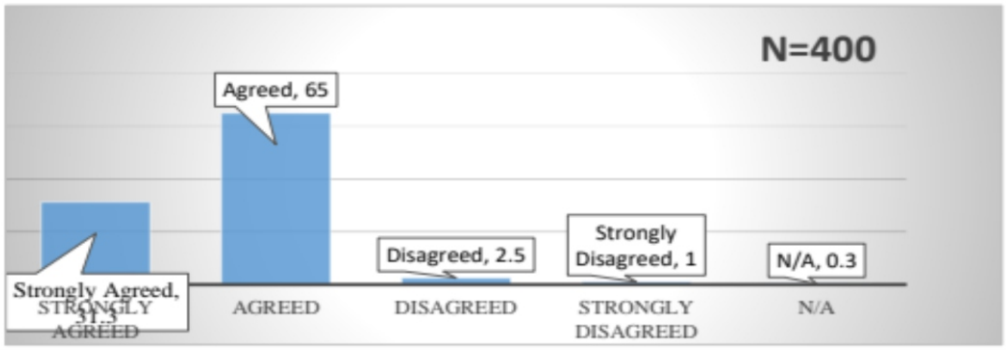

Figure 5: Rise in Standard of Living as a Major Cause of Urban Sprawl
Source: Researchers' Field Survey, 2022

All respondents are of the view that lack of planning causes urban sprawl as 271 respondents representing 67.8% agrees to that and 129 respondents representing 32.3% strongly agrees (See figure 6).

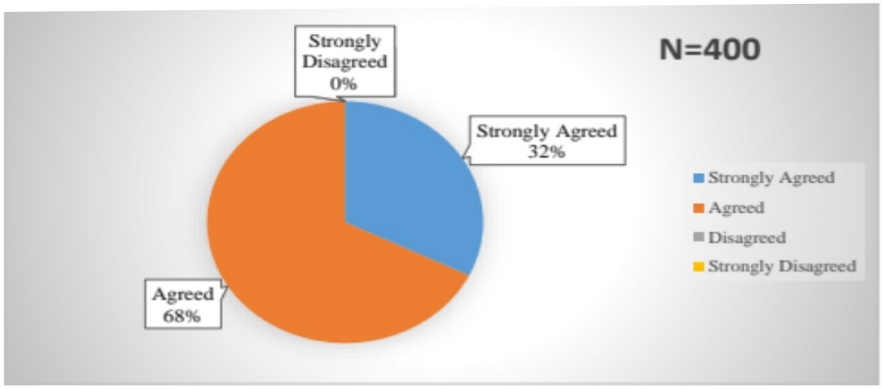

Figure 6: Lack of Urban Planning as a Major Cause of Urban Sprawl
Source: Researchers' Field Survey, 2022

Conclusion and Recommendations

This research has deciphered the extent of urban sprawl and land resources decline within the identified urban fringes of Port Harcourt. The empirical review by Agbora and Weje (2019), Mairiga *et al*. (2003), Alabi (2009) and this research indicate rapid loss of natural environment to the built environment, a clear indication of the presence of urban sprawl. In line with the objectives of this research, lower land value, improved family income, improved infrastructure, rise in standard of living, lower house tax, population etc. are factors responsible for urban sprawl, these also justifies the previous researches of Aniekwe and Igu (2019), Brody (2013), Bruegmann (2015). Critical analysis of the objectives and findings of this research led to the emergence of the following recommendations:

i. Social amenities should be provided in the rural areas so as to curb the issue of mass exodus from the rural areas to Port Harcourt.
ii. Agriculture which is the basic occupation of the rural dwellers should be made more lucrative.
iii. Policies to ensure vertical growth rather than just horizontal growth should be formulated and implemented.
iv. The Port Harcourt master plan should be reviewed or the Greater Port Harcourt master plan should be fully implemented so as to curb the issue of lower tax rate, regulate urban planning and promote laws to govern growth and development of Port Harcourt and its fringes.
v. There should be laws/implementations of laws on conservation and preservation of special areas.

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Environmental Science Education: Curriculum Implementation and Challenges

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Abstract

The rapidity with which our environment is adversely changing is alarming and as one of the steps to halt and to reverse this trend, our future generation should be made aware of the problem and its enormity. The need of the hour is to have environmentally conscious citizens who are concerned about saving the environment from disaster and catastrophes. This paper explores the many-sided obstacles faced by educators and institutions in delivering effective environmental science education with reference to Nigeria's situation. It explores the dynamic nature of the field of environmental education, infusion of elements of environmental education into some existing curricula, challenges and implementation barriers of environmental science education in Nigeria were identified. Overcoming the curriculum challenges of environmental education in schools, the papa stressed the need for a paradigm shift for a proactive teaching and learning of EE in our nation that will reflect in the citizenry's positive environmental behaviour irrespective of gender, educational background, ethnic or religious affiliation.

Keywords: Environmental Education, Curriculum, Implementation Challenges

Introduction

There has been unprecedented growth in the awareness of the environment the world over, during the past three decades. The driving factors have been the concern for quality of life for the mankind. The development process and the resulting growth would remain meaningless unless they are suitably interforce with focused efforts for the protection of the environment. People are becoming increasingly conscious of varieties of problems like global warming, ozone layer depletion, acid rain, famines, droughts, flood scarcity of fuel, pollution of air and water and problem from hazardous chemical and radiation which have adverse effects on the environment. Importance of proper environment and its maintenance should be instilled in the mind of young and upcoming generation from the childhood itself. Environmental Education in Nigeria has become an undeniable awareness tool for creating environmental consciousness / awareness in pupils/students from their early educational career. The integration of this tool into education systems could stimulate children educational action. Environmental education should form a part of curriculum for the school-going children. The rapidity with which our environment is adversely changing is alarming and as one of the steps to halt and to reverse this trend our future generation should be made aware of the problem and its enormity.

From the foregoing, the need of the hour is to have environmentally conscious citizens who are concerned about saving the environment from disaster and catastrophes. This might only happen when people are; (i) knowledgeable about their environment and associated problems, (ii) skilled in the solution of these problems, (iii) and also motivated to work for that. This implies change in the attitude and behavior of all. Education has always played a crucial role in the society because it disseminates knowledge, provides necessary skills and helps in forming certain attitudes. In this instance, it will help to resolve the environmental crises by preparing environmentally conscious citizens through environmentally oriented education system (Ahove, 2011). Proper instructions in environmental

concepts is hoped, will impact on the students, the awareness, knowledge, skills, desirable attitudes, motivation, ability and interest to participate in solving environmental problems.

Place of Environmental Education in Nigeria Education Curriculum

The National Policy on Education stipulates a 6-3-3-4 structure in Nigeria which include six years primary, three years junior secondary, three years senior secondary and four years of higher education. The primary and junior secondary education constitutes basic education that is free and compulsory. The senior secondary level includes both an active curriculum provided in general secondary schools and other curriculum provided in technical colleges and vocational centres. The National Environmental Education Curriculum which was based on the various career subjects and the ecological zones in Nigeria was developed by NERDC (now NERC) under the guidance from United Nations Development Program and UNESCO (Okukpon, 2008). The curriculum was approved in 1998 with its main focus on the designing and infusing EE objectives and strategies into the teaching of the various career subjects in the school system; developing learners values, skills and information base related to eco-friendliness through effective utilization of appropriate instructional materials; designing appropriate learning experiences for the learners at every instructional encounter and motivate learners to maximize the learning opportunities involving first hand interactions (Okukpon, 2008). In furtherance of this, it can be deduced that the main goal to be achieved from this curriculum is creating an environmentally sustainable condition in the society by improving the environmental literacy rate of her citizens. This is done by motivating and informing citizens on how to apply their skills, commitments, positive attitude and adequate knowledge to identify, solve and prevent environmental problems faced now and perceived in the future. However, in accordance with the focus and ultimate goal of the EE curriculum in Nigeria, four themes made up the anchor of this curriculum in the country and the themes include

i. Ecological foundation
ii. Human environment and development
iii. Environmental change and impact
iv. Sustainable development

Thus, these themes are incorporated into the various subjects in the primary and secondary school level. EE is built into the content of the already established subjects in the primary and secondary level of education. The major subjects containing EE content and themes are stated below based on the various levels of education in the country.

According to Olusanya (2007), a great deal of effort has been invested by the Nigerian Educational Research Development Council (NERDC) to incorporate the environmental concept into many subjects in the junior and senior secondary school curricula. Hence, the incorporation of Environmental Education (EE) into the school curriculum in Nigeria is a way of enhancing the people's awareness on the danger of environmental degradation. Ahove 2011, reported that the attitude of the Nigerian nation and her citizens in particular towards the environment have not changed a bit. Our cities and institutions are still defaced with litter, Practices producing the green house and Ozone depleting gases (e.g. combustion of fossil fuels, etc.) are still on going. Environmental questions are often built around central concepts as the study of food supplies, source of energy, conservation of resources, pollution of land, air, water and use of pesticides, herbicides, fertilizers, drugs, industrial chemicals, radiation, control of human population and environmental ethics. According to him, these supposed to constitute the content of environmental education in Nigeria. Today, environmental education concepts have been integrated into disciplines such as geography, biology, health science, Integrated Science, social studies and agricultural science, in order to continue to show concern for the environment. The question one may ask is: - can the inclusion of environmental education in our curricula makes us to solve our environmental problems?

Infusion strategy of EE in Nigeria Education system

According to Okukpon (2008), the infusion strategy comprises of multidisciplinary integrated, interdisciplinary and cross-curricular approach. This strategy conforms to the interdisciplinary approach emphasized by the Belgrade Charter. Although some scholars such as Adedoyin (1988) fault the integrated approach of teaching EE in primary and secondary schools as he stated that EE should be taught as a separate subject in school. While Adebisi and Olawapo (1977) recommended integrated single subject approach to social studies curriculum in the country. Also, Jakayinfa and Yusuf (2004) and Adeyoyin (1998) recommended an integrated approach for the teaching of EE. But for this study, the researcher recommends an establish EE as a separate or distinct subject in schools in order to ensure the effective creation of environmental literate citizens or alternatively, it may be the insertion of new courses distinctive from other existing subjects into the curriculum. Accordingly, Jekenyinfa and Yusuf (2004) reported that teachers of secondary schools have low knowledge of the basic concept of EE thereby affecting its implementation. Despite the efforts in creating this EE curriculum by NERDC, Anijah-Obi, Eneji and Ubom (2012) reported that such efforts have yet to materialize into anything concrete in the country. That is the curriculum is yet to be fully operational in schools thereby denying generations of Nigerians the opportunity of being grounded in EE. Consequently, in tertiary institutions, EE is taught as a distinct or specialized program in some Nigeria Universities and colleges of Education.

Challenges of Environmental Education

It is glaring from the write up that our environment suffers great abuse by man and as a result, it is being surrounded by enormous problems. Even now that the federal government is trying to tackle environmental problems through environmental education, the challenges to this effort is numerous and persistent. Any problem in any human society requires a suitable solution. The introduction of environmental education in our education system is fundamental to solving our environmental problems in the long - term. However, the complex interdisciplinary nature of the course would not only demand changes in teacher education programmes, but also the current used of teachers who are not trained as environmental educators to handle the discipline could serve as a challenge to the implementation of the programme as well as its effectiveness in most places in Nigeria, (Ajiboye & Oyetade, 2005).

Curriculum is simply the blueprint of the school; a document showing all the learning experiences planned and directed by the school for the purposes of enabling the learners acquire basic skills, competencies, knowledge, and positive behaviours deemed appropriate for life. The society builds the school to meet her needs, therefore, the curriculum is bound to focus on those needs to ensure that school graduates meet the societal expectations. A complete education emphasizes the development of a total man, sound all-round intellectually, skilfully, and morally (Achuonye, 2019). The challenges are therefore presented under curriculum development and its implementation issues. These are summed up as:

Lack of Standardization in Development Process

Quality curriculum is obtained through standardized development process which involves all categories of educational stakeholders - the learner, labour market, teacher, professional bodies, research, government, agencies, religious and cultural sectors, global benchmarks, etc., and begins with proper needs assessment and analysis (Achuonye & Ajoku, 2013). These needs are translated into sound curriculum objectives, followed by careful selection and organization of appropriate contents, and learning experiences, and evaluation modalities. Such curriculum is functional and goal-oriented meeting present and ensuring future needs for sustainable national development. The curriculum development process therefore becomes a challenge when it is a quick, 'hit and run' one-off exercise, or fails to follow due process.

i. Unacquainted Curriculum: unfamiliar content, content being too high and above, and teachers lacking basic knowledge and skills to handle it,
ii. Stampede Curriculum: hurriedly developed or sudden inclusion of content accompanied with policy order for immediate implementation within limited time duration without due considerations for readiness of teachers, and the learning environment. Insufficient educational information could lead to ignorance of some important issues pertaining to global and regional concerns.

Implementation Issues

These are challenges associated with the process of putting the curriculum document into use. They include:

Poor Teacher Quality

The classroom, whether virtual or physical, is the centre for curriculum implementation; and the teacher is the key person. The role of the teacher in curriculum implementation is very enormous ranging from proper interpretation of curriculum document to adequate galvanization of all other components of the classroom system. The teacher, therefore, should be able to -

i. accurately interpret and translate the curriculum into working document, as failure to do so will result to curriculum failure,
ii. draw from deep knowledge of the subject matter,
iii. select and use diverse suitable teaching methods and skills,
iv. understand, control, and positively inspire the learners, and
v. plan and execute class activities.
vi. resourceful, readily using every available material around the environment to ensure learning and meaningful transfer of learning,
vii. innovative in teaching applying innovative modern teaching methods to boost class interest and active participation through real-life experiences,
viii. collaborative with students and professional colleagues far and near to ensure regular updates in both content, resources, and methodology,

Learner Issues: Learner is the person who does the learning; therefore, the quality is very necessary for successful curriculum. Such qualities include his capability, pre-requisite knowledge and skill, age, perception, and attitude. Capability is the state of being capable - physically, intellectually, socially, etc. which promotes intrinsic motivation, self-efficacy, and self-esteem (Achuonye, Ezekoka & Ifegbo, 2019). Learning is continuous process; therefore, pre-requisite knowledge is relevant to acquisition of new knowledge and skill. Research has consistently revealed that age is a strong contender in learning as it a determinant of what a person can learn or do at a given time (Achuonye, 2011).

Poor Funding: Good financial support makes for up-to-dated learning environment, suitably accompanied by hands-on learning activities and project-based learning. Poor funding deters education, and can be in form of low allocation, and/or diversion of funds.

The implication obrain-drain rising from poor and/or withheld staff salaries and allowances - poor motivation, incessant agitations, and strikes, and distorting academic calendar, inadequate infrastructure and facilities, overcrowded classrooms and laboratories, and so, hinders effective practical experiences, insufficient, outdated, and poorly maintained learning materials/equipment

Overcoming the Curriculum Challenges

With the high natural tendencies towards environmental science education, addressing the curriculum challenges in Nigeria is inevitable and requires a holistic well-coordinated approach involving

government, educational institutions, industry stakeholders, and the community in the following ways:

Change in Curriculum

Co-ordination of EE in the school syllabus and its realization depends on educational planners and government. Realization of EE objectives of included in the curriculum demands experts to impact the knowledge training/retaining of teachers towards the new programmes.

Specially designed programmes for teachers/would be teachers in relation to duration, content, mode of practice, this would enhance new knowledge frontiers, and also, willingness and commitment from government to meet its goals and objectives.

Change in Attitude

The attitude of people into different levels might help in the learning/teaching of EE. The teacher, pupil, administrative ordinary people on the street by living a discipline, dedicative selfless, honest and care of our environment might be a key to achieving the objectives of the new educational policy. Finally, there should be mass support of EE in school syllabus at any educational 'level' whatsoever means of meeting the demands and challenges of the new 'jet era' caused by everyday advancement in science and technology which affects the environment intensively. Environmental education is essential for developing a healthy, sustainable society.

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Theme C:
Environmental Modelling, Mapping and Big Data

A Geospatial Evaluation of Oil Spills on Environmental Sustainability in Obio Akpor Local Government Area

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Abstract

Environmental degradation from oil spills has emerged as a critical issue requiring immediate attention. This study investigates the impact of oil spills in Obio Akpor Local Government Area of Rivers State utilizing geospatial techniques. Landsat images and historical oil spill data were used in carrying out this study. The images were Pre-processed through atmospheric and geometric corrections. Spatial pattern analysis of four remote sensing indices-Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Land Surface Temperature (LST), Normalized Difference Built-Up Index (NDBI) were performed in ArcGIS 10.5 software environment. An examination of the temporal dynamics of the indices revealed that, NDVI values ranged from -0.12 to 0.68 in 2003, -0.19 to 0.76 in 2013, and 0.17 to 0.63 in 2023 while NDWI ranged -0.56 to 0.19 in 2003, -0.64 to 0.31 in 2013, and -0.52 to 0.29 in 2023. The NDBI range was from -0.48 to 0.39 in 2003, -0.48 to 0.29 in 2013, and -0.44 to 0.31 in 2023. These result shows a significant change in oil spill susceptibility over time. From no point of spill in 2003 to four areas North Eastern ward in 2013, to fifteen areas spreading South Eastern ward in 2023, the oil spill index between 2003 and 2013 shows a mix of increases and a little decrease in oil spill susceptibility across different regions that suggests a worsening of environmental conditions or an escalation in factors contributing to oil spill risks across the study area. The study recommended a continuous periodical environmental assessment to provide environmental protection, the safety of the inhabitants of the location and for improvement in oil spill responses.

Keywords: Environment, Geospatial, Index, Oil Spill, Susceptibility

Introduction

Crude oil is a naturally occurring liquid located underneath the earth's surface and can be converted into fuel (Grema et al. 2023). It is a mixture of hydrocarbons (Sephton and Hazen, 2013). However, the extraction process due to poor management has led to oil spills. An oil spill is the intentional or unintentional release of liquid petroleum hydrocarbon into the environment. Many oil spill incidents occur due to ageing infrastructure, equipment failure, operational accidents, sabotage, and theft (Ejiba et al. 2016). The dangers associated with oil spills are numerous and could make life unbearable for the inhabitants of impacted regions. It is a common saying that a shared problem is half solved. Hence, to address solutions to the problems of oil spills, periodic impact assessment with proper data analysis and presentation is needed.

The remote sensing device effectively determines the location and size of oil spills since it covers the region of interest quickly and thoroughly (Khargharia, 2021). According to the National Aeronautics and Space Administration, geographic information systems (GIS) are useful tools for combining spatial data from many sources, such as field surveys, GPS, and remote sensing, to provide a comprehensive overview of the situation. The utilization of Geographic Information Systems (GIS) and Remote Sensing (RS) has improved the capacity to detect alterations on the surface of the Earth (Bari et al., 2021). The Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Land Surface Temperature (LST), and Normalized Difference Built-Up Index (NDBI) were collected and analyzed, using GIS and remote sensing data (Landsat images). The Normalized Difference Vegetation (NDVI) is a spectral index that can be used to identify long-term

variations in the coverage and condition of vegetation (Fathizad et al., 2017). NDVI is a tool used to measure the greenness of vegetation, and its density, as well as assess changes in plant health (Alademomi et al., 2022). In this study, NDVI was utilized for recognizing vegetation stress and potential damage from oil spills. The Normalized Difference Water Index (NDWI) introduced by McFeeters, is one of the most commonly used water indices to detect open surface water bodies (Mcfeeters, 1996; Ozelkan, 2019). It is effectively used for mapping and detecting surface water bodies (Ozelkan, 2019). In the context of oil spills, NDWI was used to identify oil-contaminated water bodies.

Land surface temperature (LST) is the radiative skin temperature of the land as determined by solar radiation (Salahuddin & Mahmoud 2020). It is a measurement of the temperature at which certain locations on the earth's surface would feel hot to touch (Alademomi et al., 2022). When assessing oil spills, LST was used to find regions where there are very high temperatures, which could mean that oil is present. One spectral index that makes it possible to extract and quantify sealed surfaces and built-up regions from satellite imagery is the Normalized Difference Built-up Index (NDBI) (Karanam and Neela, 2017). It details the degree of land cover change and urbanization in an area. Areas with high human activity levels may be more vulnerable to oil spills; this makes it useful for oil spill detection. The oil spill index maps assist stakeholders in identifying vulnerable areas that could be impacted by oil spills, help decision-makers comprehend the effects of oil spills on the ecosystem, and enable the visualization of complicated spatial relationships. Stakeholders can then decide how to reduce negative effects on the environment.

Obio/Akpor Local Government Area (LGA) in Rivers State has had repeated incidents of oil spills because of the region's considerable oil extraction activities, according to the joint investigation reports of Shell Petroleum Development Company Nigeria Limited. Furthermore, oil spills have the potential to destroy the ecosystem if left unchecked or poorly managed (Agunobi et al., 2014). The high consequences of oil spills are making life in this region increasingly intolerable, and several communities in the area still suffer from the harmful impacts of oil spills (Oyem, 2001). The residents of Obio/Akpor Local Government Area have cried out for assistance regarding the frequent oil spills, to Shell Petroleum Development Company (SPDC), humanitarian organizations, and state and local governments (Naku, 2020). Therefore, it is necessary to properly analyze data and offer information on this matter. To investigate the extent, severity, and impact of these spills on environmental parameters such as vegetation, waterbodies, land surface temperature, and built-up areas, a need for thorough geospatial evaluation was necessary and conducted systematically in this research.

Literature Panorama

Various studies have been done on oil spill-related topics. For instance, Mohamadi et al. (2016) used multi-endmember spectral mixture analysis (MESMA) and statistical method to determine the detrimental impact of oil spills on vegetation, Dutsenwain et al. (2017) and Oweikeye (2017) interest was on the impact of the spill on vegetation based on the frequency and quantity of spill. Orimoogunje & Ajibola-James (2013) and Balogun (2015) examined specifically the recovery pattern of vegetation after the spill, while Anifowose, et al. (2011) provided a quantitative and geographical study on the causes of the spill such as attacks (interdictions) on Nigerian oil pipelines. Onojeghuo, et al. (2016) did experimental research by conducting soil sample tests to determine the impact of oil spills on soil quality. Adamu, et al. (2013) and Wekpe, et al (2022) worked on detecting and tracking oil pipeline leaks and contaminated locations using multispectral data. On the other hand, Ordinioha and Brisibe (2013) focused on the health implications of oil spills. Grema, et al. (2023) were interested in how oil spill tampers with the food chain while Anejionu, et al. (2015) expressed the lapses in the legal action imposed on oil and gas companies that contaminate the environment.

Though most studies only looked at the impact of oil spills on vegetation, after reviewing all of these

studies and more, this study adopted the technique of using a geospatial approach by integrating environmental remote sensing indices to assess the impact of oil spills on vegetation, waterbodies, built-up environments, and surface temperature. This study's methodology is unique in that it developed a robust way to integrate the weighted criteria of NDVI, NDWI, LST, and NDBI into one Oil Spill Index map. This ensures that the spatial representation accurately captures the combined influence of these parameters on oil spill assessment. Other research works related to this study used different methods.

The Study Area

The study area (Figure 1). Obio-Akpor Local Government Area is situated geographically between Latitudes 4°45'N and 4°55'N and Longitudes 6°55?E and 7°05?E. According to Ayo, et al. (2017), Obio/Akpor LGA is bordered to the west by Emohua LGA, to the east by Oyigbo LGA, to the south by Port Harcourt LGA, and to the north by Ikwerre LGA. Obio Akpor LGA is one of the 23 local governments in Rivers State, which is located in what is known as the south southern part of Nigeria, Niger Delta Region. Rumuodo-Maya is home to its administrative centre. The Port Harcourt metropolis comprises the LGAs of Eleme, Port Harcourt, and Obio-Akpor (Ayo et al., 2017). Obio-Akpor is one of the four local governments dominated by the Ikwerres. Fishing, farming, lumbering, and hunting are the region's ancestral occupations. It had 464,789 residents in 2006, 487,751 in 2015, and 540,308 in 2020, according to estimates. Construction, engineering, civil service, administration, manufacturing, mining, sand dredging, printing, public service, etc. are among the new occupations that have emerged in this region as a result of greater urbanization brought on by the growing population (Okwakpam & Augustine, 2019). The research area's equatorial location is near the equator, where typical temperatures range from 25 to 28 degrees Celsius and yearly precipitation ranges from 2000 to 2500 millimetres between April and October. Due to its latitudinal location, the region's high temperatures throughout the year generate increased humidity (Eludoyin et al., 2011; Menegbo, 2022). According to Eludoyin et al. (2011), the local vegetation typical of the Niger Delta includes mangrove forests, raffia palm groves, tropical rain forests, and mangrove areas along the shore (Eludoyin *et al,* 2011; Menegbo, 2022).

Figure 1: Map of Nigeria Showing Rivers State showing the Study Area

Source: 2023 maps of world.com &Ministry of Land & Housing Rivers State

Material and Methods

The data acquired for this research are shown in Table 1.

Table 3.1: The Adopted Data and their Attrib utes

Data	Source	Year	Resolution	Relevance
LANDSAT 8 OLI/TIR	United States Geological Survey (USGS)	2023, 2013	30 m	For remote sensing indices calculation
LANDSAT 7 TM		2003	30 m	

Data	Source	Year	Resolution	Relevance
Administrative map	Rivers state ministry of lands and survey.	2023	1:17000	Extract the boundary of the study area
Coordinates of oil spill points in the study area	Shell Plc. Yearly Spill Incident Data	2023, 2022 2021, 2020 2019, 2012		For validation of results

The acquired data were corrected for radiometric and geometric corrections for the purpose of converting the digital numbers in the Landsat imagery to reflectance values and removal of atmospheric interference. Landsat imagery spectral bands- Red, Green , NIR(near-infrared), SWIR (short-wave infrared) were used for the calculation of NDVI, NDWI, and NDBI needed with the thermal band for the calculation of Land Surface Temperature (LST). These required bands were staked together into a single image file using ArcGIS 10.5 software. The Normalised Differential Vegetation Index NDVI, Normalised Differential Water Index NDWI, and Normalised Differential Built-up Index NDBI were calculated using the raster calculator in the ArcGIS 10.8 software environment from the formulae in Table 2.

Table 2: Indices Calculation

Index	Formulae	Landsat 7	Landsat 8
NDVI	$\frac{NIR-Red}{(NIR+Red)}$	$\frac{band\ 4-band\ 3}{band\ 4+band\ 3}$	$\frac{\text{band 5}-\text{band 4}}{(\text{band 5}+\text{band 4})}$
NDWI	$\frac{Green-NIR}{(Green+NIR)}$	$\frac{band\ 2-band\ 4}{band\ 2+band\ 4}$	$\frac{band\ 3-band\ 5}{(band\ 3+band\ 5)}$
NDBI	$\frac{(SWIR-NIR)}{(SWIR+NIR)}$	$\frac{band\ 5-band\ 4}{band\ 4+band\ 4}$	$\frac{\text{band 6}-\text{band 5}}{(\text{band 6}+\text{band 5})}$

Note: Index values typically range from -1 to 1. Higher NDVI values indicates denser and healthier vegetation and lower indicates otherwise. Higher NDWI values indicates water bodies and lower values indicating non-water features and higher NDBI values indicating built-up areas and lower values indicating non-built-up areas.

LST calculation: The thermal infrared bands of Landsat 8 and Landsat 7 imagery from 2023, 2013, and 2003 respectively were used to retrieve LST. The thermal infrared bands (Band 10 for Landsat 8 and Band 6 for Landsat 7) were converted to top-of-atmosphere (TOA) by converting the digital numbers to TOA spectral radiance using sensor radiometric calibration coefficients.

$$TOA\,(L) = ML * Qcal + AL \qquad Equation\ 1$$

where:
*M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_**x**, where x is the band number), Q_{cal} = corresponds to band 10, AL = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_**x**, where x is the band number).*

The TOA spectral radiance values were converted to brightness temperature (T) using Planck's Law and the thermal band wavelength using equation 2.

$$Bt = \left(\frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}\right)} + 1\right) - 273.15$$

Equation 2

Where:

T is the brightness temperature, K_1 and K_2 are band-specific thermal conversion constants, L_λ is the TOA spectral radiance.

The proportion of vegetation *Pv* was calculated using equation 3:

$$Pv = \left(\frac{NDVI\text{-}NDVImin}{NDVImax\text{-}NDVImin} \right)^2$$

Subsequently, the land surface emissivity (*e*) was calculated using

$e = 0.004 \times pv + 0.986$ Equation 4

After the emissivity-corrected land surface temperatures were estimated in degrees Kelvin, the values were converted to degrees Celsius for easy comprehension. This conversion was achieved using the relation in equation 5

$LST(°C) = LST(K) - 273.15$ Equation 5

AHP method was applied for weighting the sensitivity of NDVI, NDWI, LST, and NDBI to oil spill. An AHP matrix was constructed comparing each criterion to every other criterion. Comparisons were made using Saaty's 9-point scale, where 1 indicates equal importance and 9 indicates extreme importance of one criterion over another. As part of the AHP process, the raw comparison matrix was normalized to derive ratio scale priority vectors. Normalization was achieved by dividing each value in a criterion's column by the sum of the column. This converted the comparisons to a proportional ratio scale while maintaining their relativity. The normalization process was applied to each column of the comparison matrix. This enabled priority vectors to be extracted that represented the relative weights or priorities of each criterion proportional to the others.

After assigning weights to NDVI, NDWI, NDBI, and LST for the development of an oil spill index, reclassification of these variables was done before integrating them. Reclassification helps standardize the scales of different variables to ensure comparability and consistency. Since NDVI, NDWI, NDBI, and LST have different measurement ranges and units, reclassification enables harmonization by converting them into common classes or categories. The reclassification interval was assigned a rank weight ranging from 1 to 5 (low to high) corresponding to their influence on oil spills. Classes with a high likelihood of sensitivity were designated with a rank of 5, while those expected to have little or no impact were assigned a rank of 1.

An AHP matrix was constructed comparing each criterion to every other criterion. Comparisons were made using Saaty's 9-point scale, where 1 indicates equal importance and 9 indicates extreme importance of one criterion over another.

Table 3: Saaty Scale for Various Elements Comparison

Scale	Judgment of preference	Description
1	Equally important	Two factors contribute equally to the objective
3	Moderately important	Experience and judgment slightly favour one over the other
5	Important	Experience and judgment strongly important favor one over the other
7	Very strongly important	Experience and judgment strongly important favor one over the other
9	Extremely important	The evidence favouring one over the other is of the highest possible
2, 4, 6, 8	Intermediate preference between adjacent scales	When compromised is needed

Source: Saaty (1980)

As part of the AHP process, the raw comparison matrix was normalized to derive ratio scale priority vectors. Normalization was achieved by dividing each value in a criterion's column by the sum of the column. This converted the comparisons to a proportional ratio scale while maintaining their relativity. The normalization process was applied to each column of the comparison matrix. It enabled priority vectors to be extracted that represented the relative weights or priorities of each criterion proportional to the others.

The normalized comparison matrix retained the original criteria relationships while transforming values to a 0 to 1 scale suitable for quantifying the relative importance or weight of each factor in the suitability analysis.

The consistency of judgments in the AHP comparison matrix was evaluated to ensure logical, high-quality criteria weights. Consistency was measured by first calculating a consistency index (CI) for the matrix. CI indicates the level of consistency in the comparisons, with lower values being more consistent.

CI was compared to a random index (RI) based on the number of criteria, to derive a consistency ratio (CR). Saaty (1980) established that CR should be less than 0.1 to indicate acceptable consistency.
A consistency table was generated showing the CI, RI and CR values. If CR exceeded 0.1, the most inconsistent judgments were identified and the comparisons were revised to improve consistency.

This consistency evaluation ensured that irrational or random comparisons did not propagate into the final AHP weights. Logical, high-quality judgments translated to reliable, data-driven criteria priorities for the suitability analysis. The consistency table provided quantitative verification that the AHP process produced a consistent, robust weighting of factors for the oil spill index map.

$$\sum_{j=1}^{n} (N_{ij} * Weight_j) \qquad \text{Equation 6}$$

- *Weighted Sum Value i: Weighted sum for criterion i.*
- *Nij: Normalized value for the pairwise comparison between criteria i and j.*
- *Weight j: Weight for criterion j.*
- *n: Number of criteria.*

$$\textbf{Principal eigenvalue } (\lambda max) = \frac{\frac{Sum(Weigthed\ Sum\ of\ each\ Criterion)}{Normalized\ Weight}}{n} \qquad \textbf{Equation 7}$$

$$C.I = \frac{\lambda max - n}{n-1} \qquad \textbf{Formula: } C.R = \frac{C.I}{R.I}$$

***C.I*: Consistency Index. λmax: Principal eigenvalue of the matrix, *n*: Number of criteria.**

Table 2 Random Index Matrix of the Same Dimension

Number of criteria	2	3	4	5	6	7	8	9	10	11
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Source: Saaty (1980)

Pairwise	NDVI	NDWI	NDBI	LST	
NDVI	1	3	5	3	3.00
NDWI	1/3	1	3	1	1.33
NDBI	1/5	1/3	1	1/3	0.47
LST	1/3	1	3	1	1.33
	1.87	5.33	12.00	5.33	

Normalized	NDVI	NDWI	NDBI	LST	Weight
NDVI	0.54	0.56	0.42	0.56	0.52
NDWI	0.18	0.19	0.25	0.19	0.20
NDBI	0.11	0.06	0.08	0.06	0.08
LST	0.18	0.19	0.25	0.19	0.20
					1.00

Consistency	NDVI	NDWI	NDBI	LST	Weighted Sum	
NDVI	0.52	0.60	0.39	0.60	2.12	4.08
NDWI	0.17	0.20	0.24	0.20	0.81	4.04
NDBI	0.10	0.07	0.08	0.07	0.32	4.02
LST	0.17	0.20	0.24	0.20	0.81	4.04
Max	4.08					

C.I	0.01					

Consistency Ratio	0.02					

The normalized indices were combined using a weighted summation approach. Each index was multiplied by its corresponding weight and results were summed using the raster calculator tool to obtain a single composite index representing the oil spill potential for the different years.

The basic formula used in computing the oil spill index *OSI* based on the weighted combination of the normalized indices was:

$$OSI = w\text{NDVI} \times \text{NDVI} + w\text{NDWI} \times \text{NDWI} + w\text{LST} \times \text{LST} + w\text{NDBI} \times \text{NDBI} \quad \text{Equation 8}$$

Where: wNDVI, wNDWI, wLST, and wNDBI are the weights assigned to each index.
NDVI, NDWI, LST, and NDBI are the normalized values of NDVI, NDWI, LST, and NDBI, respectively.
The validation of the Oil Spill Index (OSI) against historical oil spill incident points plays a crucial role in assessing the accuracy and reliability of the index in predicting and identifying areas prone to oil spills. The oil spill index was validated against known oil spill incident points obtained from Shell Plc. Joint investigation reports (https://www.shell.com.ng/sustainability/environment/oilspills/spill-incident-data.html) website. This was to assess its accuracy and reliability. In doing this the study ensured spatial alignment between the oil spill index map and historical oil spill incident data by projecting both datasets to a common coordinate system.

Results and Analysis
Result of Normalized Difference Vegetative Index (NDVI)

Figures 3 present the NDVI maps for the years 2003, 2013, and 2023, revealing notable trends in

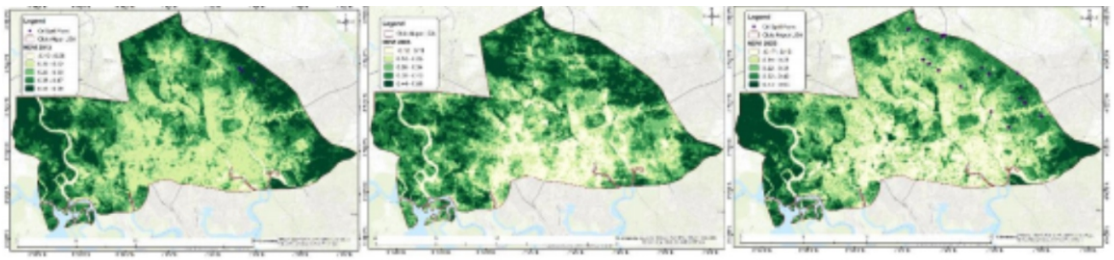

Figure 3: Normalize Difference Vegetative Index (NDVI) for year 2003, 2013 and 2023 vegetation health and density. In 2003, NDVI values ranged from -0.12 to 0.68, expanding to -0.19 to 0.76 in 2013, and narrowing to -0.17 to 0.63 in 2023. Low NDVI values typically indicate areas with sparse vegetation cover or stressed vegetation. While High NDVI values generally indicate areas with dense and healthy vegetation cover. Consistent dense vegetation was observed in the western part of the study area across all three years, contrasting with a decline in vegetation cover in the eastern part, which happens to be the part where most oil spill incidents occurred in the study area, particularly between 2013 and 2023. Analysis of oil spill points reveals a decrease generally in NDVI from 2003 to 2023, emphasizing the environmental impacts of oil spills.

An examination of the temporal dynamics of NDVI, NDWI, LST, and NDBI indices revealed that in 2003, NDVI values ranged from -0.12 to 0.68, expanding to -0.19 to 0.76 in 2013, and narrowing to -0.17 to 0.63 in 2023 while for NDWI, in 2003, the range was from -0.56 to 0.19, in 2013 from -0.64 to 0.31, and in 2023 from -0.52 to 0.29. The NDBI range was from -0.48 to 0.39 in 2003, followed by -0.48 to 0.29 in 2013, and -0.44 to 0.31 in 2023. While, the land surface temperature values in 2003 ranged from 17.63 to 31.78°C, expanding to 20.07 to 34.21°C in 2013, and then narrowing to 18.52 to 30.4°C in 2023. The result indicates that there was a reduction in NDVI and NDWI ranges over the years, coupled with fluctuations in NDBI and LST values, reflecting significant environmental changes.

Result of the Oil Spill Index

Figure 4, represents the result of the oil spill in the study area for the year 2003, 2013 and 2023 respectively. The observed trends in the oil spill index between the years 2003 to 2013 and 2003 to 2023 revealed significant changes in oil spill susceptibility over time. From no point of spill in 2003 to four areas North Eastern ward in 2013, to fifteen areas spreading South Eastern ward in 2023, the oil spill index between 2003 and 2013 shows a mix of increases and a little decrease in oil spill susceptibility across different regions while the oil spill index trend from 2003 to 2023 indicates a substantial increase in the oil spill index over the two-decade period. This drastic rise in the oil spill index suggests a worsening of environmental conditions or an escalation in factors contributing to oil spill risks across the study area.

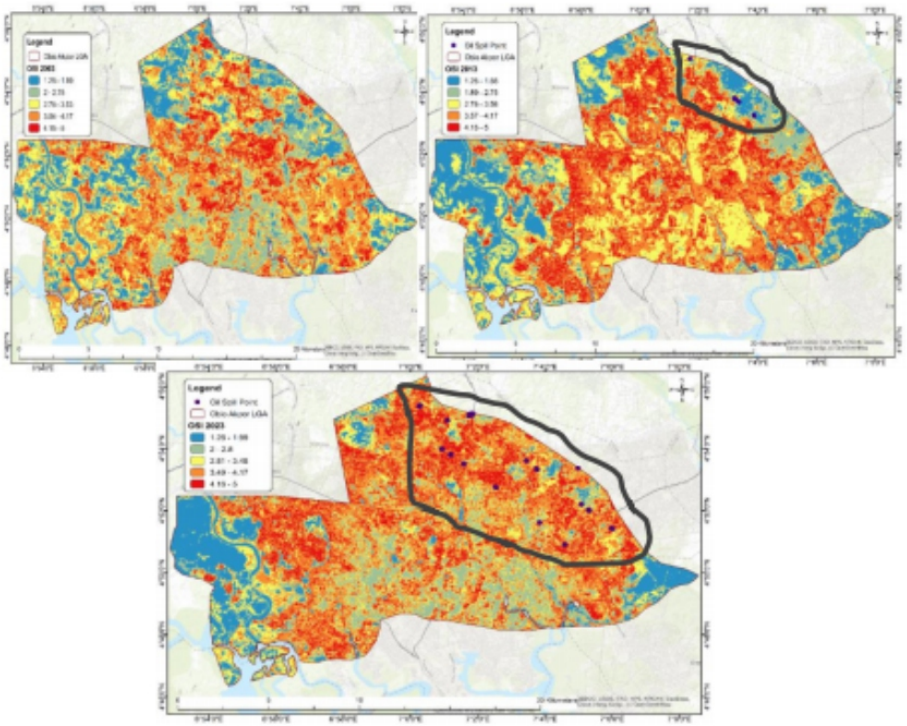

Figure 4: Oil Spill for the year 2003, 2013 and 2023
Source: Author's Work, 2023

Conclusion

In assessing the impact of oil spills and mapping environmental changes in the study area, a comprehensive oil spill index map revealed higher and increased index values observed at locations with documented spill incidents leveraging on the combined power of remote sensing data and spatial analysis techniques to enhance the understanding of oil spill dynamics and vulnerability assessment. A joint force of NDVI, NDWI and NDBI has contributed to assessing the pattern and trend of oil spill in the study area. The observed trends in the oil spill revealed significant changes in oil spill susceptibility over time. From a mix of increases and a little decrease in oil spill susceptibility to a substantial increase in the oil spill index over the two-decade period thus suggesting a worsening of environmental conditions or an escalation in factors contributing to oil spill risks across the study area. The approach has been be a more effective strategy for assessing and mitigating the impacts of oil spills, ultimately fostering environmental sustainability and resilience in the face of evolving environmental threats.

Recommendations

This study is recommended as valuable information for monitoring and assessing the environmental impact of oil spills as it shows the likelihood of the study area being damaged by oil spills as the year progresses. The research recommends the contemporary data collection and presentation technique used in this research for other environmental-related issues, especially over a large region or inaccessible locations for effective response and mitigation purposes. Additionally, this study suggests a continuous environmental assessment being conducted periodically to checkmate environmental protection, the safety of the inhabitants of the location and for improvement in oil spill responses. While the current research focused on the integration of environmental indices, future studies should consider incorporating socio-economic factors to provide a more holistic understanding of oil spill risks. This may include factors such as population density, infrastructure vulnerability, economic

activities, and community resilience, which play a significant role in shaping the impacts and responses to oil spills. A prompt attention to these recommendations will guarantee an understanding of oil spill dynamics, improved risk assessment methodologies, that will enhance preparedness and response capabilities to mitigate the environmental, social, and economic impacts of oil spills effectively.

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Remediation Site Mapping of Hydrocarbon Contamination Using Electricity Resistivity Tomography in Kegbara Dere Community

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Abstract

This investigation provides a comprehensive analysis of hydrocarbon contamination in a field at Kegbara Dere, Ogoniland, Rivers State, Nigeria, utilizing a suite of advanced geoelectric techniques, including Vertical Electric Sounding (VES) and 2D/3D Electrical Resistivity Tomography (ERT). The research employed 15 VES surveys and 12 ERT transverse profiles to delineate the extent of hydrocarbon pollution. By exploiting the distinct electrical resistivity properties of hydrocarbons, which exhibit poor conductivity, the study identified a resistivity threshold of >900 Ωm as indicative of contamination. The VES surveys revealed the presence of four distinct geoelectric layers across the study area, with specific locations (VES 4, 5, 7, 11, 12) probing up to five layers. Notably, the topsoil layer consistently exhibited resistivity values exceeding 900 Ωm. The second geoelectric layer was identified as the most severely contaminated, followed closely by the fourth layer. The detection of contamination in deeper layers suggests infiltration through permeable lithologies. The 2D ERT results, augmented by Induced Polarization (IP), while occasionally inconsistent in detecting hydrocarbons, were instrumental in distinguishing between contaminated and uncontaminated zones, aided by color-coded tomograms. The 3D ERT models developed through a smoothness-constrained least-squares inversion algorithm, unveiled six distinct subsurface layers at depths ranging from 0.00 to 21.9 meters. These models highlighted the presence of hydrocarbon plumes within the contaminated site, with resistivity values between 1000 and 10,000 Ωm, indicating recent contamination at the time of the survey. In contrast, the control site exhibited lower resistivity values and was largely devoid of contamination, likely due to the protective nature of overlying impermeable layers.

Keywords: Hydrocarbon Contamination; Electrical Resistivity Tomography (ERT); Electrical Resistivity Tomography (ERT); Subsurface Imaging

Introduction

Oil spill contamination is a significant environmental issue that has far-reaching effects on ecosystems and human health. The Niger Delta region of Nigeria has been particularly affected by oil spills for decades, resulting in severe environmental degradation and health problems for local communities. Since the commencement of commercial oil production in Nigeria in 1958, oilproducing states and communities have faced increasing environmental pollution, leading to resource depletion and other devastating consequences. Between 1976 and 1996, a staggering 4,647 incidents resulted in the spillage of approximately 2,369,470 barrels of oil into the environment, primarily due to vandalism, pipeline corrosion, human errors, and equipment failures (Nwilo & Badejo, 2001; UNDP, 2006). These spills have adversely impacted the environment, particularly groundwater and shallow wells utilized by residents for domestic water supply. The introduction of harmful chemicals into the environment, including total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAHs), and BTEX (benzene, toluene, ethylbenzene, xylene), has made environmental assessment crucial. The primary recipients of oil spills are the soil and underground water, necessitating thorough investigations into the extent of hydrocarbon pollution and its potential health implications for affected populations (Ite et al., 2018). Geophysical methods, particularly Electrical Resistivity Tomography (ERT), have proven effective in detecting contaminated zones due to the varying physical properties of different materials. ERT involves injecting electric current into the ground and measuring the resulting potential difference to obtain subsurface resistivity distribution. This method can determine the lateral and depth extensions of hydrocarbon-contaminated horizons in soil and groundwater.

Statement of the Problem

Hydrocarbon contamination of subsurface layers poses significant risks to human health and ecosystems. The water table and soil fertility are severely affected, with hydrocarbon contents exhibiting radioactive properties that can threaten living beings. Traditional methods of surface identification or drilling are inadequate for delineating the spatial extent of hydrocarbon migration. Thus, there is a pressing need for advanced geophysical methods like ERT to provide a detailed subsurface image of contamination and guide effective remediation efforts.

Materials and Methods

Survey Design

The survey was meticulously planned, utilizing resistivity survey methods. A topographic base map of the dumpsite area in Kegbara Dere, Ogoniland, was digitized using Google Earth and ArcGIS software to identify topographic highs and lowlands. The contaminant is expected to be concentrated in the eastern part of the study area, which has the highest relief. Resistivity sounding points and profile lines were strategically acquired along the low-lying areas to optimize data quality. The project included 15 Vertical Electrical Sounding (VES) points and 12 Electrical Resistivity Tomography (ERT) profile lines.

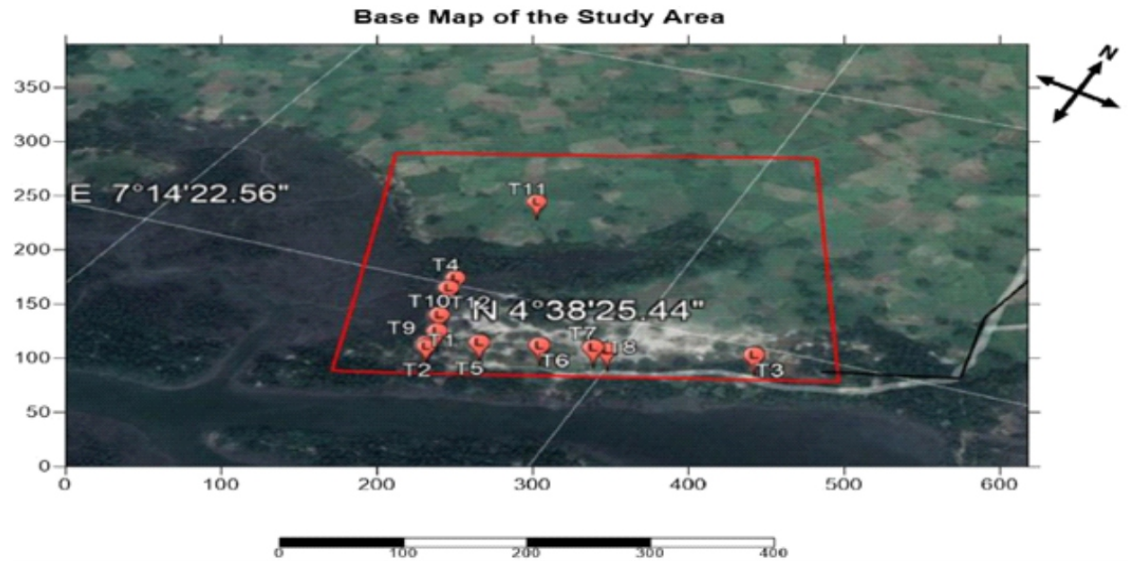

Figure 1: Base Map with GPS location of ERT Lines T1-T12 in the Contaminated Study Area in Kegbara Dere, Ogoniland, Rivers State, Nigeria

Materials Required

The materials utilized for the research included:

- **ABEM SAS 1000 Terrameter**: For resistivity measurement.
- **Metal Electrodes**: For current transmission and potential difference measurement.
- **Cables and Reels**: For connecting the Terrameter to electrodes.
- **Measuring Tapes and GPS**: For accurate data collection and georeferencing.
- **Hammer**: For driving electrodes into the ground.
- **Data Sheets**: For recording survey data.

Data Acquisition

Primary data were collected through geoelectric surveys, which included 15 VES points and 12 ERT transverse lines. The VES method involved measuring soil resistivity using a calibrated ABEM Terrameter SAS 1000, with a total electrode spread of 100m to cover a probe depth of approximately 33.3m. The Wenner array configuration was employed for both VES and ERT surveys.

Data Processing

Field resistance data were converted to apparent resistivity by multiplying by the equivalent geometric factor. VES data were processed using IPI2win inversion software for 1-D modeling, while RES2Dinv and RES3Dinv software were used for 2-D and 3-D modeling, respectively. The inversion process aimed to reconstruct a geological model that accurately represented the true resistivity distribution of the subsurface.

Results

Overview of Findings

The results of the monitoring and assessment study of hydrocarbon pollution in Kegbara Dere, Ogoniland, are presented through combined geoelectric methods, including Vertical Electric Sounding (VES) and Electrical Resistivity Tomography (ERT). The findings reveal significant contamination across various subsurface layers, indicating the extent and severity of hydrocarbon migration in the study area.

VES Results

A total of 15 VES points were surveyed, generating a comprehensive contamination map of the study area. The summary of the VES survey results is presented in Table 1, which includes layer resistivity, thicknesses, depths, and inferred contamination levels.

Table 1: VES Results Summary

VES No.	Layer resistivity ($\rho_1/\ \rho_2/\ \rho_3/.../\ \rho_n$)	Layer thickness ($h_1/\ h_2/h_3/\ldots/\ h_n$)	Layer depth ($d_1/\ d_2/d_3/\ldots/\ d_n$)	RMS Error (%)	Inference
VES 1	848.9/47.0/7.8/49.7	0.7/2.4/10.9/-	0.7/3.1/14.0/-	2.6	
VES 2	944.0/71.9/10.3/3.8	0.7/2.9/17.0/-	0.7/3.6/20.6/-	2.0	
VES 3	5241.2/477.6/88.2/23.3	0.8/3.9/17.7/-	0.8/4.7/22.4/-	2.1	
VES 4	16694.4/*918.8/131.8/570.9/40.6	0.7/1.7/4.9/14.0/-	0.7/2.4/7.3/21.3/	2.6	*Plume layer
VES 5	7468.2/*918.7/147.3/377.4/69.7	0.8/2.1/8.8/28.6/-	0.8/2.9/11.7/40.3/-	2.5	*Plume layer
VES 6	11940.2/*3438.4/*1093.1/*7425.3	0.9/3.2/18.9/-	0.9/4.2/23.1/-	2.5	*Plume layer
VES 7	3428.4/883.2/154.2/*1342.6/95.1	0.5/3.6/7.5/19.8/-	0.5/4.1/11.6/31.3/-	4.5	*Plume layer
VES 8	1301.9/72.6/25.9/136.4	0.7/3.8/19.0/-	0.7/4.5/23.5/-	2.1	
VES 9	5098.3/700.2/205.0/*1478.5	0.6/2.7/17.3/-	0.6/3.4/20.7/-	2.5	*Plume layer
VES 10	4343.1/723.8/160.7/30.1	0.8/6.5/25.7/-	0.8/7.3/33.0/-	2.4	
VES 11	10788.8/*3805.3/679.5/*2886.4/315.0	1.1/4.5/13.1/27.8/-	1.1/5.5/18.6/46.4/-	3.3	*Plume layer
VES 12	20762.7/*7241.3/*2856.2/*12025.3/*2259.8	0.8/1.9/6.2/28.7/-	0.8/2.6/8.8/37.5/-	2.5	*Plume layer
VES 13	6101.5/853.0/199.3/43.6	0.9/7.2/20.7/-	0.9/8.1/28.8/-	3.4	
VES 14	10271.6/*2992.8/578.0/143.4	1.1/3.4/28.0/-	1.1/4.4/32.4/-	3.3	*Plume layer
VES 15	13068.7/*2592.0/549.3/179.8	1.0/4.2/25.0/-	1.0/5.2/30.2/-	3.2	*Plume layer

The results indicate that several VES points exhibited resistivity values above the established cutoff of 900 Ωm, confirming the presence of hydrocarbon contamination in the subsurface layers. Notably, VES points 4, 5, 6, 11, 12, 14, and 15 showed significant contamination, particularly in the second and fourth geoelectric layers.

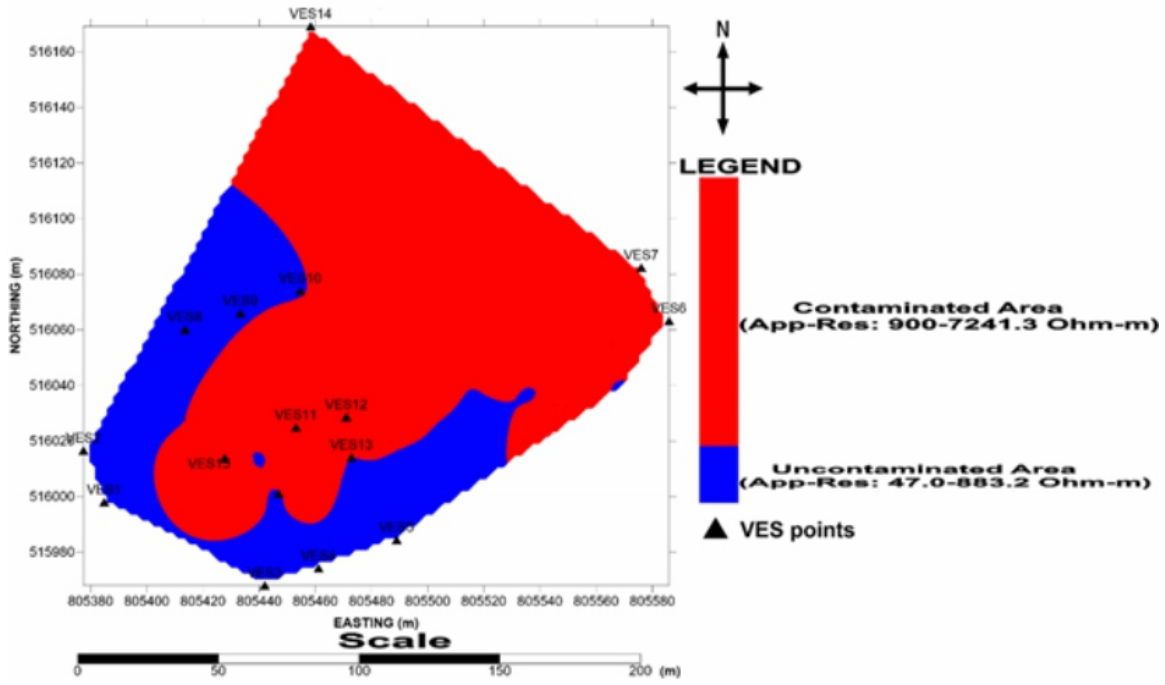

Figure 3.1: Contamination Boundary in the Second Geoelectric Layer in VES 1-15 in the Contamination Site

Figure 3.2: Contamination Boundary in the Fourth Geoelectric Layer in VES 1-15 in the Contamination Site

2D ERT Results

The 2D ERT results were generated for 12 transverse lines (T1 - T12) in the study area, revealing the lateral and depth extensions of hydrocarbon contamination. The tomograms illustrate varying resistivity values, with areas of low resistivity indicating the presence of hydrocarbons. Figures 3.3 to 3.14 showcase the tomograms, highlighting significant contamination zones at various depths across the survey area.

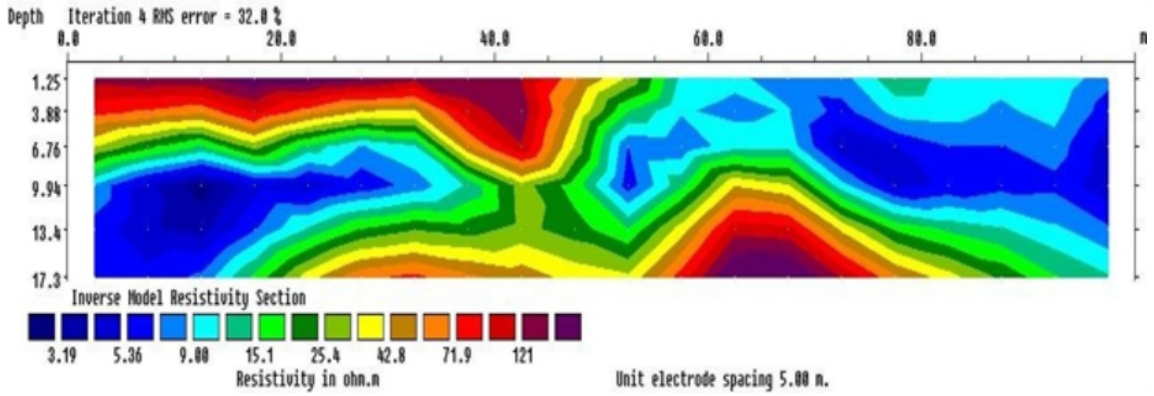

Figure 3.3: Processed Electrical Resistivity Tomogram for Transvers 1 Using RES2DINV Software

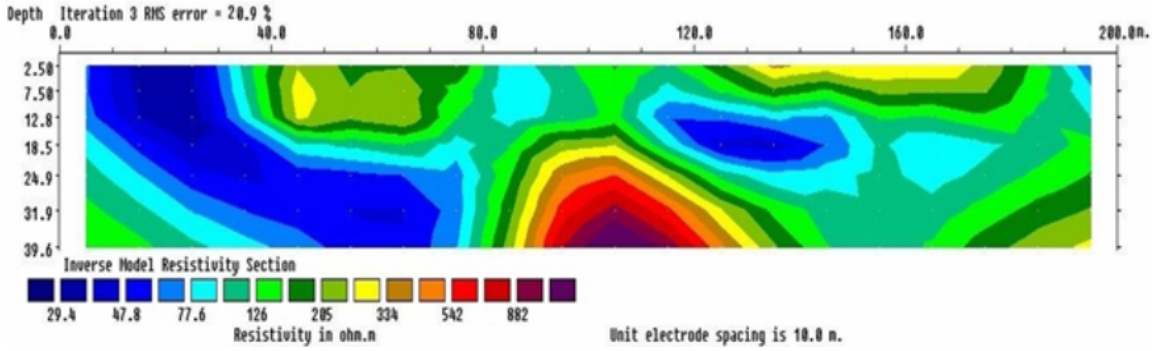

Figure 3.4: Processed Electrical Resistivity Tomogram for Transverse 2 Using RES2DINV Software

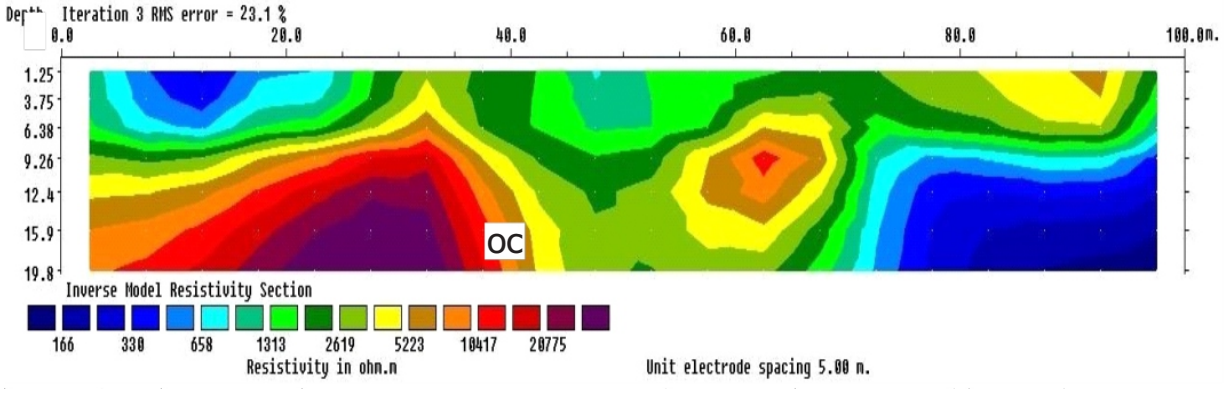

Figure 3.5: Processed Electrical Resistivity Tomogram for Transverse 3 Using RES2DINV Software. OC (Oil Contamination)

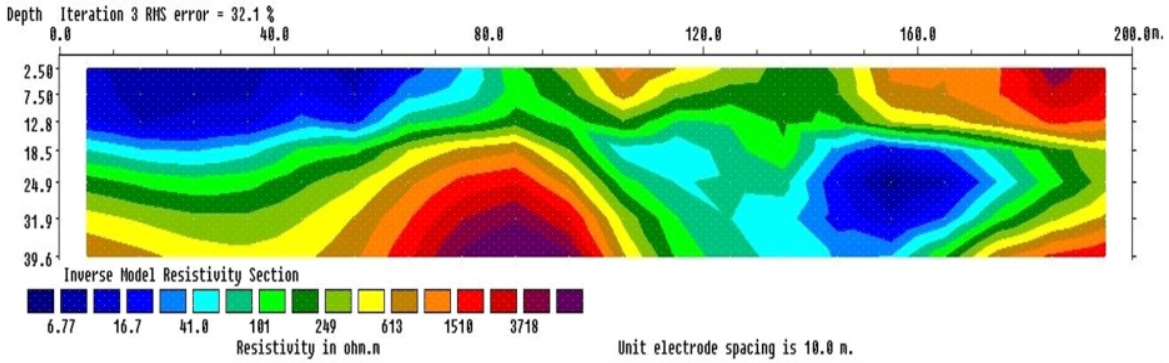

Figure 3.6: Processed Electrical Resistivity Tomogram for Transverse 4 Using RES2DINV Software. OC (Oil Contamination)

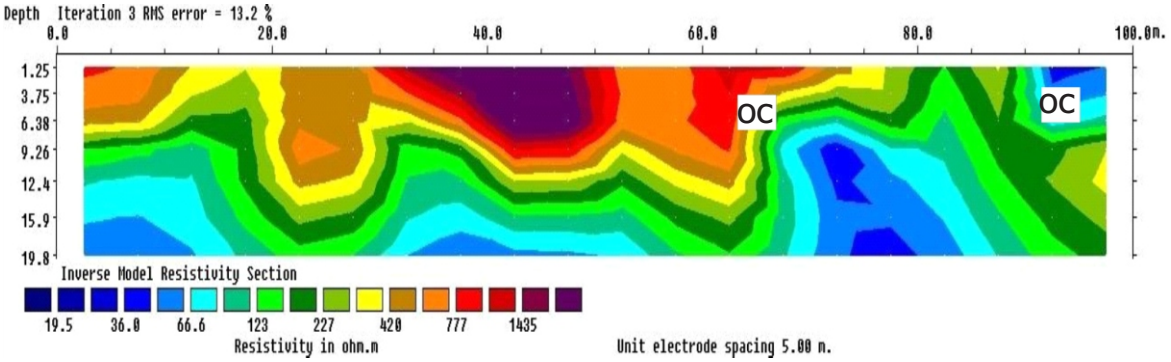

Figure 3.7: Processed Electrical Resistivity Tomogram for Transverse 5 Using RES2DINV Software. OC (Oil Contamination)

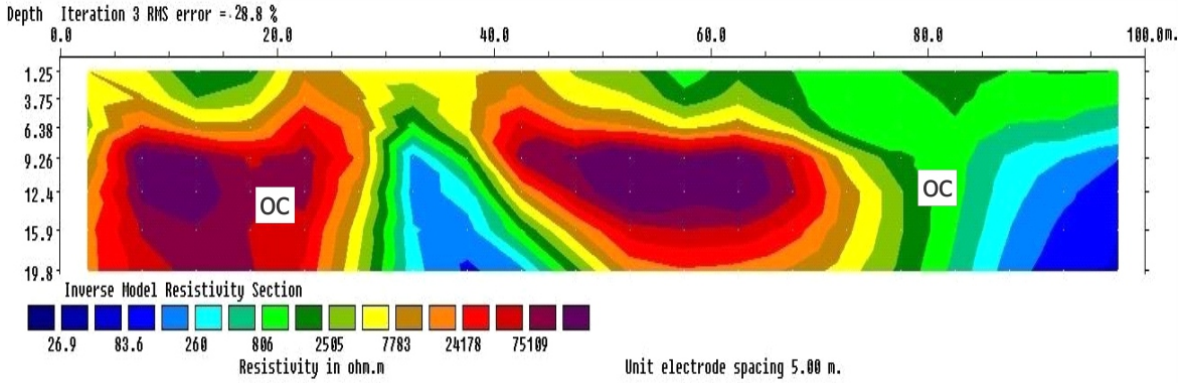

Figure 3.8: Processed Electrical Resistivity Tomogram for Transverse 6 Using RES2DINV Software. OC (Oil Contamination)

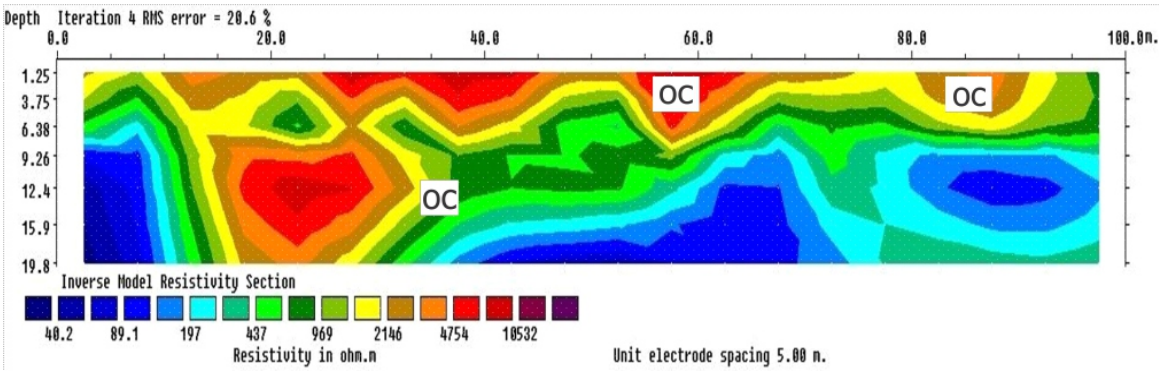

Figure 3.9: Processed Electrical Resistivity Tomogram for Transverse 7 Using RES2DINV Software.

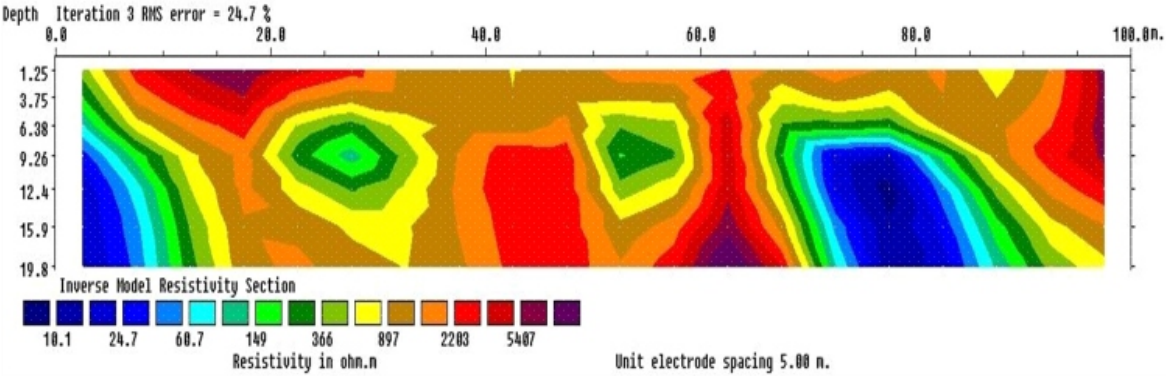

Figure 3.10: Processed Electrical Resistivity Tomogram for Transverse 8 Using RES2DINV Software. OC (Oil Contamination)

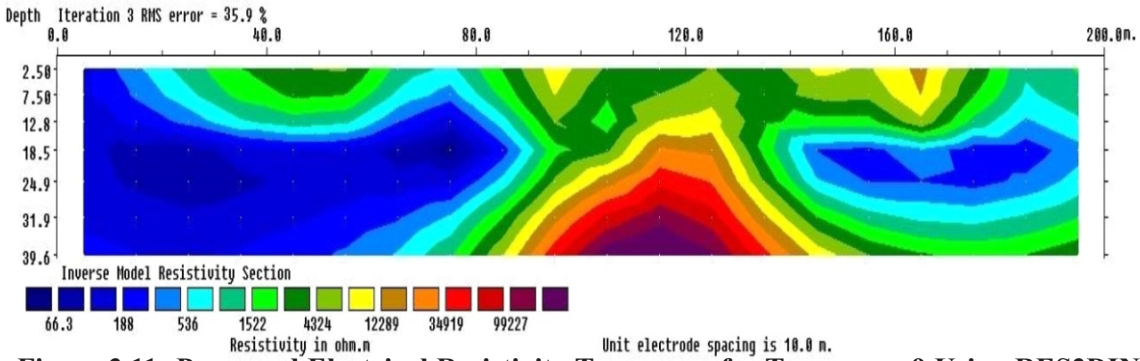

Figure 3.11: Processed Electrical Resistivity Tomogram for Transverse 9 Using RES2DINV Software. OC (Oil Contamination)

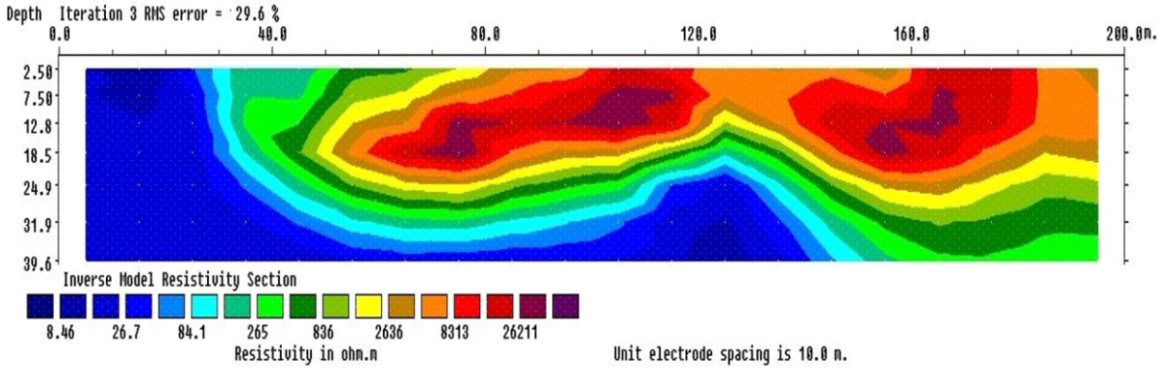

Figure 3.12: Processed Electrical Resistivity Tomogram for Transverse 10 Using RES2DINV Software. OC (Oil Contamination)

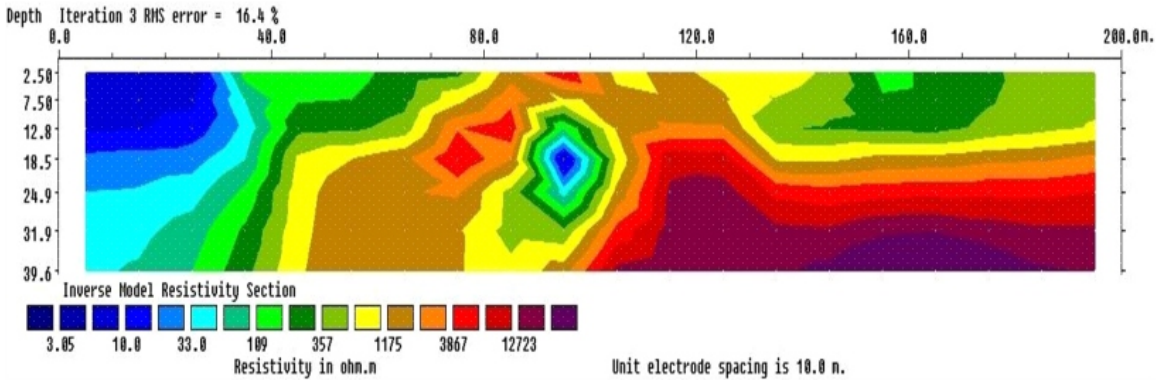

Figure 3.13: Processed Electrical Resistivity Tomogram for Transverse 11 Using RES2DINV Software. OC (Oil Contamination)

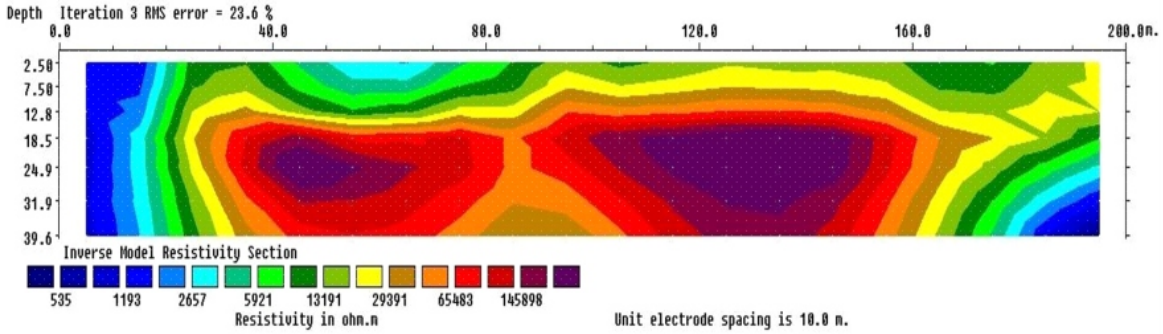

Figure 3.14: Processed Electrical Resistivity Tomogram for Transverse 12 Using RES2DINV Software. OC (Oil Contamination)

DISCUSSION

Overview of Hydrocarbon Contamination

The findings from the VES and ERT surveys indicate a significant presence of hydrocarbon contamination in Kegbara Dere, Ogoniland. The resistivity data collected from the VES points reveal that several layers exhibit resistivity values exceeding the established cut-off of 900 ?m, which is indicative of free-phase hydrocarbons. This suggests that the contamination is not only widespread but also poses a serious threat to the groundwater aquifers in the region.

VES Results Interpretation

The VES results identified four primary geoelectric layers, with some points revealing up to five layers. The first layer, approximately 1m deep, showed resistivity values consistent with contamination, while the second layer, with a maximum thickness of 7.2m, also indicated significant hydrocarbon presence. The third and fifth layers generally exhibited low resistivity, suggesting the presence of impermeable lithologies such as clay or mud, which could hinder hydrocarbon migration. However, the fourth layer displayed contamination, indicating that there are vulnerable permeable layers that allow for the movement of hydrocarbons deeper into the subsurface.The presence of high resistivity zones in the first layer suggests that surface-level remediation efforts could be effective, while deeper contamination in the second and fourth layers necessitates more advanced remediation strategies. The identification of contamination in the second geoelectric layer is particularly concerning, as it is indicative of a more extensive spread of hydrocarbons that could affect the quality of groundwater resources.

ERT Results and Spatial Analysis

The 2D ERT results provided a more detailed spatial representation of the contamination, revealing the lateral and depth extent of hydrocarbon plumes. The tomograms indicated that contamination extends to significant depths, with some plumes reaching depths of up to 39.6m. The use of Induced Polarization (IP) in conjunction with ERT allowed for a clearer distinction between hydrocarbon-contaminated zones and other lithologies, enhancing the interpretability of the data.The analysis of the ERT results shows that hydrocarbon contamination is not only confined to the surface but has penetrated deeper layers, which poses a critical risk to the underlying aquifers. The groundwater flow direction, trending from northeast to southwest, suggests that contaminants could migrate further, exacerbating the pollution problem.

Implications for Groundwater Resources

The findings underscore the vulnerability of local groundwater resources to hydrocarbon contamination. Given that the contamination has reached depths of up to 35.36m, there is a significant risk that the quality of groundwater could be compromised, affecting the health and livelihoods of the local population. The presence of free-phase hydrocarbons in the subsurface layers indicates that immediate remediation efforts are necessary to prevent further contamination and to protect the aquifers from potential pollution.

Conclusion

This study has effectively demonstrated the application of Electrical Resistivity Tomography (ERT) and Vertical Electric Sounding (VES) in assessing hydrocarbon contamination in Kegbara Dere, Ogoniland, Nigeria. The results reveal significant hydrocarbon presence across multiple subsurface layers, with resistivity values exceeding 900 ?m indicating the prevalence of freephase hydrocarbons. The contamination has penetrated deep into the subsurface, reaching depths of up to 35.36m, posing a critical threat to local groundwater aquifers.The findings highlight the urgent need for comprehensive remediation efforts to address the extensive hydrocarbon pollution in the area. The groundwater flow dynamics, moving from northeast to southwest, further complicate the contamination scenario, suggesting potential pathways for the spread of pollutants.

Therefore, immediate action is required to mitigate the environmental impact and protect the health and livelihoods of the local population.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. **Immediate Remediation Efforts:** Implement a comprehensive cleanup program targeting both surface and deeper subsurface layers. Bioremediation techniques should be employed for accessible areas, while advanced in-situ treatment technologies are necessary for deeper contamination.

2. **Continuous Monitoring:** Establish a continuous groundwater quality monitoring system by drilling deep observation boreholes. This will help track changes in contamination levels and assess the effectiveness of remediation efforts over time.
3. **Hydrogeological Assessment:** Conduct a detailed hydrogeological assessment, including drawdown and hydraulic conductivity studies, to understand the potential spread of contaminants and to inform the implementation of containment strategies.
4. **Community Engagement:** Involve the local community in remediation efforts and provide education on the risks associated with hydrocarbon contamination. Community participation is crucial for the success of remediation initiatives and for raising awareness about environmental protection.
5. **Policy Development:** Advocate for stronger environmental policies and regulations to prevent future oil spills. Ensure that oil companies adhere to best practices in environmental management and that there are strict penalties for non-compliance.
6. **Further Research:** Conduct additional studies to explore the long-term effects of hydrocarbon contamination on local ecosystems and human health. Research should also focus on developing innovative remediation technologies tailored to the specific conditions of Ogoniland.

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Towards an Enhanced Cadastral Mapping for Sustainable Environment in Nigeria: A Review of Whole-to-Parts and Fit-For-Purpose Approaches

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Abstract

Nigeria currently practiced the parcel-based land administration system which numerous mapping challenges has continued to impede the continuous mapping of improvements and hazards in the environment. The study reviewed the strength, weakness, opportunity and treats of the Whole-To-Parts (WTP) and Fit-For-Purpose (FFP) mapping approaches with Rivers State as a case study. The study adopted the expository method of data collection and depended on existing secondary data from the Rivers State Ministry of Lands and Survey publications, relevant documents guiding survey practice in Nigeria and selected articles from scholars in land administration. The results revealed that the WTP approach is highly standardized and relies on field survey and fixed boundaries whereas the FFP approach, in contrast, relies on aerial imageries and flexible boundaries with accuracy depending on the purpose of mapping. It was also noted that Rivers State currently practice the parcel-based land administration system with framework consisting of the spatial, legal and administrative whereas the FFP land administration relies on the spatial, legal and institutional frameworks. The study buttresses the need for the integration of the WTP and FFP mapping approaches to enhance rapid, fixed and flexible cadastral mapping for effective land administration and sustainable environment in Nigeria.

Keywords: Whole-to-Parts, Fit-For-Purpose, Cadastral, Mapping, Environment

Introduction

Land is the ultimate resources of the biosphere which refers to a specific area of the earth surface with physical entity in terms of its topography and spatial nature, and one of the characteristics of space that is widely recognized as a significant factor of production for planning and management purposes (Lee, 2006; Dale & McLaughlin 1998). Land forms the basis for all forms of human activity, from it we obtain the food we need, the space to work and the shelter we rest on. The usefulness of land is enormous; therefore, man has to guide it jealously considering its scarce nature (Esan, 2015; Onah, 2022).

Fekumo, (2002) noted that land is the most precious commodity of the ancient Nigeria and its value to the modern Nigerian is still very high. The resources of land are inexhaustible and enduring and its importance to human existence cannot be overemphasized. The need to map and manage land property effectively and efficiently for the use and good of mankind is very crucial, therefore, for Nigerias sustainable development, information relating to the location, size, use, (residential, commercial, agricultural, industrial, educational, recreational, and cultural, contents/value, ownership, improvements and state of land must be aggregated as a system so that it administration would be less cumbersome and people driven. (Williamson, Enemark, Wallace & Rajabifard, 2010).

The nexus between man and the physical environment is complex and multifaceted. Human activities have great impacts on the environment, this impact can be negative or positive and leads to land use and developments. Improvements on land such as construction of roads, buildings, recreational centers, rails, pipelines and bridge, amongst others are map to determine their locations, extent and terrain

characteristics. Furthermore, environmental treats such as oil spillage, erosion, flood, earthquake, structure deformation and land subsidence are mapped to also ascertain its location, extent and terrain characteristics.

However, the information concerning these activities of man on the environment can be obtain through continuous mapping approach which the FFP approach represent, this will ensure the constant updating of information of human activities for sustainable environment.

Plate 1: Specimen of Survey Beacon Use for Fixed Boundary
Source: Authors' Field Data, 2024

Plate 1 shows some survey monuments used for fixed boundary during whole-to-parts mapping. The whole-to-parts mapping relies on conventional surveying techniques which field data are referenced to already established ground controls and forms the key spatial / geodetic framework of a state land administration.

What Happen to the Survey Beacon After Land Development?

Plate 2: Survey Beacon Removed during Land Development at Aggrey Road, PH
Source: Authors' Field Data, 2024

The Fit-For-Purpose Land Administration (FFLA) approach to land administration has emerged as a game changer for developing countries and offers a viable, practical solution to map flexible boundaries and provide continuous security of tenure for all, quickly and affordably, and to enable control of the use of all land. As shown in Plate 2, the boundary beacon may have been removed during land development of human activities in the environment, the boundary is no longer fixed but flexible, and can only be mapped using the FFP approach.

Some related literatures reviewed noted the strength, weakness, and opportunities of the FFP approach. Enemark, Mclaren and Lemmen (2016) proposes the FFP approach which is intended to provide a new, innovative and realistic solution to land administration, with main focus on developing countries, where current land administration solutions are not delivering. The solution is directly aligned with country specific needs, is affordable, is flexible to accommodate different types of land tenure, and can be upgraded when economic opportunities or social requirements arise. It is highly participatory, can be implemented quickly and will provide security of tenure for all. Most importantly, the FFP approach can start quickly using a low-risk entry point that requires minimal preparatory work. It can be applied to all traditions in land tenure across the globe.

Odeyemi, Dairo and Sulaiman, (2023) adopted the Framework for Effective Land Administration (FELA) to appraise the processes and limitations of Land Administration System (LAS) in Ekiti State of Nigeria. The study which was titled "Evaluating Land Administration System in Ekiti State" buttressed that effective administration and management of land will significantly ezeinfluence better land use planning and socio-economic development of the study area, despite the economic meltdown in Nigeria States. The study however recommended that an allencompassing land administration system with a robust strategy be put in place to ensure longterm sustainable and socio-economic development in Ekiti State.

Ushina and Todorovski, (2023) in a study Titled: Assessment of Transparency and Open Data in Land Administration in Ecuado, some solutions to the treats of sustainable land administration and environment in Equador where highlited, these includes the adoption of mapping models focused on intelligence, interactivity, interoperability, incorporation, inclusivity and investment. Which will in no small measure enhance transparency, accountability, reliability in cadastral mapping. The study stressed that good land governance and information / communication technologies are the engines to embrace a change for a better land administration system and sustainable environment in Equador. Part of the research motivation was the non-existence of any land administration system in Equador as each municipal manages its cadaster and land registry and performs land use and valuation functions whereas the central Government creates national policies and norms and the local governments autonomies, making the local land administration systems to adopt new technologies based on their priorities and available economic resources.

With respect to reviewed related literatures, research scholars in Surveying and Land Administration have continue to advocate the adoption of the proposed countries Framework for Effective Land Administration rather than solely dependent of the whole-to-parts mapping approach, this prompted the need for the present study.

Study Area Description

Rivers State is presently one of the States in the South-South Geo-political zone and Niger Delta Region. The State was created in 1967 when it split from the then Eastern Region. (Owei & Obinna, 2011). The study area lies approximately between geographical coordinates of longitude 60 55' 0" and

latitude 40 35' 0" to longitude 70 55' 0" and latitude 50 10' 0" and bounded to the North by Imo and Anambra States, Abia and Akwa-Ibom to the East, and to the weat, Bayelsa and Delta. The State Capital, Port Harcourt is known for its metropolitan and cosmopolitan nature and is knownto be the commercial center of the Nigerian Oil Industry.

The study area is influenced by industrialization or urban sprawl where small communities have merged and formed megacity due to high influx of people resulting to rapid growth of population overtime, the is due to the influx of people resulting to rapid growth of the population and can also be hinged on the expansion of the oil and allied industries (Sunny & Weli, 2021).

Study Area Maps

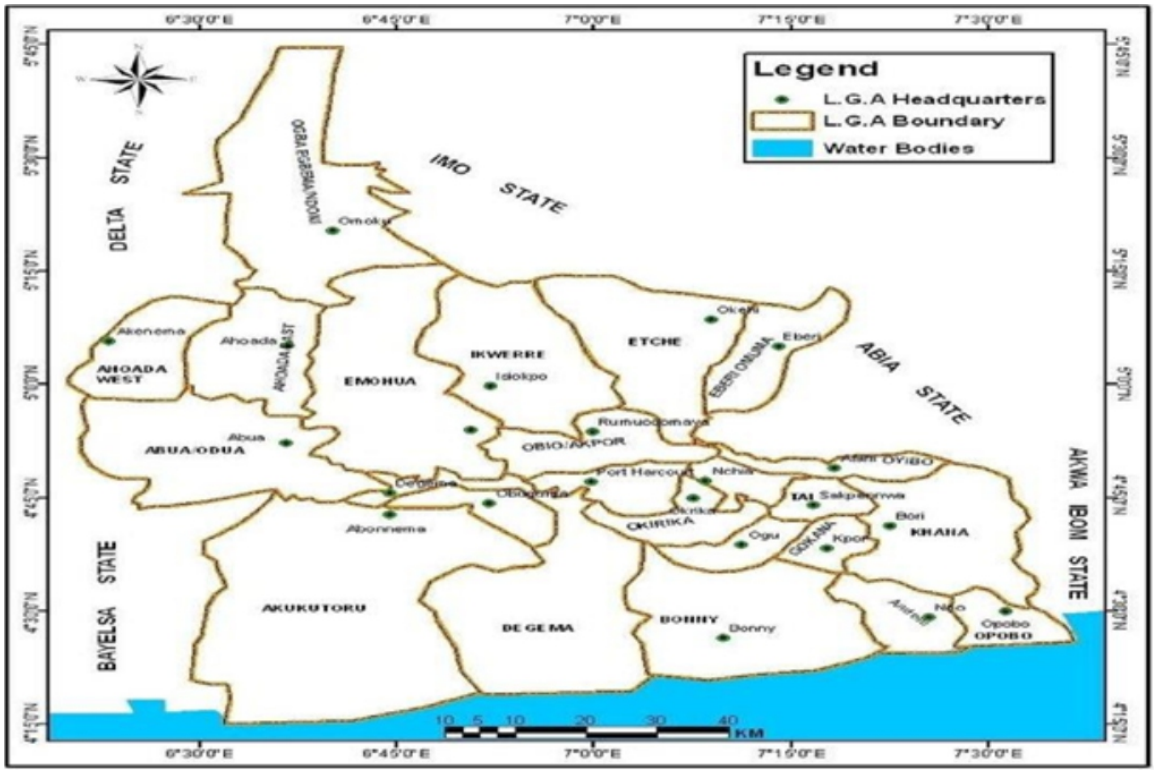

Figure 1: Map of Rivers State of Nigeria
Source: Edokpa & Nwaerema, 2019

Research Methods

Secondary Data Sources

Secondary data sources include data from Surveyors Council of Nigeria (SURCON) publications of specifications for survey projects in Nigeria, Framework of Land Administration in Rivers State and research articles from renowned scholars in land administration.

Primary Data Sources

Primary data sources include data collected from enquiry surveys and unstructured interviews. The sequential primary data collection processes are as follows:

i. Enquiry Surveys and Interviews

One of the methods adopted in this study is the scientific method of enquiry which is patient oriented as recommended in (Morgan, 2007). A visit to the Rivers State Ministry of Lands and Survey blocks and

the Office of the Surveyor General of Rivers State were made to obtain information and publications on the locations of offices and departments, operational codes cum framework of land administration in Rivers State

List of Departments in the Office of the Surveyor General of Rivers State

I. Administrative department
ii. Special Surveys Department
iii. Field Survey Department
iv. Geospatial Information System Laboratory
v. Certificate of Deposit and Upload Department
vi. Business Development Department

Table 1: Office Codes in Rivers State Ministry of Lands and Surveys

Office Codes	Office Description	Building Floor Locations
LO	Land Officers	Ground Floor
DOME	RIVLANDS Data Center / Warehouse	1st Floor
SA	Office of the special Adviser	2nd Floor
DFA	Department of Finance and Accounts	2nd Floor
CR	Conference Room	2nd Floor
PS	Office of the Permanent Secretary	3rd Floor
DL	Director of Lands	3rd Floor
DR	Deed Registrar	3rd Floor
DA	Department Administration	3rd Floor
OR	Open Registry	3rd Floor
GIS	Geographic Information System Laboratory	3rd Floor
DLUA	Department of Land Use and Allocation	4th Floor
PRS	Department of Planning, Research and Statistic	4th Floor
DAVC	Department of Acquisition, Valuation and Compensation	4th Floor
DLE	Department of Litigation and Enforcement	4th Floor
CAFÉ	Billing Café / RIVLANDS Helpdesk	4th Floor
OSG	Office of the Surveyor General	Moscow Road

Source: Rivers State Ministry of Lands and Surveys

Results and Discussions

The results are presented and discussed with respect to the objectives of this study;

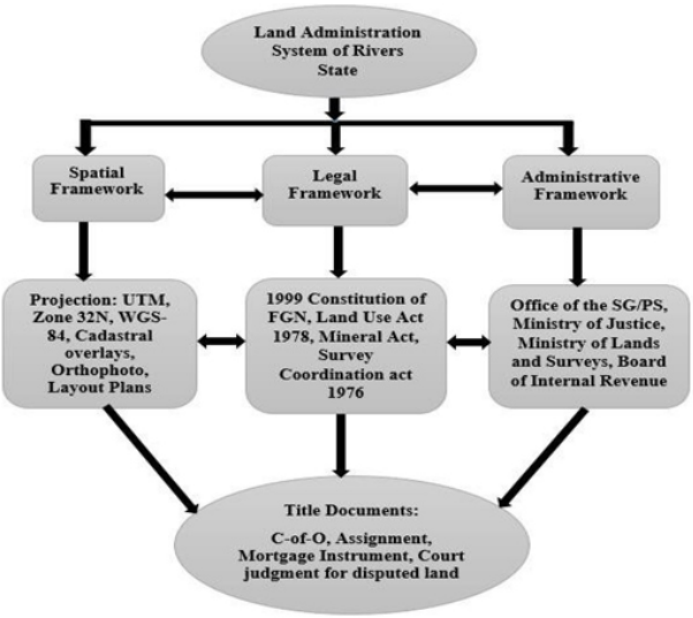

Figure 2: Flow Chart of Land Administration Domain Model in Port Harcourt Urban
Source: Authors' Field Result, 2024

Figure 3: FFP Proposed Country Framework
Source: Authors' Concept (2024), after Enemark, Mclaren and Lemmen, (2021)

Table 2: Benefits of FFP Land Administration Framework

Spatial Framework	Legal Framework	Institutional Framework
Visible (physical) boundaries rather than fixed boundaries.	A flexible framework designed along administrative rather than judicial lines.	Good land governance rather than bureaucratic barriers
Aerial/satellite imagery rather than field surveys.	A continuum of tenure rather than just individual ownership.	Integrated institutional framework rather than sectorial silos
Accuracy relates to the purpose rather than technical standards.	Flexible recordation rather than only one register	Flexible ICT approach rather than high-end technology solutions.
Demands for updating and opportunities for upgrading and ongoing improvement.	Ensuring gender equity for land and property rights.	Transparent land information with easy and affordable access for all.

Source: Authors' insights (after Enemark, Mclaren & Lemmen (2016)

Key Findings from the Review of the Whole-to-Parts and FFP Land Administration While the whole-to-parts (conventional cadastral mapping) use documentation of the surveyed land parcels as a basis for entering rights into a land registry, the FFP approach uses aerial or satellite imagery in the field to identify, delineate, and adjudicate the visible land parcel/spatial unit boundaries, and the rights are determined and entered directly into a register. This is a participatory approach undertaken by locally trained land officers and involves all stakeholders. Furthermore, while the whole-to-parts (conventional cadastral mapping) approaches are highly standardized, the FFP approach, in contrast, is flexible in terms of accuracy and in relation to the variety of tenure types to be secured. The land administration system can be upgraded and incrementally improved over time. The FFP approach has been successfully implemented in a number of developing countries like, Kenya, Equador, and Brazil, and the results provide excellent best practice for other countries to use. New FFP approaches have recently been tested in implementing countrywide land administration solutions in countries such as Rwanda, Ethiopia and Kyrgyzstan.

Discussions

Enemark, Mclaren and Lemmen (2016) proposed a guide that is primarily designed to allow a range of stakeholders in developing countries to make a decision on adopting the overall FFP approach. It also provides guiding principles on building the spatial, legal and institutional frameworks in support of designing the country specific strategies for implementing FFP land administration. It is not an instruction manual for implementing the FFP approach in a country as the strategy and implementation methods will be country specific. It presents the FFP concept and the connected key principles to be applied in developing a country- specific FFP strategy for land administration. It acts as a design guide to ensure that the appropriate spatial, legal and institutional frameworks are specified for implementing the FFP solution within the country. Figure2 illustrate the proposed frameworks for FFA which includes the spatial, legal and institutional frameworks. The proposed spatial framework consists of an aerial imagery for quick mapping, country wide participatory, field adjudication, incremental improvement and continuous accuracy whereas the legal framework comprises of an enshrine FFP approach in law, security of all land rights for all human rights, gender equity and continuous tenure, hence the concept of Social Tenure Domain Model (STDM). However, the

institutional framework was proposed to be holistic, transparent and cost effective with sustainable information technology approach, continuous capacity development and effective service delivery.

The FFP concept includes three interrelated core components that work together to deliver the FFP approach: the spatial, the legal and the institutional frameworks. The spatial framework supports recording the way land is occupied and used. The scale and accuracy of this representation should be sufficient for securing the various kinds of legal rights and tenure forms recognized through the legal framework. The institutional framework is designed to manage these rights and the use of land and natural resources and to deliver inclusive and accessible services. The FFP approach includes four core principles for each of the three frameworks as contained in table 2.

Conclusion

The expository research methodology was greatly utilized during the review. This study revealed the uniqueness of the FFP mapping, especially its flexible mapping approach in terms of accuracy and participatory approach rather than the conventional cadastral systems which are highly standardized base on flexible mapping specifications and accuracy standard of a jurisdiction.

Recommendations

i. The whole-to-parts and Fit-For-Purpose mapping approaches should be integrated to map fixed and flexible boundaries and continuous mapping of improvements land over time, this will enhance cadastral mapping for effective land administration and sustainable environment.

ii. A review of the legal framework of mapping in Nigeria is necessary and possible legislative action is needed to incorporate the two mapping approaches for effective land administration and sustainable environment.

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Analysis of Pollutants Emission Dispersion Pathway from Artisanal Petroleum Refining Sites and Human Exposure in Niger Delta, Nigeria.

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Abstract

There is an increasing trend in artisanal petroleum refining in the Nigeria's Niger Delta region leading to the emission and dispersion of various pollutants in to the environment. This has detrimental effect on the human population that are exposed to the pollutants. The aim of this study is to model pollutants emission dispersion pathway from artisanal petroleum refining site and measure their level of concentration and compare them with regulatory standard as well as their impact on human exposure in the area. The study adopted the experimental and Gaussian emission-dispersion model research approach. Air sampling was carried out on an artisanal petroleum refining site, where A DM 106./particulate (Mass Monitor) was used to measure the level of concentration of suspended particulate matters (PM_1, $PM_{2.5}$ & PM_{10}). Equally, the concentrations of NO_2, VOC_s and SO_2 were obtained using the Aeroqual 300 device and the meteorological parameters of temperature, humidity, wind, speed and wind direction were measured using portable extech 45156 weather station and compass. The Gaussian emission – dispersion model was used to determine the emission and dispersion pathway and the pollution trajectory to ascertain the impact on population exposure to the pollution levels. The general mapping of the study area was done with dispersion of pollutant from source to distance up to 50m to 1000m depicted. Findings of the study revealed that high level of concentration of the various pollutants was recorded when compared with recommended regulatory standards. The study thus concludes that there is higher pollution concentration level at the artisanal refining sites, and this telling effects on the life span and expectancy of the exposed human population. It is recommended that the licensing of operations of modular refineries be prioritized by the government and the strengthening of oil regulatory institutions be done to mitigate the externalities of artisanal refining activities in the area.

Keywords: Artisanal-refining, Modelling Pollutants, Human-Health

Introduction

The discovery of crude oil in commercial quantity in 1956 in Olobiri in the present day Bayelsa State and its subsequent production three years after signaled the beginning of environmental and human health challenges in the Niger Delta region (Ikezam, Elenwo & Oyegun, 2021; Agoha, 2019 and Akpan-Idio, Ibrahim & Udo, 2012). Since then, Nigeria had prided herself as one of the major producers of crude oil in the world (Albert, Amaratunga & Hougha, 2018). Sadly enough, the journey and progress recorded in the oil industry and the revenue derived from oil production do not reflect the level of socio-economic development and progress of the region. The activities involved in oil exploration and production have resulted in vegetation degradation, water quality deterioration, soil and air pollution, the consequences of which have led to reduction in farm lands, creation of food insecurity, bush fires, emission of particulate matters into the air environment and its attendant health impacts on the locals (Nkemakolam, 2018; Nwaejije, Hamidu & Obiosio, 2017; Akubi, 2015 and Amangaraba & Njoku, 2012; Ayeni, 2019 and Anejionu, Ahiarammunnah & Nri-Eze, 2015; Digha, Clark & Asuomo, 2022; Digha, *et al*, 2022). It is estimated that between 200,000 and 300,000 barrels of oil is lost daily to oil theft, known in the country as illegal bunkering (Obenae, 2014; Elsever 2011; Digha, *et al*, 2022). As defined by Digha, *et al* (2022), artisanal or illegal refining of oil (petroleum), is the locally and rudimentary refining of oil in the Niger Delta region referred to as "Kpo-Fire", is a high-

risk and labour intensive processing of crude oil into various refined oil products such as petrol, kerosene, and diesel, using locally fabricated equipment in makeshift refineries (Onakpohor, *et al*, 2020; Brakstad, Lofthors, Rebicic & Netzev, 2017; Coderoni & Perio, 2020; Beebeteidoh, Pazouki & Normau, 2020 and Beshiru, Okareh, Chigor & Igbinosa, 2018).

It is thus imperative to in view of the above, it has become necessary to model pollutants emission dispersion pathway from artisanal petroleum refining sites and human exposure impact in Nigeria's Niger Delta Region so as determine the human health impact of the concentration of the pollutant in the atmosphere.

Literature Review

Research Theoretical Foundation

The theoretical basis and foundation for this work is hinged on the theory of Paradox of Plenty. The theory of paradox of plenty was propounded by Sachs and Warner in 1995. The theory states that a high endowment in natural resources may be detrimental for economic growth and societal development. This theory is otherwise called the "Resource Curse", and states that a nation or region of the world with an abundance of natural resources (such as fossil fuel and certain minerals), usually have less economic growth indices, less potential for societal development, less democracy, or worse development outcome than regions or nations with fewer or less natural resources. In effect, this theory emphasizes the idea that the possession and abundance of natural resources particularly is the form of crude oil or minerals as in the Niger Delta region of Nigeria does not necessarily means that the area or region will develop economically and otherwise, and that the resources and wealth can even have a structural negative impact on long term economic development in the area (Moti, 2019).

While it seems strange to suggest that a region could be economically (as well as socially and physically) hindered from growth and development, by its possession of valuable and often essential economic inputs, scholars who believe in the idea of resource curse, suggest that, more often than not, resource rich or resource dependent countries or regions of a countries or the regions with few natural endowments is usually undeveloped. Thus, Darwin & Guerreiro (2016), had noted that the theory of paradox of plenty emphasized that countries and regions of the world that are highly endowed with bounty of natural resources have tended to fail to benefit from them, and sometimes have performed worse than less endowed regions or countries. On this premise, there are some conventional wisdom and ideas that have spread in the academic literature source the mid-1990s about the proposition of the theory of paradox of plenty as seen in the Nigeria's Niger Delta region recording low performance in economic, physical and social growth and development albeit the huge oil wealth potential (Ikezam, *et al*, 2021 and Ordinioha & Brisibe, 2013). This ideas and wisdom stemmed from the fact that managers of the oil wealth and government have carted away the resources for the development, empowerment and sustainable investments of their areas, leaving the Niger Delta region improvished, degraded, marginalized, strangulated and imperialized. Thus, the youths have no option than to engage in oil theft, bunkering and illegal refining business to make out a living for themselves.

The theory of Paradox of Plenty is used here to best explain the chronic and deplorable levels of deprivation, improvishment, and economic down trodden of the Niger Delta region due to years of neglect, despite the huge potential wealth carted away from the region. There had been high level of poverty and lack of access to oil wealth by the Niger Delta locals, which had made the people aggressive, restive and had decided to take and to be in control of their God given wealth. Thus, the evidence of the Niger Delta's predicament is presumptuous of the assumption of their devastating environmental and deteriorating human health conditions predicated in the underline principle of the theory of Paradox of Plenty. Hence, its application in this study.

Artisanal Refining and Air Pollutants Dispersion Models

As documented in the literature, the Gaussian Plume Model was propounded by Boayant Gaussia in 1930 (Abdel-Rahman, 2008). The Gaussian Plume Model uses a realistic description of dispersion, where it represents an analytical solution to the diffusion equation for idealised circumstances. According to Bhattacharya (2021), the atmospheric dispersion model uses the Gaussian Plume Model, which is a mathematical simulation of the physics and chemistry governing the transport, dispersion, and transformation of air particulate matters and pollutants in the atmosphere. It is a means of estimating downwind air pollution concentrations, given information about the pollutant emissions and nature of the atmosphere. The model assumes that the atmospheric turbulence is both stationary and homogenous. In reality, none of these conditions is fully satisfied. However, Gaussian Plume Model has been successfully used for rural configurations. This model is the most widely used plume model, and is the basis for most of the computer models used for the prediction of yearly averaged atmospheric concentration of criterion ground level air pollutants (Bhattacharya, 2021), and is adopted in this study.

In this model, determining the pollutant concentrations at ground level beneath an elevated plume involves two main steps; first, the height to which the plume rises at a given downwind distance from the plume source is calculated. The calculated plume rise is added to the height of the plume's source point to obtain the so-called “effective stack height”. Second, the ground level pollutant concentration beneath the plume, at the given downwind distance is predicted using the Gaussian dispersion equation written as:

$$C(X,Y,Z) = \frac{Q}{2\pi\pi y\ \delta_{zu}} \exp\left(-\frac{y^2}{2\delta_y^2}\right) \left\{\exp\left(\frac{(z-H)^2}{2\delta_z^2}\right) + \exp\left(-\frac{(z-H)^2}{2\delta_y^2}\right)\right\} (1)$$

Where C = the concentration
Q = emission rate of pollutant from the source
U = the wind speed which defines the direction x
y = the horizontal distance perpendicular to the wind direction
z = the vertical direction
H = the effective height of the plume

δ_y, δ_z = the parameters of the normal distributions in y and z directions, usually called the dispersion coefficients in y and z directions respectively. A definition sketch of the plume dispersion is shown in Figures 1 and 2.

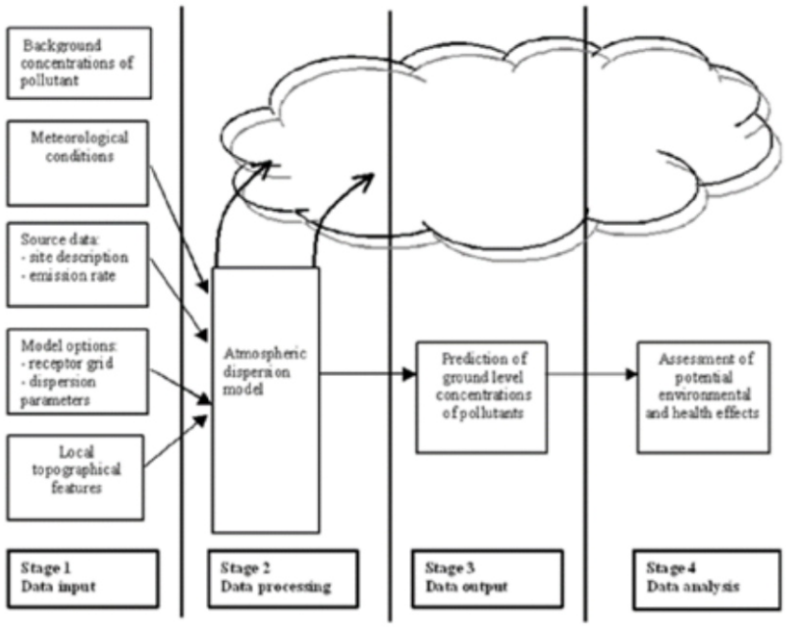

Figure 1: The Gaussian Dispersion Plume Model
Source: Abdel-Rahman, 2008

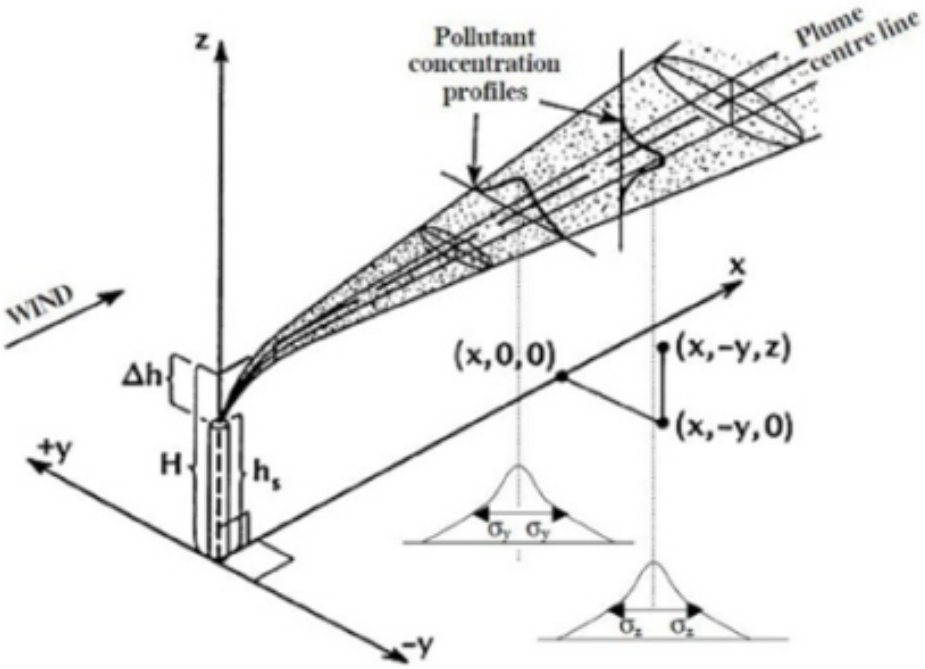

Figure 2: The Gaussian Dispersion Plume Model Sketch
Source: Abdel-Rahman, 2008

The Gaussian Plume dispersion model can be analysed based on the following assumptions:

1. Continuous emission and negligible diffusion in the direction of travel
2. The material diffused is a stable gas or aerosol, with a negligible deposition rate
3. Mass is conserved through reflection at surfaces.
4. Background pollution is negligible
5. Steady- state conditions
6. Constant wind speed and direction with time and elevation

7. Negligible wind shear effect on horizontal diffusion
8. The dispersion parameters and assumed to be functions of x (and hence y alone)
9. The terrain is relatively flat, open country.

Pollutant and Human Exposure Pathways

Pollutants exposure pathway is the link between an environmental release or source of the point where a population might come into contact with or be exposed to, the environmental contaminant (Dong, Wang, & Li; 2023). Pollutants enter the human body in three main different ways: by inhalation, ingestion and skin absorption. The amount of any given pollutant that is received is often termed the dose; and the dose will be dependent on the duration and intensity of the exposure (Dong, *et al*, 2023). Thus, every environment and site present unique challenges and exposure scenarios. Health stressors need to consider site specific factors that might enhance, prevent, or modify exposures to environmental pathways to evaluate the ways in which people might come into contact with that and these include contaminant source; environmental fate and transport; exposure point; exposure route; and the potentially exposed population. Typical exposure pathways for pollutants and environment stressors of artisanal petroleum refining in the Nigeria's Niger Delta region are shown below thus (Figures 3 and 4).

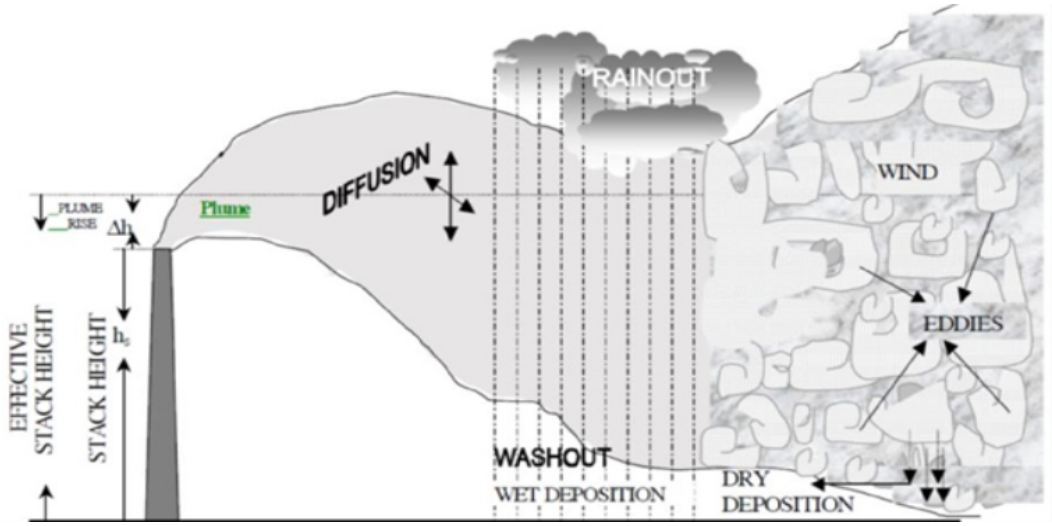

Figure 3: Behaviour of Effluents Released to the Atmosphere
Source: Dong *et al*, 2023

Radiation exposure from an atmospheric release could results in external exposure, that is direct radiation from plume (immersion) and deposited radio nuclides on surfaces (ground shine) as well as internal exposure such as inhalation of radio nuclides in air, and ingestion of foods, contaminated by radio nuclides as shown below:

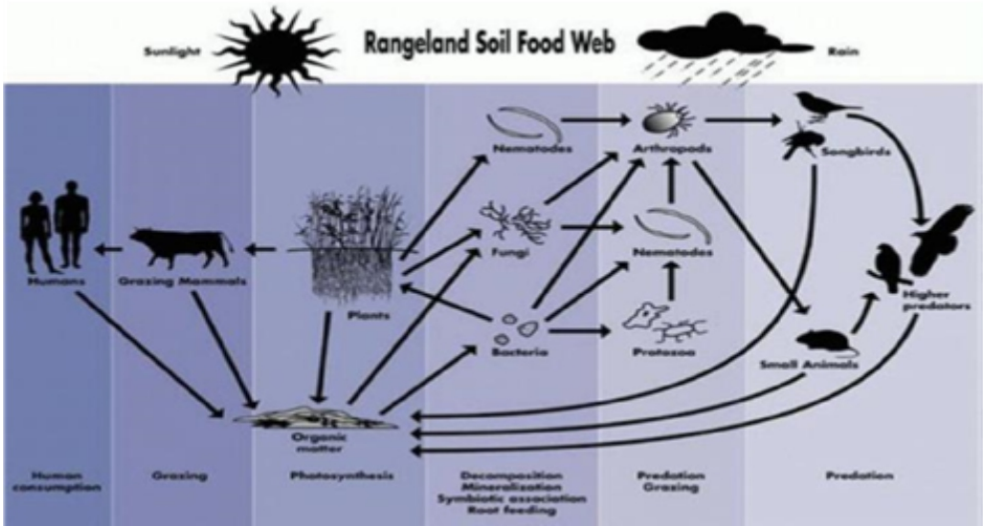

Figure 4: Exposure Behavior Pathway
Source: Dong *et al.,* 2023

Materials and Methods

The Study Area

Geographically, the Niger Delta is bounded by the Atlantic Ocean separated by barrier island ridges bordering the Atlantic Ocean falling within the classification of a generally low-lying terrain consisting of unconsolidated mud and sandy particles resulting in little or no resistance to tidal and wave impact on its shoreline (Anitowose, Lawler, Vander Horst & Chapman, 2014; Asimua & Omokhua, 2013; Asimea & Omokhua, 2013; Antiowose *et al*, 2014; Ordinwha & Brisibe, 2013; Agoha, 2019; Ikezam, *et al,* 2021; Niger Delta Environmental Survey) NDES, 1997); (Atubi, 2015). (Ikezam, *et al*, 2021). It is made up of 7.5% of Nigeria's land mass (Figure 5).

The area stretches approximately on the coast of the Bight of Benin within Latitude 4° 12′ 30.892″ N through Latitude 4° 50′ 10.7″ N and Longitude 4° 56′ 15″E through Longitude 9° 40′ 2.654″ E (Ikezam *et al*, 2021; Ikezam, *et al*, 2021; Bushuru *et al*, 2018; Akpan, *et al*, 2012; NDES, 1997). (Figure 5).

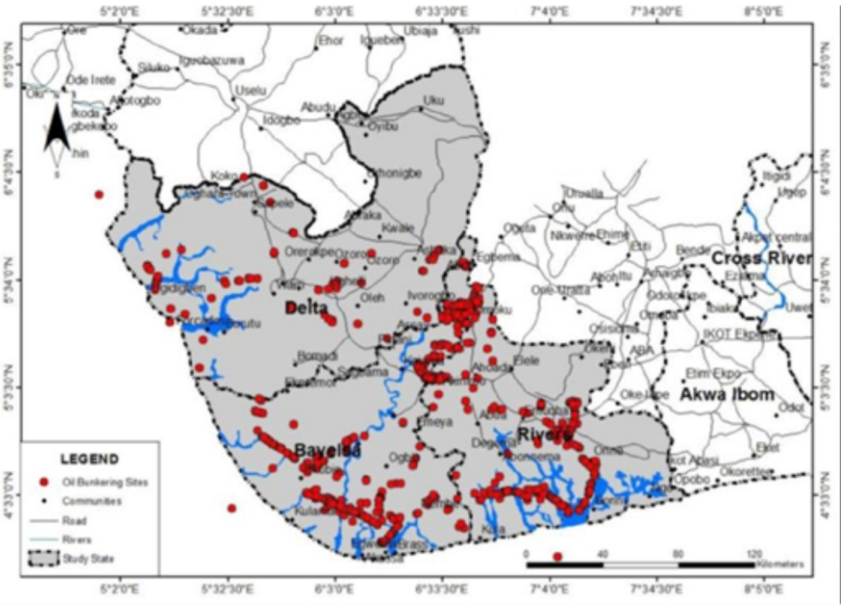

Figure 5: Artisanal Oil Refining Sites in Niger Delta Area
Source: Ikezam *et al,* 2021

Materials

The materials used in carrying out the study include Aeroqual 300, DM 106 – particulate Mass Monitor, Portable Extech 45156 Weather station, compass and GIS based Model tool (ArcGIS).

Methods and Procedure

A DM 106 – particulate Mass Monitor was used to measure the mass of PM_1, $PM_{2.5}$ and PM_{10}, were the equipment was held at 1.5m above ground level, making sure that the efficiency of the equipment can detect what an average human can inhale at that height and avoid dust from the ground. This instrument, was held sensor wise in the direction of the prevailing wind. The pollutants from Artisanal refining site was measured at the stable stand of the sensor in the instrument. Furthermore, NO_2, VOC_2, SO_2 was collected and measured using Aeroqual 300 series where the sensor was placed on the height of about 1.5m above ground level to avoid contaminants from the ground. In this wise, the sensor was placed in prevailing wind direction and thereafter, the sensor was warmed up, and the results displayed. A portable Extech 45156 weather station equipment was used to measure the meteorological parameters such as the prevailing level of humidity, temperature, wind speed, and a compass was used to detect the prevailing wind direction. This method as adopted in this study was also used by Adeloye & Ekade (2021) in modeling of pollutants form artisanal refining of crude oil in Port Harcourt; the case of Eagle Island

Figure 6: Pollutants Emitting and Dispersing from Artisanal Refining Location in Niger Delta

Source: Digha, *et al.*, 2022

Results and Discussion

Morning and night air qualities were carried out through the concentration in gases of air quality parameters with (PM_1, $PM_{2.5,}$ PM_{10}, NO_2, SO_2 and VOCs) being determined for morning and night measurement of distance from the refining source on the day measurement noted. The air quality results is shown in Tables 1 and 2 and Figures 7 to 9 and 10 to 12 thus.

Table 1: Concentration of Air Quality Parameter for Morning

Distance (m)	Concentration of NO_2 (mg/m^3)	Concentration of SO_2 (mg/m^3)	Concentration of VOC (mg/m^3)
50	0.032	0.060,	179.100
100	0.046	0.020	81.100
200	0.028	0.010	63.100
300	0.790	0.010	61.100
400	0.059	0.0	49.200
1000	0.059	0.0	45.00

Table 2: Concentration of air quality parameter for night

Distance (m)	Concentration of NO_2 (mg/m^3)	Concentration of SO_2 (mg/m^3)	Concentration of VOC (mg/m^3)
50	0.041	0.050	116.100
100	0.043	0.020	64.800
200	0.007	0.010	61.100
300	0.080	0.010	64.100
400	0.052	0.0	62.300
1000	0.031	0.0	46.00

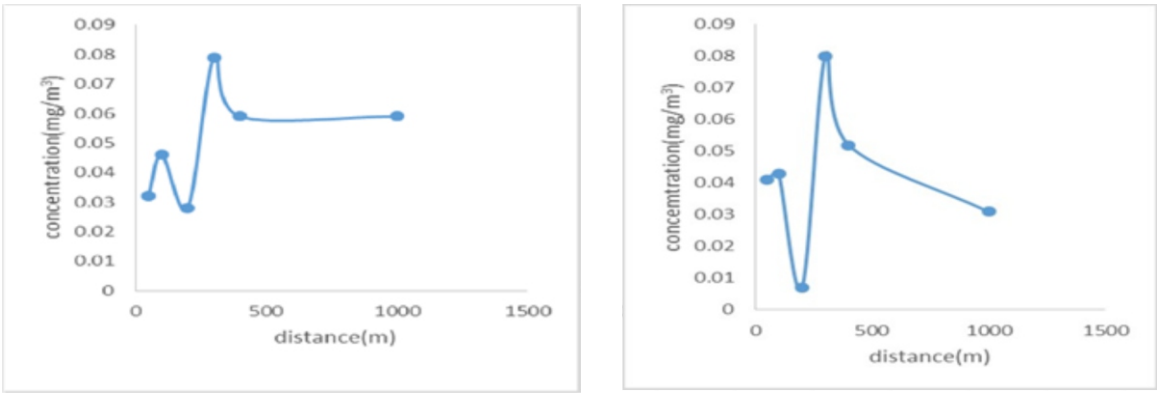

Figure 7 Plots of NO_2 against Distance (Morning and night)

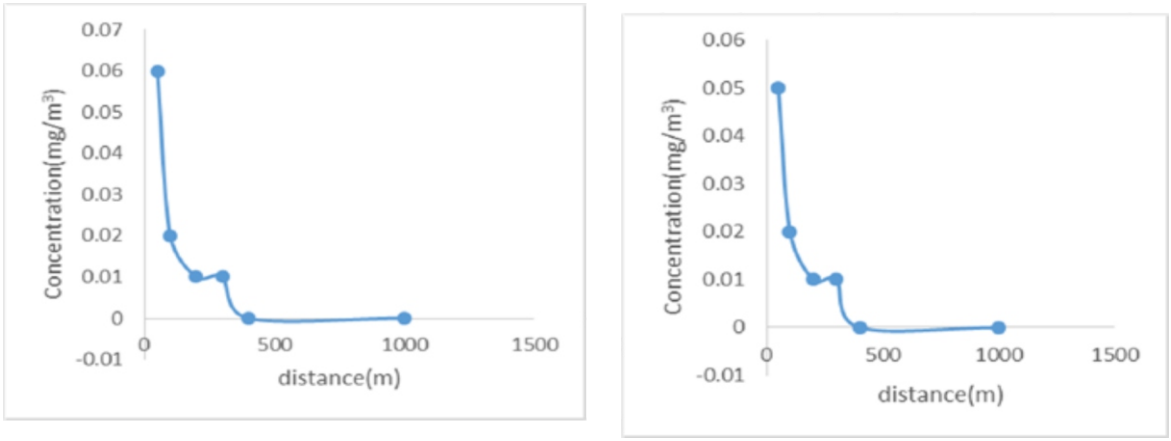

Figure 8 Plot of SO_2 against Distance (Morning and Night)

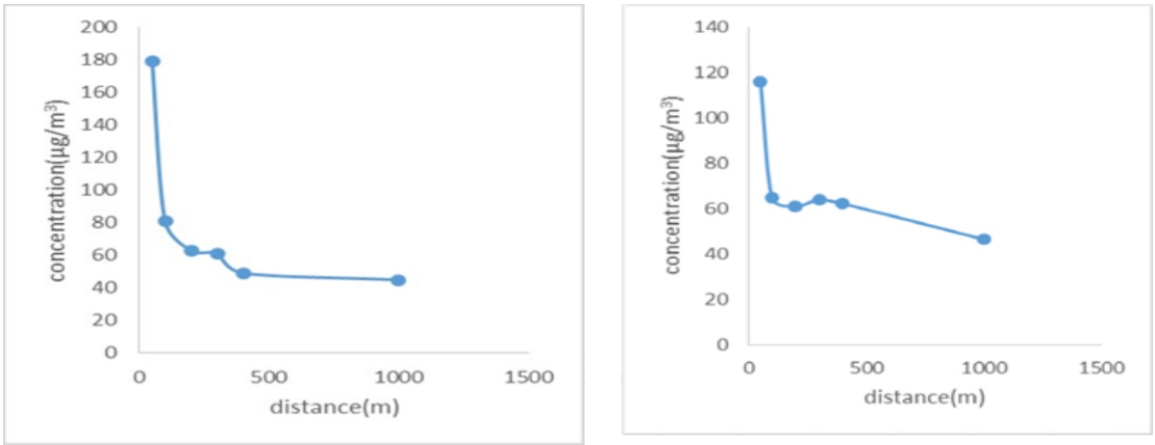

Figure 8 Plot of VOCs Concentration against Distance (Morning and Night)
Suspended Particulate Matters

The suspended particulate matters concentration for morning and night were also determined through the application of Geographic Information System (GIS). The suspended particulate matters data for the research study is presented thus.

Table 3: Suspended Particulate Matters

Location (m)	Morning (µg/m³)			Night (µg/m³)		
	PM 1	PM 2.5	PM 10	PM 1	PM 2.5	PM 10
50	11.0	21.0	27.0	13.0	22.0	29.0
100	16.0	25.0	30.0	15.0	26.0	34.0
200	11.0	17.0	26.0	9.0	18.0	27.0
300	7.0	12.0	14.0	8.0	13.0	14.0
400	7.0	12.0	17.0	6.0	12.0	14.0
1000	8.0	15.0	14.0	8.0	15.0	15.0

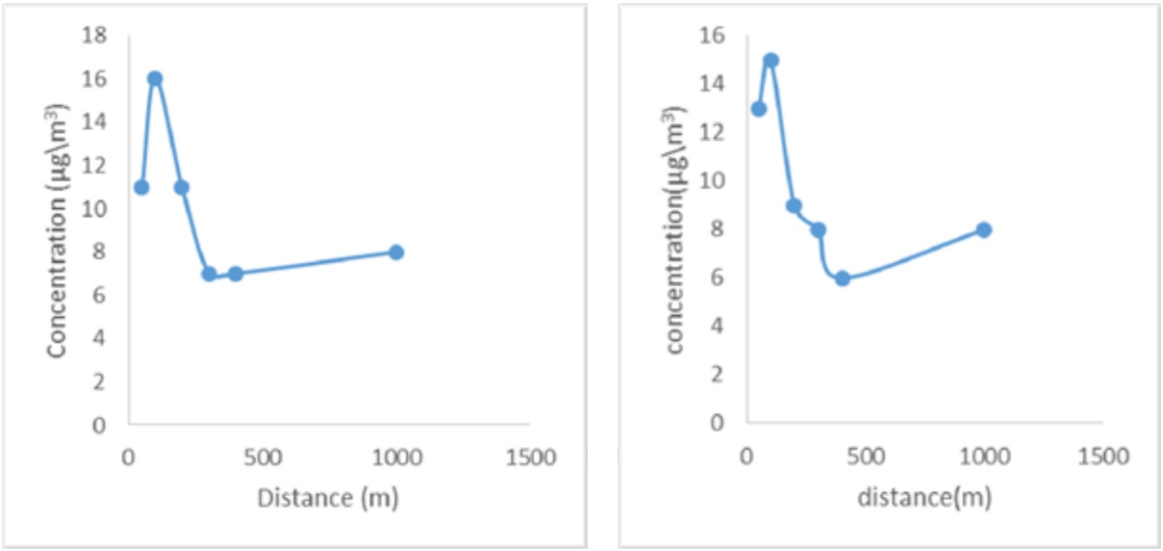

Figure 10 Plot of SPM1 against Distance (Morning and Night)

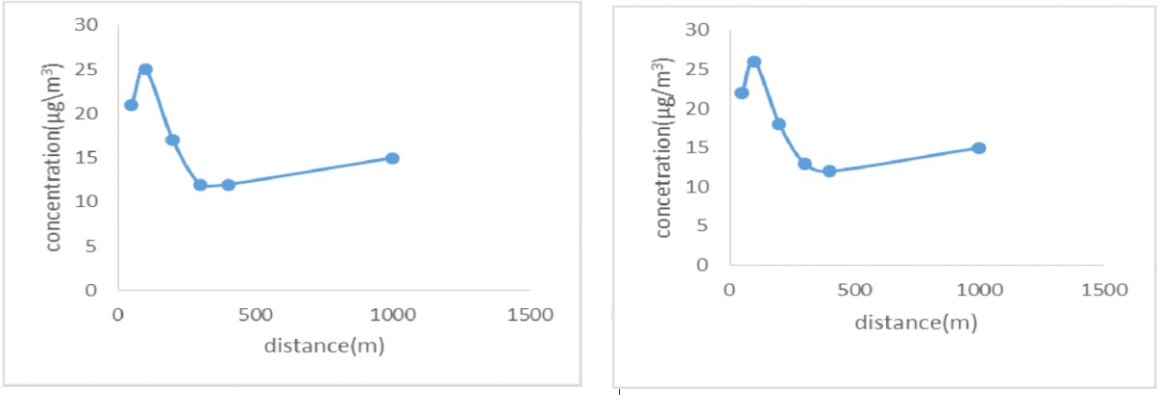

Figure 11: Plot of SPM2.5 against Distance (Morning and Night)

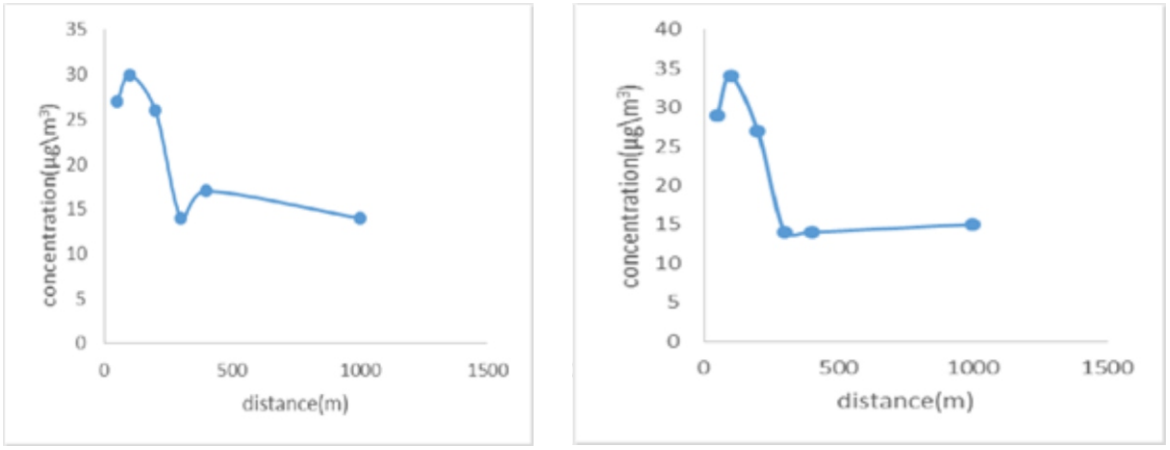

Figure 12 Plot of SPM10 against Distance (Morning and Night)

Conclusion

The analysis in the above show that high levels of concentration at farther distances from the source due to wind spend and wind direction and the rate of dispersion. The environment is now at the risk of degradation of plant cover, soil degradation and pollution, water pollution and the emission of obnoxious gases sand particulate matters leading to serous environmental and human health issues occasioned in the loss of respiratory and cardiovascular system functioning, irritation of the sensory organs, and congenital disabilities.

Recommendations

Based on the foregoing, it is recommended that the government should strengthen oil regulatory institutions, licensing of operations of modular refineries to mitigate the externalities of artisanal refineries as well as the promotion and strengthening of local content requirement in the industry for the development of competence.

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Spatial Distribution of Energy Stations and Monitoring of Air Quality in Port Harcourt, Rivers State, Nigeria

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Abstract

This study was carried out to examine the geospatial distributions of energy service stations, to ascertain their locations if they conform to standard practice, the monitoring of the various pollutants as identified in the various energy service stations was also carried out to ascertain the air quality within the vicinity of the energy stations. The study was carried out in Obio/Akpor and PHALGA Local Government Area, Rivers State. From the analysis carried out, it was revealed that the identified energy stations do not fall within the standard of 15 metres away from the road to the energy pumps as stipulated by DPR (Department of Petroleum Resources). The use of GIS/Remote sensing buffer geostatistical analysis was employed in carrying out the proximity analysis. Also, the observed air quality within the identified energy stations was compared to the NESREA (National Environmental Standards and Regulations Enforcement Agency) standard. The various pollutants examined are PM 10, PM 2.5, carbon monoxide (Co), Nitrogen Dioxide (No2), ground-level ozone (O3), and Sulfur dioxide (S02). The result reveals that although there are present of all the pollutants in the energy stations where measurements were carried out, their concentration values fall within the permissible limit as specified by NESREA. The one-way ANOVA result reveals that there is no statistical variation in the air quality at the various energy service stations across the various times of the day as the p-value was significant at ($p = <. 000$) at the NNPC energy service station, ($p = < 0.01$) at TOTAL energies service station and ($p = < 0.01$) at CONOIL energy stations respectively. But quite disturbing, carbon dioxide (CO2) which is discovered to be the primary pollutant was extremely highly than the permissible limit of 400 (ppm). The concentrations were mostly high in the afternoon and evening. This is attributed to the influx of vehicles that buy fuel from the energy stations at that time of the day. The concentration of (C02) poses a serious health effect on the pump attendants due to their constant inhaling of the pollutants. The study concludes that energy service stations should be cited at the approved DPR standard of (15 meters) and actionable measures should be put in place to aid in the reduction of CO2 within the energy stations. The study therefore recommends that immediate attention should be given to the locations of energy stations and DPR should be strict in the compliance level before approvals are given as this will aid in the prevention of disaster in the event of the occurrence of one.

Keywords: Geospatial Analysis, Energy station locations, Ambient Air Quality

Introduction

Air pollution can directly or indirectly affect human health, causing physical discomfort and leading to disease or even death. Studies have shown that when the human body is exposed to highly polluted air for a long time, the mortality rate increases. (Tharby, 2002). With the rapid development of the economy and booming population growth, an enormous number of resources (e.g., energy, water, and food) are required in our society to sustain our activities. As a result, various kinds of pollution have been produced. Among the various pollution problems, air pollution has caused major concern over the world due to its widespread nature, damage to our environment and potential health risks to humans. Although concern has been raised regarding the emission of air pollutants from anthropogenic sources, our society still relies heavily on fossil fuels for various applications such as electricity generation, transportation, industrial and domestic heating, and so on. An obvious result of this is the deterioration of air quality, particularly in developing countries. Air pollution has become a public concern problem in modern metropolises. (Seinfeld, 1986). Air pollution may be defined as any atmospheric condition in which certain substances are present in such concentrations that they can

produce harmful effects on man and his environment. Unpolluted air on the other hand is a vital requirement for the growth and survival of all living species. The life expectancy of both man and animal species within a given environment is reliant on the quality of air present (PSMAG, 2018). Of worth noting, humans require oxygen for efficient respiration in other to facilitate and enhance metabolic activities. Air is a vital component for the sustenance of all life forms on earth, thereby, making air an indispensable tool for the survival of man. Good air is supposed to be free and safe for human inhalation. Unfortunately, due to urbanization, and the introduction of several anthropogenic activities such as the sales of premium motor spirit (PMS), which has contributed to the contamination of the ambient outdoor air quality thereby posing serious health risks concern (Cavanagh *et al.,* 2009). According to a report by Shola (2018), the increasing urban population in Nigeria and her dependence on PMS exhibits a heightened vulnerability to human health. As stated by Power et al. (2018), the detrimental effects of air pollution negatively affect human health, ecosystems, and the overall biosphere. Air pollution poses a significant concern in developing nations characterized by the presence of unregulated industries such as filling stations. Air pollutants such as particulate matter (PM 10 & PM 2.5), carbon monoxide (Co), Nitrogen Dioxide (No2), ground-level ozone (O3), and Sulphur dioxide (S02) have detrimental effects on the wellbeing and physiological stability of people and other organisms. Moreover, the World Health Organization (WHO) has consistently emphasized the role of air pollution in the prevalence and intensification of diseases such as tuberculosis, asthma, and cancer, as well as respiratory and dermatological ailments. These health conditions have resulted in a higher mortality rate compared to AIDS, as reported by Mehta *et al.* (2013).

In a study conducted in 2012 by the World Health Organization (WHO), it was stated that around 10% of the global population, equivalent to 7 million individuals, succumbed to mortality because of air pollution (WHO, 2014). In 2019, the global yearly mortality rate reached 2.9 million individuals, a statistic predominantly observed in developing nations, accounting for almost 85% of the total deaths (World Health Organization, 2016). Of worth noting, one of the major contributors to air pollution is fumes generated from vehicles at various filling stations at the purchase of PMS, gases released from the nozzles from pumps at filling stations etc which affect air quality and, in most cases, leads to mortality (Mehta: 2013; Obanya: 2018; Ogundipe: 2018; Alani: 2019) listed emission of fumes from vehicles as a major pollutant of air quality in filling stations which causes difficulty in breathing, wheezing, and sneezing. Notably, this is a result of the concentration of gases that has engulfed the filling station environment. This problem is synonymous across all filling stations. As stated by Ashmore, (2005), it is also suspected that industrialization and the presence of various business centres that emit carbons through from their daily activities could be responsible for the indiscriminate emissions of the obnoxious gases. This in return could pose a serious health effect to the staff and those doing business in the filling station vicinity. To ascertain the air quality within the various energy stations, the distances of the locations of the energy stations were examined to verify if they fall within the permissible limit as specified by DPR (Department of Petroleum Resources).

Materials and Methods

Study Area

The study area is situated within the Port Harcourt metropolis which is made up of Obio/Akpor L.G.A. and Port Harcourt City L.G.A. It is situated between 4°42 and 4°52' North and between latitudes 6°53' and 7°08' East. It is in the South-South region of Nigeria. Port Harcourt is often regarded as the garden city of Nigeria, it was established by the British Colonial administration under Lord Lugard to meet the pressing economic needs of the Europeans. The study area is located in Obio-Akpor and Port Harcourt L.G.A. respectively. However, it is bounded by Eleme L.G.A. to the West, Oyibo L.G.A. to

the East, and Degema L.G.A. to the South. See **(fig 1**). The study area is highly characterized by the presence of energy service stations. Due to the urbanization in the study area, it is characterized by several energy service stations and associated business centres which is likely to influence the air quality in these areas. It is characterized by alternate wet and dry seasons. (Hoje, 1972) with annual total rainfall of between 160mm and 294mm; relative humility of over 90% and mean temperature of 27°c. The detailed geology of the area has been described by Allen (1965), Rayment (1965), and Short and stauble (1967). The local geology of the area consists of stratified sediments starting with the Benin Formation underlain by the Miocene Agbada Formation and under compacted Akata Formation respectively (Short and Stauble, 1967). The Benin Formation consists of massive highly porous sands and gravels of fluviatile origin. Agbata formation is also of Eocene-recent in age, and it consists of an admixture of inter-bedded sands, which are fluviatile coastal, fluvio-marine and shale in origin. Akata formation is also predominately shale or clay but is relatively under-compacted. (Ehirim et al, 2009). The mean maximum temperature all year round in the study area is 30°C. The dry season months of February, March, and April record the highest mean diurnal temperature for the period of ten years (1985-1994), the month of March recorded 36°C while February recorded 35°c1°c. The temperature within the Study area is 33°c.

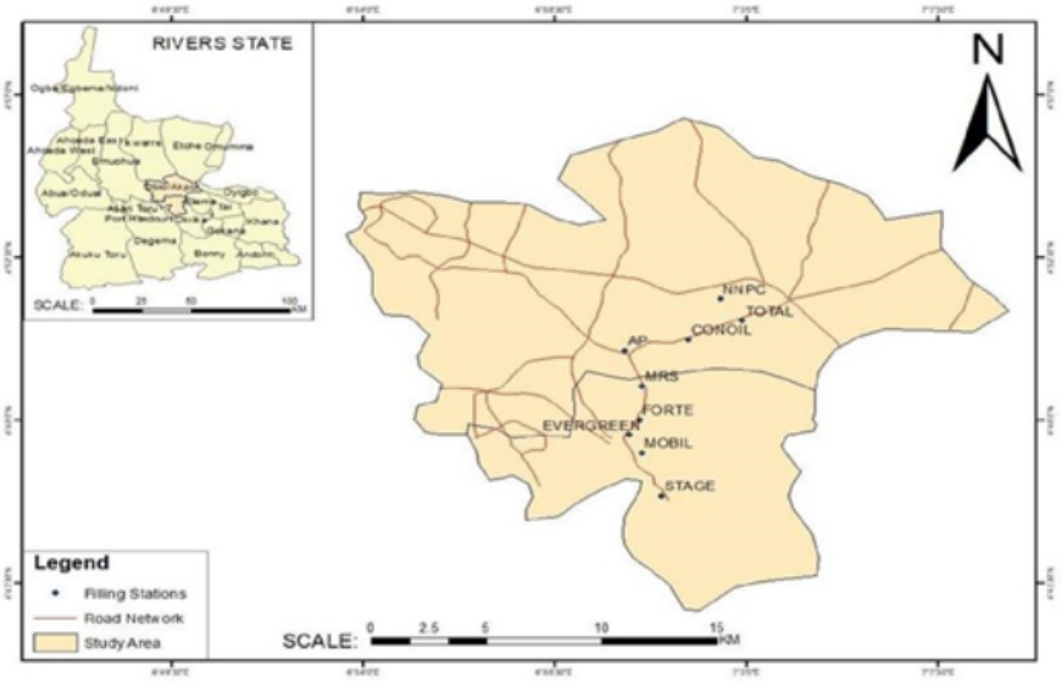

Fig. 1: Study Area-Geospatial Locations of Filling Stations Within the Study Area

Type of Data/Method of Data Collection

The information utilized for this research constitutes primary data. Primary data refers to the data gathered directly from the field through direct field measurements. This involves the use of field instruments to directly collect the sample for investigation. The various coordinate points were also collected with the use of a hand-held GPS (Global Positioning System) device. The distances from the major road to the filling station locations were collected in the entire study area across the various filling stations sampled with hand-held tape. Also, the air quality data were examined to ascertain their concentration levels in the atmosphere. The following pollutants were examined to ascertain their presence and concentrations. They are PM 10, PM 2.5, carbon monoxide (Co), Nitrogen Dioxide

(No2), ground-level ozone (O3), and sulfur dioxide (S02). The air quality reader (AERO-QUAL 500 SERIES) was utilized in the data collection. The data was collected at different times of the day; 10 am, 12 pm and 5 pm respectively. This is done by the methods specified by Francis Tuluri, and Amit Kr. Gorai, Aaron James(2007). The air quality instruments are specified below.

Method of Data Analysis

The various air quality data from different stations were investigated to ascertain the station that has the highest pollutant concentration using descriptive statistics (mean, and standard deviation). The result was further used to ascertain if it falls within NESREA (National Environmental Standards and Regulations Enforcement Agency), the permissible limit for outdoor air quality. while the one-way analysis of variance (ANOVA) and probability level set at ($P < 0.05$) was considered to indicate statistical significance. This was done to ascertain if statistically, there exists a significant variation in the air quality across the filling stations within the study area.

The table 1, depicts the various coordinate locations of the nine (9) filling stations in the study area. Field measurements were recorded for the various distances in metres to ascertain the locations of the various filling stations away from the major roads in the study area. DPR is the sole regulatory agency that spearheads the activities of filling stations in Nigeria. They are the regulatory agency saddled with the responsibility of siting filling stations across Nigeria. Furthermore, the latitude and longitude of the various filling stations were also recorded.

Table 1: Geo-Spatial Locations of Energy Service Stations

S/No.	Sample Places	Distance(s) Metres	Coordinate Points	
			Longitude	Latitude
1	NNPC Filling Station	2	7.039777	4.856064
2	TOTAL Filling Station	3	7.048483	4.845983
3	CONOIL Filling Station	2.5	7.027405	4.837277
4	AP Filling Station	0.2	7.002662	4.832237
5	MRS Filling Station	0.1	7.009077	4.815741
6	Forte Oil filling Station	2	7.00816	4.800162
7	Evergreen Field Oil	0.05	7.004037	4.793289
8	Mobil Filing Station	0.5	7.009077	4.785041
9	Stage Oil Filling Station	0.05	7.016866	4.765338
	DPR Standard (Decree)	15 (Metres)		

Source: Researchers' Field Work, 2024

Accordingly, as specified by DPR, (2016), all filling stations must be situated within a distance of 15metres from the road. Out of the identified energy stations, three (3) major marketers were used in the study to ascertain the quality of air. However, the various distances across the nine (9) energy stations were used in the study to also verify their distances if they fell within the permissible limit as specified by DPR.

Plate 1: Hand-Held Extect Air Quality Reader

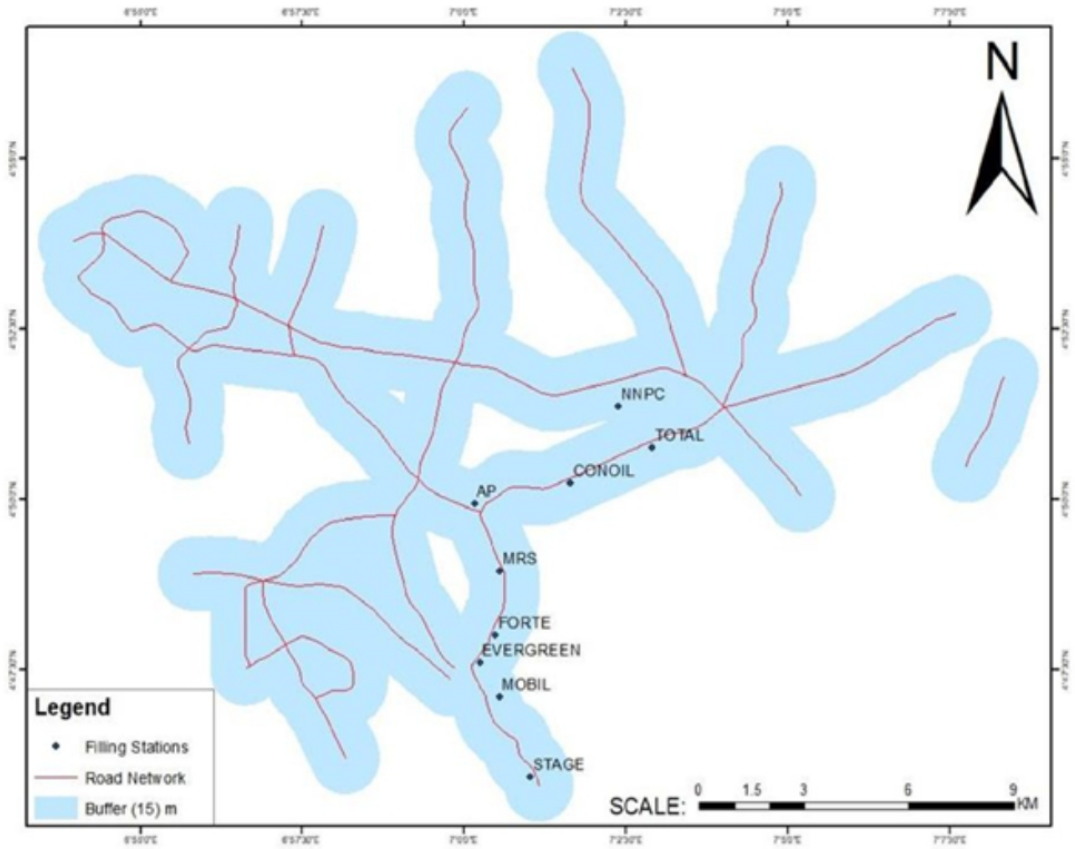

Fig 2: 15 Metres Buffer of Filling Station Locations **Source: Researcher's GIS/Remote sensing analysis, 2024**

The map presented in (Fig 2) is a 15-metre buffer analysis of the various filling station locations in the study area. From the result of the analysis as presented in the map above, it is obvious that all the filling stations did not adhere to the DPR standard (decree) which states that the actual distance from the main road to the location of any filling station must be 15 metres. Interestingly, the petroleum filling station amendment decree no. 37 of 1977 safety rules and regulations stipulate site inspection by DPR of the proposed filling station, among other things, issue report on the following basic requirements: - (i) Size of the proposed land site.

(ii) Whether the site lies within a pipeline or electricity high tension cable Right of Way (ROW).
(iii) Distance from the edge of the road to the nearest pump (not less than 15 meters).
(iv) The number of petrol stations within a 2km stretch of the site on both sides of the road will not be more than four, including the one under consideration.
(v) The distance between an existing station and the proposed one will not be less than 400 (four hundred) meters.
(vi) The drainage from the site will not go into a stream or river.
(vii) In some instances where the site is along the Federal Highway, a letter of consent from the Federal Highway is required.
(viii) DPR guided/supervised EIA study of the site by DPR accredited consultant.

This study is concerned with a regulation number (iii) which states that:
a) The distance from the edge of the road to the nearest pump will not be less than 15 meters.

Presentation of Air Quality Results Across Major Filling Stations
Table 2: NNPC Filling Station

Pollutants	S.I Unit	Morning	Afternoon	Evening	Mean	Standard Deviation	NESREA Standard
Co	(ppm)	0.08	0.6	0.10	0.26	0.294618	0.06
SO2	(ppm)	0.06	0.9	0.8	0.586667	0.458839	0.05
03	(ppm)	0.03	0.023	0.32	0.124333	0.169488	0.06
PM2.5	(ppm)	0.006	0.009	0.004	0.006333	0.002517	0.2
PM10	(ppm)	0.004	0.009	0.003	0.005333	0.003215	0.4
CO2	(ppm)	994	1025	933	984	46.80812	400

Source: Researchers Field Work, 2024

The result above reveals the various parameters and the associated results as presented in Table (2). Six parameters were investigated at different times of the day (10 am, 1 pm and 5 pm). This was done to ascertain the time that has the highest concentration of the gas. Carbon monoxide was absent in the morning while sulfur dioxide was minute with a value of 0.01, and ground-level ozone was absent also. Pm2.5 has a value of 0.008 while PM10 has a value of 0.010. However, carbon dioxide was present with a value of 1077. In the afternoon, both Cabon monoxide, sulfur dioxide and ozone were absent while PM2.5 and PM10 had a value of 0.002 and 0.001 which is lesser than the value in the morning and carbon dioxide was 1025. In the evening, carbon monoxide was 1.8 while sulfur dioxide was absent. Also, ozone was not present while PM2.5 and PM10 had the same reading of 0.003 respectively. Quite noticeably, carbon dioxide has a value of 1099. This is a clear indication that carbon is more concentrated in the evening than at any other time of the day within the NNPC filling station.

Table 3: Total Energies Service Station

Pollutants	S.I Unit	Morning	Afternoon	Evening	Mean	Standard Deviation	NESREA Standard
Co	(ppm)	0.8	0.4	0.6	0.6	0.2	0.06
SO2	(ppm)	0.6	0.9	0.6	0.7	0.173205	0.05
03	(ppm)	0.03	0.023	0.032	0.028333	0.004726	0.06
PM2.5	(ppm)	0.002	0.001	0.003	0.002	0.001	0.2
PM10	(ppm)	0.003	0.006	0.009	0.006	0.003	0.4
CO2	(ppm)	994	1025	933	984	46.80812	400

Source: Researchers Field Work, 2024

The result presented in Table (2) is the air quality result of Total energies service Station. Six air quality parameters were tested at different times of the day (10 am, 1 pm and 5 pm). This was done to ascertain if there are presence of any of them and in what quantity. However, it was discovered that Carbon monoxide (CO) which is a colourless, odourless gas which also results from incomplete combustion and is emitted by a wide variety of combustion sources, including motor vehicles was present with a value of 0.8 (ppm) while sulfur dioxide was absent, however, groundlevel ozone was present with a value of 0.03 (ppm). Remarkably, it was discovered that PM2.5 has a value of 0.002 while PM10 has a value of 0.001 while carbon-dioxide was present with a value of 1051. In the afternoon, both Cabon monoxide and dioxide were absent. Ground-level Ozone was present with a value of 0.012 while PM2.5 and Phad had a value of 0.002 and 0.002 respectively. However, carbon-monoxide was 998. In the evening, carbon monoxide was 1.0 while sulphur dioxide was 0.1 and ground-level ozone was absent. Coincidentally, PM2.5 and PM10 have the same reading of 0.002. Carbon monoxide (CO) is a colourless, odourless gas which results from incomplete combustion and is emitted by a wide variety of combustion sources, including motor vehicles etc. has a value of 1016 which is far higher than the morning and afternoon.

Table 4: Conoil Energy Service Station

pollutants	S.I Unit	Mornin g	Afternoon	Evening	Mean	Standard Deviation	NESREA Standard
Co	(ppm)	0.6	0.2	1.8	0.86666	7	0.06
SO2	(ppm)	0.9	0.6	0.5	0.66666	7	0.832666
03	(ppm)	0.000	0.00	0.000	0	0	0.06
PM2.5	(ppm)	0.008	0.002	0.003	0.00433	3	0.05 0.208167
PM10	(ppm)	0.010	0.012	0.019	0.01366	7	0.2 0.003215
CO2	(ppm)	1077	1025	1099	1067	38	0.4 0.004726 400

Source: Researchers Filed Work, 2024

The table above shows the results of the air quality as presented in table (4). air quality data was collected from a Coniol energy service station along the Port Harcourt Aba expressway. However, it was discovered that Carbon monoxide was present with a value of 56.4, Sulphur oxide was present with a value of 4.5 and ozone was absent. PM2.5 has a value of 0.008 while PM10 has a value of 0.007. Carbon dioxide has a value of 1121. In the afternoon, carbon monoxide declined with a value of 37.5 and sulphur-oxide was absent alongside ozone. PM2.5 and PM10 were read at the same value of 0.006 and 0.008 respectively. Carbon dioxide was present with a value of 989. In the evening, both carbon monoxide, sulphur oxide and ozone were absent. This could be because of reduced or absence of social activities. PM2.5 and PM10 were 0.006 and 0.012. Carbon oxide was present with a value of 976 which is lower than the morning and afternoon session. This is possible because of the reduced activities within the filling station during that time of the day.

Permissibility of Air Quality as Specified by NESREA

Table 5: Standard for Air Quality from Industrial

S/N	Pollutants	Maximum Permissible Limits (ppm)
1	Co	0.06
2	SO2	0.05
3	03	0.06
4	PM2.5	0.2
5	PM10	0.4
6	CO2	400

Sources/Operations **Source: NESREA, 2020**

The table 5, depicts the air quality permissible limit as specified by NESREA (National Environmental Standards and Regulations Enforcement Agency). In comparison to the measured air quality within the major filling stations along Port Harcourt Aba Expressway. As specified by NESREA, Carbon monoxide (CO) which is a colourless, odourless gas which also results from incomplete combustion and is emitted by a wide variety of combustion sources, including motor vehicles should not exceed 0.06 (ppm). Also, Sulphur dioxide (SO_2) is a colourless gas with a sharp odour. It is produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulphur, NESREA specified that its concentration should not exceed 0.05 (ppm), furthermore, Ozone at ground level, not to be confused with the ozone layer in the upper atmosphere which is one of the major constituents of photochemical smog and it is formed through the reaction with gases in the presence of sunlight should not exceed 0.06 (ppm). Particulate matter (PM) PM 2.5 and PM 10 which is a common proxy indicator for air pollution. There is strong evidence for the negative health impacts associated with exposure to this pollutant. The major components of PM are sulphates, nitrates, ammonia, sodium chloride, black carbon, mineral dust, and water. NESREA specified that its concentrations should not exceed 0.2 and 0.4 (ppm) respectively. Finally, Carbon dioxide which is an important chemical needed for the survival of all life forms in the environment was also analysed to ascertain its concentration. The permissible limit as specified by NESREA is 400 (ppm). At a high level, this pollutant becomes dangerous to humans.

Findings

Carbon dioxide is an important greenhouse gas, it is a by-product of the burning of fossil fuels with a

half-life of 50-200 years and global warming potential (Gattuso, and Hansson 2011). CO2 at high levels above permissible limits may result in environmental hazards such as ocean acidification. According to NESREA, the minimum permissible limit for CO2 is 400 (ppm), once it goes higher, it becomes hazardous. The values of CO2 recorded across the different sample locations were higher than the standard given by NESREA (2020). The highest concentration of CO2 at 1521 ppm was obtained at the Conoil filling station. The high rate of CO2 emission in the study area is a result burning of activities that go on within the environment, the high influx of vehicles buying fuel and the fumes from their exhaust pipes, also from business generators, heavyduty trucks etc. This result agrees with the works of Tse and Oguama (2014) who also record high levels of CO2 concentration in their study. Nitrogen dioxide is an important environmental pollutant. It is introduced into the air through gas stoves; it causes photochemical smog at high concentrations as well as other health effects such as pulmonary oedema and haemorrhage (Searl, 2004). This is because of the high rate of vehicular emissions from cars and motorbikes which are constantly on the move. Indeed, motor vehicles produce more pollution than any other single human activity (Ukemenam, 2014). Tse et al (2014) also recorded high concentrations of CO around commercial areas in their study and at filling stations. Carbon monoxide is a colourless, odourless, and tasteless gas toxic gas which is produced from the incomplete combustion of fossil fuel in generators and automobiles. Exposure to carbon monoxide may cause significant damage to the heart and central nervous system (Kampa, and Castanas, 2008). Pollution due to traffic constitutes 90-95% of the ambient CO levels and poses a serious threat to human health (Uyigue and Agho, 2007). The risk of the fuel pump attendants who inhale this gas daily is quite high and may have long-term negative health consequences. The highest concentration of SO2 was recorded in the various sampled energy stations with a value of 0.9 (ppm) and it is highly concentrated in the afternoon. This is because of emissions from the fleet of cars that come in and go out to purchase fuel. This finding is in tandem with the results of Tse et al (2014) who also recorded high levels of SO2 in filling stations in their study. Sulphur dioxide (SO2) is an environmental pollutant and the main component of acid decomposition. SO2 is emitted directly into the atmosphere from sources such as coal and oil power plants, oil refineries smelters, generators and automobiles and can remain suspended for days allowing wide distribution of the pollutant (Ukernenam, 2014). Excess concentration of S02 can lead to respiratory problems, severe headaches, irritating lungs, and damage to vegetation. It can also cause an increased rate of corrosion of Iron, Zinc, Steel, and aluminium (Anderson, 2005). Also, they were the presence of particulate matter (PM2.5 & PM 10) at the various energy stations. Although their values were within the permissible limit as specified by NESREA. Other particulates recorded lower concentrations of pollutants in many of the samples. PM2.5 is a more serious health concern since smaller particles can travel more deeply into our lungs and cause more harmful effects. This result also agrees with the findings of Tse et al, (2014) who compared the indoor and outdoor air quality as it relates to particulate matter within business environments and residential areas and found the concentration of particulates to be higher outdoors. The air quality within the study area can be said to be poor with high concentrations of pollutants that deter the quality of air within the various filling stations. Air quality monitoring helps to assess the quality of air within an environment. It is an activity that must be carried out continuously at intervals; not just for the sake of measurement but to ensure that steps are taken to reduce the act of air pollution to the barest minimum. Particulate matter is the sum of all solid and liquid particles suspended. Atmospheric suspended particles which cause impairment of visibility (Dayan & Levy, 2005). The reduction of visibility is caused by buildup of the atmospheric particles. Particulates are the deadliest form of air pollution due to their ability to penetrate deep into the lungs and blood streams unfiltered, causing permanent DNA mutations, heart attacks, asthma, cough catarrh, chronic bronchitis, and premature death.

The result of the one-way ANOVA reveals that there is no statistical variation in the air quality across the various times of the day i.e., (Morning, Afternoon, Evening) at the various energy stations in the pollutants concentrations. The p value was set at p (<0.05). However, the associated results reveal that

p value was sig. at p< (.000) in NNPC energy station, p < (.001) at Total energy station and p < (.001) at CONOIL energy station.

Conclusion

This study has revealed that the majority of the filling stations along the Port-Harcourt ABA expressway are not situated 15 metres away from the major road as specified by DPR. This is a death trap for commuters as any activity that results in to fire outbreak will cause a lot of harm and loss of lives and properties. The study also concludes the air quality within the various energy stations is polluted, but amongst other pollutants as observed, CO2 is the major air pollutant with values higher than NESREA standards for outdoor air quality.

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As-Built Metrology and Sustainability Imperatives of the Entrepreneurship Centre, Rivers State University, Port Harcourt, Nigeria

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Abstract

The physical environment is dynamic; given that it undergoes transformations over time due to human activities. The university is an example of changing environment that undergoes transformations solely because of increase in the population of students and staff and the need for adequate space to enhance learning and research. However, these transformations which are sometimes construction of new Buildings or re-modelling of existing ones need to be documented in what is known as an As-built database, which is a repository for the As-built information. This paper is gear towards providing as-built information of the dimensions of the internal space of the prototype buildings constructed for learning, training and research using the total station on reflector less mode to carry out this measurement. A simple traverse was run and the method of least squares (observation method) was used. A data base for the various prototype building design and production of as-built metrology Map was produce. A total of 19 office spaces and 7 Lecture Halls exists within the Entrepreneurship Centre of the university campus. The result shows that there exist deviations among the various prototype building blocks. The variation in terms of veranda space, lecture hall, office spaces are more in block8 having the highest as compare to Block 3, Block 7, and Block 9.

Keyword: Environment, As-Built, Entrepreneurship, Mapping, Database

Introduction

Often times, deviations occur between the design building and the new and remodelled building. If the fundamentals of geometric dimensions and tolerance are undermined, the degree of deviation become very large. The consequences can be costly both in monetary values and in reputation. If a building is constructed that is not fit for purpose, not only will the functionality and life span be affected but it optimal use would have been compromised (Bekwele and Solomon, 2018). Again, if the various components of the building are grossly constructed, the building may not stand the test of a simple earth tremor. To overcome these challenges, there has to be a way of measuring or setting out of the design accurately using the right equipment and professional especially in the built environment.

As-Built Metrology is the measurements carried out to determine the actual condition of a construction e.g. building, road etc. during and after completion stage. So, it is the detail survey performed to ascertain the true position of features on, beneath and above the surface of the earth resulting from construction. This is a critical distinction, because a constructed building almost never corresponds exactly to the intended design drawings. For this reason, when starting a new or remodel project on a residential or commercial building, the architect will always create or commission an As-Built Metrology, rather than trying to rely on existing building plans. Discovering an error on the plans that can result in additional costs or delays to the project is just too big of a risk to take. Measurements are performed to obtain horizontal and/or vertical dimensional data so that constructed improvements may be located

The tendency for deviations of Built structures from their intended design can be great when the services of measurement experts are not employed. The causes of these non-aligning constructions ranges from unforeseen environmental condition, site conditions, social unrest, builder's discretion, undermining the application of metrology, it is necessary to carry out As-Built Metrology to check the degree of correlation existing among the various prototype building blocks. These measurements are necessary for purposes of validation and records keeping. This is predicated on the following objectives which include

i. To determine the extent of the buildings within the entrepreneurship Centre.
ii. To carry out As-Built metrology by measuring inside and outside of the buildings.
iii. To create a database of the Entrepreneurship centre which will facilitate the degree of deviation among the prototype building.

Study Area

The area of study is the Entrepreneurship Center in Rivers State University Main campus, Port Harcourt. The center is sharing boundary with the University Arena and directly opposite the center is the senate building while the Catholic Church building is adjacent to the center. It takes approximately two (2) minutes' drive from the main gate entrance to the center. It has coordinate of; (276162.14mN and 530985.12mN) to (276290.58mE and 531118.45mE) on the Universal Transvers Mercator (U.T.M) projection system which lies in zone 32N.

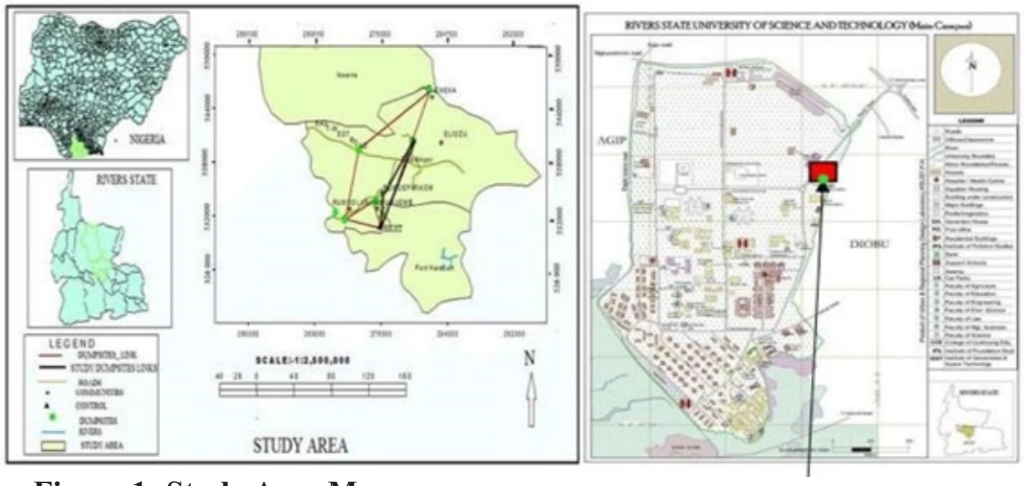


Figure 1: Study Area Map

Data Acquisition

The conventional method of traversing was deployed in these work using total station (Leica TSO9) and the data was process using the least Square technique (Observation equation). The internal spaces in the building was measured with laser based instrument (Leica TS09), by employing the Reference Line Module in the programme menu of the total station. The heights were equally determined using the same instrument by using the Remote Height Module in the same programme menu of the equipment.

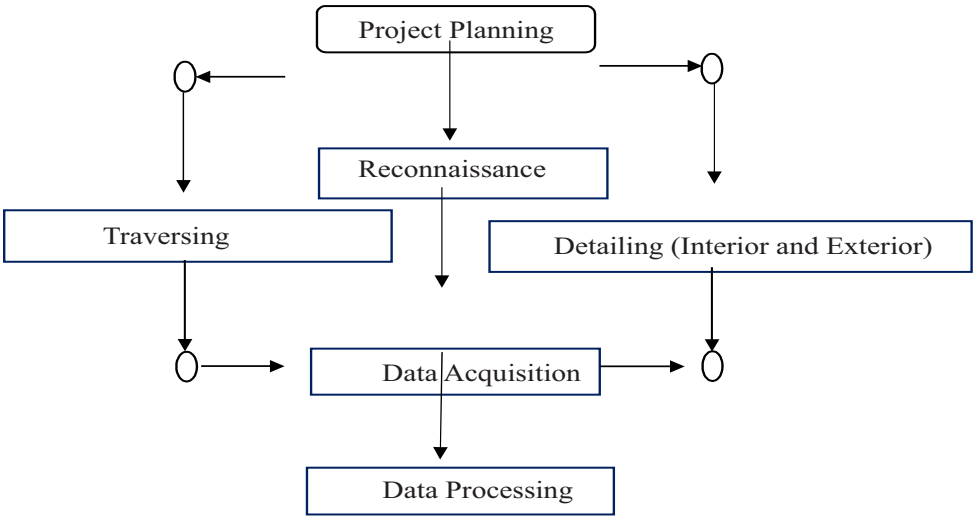


Fig. 3.1: Project Design and Flow Chart (Source: Author)

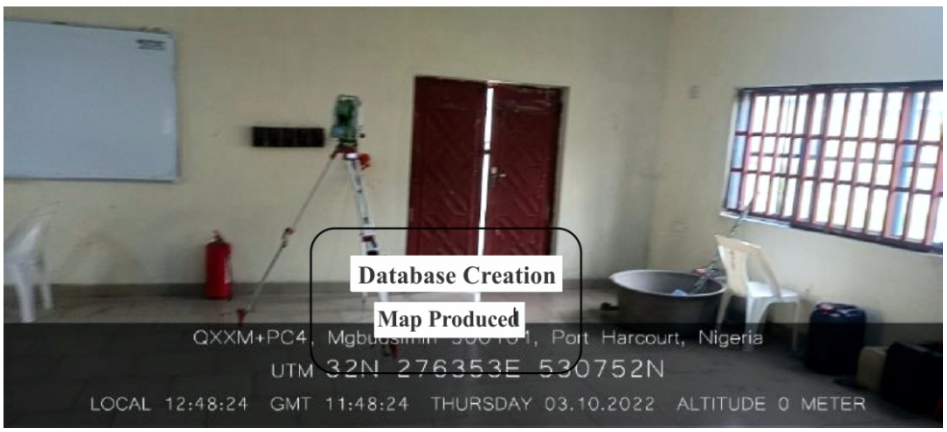


Figure 2: A Specimen of a Lecture Hall

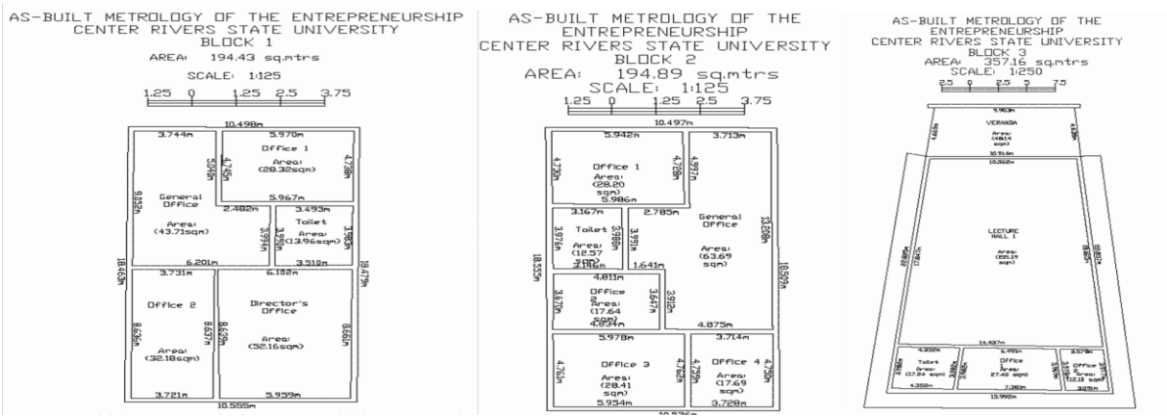
The measurement started with hall 1 which is designated as block 3 and ended with hall 2 which is the administrative block. The figure 3.1a, b and c show the internal space of the hall to be measured.

Figure 3: A Specimen of a Seminar Hall

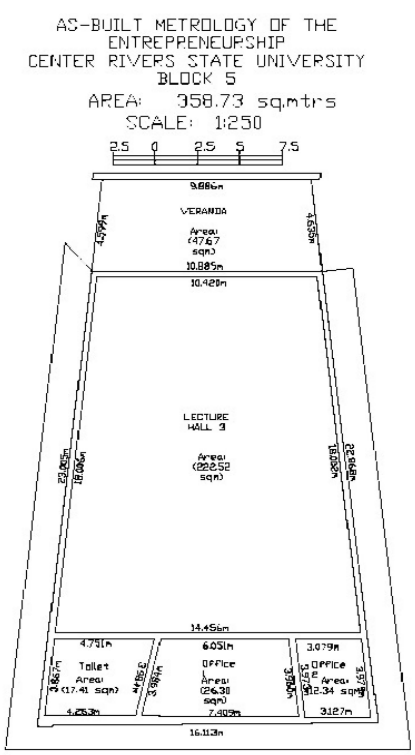
Results

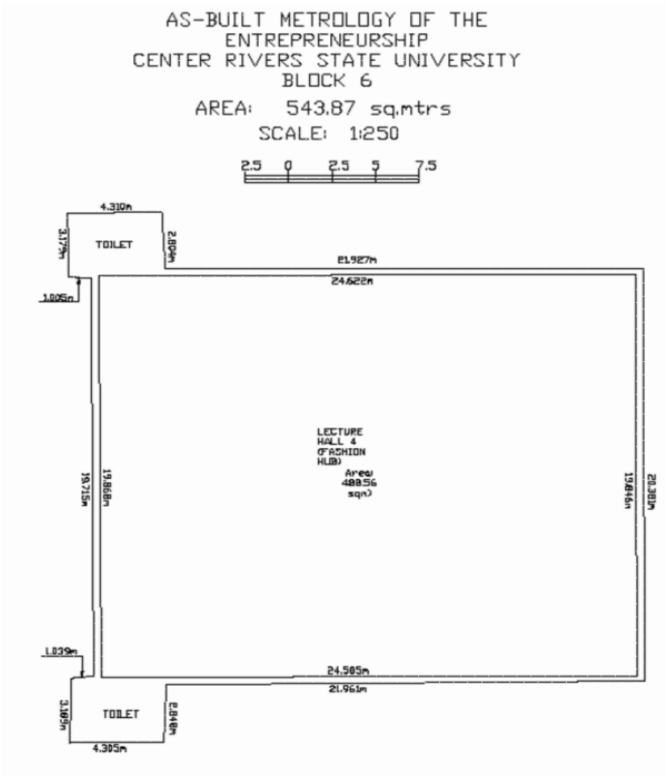
Data Presentation and Analysis

Total area enclosed by the entrepreneurship centre River State University is 1.582 hectares. The perimeter is 497.655meters. There are nine (9) bungalow blocks within the entrepreneurship centre. Two (2) of which are administrative blocks and seven (7) contains lecture halls and offices.



Figures 4: A Sample Plans for Blocks 1 to 3





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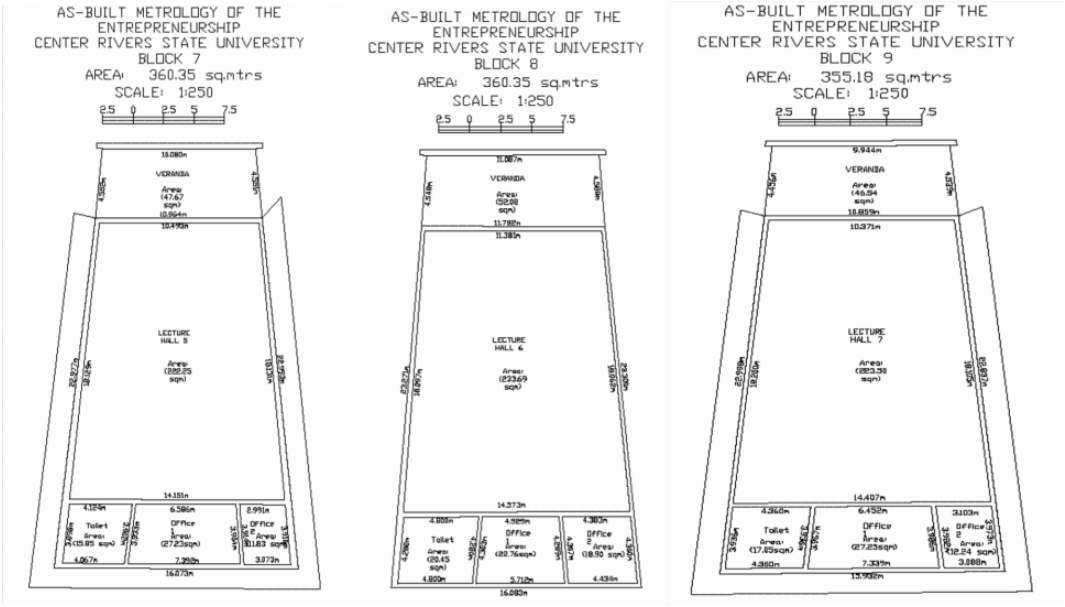
Figures 5: A Sample Plans for Blocks 4 to 6



Figures 6: A Sample Plans for Blocks 7 to 9

Block 1 and Block 2 (the two Administrative Buildings I and II) and Blocks 3, 5, 6, 7, 8 and 9 (Lecture Hall 3, 5, 6, 7, 8 and 9). At the end of the as-built metrology, the following Database were generated for the various building blocks in particular for the Lecture Hall that contains lecture hall, office and convenience.

Table 1: Showing Prototype Building Blocks on the Basis of Height Comparison

S/No.	Description	Veranda (m^2)	Lecture hall (m^2)	Office 1 (m^2)	Office 2 (m^2)	Toilet (m^2)
1	Block 3	3.357	3.376	3.439	3.452	3.452
2	Block 5	3.527	3.418	3.376	3.364	3.376
3	Block 7	3.452	3.394	3.358	3.438	3.438
4	Block 8	3.671	3.726	3.801	3.789	3.801
5	Block 9	3.409	3.356	3.376	3.401	3.401

Table 2: Showing Prototype Building Blocks on the Basis of Surface Area Comparison

S/No.	Description	Veranda (m^2)	Lecture hall (m^2)	Office 1 (m^2)	Office 2 (m^2)	Toilet (m^2)
1	Block 3	48.14	221.19	27.4	12.1	17.24
2	Block 5	47.67	222.52	26.3	12.34	17.41
3	Block 7	47.67	222.25	27.23	11.83	15.85
4	Block 8	52.08	233.69	22.76	18.9	20.45
5	Block 9	46.54	223.5	27.25	12.24	17.05

Table 3: Showing Prototype Building Blocks on the Basis of Volume Comparison

S/No.	Description	Veranda (m^2)	Lecture hall (m^2)	Office 1 (m^2)	Office 2 (m^2)	Toilet (m^2)
1	Block 3	161.606	746.737	41.769	94.229	59.512
2	Block 5	168.132	760.573	88.789	41.512	58.776
3	Block 7	164.557	754.317	91.438	40.672	54.492
4	Block 8	191.186	870.729	86.511	71.612	77.730
5	Block 9	158.655	750.066	91.996	41.628	57.987

Discussion of Results

The prototype bungalow building constructed are Nine (9) in number built in a circular form. Two (2) out of the nine is the administrative block while the remaining seven contains the lecture hall that have office space and convenience attached to the building. The measurement as seen in table 1 to 3 shows the deviations in terms of lecture hall height, veranda into the hall, office spaces and general toilets. The comparism was done for only block 3, 5, 6, 7, 8 and 9. It was observed that the maximum deviation among this prototype building was conspicuous in block 8.

Conclusion

Having seen the various deviation that exist for a prototype building whose dimension are to be the same in all ramification has shown in the various tables. We therefore advocate that the right professional be engaged when starting a project and monitor the project to the end so as to effectively put on ground the actual design as designed by the architect. The As-Built database will serve as impeccable reposition for vital as-built information that will aid future planning and development in the facilities building which constitute the study area.

Recommendations

Having mapped, by taking physical measurement to show the variations in the various blocks within the entrepreneurship centre, the following are recommendation that

1. A Surveyor should be on ground from start to finish whenever any land development needs to be undertaken
2. As-built Surveys should be carried out on other facilities to produce an As-built database of those facilities within Rivers State University.

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Remotely Sensed Surface Temperature Estimation and its Imperatives in Parts of Abia, Akwa-Ibom and Rivers States

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Abstract

Quantitative surface temperature estimation reveals the subtle misconceptions on the energy available at the earth surface that drives all physical and biological processes. Unfortunately, this energy is altered by changes in land use and land cover (LULC) resulting from factors such as urbanisation. These changes in LULC influence emissivity and albedo which collectively determine the amount of surface temperature (S_t) retained by any LULC type. As such, with LULC changes analysis, this study examined the impact of urbanization on S_t in the study area from 1986 to 2022 using Landsat datasets. A supervised LULC classification for the studied area using seven classes namely built-up, bare earth, water body, marine vegetation, other vegetation, plantation and void. Based on these LULC classes, digital values were extracted from the thermal bands of these datasets and S_t were estimated using the radiative transfer equation. Analysis of results showed that changes in LULC were majorly from Marine vegetation, water bodies and bare earth to built-up areas while S_t for water bodies and marine vegetation are low compared to built-up areas and bare earth. S_t results showed areas of consistently high temperatures than usual, potential urban heat island (UHI), especially in densely populated commercial areas. Hence, Built-up areas and bare surfaces had higher S_t than vegetation and water bodies especially in the 2003. As such, Port Harcourt and Aba are experienced radial urban growth between 2003 and 2022. However, urban growth should be adequately monitored, mitigating the effect of urbanising more rural lands.

Keywords: Change, Classification, Radial, Surface Temperature, Urbanisation

Introduction

Human activities especially in urban areas are becoming more industrialized resulting to changes in land use and land cover (LULC). These changes mostly favor those LULC types that support emissions of atmospheric pollutants such as carbon dioxide and anthropogenic heat (Anup, 2013). These pollutants form a blanket in the atmosphere that traps heat within the earth's surface by absorbing and reemitting long wave radiation to the Earth's surface, a phenomenon called radiative trapping (Wayne, 2013). The trapped heat raises the temperature of some areas above that of the surrounding areas creating heat islands that contributes to human discomfort and drives climate change (Wayne, 2013). Anup (2013) identified the problem of increased surface temperature is very typical of urban areas because of anthropogenic activities that accompany urbanization hence termed urban heat island (UHI).

Despite the many applications of S_t, its measured data is rarely available and often with errors due to the technical and economical limitations associated with direct measurements (Wang and Liang, 2008). Remote sensing plays an important role in climate studies by providing data on variables useful in derivation of net radiations such as S_t, LULC, albedo, cloud cover density and height, emissivity etc. This study estimated S_t for the different LULC types in Lagos metropolis and environs (Figure 1) to ascertain the relationship between NDBI and S_t so as to estimate the effect of changes in NDBI on thermal comfort and to identify potential UHI for possible mitigation strategies.

The aim of this study is to estimate S_t of the study area using Landsat datasets. The objectives are;

1. Mapping LULC changes over a 36-year (1986 - 2022) period of the study area.
2. Estimating S_t and identifying potential UHIs based on the different LULCs.
3. Analyzing climatic implication of changes in S_t in the study area.

The study areas physical boundaries lie between Eastings (260292 – 378415m) and Northings (550995 – 444210m) on the Universal Traverse Mercator (UTM) projected coordinate system which covers an approximate area of 12,614km^2. Port Harcourt City as its administrative capital of Rivers State, Nigeria which lie in central part of the state. Port Harcourt City is the core of the state and having oil and gas resources within her territorial space. The study area as shown in figure 1 includes all of Port Harcourt, Obio/ Akpor, Oyigbo, Tai, Eleme, Gokana, Khana, Opobo/ Nkoro, Andoni, Bonny, Okrika, Ogu/ Bolo, Degema, Akuku Toru, and parts of Asari Toru, Abua/ Odual, Emouha, Ahoada East, Ikwerre, Etche and Omuma local government areas (LGA) of Rivers State.

The study area includes all of Ukwa East, Ukwa West, Ugwunagbo, Aba South, Aba North and parts of Osisioma Ngwa, Obio Ngwa LGA of Abia State and lastly, Ika LGA and parts of Essien Udim, Etim Ekpo, Ukanafun, Oruk Anam, Ikot Abasi and Eastern Obolo of Akwa Ibom State**.** The distance between Port Harcourt and Aba is approximately 65km as such Aba is predominantly a commercial town that has undergone rapid expansion during the last decade. Topology has been largely responsible for the present shape of the town in its growth northwards. Only now, as the landward side of the swamp are being reclaimed thresholding alternative physical opportunities for the town's growth.

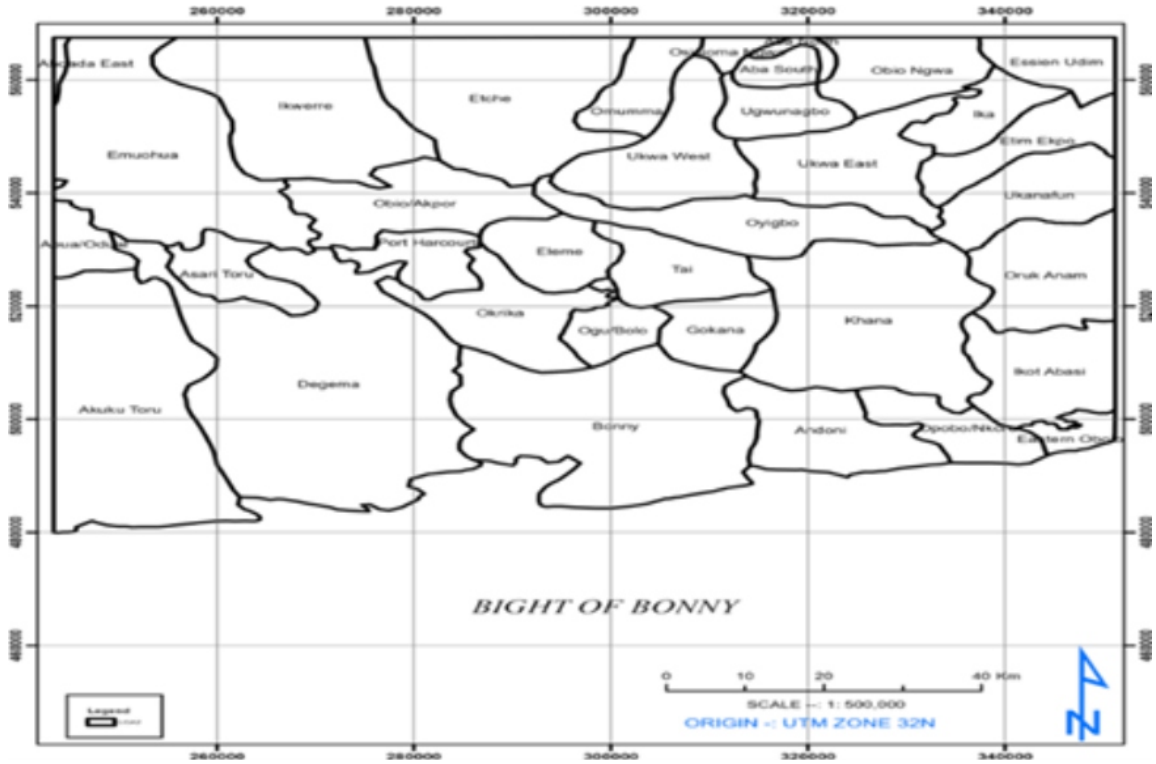


Figure 1: The study area

Materials and Method

Materials/Datasets

Landsat datasets utilized are a standard data for earth observations with an approximate scene size of 170 km north-south by 183 km east-west. The thermal band(s); bands 6.1 and 6.2 for ETM$^+$ and bands 10 and 11 for OLI/TIRS datasets allows for the calculation of the energy balance components such as net radiation from different land surface types. Thus, the study used four Landsat datasets (Table 1) and other in-situ datasets to provide apriori information about the study area.

Temperature data from NIMET obtained at screen height level in stations located at 1.2m above sea level with area coverage of 1.25m used as ground truth data. Data on geographical location, physical and socioeconomic parameters of the study area were obtained from existing literature and field studies. Software used and purpose used for include ERDAS ER Mapper for data preprocessing, ENVI 4.5 for processing and LULC classifications, and ArcGIS 10.3 for spatial analysis and data presentation.

Table 1: Quad-resolution parameters for Path 188 and Row 057 datasets.

S/N	Sensor	Acquired Date (d-m-y)	Temporal separation (T) (y, m, d)	Seasonal Difference (Days)	Epochal count (Years)	Temporal Epoch Difference	Temporal Spacing (Days)	Approx. Spatial Resolution (m)	Spatial Resolution (bit)	T_ Spacing Required	Spectral Bands
1	L5/TM	17/01/1986			T_o				30	8 (0-255)	1 to 7
2	L7/ETM+	17/12/2003	17, 11 & 0	31	T_1	T1-T0	6543	17.914	15	8 (0-255)	1 to 8
3	L8/OLI &	4/01/2022	18, 0 18	18	T_2	T2-T1	6593	18.051	15	8 (0-255)	1 to 11

T_Spacing = Temporal spacing and R_metric = Radiometric Resolution

Table 1 shows the quad-resolution parameters for Path 188 and Row 057 datasets with the following information: serial number, platform/ sensor, acquired date, temporal separation, seasonal difference, epochal count, temporal spacing in days and spectral bands used. The aforesaid table is divided into twelve (12) parameters with column one (1) indicating the epoch under review. Column two (2) shows the corresponding space borne platform and on-board sensor for each epoch under review. These information's were obtained from the metadata attached to the downloaded satellite dataset.

Column three (3) shows the date of satellite over pass or date of data capture by the sensor in the format of day, month, and year. Column four (4) shows the computed temporal separation between successive dates in years, months, and days as 17 years, 11 months and 18 years, 18 days respectively while column five (5) shows the seasonal difference in days between the aforesaid dates as 31days and 18 days respectively. Columns six (6) shows the epochal count start from T_0 as initial date and T_2 as the final date while column seven (7) shows the epochal difference between two successive dates.

Columns eight (8) and nine (9) shows temporal spacing in days as 6543 and 6593 days respectively and approximate temporal spacing in years between successive dates as 17.91 years and 18.05 years respectively. Column ten (10) shows the spatial resolution of datasets; 30m for 1986 and 15m for 2003 and 2022 datasets respectively. Column eleven (11) shows the radiometric resolution of the datasets acquired are of 8 bits that have value ranges from 0 - 255 while column twelve (12) shows the spectral bands used; for the first date bands 1 to 7 was used, for the second date bands 1 to 8 was used and for the last date bands 1 to 11 was used.

The study area covers a total area of 11418.25sq.km that consists of a total of 179,234 pixels of $30m^2$ for

January 1986 dataset, 552,558 pixels of $15m^2$ for December 2003 dataset and 552,558 pixels of $15m^2$ for January 2022 datasets. Therefore, the adoption of a common pixel size for all three epochs, the 2003 and 2022 total pixels used was divided by 4 which gives 138,140 as pixels used while the difference in pixels used 41,094 of 30m by 30m. The results presented and analysed below in this section represent the comparative spectral sensing assessment for selected environmental indices using the various methods stated in the methodology section of this study and are in line with the objectives of this research work.

Method

Using spatial and non-spatial datasets, the study integrated remote sensing, geographical information systems and statistical techniques to derive information on LULC and S_t. Verification of LULC and S_t results was possible using LULC classification from previous studies, temperature data from Nigerian Meteorological (NIMET) Centre.

Data Preprocessing and Processing

The study area was clipped out from the stalked bands of the acquired datasets were processed for further analysis by reprojecting them to World Geodetic System (WGS) 1984. TM bands (1 to 5 and 7) and ETM+ bands (1 to 5, 7 and 8) stacked to form multi-spectral image set were preprocessed using ERDAS ER Mapper and further resampled to a 15m resolution using the panchromatic band (band 8) so as to enhance the resolution of the datasets while band 6 was processed separately for all dates. The study identified and matched twenty-four (24) control points (GCPs) on raw data approximately six for each year under review. The brightness value of the Landsat datasets was enhanced by the balanced contrast enhancement technique (BCET). The BCET technique that matches histogram was adopted for this study because of its flexibility and better output over similar techniques.

Land Use Land Cover Classification (LULC) and Change Detection

The images used for the study were carefully inspected taking into consideration their resolutions and minimum mapping unit. The modified US Geological Survey Classification System (Campbell, 1996) was adopted and a total of four classes used for the study included bare earth, built-up, vegetation and water bodies. A supervised classification was carried out on the transformed Landsat images using band combination 543 and LULC maps. Statistics for the different study years (1986, 2003 and 2022) were generated based on the LULC classes and maps of change detection were generated for further analysis.

Land Surface Temperature (LST) Estimation and Change Detection

The Digital Numbers (DN) of the Landsat images were converted to radiance values and subsequently to LST for the different study periods using equation (1).

$$T_{kelvin} = K_2 / \ln((K_1 * E) / B_{6\,Radiance} + 1) \quad (1)$$

Using the band math function of the ENVI 4.5 software, the equation was scripted into the software to convert radiance images to S_t assuming a uniform emissivity (E) of 0.95 which gave S_t in Kelvin. B6 was defined as the radiance image and K1 and K2 values for the different sensors were specified. To convert temperature values from Kelvin to Degrees Celsius, equation (2) was scripted into the software with B6 as the temperature image in Kelvin and S_t values were obtained in Degrees Celsius. These images were exported to ArcGIS for map production and statistics were extracted for further analysis. The S_t values gotten were validated using NIMET temperature data.

$$B_6 - 273.15 \quad (2)$$

LST statistics and maps for the different study periods were analyzed for change detection. This was done by comparing the maximum, minimum and mean values for the different years. S_t was also examined looking at the different LULC types for the different study periods to ascertain the LULC types with the highest and lowest S_t values for each year.

S_t Estimation and Change Detection

The study estimated the difference between these two fluxes by using solar radiation values obtained from NIMET as the incoming solar radiation and radiance values obtained from Landsat images as the outgoing radiation. The radiance values were used as the outgoing long-wave radiation based on the assumption that the sensor only registers the energy that goes out from a LULC type (reflected or emitted energy).

$$Rs - B_6 \quad (3)$$

Identification of UHI and Assessment of Climatic Implication of S_t Changes

Based on the S_t of the different study years, potential UHIs were identified as areas with persistently high temperature throughout the study period. This was done by assessing S_t maps for the different study periods. Climatic implication of S_t was deduced from existing literature and the findings of this study.

Results and Discussion

LCLU Area Coverage for 1986, 2003 and 2022 datasets

Data gotten from the study were analyzed and results were displayed using tables, maps and charts. In line with the objectives of the study, emphasis is given to the area extent of LCLU of the different classes over the periods under consideration as shown in table 2. Table 2 shows spatiotemporal changes in LU/LC in the study area which covers a total area of 11,418.25sq.km which are classified into Built-up, Bare Earth, Water body, Plantation, Marine Vegetation and Other Vegetation. The table 2 shows LULC for three (3) epochs, and details of the LULC coverage all in square kilometers, hectares and percentages.

Table 2: Class Distribution Summary for 1986, 2003 and 2022

LULC	Jan-86			Dec-03			Jan-22		
	(sq.km)	(ha)	(%)	(sq.km)	(ha)	(%)	(sq.km)	(ha)	(%)
Built-Up	258.78	25877.52	2.27	476.00	47599.65	4.17	820.67	82066.95	7.19
Bare Earth	25.93	2592.72	0.23	87.69	8769.06	0.77	23.53	2353.05	0.21
Water Body	3327.70	332770.32	29.14	3187.14	318713.75	27.94	3544.87	354487.05	31.05
Plantation	918.42	91842.12	8.04	1263.90	126390.33	11.08	4026.55	402655.23	35.26
Marine Veg.	4632.57	463256.64	40.57	3353.78	335378.07	29.40	2110.98	211097.52	18.49
Other Veg.	2137.89	213789.24	18.72	2921.18	292118.22	25.61	763.05	76305.06	6.68
Void	116.96	11696.4	1.02	118.56	11855.88	1.04	128.60	12860.10	1.13
Total	11418.25	1141824.96	100.00	11408.25	1140824.96	100.00	11418.25	1141824.96	100.00

Marine vegetation shrunk significantly over the study years while other vegetation spiked in 2003 and shrunk in 2022 maybe as a result of reclamation of marine vegetation. There was a significant increase in bare earth in 2003 which could be accounted for the clearing of either marine vegetation or other vegetation for development during this period. Water bodies shrunk in 2003 and increased in 2022

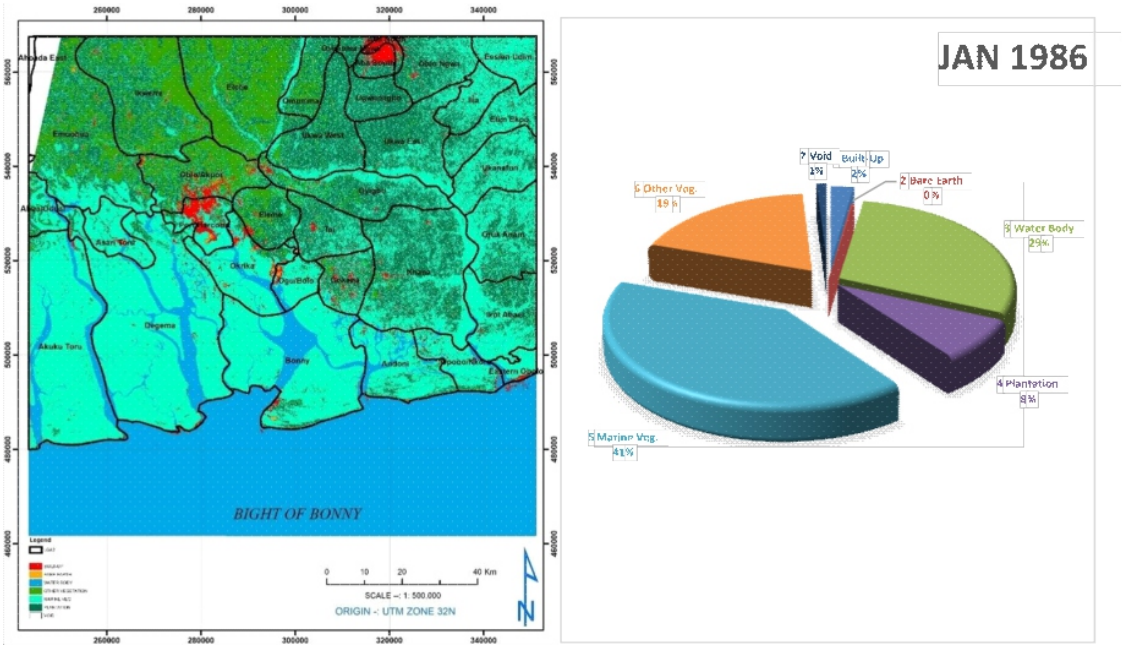
even more than the initial coverage in 1986. Though lower volumes of water bodies were recorded in 2011, it had a wider spread over land as a result of the recorded floods and increased replacement of vegetal cover and bare earth surfaces. As such the coverage of clipped section of the study area classed as Void for the three (3) epochs is approximately 1% of the study as shown in to figures 2 to 4. For the period under investigation the following deductions were made from table 2.

Figures 2 shows Built-up area covers 253.78sq.km with 2.27%, Bare-earth covers 25.93 km^2 with 0.23%, Water body covers 3,327.70km^2 with 29.14%, Plantation covers 918.42km^2 with 8.04%, Marine vegetation covers 4,632.57km^2 with 40.57%, while other vegetation covers 2,137.89km^2 with 18.72% and Void covers 116.96km^2 with 1.02% for January 1986 dataset.

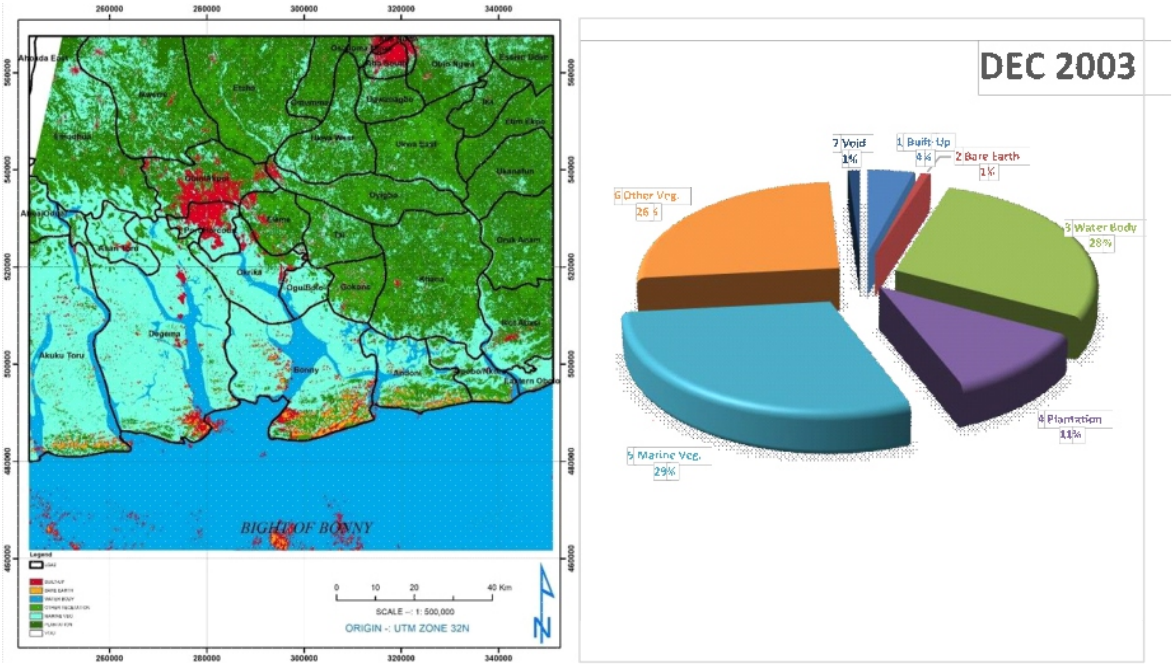
Similarly, Figures 3 shows Built-up area covers 476.00km^2 with 4.17%, Bare-earth covers 87.69km^2 with 0.77%, Water body covers 3,187.14km^2 with 27.94%, Plantation covers 1,263.90km^2 with 11.08%, Marine vegetation covers 3,353.78km^2 with 29.40%, while other vegetation covers 2,921.18km^2 with 25.61% and Void covers 118.56km^2 with 1.04% for December 2003 dataset.

Therefore, for the last epoch figures 4 shows Built-up area covers 820.67km^2 with 7.19%, Bareearth covers 23.53km^2 with 0.21%, Water body covers 3,544.87km^2 with 31.05%, Plantation covers 4,026km^2 with 35.26%, Marine vegetation covers 2,110.98km^2 with 18.49%, while Other Vegetation covers 763.05km^2 with 6.68% and Void covers 128.60km^2 with 1.13% for January 2022 dataset. The LULC analyses from table 4.2 clearly shows LULC classes with a fluctuating statistic over the study period.

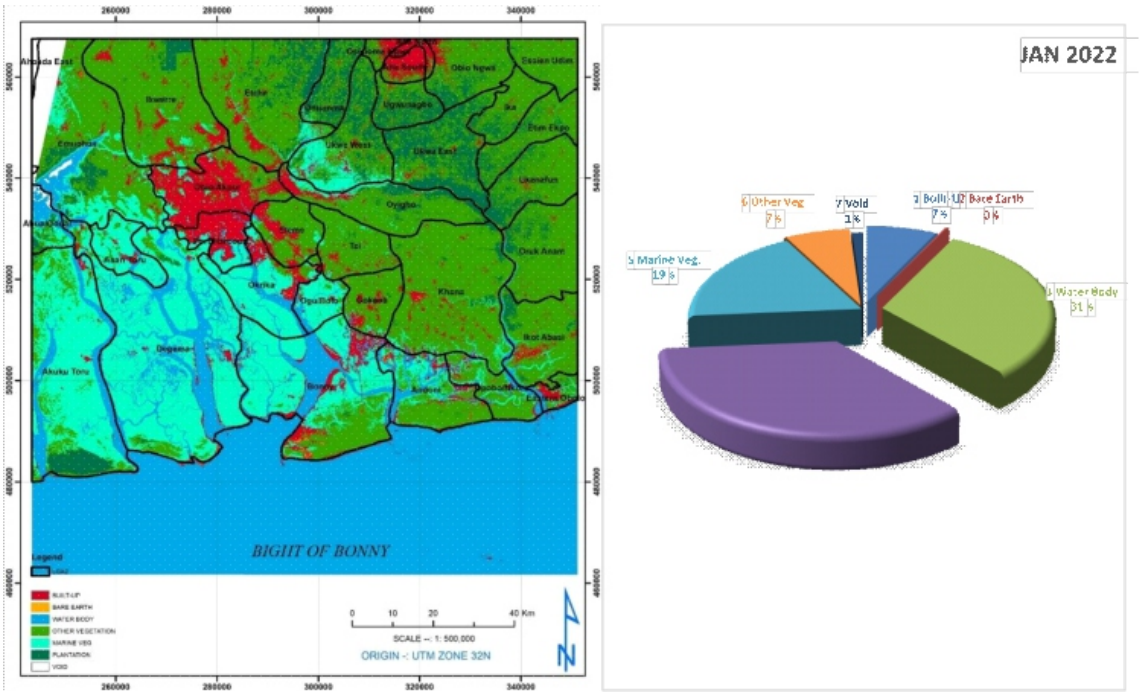
These changes are attributed to the fast pace of urbanisation and industrialization in Port Harcourt and Aba metropolis and its environs. From the deduction shown in the aforesaid table vegetation was highest in 1986 and 2003 dataset followed by water body in both epochs; while in 2022 Plantation recorded the highest coverage followed by water body and marine vegetation.



Figures 2: LULC Map and Chart for January 1986 Dataset



Figures 3: LULC Map and Chart for December 2003 Dataset



Figures 4: LULC Map and Chart for January 2022 Dataset

Nature and Locations of LULC Change Results

The LULC change analysis (Table 2) clearly showed changes in LULC classes with marine vegetation, water bodies and bare surfaces losing land cover to built-up areas over the study period. These changes are attributed to the fast pace of urbanization and industrialization in studied area. Change analysis showed that marine vegetation was highest in 1986 followed by 2003 and 2022 respectively. The depreciation in vegetal cover (marine and other vegetation) could be explained by the need for urbanised spaces, industrialization and lack of awareness of the importance of all forms of vegetation as a carbon sink. Though errors in classification may tilt data a little in favour of some

LULC types, results remain relatively valid. The 2003 dataset had cloud cover and was impaired thus an aggregate of 1986 and 2022 dataset was used to measure LULC change. Increased other vegetation cover in 2003 compared to 1986 was attributed to the closure of some industries as a result of power crisis (Nwilo et al., 2012). Hence, a further depreciation in 2022 depicts infers either increase in population and intense urbanization.

It is worth noting that the period of data acquisition corresponds to same season favoured by the presence of vegetal cover and less cloudy datasets. Datasets of similar climatic seasons would have been used for a study like this but the availability remains a constraint. What is changing and where it is heading are both aspects of the nature of LCLU change. Due to the fact that land is one of the most essential resources upon which human survival relies, human actions in the region are responsible for this shift. The LCLU pattern of a region is the end result of human interaction with the environment and society through time and place (Rimal, 2011). A pixel-by-pixel comparison of the datasets from the study years using cross or overlay operations exposes changes that are both desired and undesired outcomes, that penultimately provides important information for making decisions. Changes in LCLU nature reveal a trend, whereas stable LCLU classes serve as a reference point for future research (which indicate the spatially consistent or unchanged part of a particular LCLU class).

Table 3: Built-Up LULC Class Change Statistics

S/No	Interval	Before Impact Area (km^2)	After Impact Area (km^2)	Change Area (km^2)	Annual change Rate (km^2/yr)	Inference	Spacing in years
1	1986 2003	258.78	476.00	217.22	12.07	Gain	18
2	2003 2022	476.00	820.67	344.67	19.15	Gain	18

Source: Researchers' Field Survey, 2022

Table 3 shows that Built-Up changed from 258.78km^2 to 476.00km^2 in between 1986 and 2003 with a 217.22km^2 change to its area extent with an annual change rate 12.07km^2 having an inference of gain. Also, this class changed from 476.00km^2 to 820.67km^2 in between 2003 and 2022 with a 344.67km^2 change to its area extent with an annual change rate 19.15km^2 having an inference of gain. Thus, the growth in built-up class is as a result of burdened by other human activities in the study area over the last decade due to increase in built-up areas, industrial settlements and other urban land practices.

Table 4: Bare Earth LULC Class Change Statistics

S/No	Interval	Before Impact Area (km^2)	After An Impact Area (km^2)	Change Area (km^2)	nual change Rate Area (km^2/yr)	Inference	Spacing in years
1	1986 2003	25.93	87.69	61.76	3.43	Gain	18
2	2003 2022	87.69	23.53	-64.16	-3.56	Loss	18

Source: Researchers's Field Survey, 2022

Table 4 shows that Bare Earth changed from 25.93km^2 to 87.69km^2 in between 1986 and 2003 with a 61.76km^2 change to its area extent with an annual change rate 3.43km^2 having an inference of gain. Also, this class changed from 87.69km^2 to 25.53km^2 in between 2003 and 2022 with a 64.16km^2 change to its area extent with an annual change rate -3.56km^2 having an inference of loss.

Table 5: Water Body LULC Class Change Statistics

S/No	Interval	Before Impact Area (km^2)	After Impact Area (km^2)	Annual change Rate Area (km^2/yr)	Change (Area km^2) Inference	Spacing in years
1	1986 - 2003	3327.70	3187.14	-140.57	-7.81 Loss	18
2	2003 - 2022	3187.14	3544.87	357.73	19.87 Gain	18

Source: Researchers' Field Survey, 2022

Table 5 shows that Water Body changed from 3327.70km^2 to 3187.14km^2 in between 1986 and 2003 with a -140.57km^2 change to its area extent with an annual change rate -7.81km^2 having an inference of loss. Also, this class changed from 3187.14km^2 to 3544.87km^2 in between 2003 and 2022 with a 357.73km^2 change to its area extent with an annual change rate 19.87km^2 having an inference of gain.

Table 6: Plantation LULC Class Change Statistics

S/No	Interval	Before Impact Area (km^2)	After Impact Area (km^2)	Change Area (km^2)	Annual change Rate Area (km^2/yr)	Inference	Spacing in years
1	1986 2003	918.42	1263.90	345.48	19.19	Gain	18
2	2003 2022	1263.90	4026.55	2762.65	153.48	Gain	18

Source: Researchers' Field Survey, 2022

Table 6 shows that Plantation changed from 918.42km^2 to 1263.90km^2 in between 1986 and 2003 with a 345.48km^2 change to its area extent with an annual change rate 19.19km^2 having an inference of gain. Also, this class changed from 1263.90km^2 to 4026.55km^2 in between 2003 and 2022 with a 2762.65km^2 change to its area extent with an annual change rate 153.48km^2 having an inference of gain.

Table 7: Marine Vegetation LULC Class Change Statistics

S/No	Interval	Before Impact Area (km^2)	After Impact Area (km^2)	Change Area (km^2)	Annual change Rate Area (km^2/yr)	Inference	Spacing in years
1	1986 2003	4632.57	3353.78	-1278.79	-71.04	Loss	18
2	2003 2022	3353.78	2110.98	-1242.81	-69.04	Loss	18

Source: Researchers' Field Survey, 2022

Table 7 shows that Marine Vegetation changed from 4632.57km^2 to 3353.78km^2 in between 1986 and 2003 with a -1278.79km^2 change to its area extent with an annual change rate -71.04km^2 having an inference of loss. Also, this class changed from 3353.78km^2 to 2110.98km^2 in between 2003 and 2022 with a -1242.81km^2 change to its area extent with an annual change rate -69.04km^2 having an inference of loss.

Table 8: Other Vegetation LULC Class Change Statistics

S/No	Interval	Before Impact Area (km^2)	After Impact Area (km^2)	Change Area (km^2)	Annual change Rate Area (km^2/yr)	Inference	Spacing in years
1	1986 2003	2137.89	2921.18	783.29	43.52	Gain	18
2	2003 2022	2921.18	763.05	-2158.13	-119.90	Loss	18

Source: Researchers' Field Survey, 2022

Table 8 shows that Other Vegetation changed from 2137.89km^2 to 2921.18km^2 in between 1986 and 2003 with a 783.29km^2 change to its area extent with an annual change rate 43.52km^2 having an inference of gain. Also, this class changed from 2921.18km^2 to 763.05km^2 in between 2003 and 2022 with a -2158.13m^2 change to its area extent with an annual change rate of -119.90km^2 having an inference of loss.

Table 9: Void LULC Class Change Statistics

S/No	Interval	Before Impact Area (km^2)	After Impact Area (km^2)	Change Area (km^2)	Annual change Rate Area (km^2/yr)	Inference	Spacing in years
1	1986 2003	116.96	118.56	1.59	0.09	Gain	18
2	2003 2022	118.56	128.60	10.04	0.56	Gain	18

Source: Researchers' Field Survey, 2022

Table 9 shows that Void class changed from 116.96km^2 to 118.56km^2 in between 1986 and 2003 with a 1.59km^2 change to its area extent with an annual change rate 0.09km^2 having an inference of gain. Also, this class changed from 118.56km^2 to 128.60km^2 in between 2003 and 2022 with a 10.04km^2 change to its area extent with an annual change rate 0.56km^2 having an inference of gain.

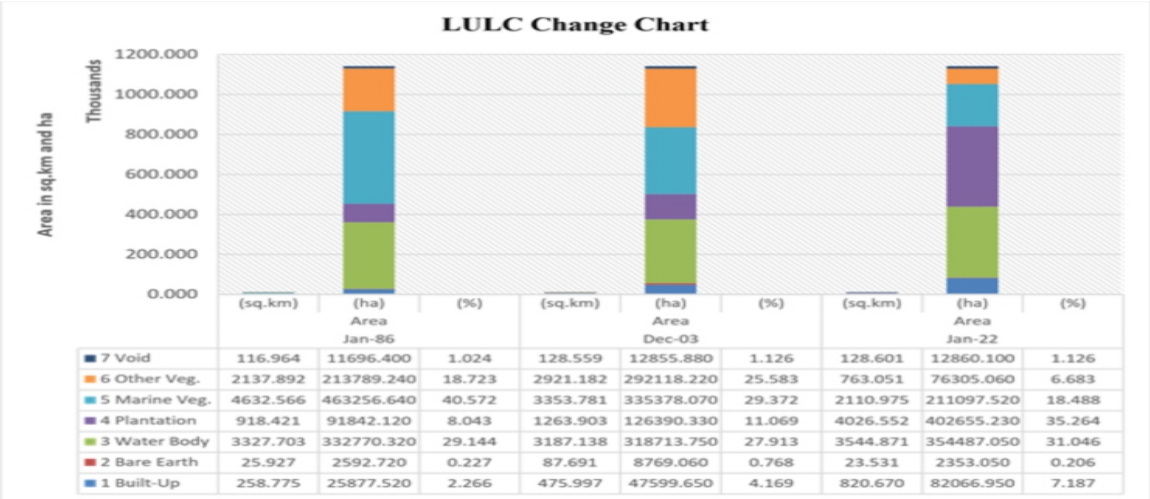


Figure 5: LULC Change Chart for the Three Dates

Though errors in classification and cloudy datasets may tilt data a little in favour of some LULC types, hence the results obtained from the classified 2003 dataset remains relatively valid. The 2003 dataset had cloud cover and was impaired thus the classified 2003 and 2022 datasets were used to produce land transformation map since the both images have same spatial resolution. On the other hand, the 3 epochs were used to detect and measure LULC changes, since the results obtained from the classified 2003 dataset remains relatively valid.

LULC Results and Change Analyses between Successive Epochs

LULC Results and Change Analyses between January 1986 and December 2003

The study area covers a total area of 11418.25km^2 which are classified into Built-up, Bare Earth, Water body, Plantation, Marine Vegetation and Other Vegetation. As such the coverage of clipped section of the study area classed as Void for the three (3) epochs measures approximately 1% of the study area for the three dates under review.

Table 10: LULC Summary for 1986 and 2003 with Change and Directio nal Remark

S/N	LULC Class	Colour	Classified 1986 (C1)		Classified 2003 (C2)		Difference	Change rate/ year (Km^2)	Remarks
			Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	C2 - C1 (Km^2)		
1	Built-Up	Red	258.775	2.266	475.997	4.169	217.221	12.068	Gain
2	Bare Earth	Green	25.927	0.227	87.691	0.768	61.763	3.431	Gain
3	Water Body	Blue	3327.703	29.144	3187.138	27.913	-140.566	-7.809	Loss
4	Plantation	Yellow	918.421	8.043	1263.903	11.069	345.482	19.193	Gain
5	Marine Veg.	Cyan	4632.566	40.572	3353.781	29.372	-1278.786	-71.044	Loss
6	Other Veg.	Magenta	2137.892	18.723	2921.182	25.583	783.290	43.516	Gain
7	Void	Black	116.964	1.024	128.559	1.126	11.595	0.644	Gain
	Total		11418.250	100.000	11418.250	100.000	0.000	0.000	

Source: Researchers' Field Survey, 2022

From table 10, Built-Up changed from 258.775km^2 to 475.997km^2 in 1986 and 2003 respectively with a 217.221km^2 change to its area extent with an annual change rate 12.068km^2 with an inference of built-up gain. Bare Earth changed from 25.927km^2 to 87.691km^2 respectively, difference in area extent of 3.431km^2 with an indication of increase in bare earth. Water body changed form 3,327.703km^2 to 3,187.138km^2 with a change in its area extent at -140.566km^2 and an annual rate of change of about -7.809 km^2 which indicates decrease in water body. Plantation had 918.421km^2 and 1,263.903km^2 between 1986 to 2003 respectively with an annual rate of change of 345.482km^2 with an indication of gain of 19.193km^{2}annual change rate.

Marine vegetation had a change of 4,632.566km^2 and 3353.781km^2, difference in change extent of -1,278.786km^2 and an annual rate of change -71.044km^2 which recorded one of the biggest lost in the period under review while Other vegetation had an area change of 2137.892km^2 to 2921.182km^2 with a difference in area extent of 783.290km^2 and an annual rate of change of 43.516km^2 depicting increase in other vegetation had the most significant and absolute gain in area extent, hence has encroached on other land classes. Void class had an area change of 116.964km^2 to 128.559km^2 with a difference in area extent of 11.595km^2 and an annual rate of change of 0.644km^2 depicting increase in void area extent, hence has encroached on other land classes.

Table 10: LULC Summary for 1986 and 2003 with Change and Directional Remark

S/N	LULC Class	Colour	Classified 1986 (C1) Area (Km^2)	Classified 1986 (C1) Area (%)	Classified 2003 (C2) Area (Km^2)	Classified 2003 (C2) Area (%)	Difference C2 - C1 (Km^2)	Change rate/ year (Km^2)	Remarks
1	Built-Up	Red	258.775	2.266	475.997	4.169	217.221	12.068	Gain
2	Bare Earth	Green	25.927	0.227	87.691	0.768	61.763	3.431	Gain
3	Water Body	Blue	3327.703	29.144	3187.138	27.913	-140.566	-7.809	Loss
4	Plantation	Yellow	918.421	8.043	1263.903	11.069	345.482	19.193	Gain
5	Marine Veg.	Cyan	4632.566	40.572	3353.781	29.372	-1278.786	-71.044	Loss
6	Other Veg.	Magenta	2137.892	18.723	2921.182	25.583	783.290	43.516	Gain
7	Void	Black	116.964	1.024	128.559	1.126	11.595	0.644	Gain
	Total		11418.250	100.000	11418.250	100.000	0.000	0.000	

Source: Researchers' Field Survey, 2022

Built-Up changed from 475.997km^2 to 820.670km^2 in 2003 - 2022 respectively with a 344.67km^2 change to its area extent with an annual change rate 19.149km^2. Bare Earth changed from 87.691km^2 and 23.531km^2 in 1986 - 2022 respectively with a -64.16km^2 change to its area extent with an annual change rate -3.56km^2. Thus, bare earth has been burdened by other human activities in the study area over the last decade due to increase in built up areas, industrial settlements and other urban land practices. On the other hand, Water body changed from 3187.138km^2 to 3544.87km^2 in 1986 and 2022 respectively and a percentage change of 357.73km^2, annual rate of change of 19.87km^2. For the period under investigation the notable changes were observed from table 4.3 and recorded as follows; Built-up area from 253.78km^2 to 820.67km^2, Bare-earth from 25.93km^2 to 23.53km^2, Water body 3327.70km^2 to 3544.87km^2, Plantation from 918.42km^2 to 4026.55km^2, Marine Vegetation 4632.57km^2 to 2110.98km^2, Other vegetation covered from 2137.89km^2 and 763.05km^2 while other Void covered from 116.96sq.km and 128.60km^2 for 1986 and 2022 respectively, see figure 5.

LULC Results and Change Analyses between December 2003 and January 2022

Table 11: LCLU Summary for 2003 and 2022 with Change Rate and Directional Remark

S/N	LCLU Class	Colour	Classified 2003 (C1) Area (Km^2)	Classified 2003 (C1) Area (%)	Classified 2022 (C2) Area (Km^2)	Classified 2022 (C2) Area (%)	Difference C2 - C1 (Km^2)	Change rate/ year (Km^2)	Remarks
1	Built-Up	Red	475.997	4.169	820.670	7.187	344.673	19.149	Gain
2	Bare Earth	Green	87.691	0.768	23.531	0.206	-64.160	-3.564	Loss
3	Water Body	Blue	3187.138	27.913	3544.871	31.046	357.733	19.874	Gain
4	Plantation	Yellow	1263.903	11.069	4026.552	35.264	2762.649	153.481	Gain
5	Marine Veg.	Cyan	3353.781	29.372	2110.975	18.488	-1242.806	-69.045	Loss
6	Other Veg.	Magenta	2921.182	25.583	763.051	6.683	-2158.132	-119.896	Loss
7	Void	Black	128.559	1.126	128.601	1.126	0.042	0.002	Gain
	Total		11418.250	100.000	11418.250	100.000	0.000	0.000	

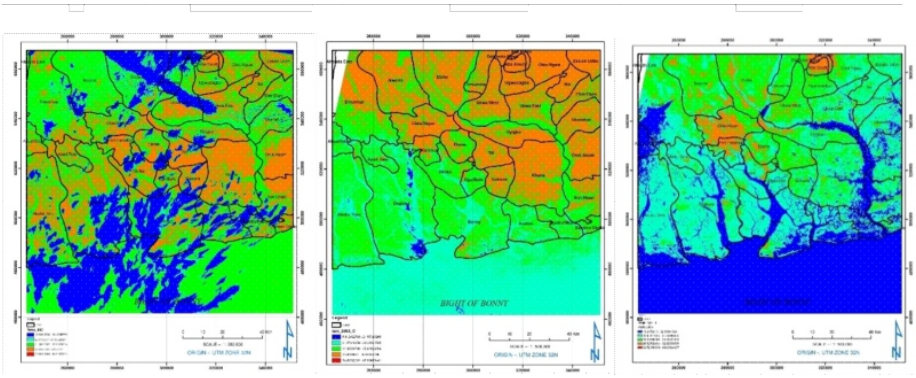
Since losses to a class indicates an encroachment on that particular class at time C1 or C2 by other class(es) at time C2 or C3 respectively. In the same way, gain to a class is an emergence of that particular class on other class(es) at a later date (Adeniyi and Omojola, 1999), thus, Bare Earth, Marine vegetation and other vegetation were mainly encroached by Plantation, Water body and Built-up areas associated with all other forms of urban activities springing up in the region due to urbanisation.

S_t Changes and Validation

S_t fluctuated over the study years across the seven (7) different LULC types. The highest S_t mean was recorded in 1986. With increased carbon sinks (vegetal cover and higher volumes of water bodies) as at 1986, one will expect a decrease in S_t thus a holistic view of factors contributing to S_t changes is required since an aggregate of factors ranging from anthropogenic activities to season of year contributed to yield changes in S_t. The lowest mean was recorded in 2003 followed by 2022 as shown in Table 13.

Table 13: S_t for the Study Period

S/No	Date of Acquisition	Estimated LST Mean	Measured LST Mean
1	17/01/1986	28.955	28.95
2	17/12/2003	27.352	27.35
3	04/01/2022	25.367	25.37



Figures 6: Surface Temperature Map for 2022 Dataset

Bare earth had its highest estimate of S_t recorded in 2003 decreasing orderly over the study years to 2022. Built-up had its highest estimate of S_t recorded in 1986 followed by 2003 and 2022 recorded the lowest S_t mean estimates. Water bodies had the highest S_t mean recorded in 1991, 1984, 2001 and 2011 in that order. This is obtainable with higher volumes of water in 2003 and 1986. Vegetation had its lowest S_t mean estimate in 1986, 2022 and 2003.

Estimating Epoch-based S_t on Different LULCs and Identifying Potential UHI

The surface reflectance and roughness of different land use types are different, thus leading to differences in surface temperature (S_t). Several studies confirmed that the presence of the aforesaid can accelerate the effect of UHI while water body and vegetation spaces can reduce the UHI intensity (Guha et al., 2018; Song et al., 2014). Physical examination of the obtained S_t images for the study area shows that two (2) main heat islands were identified in Abia and Rivers states. The locations of the aforesaid UHI are Aba metropolis with LGAs such as Aba North, Aba South, Osisioma Ngwa and Obio Ngwa, in Abia and Port Harcourt metropolis made up of Port Harcourt City and Obio/ Akpor in Rivers State.

The study also identified the following LGAs such as Ikot Abasi, Ukanafun, Ika and Essien Udim in Akwa Ibom State; Oyigbo, Eleme, Tai, Khana, Gokana, Okrika, Bonny, Degema, Akuku Toru, Asari Toru, Emouha, Ikwerre, Etche and Omuma in River State as potential heat islands since they have consistently recorded high temperature values from 1986 to 2022. These urban regions are often characterized by a high concentration of built-up areas which indicates the presence of structures and human settlements. The trend in changes in S_t in the study area between 1986 and 2022 is neither a definite nor constantly increasing nor decreasing; as such it could be best described as fluctuating. As such, if temperature values are High (above 24^0C) and low (below 16^0C) they can cause human thermal discomfort.

With the increasing rate of urban encroachment into neighbouring rural settlements triggered by population surge in Port Harcourt and Aba metropolis is expected to experience rapid replacement of vegetal cover by habitable grey surfaces. The aforesaid occurrence will accompany the following feedbacks which includes increased frequencies of rainfall that will eventually lead to flooding and in some cases erosion, salt water intrusion, shoreline retreat and rise in water level, thus affecting the environmental sustainability of the Port Harcourt and Aba metropolis.

Conclusion

The highest value of S_t was recorded in 2003 while the lowest in 2003 respectively. S_t for all dates were examined for the study area and potential UHI identified as areas of consistent high temperatures were evident in Aba, Osisioma, Obio Ngwa, Port Harcourt City and Obio/ Akpor respectively.

Changes in S_t showed that built-up areas and bare surfaces had higher S_t than vegetation and water bodies especially in the 2022. Higher S_t values results to UHI which cause human discomfort and climate related issues. S_t is sensitive to vegetation and soil moisture hence, it can be used to detect LULC changes and their feedbacks for example, it can be used to examine tendencies towards urbanization, deforestation etc.

Consistently high S_t leads to UHI and in Port Harcourt and Aba urban, UHI have been formed in some areas as a result of increased population and commercial activities. These high values of S_t necessitate floods in within the studied area since construction introduces more impervious surfaces especially in 2022 dataset.

Despite the rigor of the study, it could not verify if LULC-induced changes in S_t resulted to climate change in portions of Abia, Akwa-Ibom and Rivers, States rather it made evident the resultant climatic fluctuations experienced within the region.

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Improving the Functionality of Traditional Surveying Techniques with Geospatial Big Data Analytics: Lessons from the Dutch Water Management System

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Abstract

Geospatial big data is an important research topic that has attracted global interest. The ever-dynamic nature of the spatial domain, in terms of its size, variety, and update frequency, often overwhelms the potential and contributory capacity of traditional surveying. However, geospatial big data offers a promising solution to this challenge. It can support better spatial decision-making, reduce the cost of project implementation, provide real-time information, and enable a variety of land-based evaluations of topological patterns. Despite the tedious and time-consuming methods of acquisition, standard errors, and uncertainties that often require rigorous mathematical computations to adjust, minimise, or even eliminate, traditional surveying and their respective spatial data genres, rasters, vectors, and graphs remain the core of many geospatial applications, particularly in data-sparse developing countries (DCs). With the rapid emergence of geospatial infrastructure, which extends the availability of big data, it is crucial to consider the theoretical and practical issues surrounding the synergy of geospatial big data analytics with the widely used traditional survey geospatial data genres. This is an exciting enquiry that can broaden geospatial big data research and, therefore, forms the main aim of the present study, which examines the opportunities and challenges of integrating geospatial big data into their traditional surveying counterparts. This study draws mainly from the Dutch water management experience and provides logical and credible insights into what might address the prevalent data limitations within DCs. The implications of this study are practical and far-reaching, underpinning the expected goals of smart surveyors in land and water management and equipping the audience with valuable knowledge for their work.

Keywords: Geospatial Big Data, Traditional Surveying, GIS, Netherlands, Land Information System, Developing Countries, Smart Surveyors

Introduction

Land surveying is an age-long technique for determining the absolute and relative positions of points on Earth's surface. Through a generalised principle of working from whole to part, the traditional surveying operation begins with a reconnaissance, which mainly determines a project bid's technical and economic requirements. The positioning of points begins with the measurement of angles and distances directly from the field. These measured parameters are then transformed into earth-fixed positions, underpinned by a chosen geoid and coordinate datum, by applying various (from simple to complex) mathematical and statistical concepts (e.g. trigonometry, leastsquare adjustment concepts, error analysis, potential theory, Fourier transform, numerical decompositions, etc.). The land surveyor uses these coordinates to make maps, often regarded as the leading traditional deliverable of land surveying, which serves a myriad of purposes not limited to land ownership and administration and boundary demarcation and identification. In a broader sense, the purpose of maps, which somehow extend the responsibilities of a traditional land surveyor, has now embraced 'Big data' issues and modern cartography that both serve the objectives of political governance, globalisation, strategic management and administration, national security, climate change, crises and disaster management, entrepreneurship and industrialisation, soil and land management urbanism and tourism development at national and continental scales (Cheng & Mok, 2008; Greenfeld, 2011). These functions and objectives have also prescribed innovation, creativity, and versatility in developing novel methodologies, placing a far greater demand on land surveying (El Meouche *et al.,* 2016; Coutts & Strack, 2019).

In today's academic milieu, land surveying has condensed into geomatics, geoinformation, or geoinformatics, which provides a more comprehensive and all-encompassing parlance, given the due expression of both the past and the present applications of land surveying in addition to its future expectations. Geoinformatics is science, technology, and art that deals with the structure and character of geospatial data. It is now a pivotal science embracing all the techniques that deal with geospatial data acquisition, storage, analysis, modelling, and visualisation. With Geographic Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS), geoinformation technology highlights the importance of geospatial data, which is now a key data industry with emerging data-sharing platforms for researchers and practitioners (Li *et al.,* 2016). Geospatial data requirements must be extensive to deal with the vast environmental, social, and geographical needs within a regional or global context. This new data size (Lee & Kang (2015) reported a 20% data growth rate), which often exceeds the size of current computing systems and presents real trouble for the conventional GIS software that can quickly manipulate traditional surveying datasets and describes geospatial big data (Kashyap, 2019). It is an important concept that has become a major research theme within the geoscience academy. Over the last six years, it has resulted in at least six high-quality journals dedicated to publishing cutting-edge dialogues and findings. Although handling geospatial big data is still an active research question, it is a realistic ambition to harness the potential within such a data structure and its present analytics to reinforce the traditional survey framework. This will undoubtedly improve the availability of quality geospatial datasets in data-poor areas, particularly in developing countries (DCs).

The background set up by the preceding paragraphs raises an important research question: "How can geospatial big data address quality data issues in the DCs?". Therefore, this study aimed to address this question. Traditional surveying has been an element in the development of the human environment since the beginning of recorded history, and in recent times, its focus and demand have expanded. Thus, it is necessary to widen the scope of its operations and methodologies to find a way to fix its present technical challenges vis-à-vis recent geospatial needs. The main aim was to explore and highlight the opportunities and challenges of integrating big data and analytics into their traditional surveying counterparts. This study draws mainly from the Dutch experience of urban and rural land management systems. It provides insight and validation of the potential of geospatial big data to address data limitations and enhance geospatial applications across various contexts. The implications of this study are extensive and highly representative of the research studies that underpin the expected goal of smart surveyors in land and water management. The authors expect this study to highlight the new and burgeoning responsibilities of a *21st Century* '*smart surveyor*' in the built environment profession and land management.

Description of Research Method

The most important practical work in this study utilised a case study approach. Stake (1995) describes a case study as "*the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances*". Gerring (2006) agrees with Stake's opinion but thinks that case study research is not limited to a particular case or concept—it may be one or two minor cases in which an investigator is eager to give a go for a deeper investigation, as opposed to superficial enquiries into multiple cases, which the author described as cross-case methods. In the present study, the Dutch water management system is a single case, and the particularity and complexity of this are under study. An in-depth investigation clarifies how combined geospatial big data analytics and traditional surveying will affect diversity in geoinformation applications, which is imperative for this study. The propositions, objectives, and questions to identify what to study are essential when conducting a case study. Here, the proposition and objectives are (1) how 'Big data' analytics fit with the expectations of *21st Century* geospatial application in enhancing the provision of quality geospatial datasets for DCs.? (2) What are the prospects and challenges of combining such a large data

infrastructure with traditional surveying? Based on these propositions, objectives, and questions, the present study searches for real-world cases from established research evidence that considers the application of geospatial big data. The Dutch experience of water management, chosen as the single case for investigation, is vital because its conceptualisation lies within the general framework of geoinformation, geoscience, and environmental science research.

Geospatial Big Data Analytics Vs. Traditional Surveying

Geospatial big data reflect a somewhat inevitable growth in the binary size of regular geospatial data, such as mosaics of high-resolution multispectral or hyperspectral images, point cloud datasets, and digital elevation models (DEMs), and their coverage often extends over national or continental scales, to terabytes or even petabyte storage capacities and varying data formats. These types of datasets are often not the focus of traditional surveying, which naturally considers field measurements of distances and angles, computation of bearings and coordinates, and cartographic designs of maps. Traditional surveying data have supported human and societal development in various ways; however, the operations involved in traditional surveying are tedious, timeconsuming, error-prone, and capital-intensive. Instrumentation is a major impasse, and poor technology transfer is disturbing in many places that still practice traditional surveying extensively. Therefore, the instruments for traditional surveying are old and inflexible, and most of their outputs do not offer themselves easily for manipulation on the fly or transfer to a digital medium. These traditional surveying outputs rarely align with a global coordinate system without requiring coordinate transformation parameters, which often raises the problem of geodesy in defining the local geoid, ellipsoid, and gravity parameters. The workload within the framework of traditional surveying causes the development of simple or complex programs and routine algorithms to enable iteration, accuracy, and automation. Although traditional surveying remains a rich source of geospatial data for a range of land- and water-related applications, it is limited in spatial coverage. The technique cannot address the geographical issues of sharpness, granularity, and nuances stipulated by a rapidly evolving, complex human society.

Unlike traditional surveying, geospatial big data are helpful because they offer geospatial data desirable to meet the needs of the present times. This applies to DCs to the same extent as in developed societies. Uniquely, geospatial big data issues that arise concerning DCs possess some time-based properties which constrain traditional surveying and significantly impact the quality of decisions made with traditional surveying data. A typical example is the routine analyses of land use and land cover change covering an extensive epoch, for example, 50 years, which requires large amounts of geospatial data. This issue needs to be addressed for DCs, and it becomes even more crucial for geospatial big data considering the rapid rate of urbanisation and population growth with future estimations in the DCs. However, these advantages increase the challenges, fuzziness, and complexity of geospatial data storage, processing, analysis, visualisation, and distribution over client and open-source platforms. Although the concept of geospatial big data is of global significance, the interest and attention of academia, industry, government, and other organisations have been polarised by the difficulties in developing generic models and tools for handling emerging geospatial data. In response to this issue, the International Society for Photogrammetry and Remote Sensing (ISPRS) conducted several studies to investigate the data-handling capabilities of existing geospatial data-handling methods and theories.

A particular study in this ISPRS research relates to Liu *et al.* (2016), using various case studies as evidence. This study provides exciting findings regarding data collection, processing, and analysis of geospatial big data in data research. First, although geospatial big data now makes diverse geospatial data available for use by various users, the problem of "inauthentic data collection, information incompleteness and noise of big data, unrepresentativeness, consistency and reliability, and ethical issues". Second, geospatial big data has provided the window for more scientific studies because some previously complex research related to poor data availability is now possible. Third, despite the liberation in geospatial research, the "big errors" associated with geospatial big data stipulate that to use

these as supplementary data for sound research design and solid theories, the researcher may face some significant uncertainties. Given these findings, Liu *et al.* (2016) proposed that big data research should adhere to good scientific practices and seek to develop techniques and methods to address the inherent challenges of geospatial big data. This highlights the need for analytics in geospatial big-data technology. Although there is a lack of a generic tool or technology to help with all geospatial big datasets, ample research has provided critical ideas that now inform choices and improve the means to address the challenges imposed by geospatial big data.

Over the last five years, research has been conducted in geospatial data analytics and spatial data infrastructure (SDI), an important framework for sharing geospatial big data using the Web. Recent studies have increasingly supported the prospects of SDI integration with cloud computing, which has led to the emergence of cloud SDI as a tool for the transmission, processing, and analysis of geospatial data (Schäffer *et al.,* 2010; Evangelidis *et al.,* 2014). Cloud Geographic Information Systems (CloudGIS) have emerged as a tool for analysing, processing, and transmitting geospatial data, and this seems to have triggered the evolution of several open-source compression techniques now available for reducing the transmission to the cloud (Yang *et al.,* 2017). In 2016 and 2017, the IEEE (Institute for Electrical and Electronics Engineers) organised key conferences where researchers presented several innovative discussions on big data analytics. We review these discussions and other studies in the current literature about some well-known geospatial big data analytics and present a summary of our findings in Table 1.

One of the significant improvements in geospatial big data analytics and SDI is the development of a fog computing framework that decentralises the cloud computing infrastructure such that it situates data storage and analyses somewhere between the data source and cloud (Stojmenovic & Wen, 2014; Mouradian *et al.,* 2017). Unlike cloud systems, fog computing drives clouds' potential and dynamics closer to the data acquisition and processing site. Barik *et al*. (2016) made one of the novel fog computing designs, *FogGIS*, for mining analytics from geospatial data. This design followed a similar study by Barik *et al.* (2015), in which they proposed *the MistGIS framework* for the Ganga River management system. *MistGIS*, based on mist computing, is a computing paradigm in which fog devices help reduce the latency period and increase throughput near the edge device of the client. The preliminary analyses of these systems showed the potential of fog computing for geospatial big data analysis. Barik *et al.* (2017) leveraged the ability of fog computing to reduce latency and increase throughput by processing data near a body sensor network. The authors proposed *SoA-Fog*, a three-tier secure framework for efficiently managing health data using fog devices to assist smart health paradigms that use Internet-connected wearables for electronic monitoring and diagnosis and provide inexpensive healthcare solutions. Similarly, Barik *et al.* (2019) developed and tested a fog-based SDI framework called *GeoFog4Health* for mining analytics from geo-health big data. These developments reveal the high profitability of fog computing in terms of data loss reduction, energy savings, cost reduction, and modularity. In addition to scalability and efficiency in data processing, the fog computing framework fits well into various applications, a potential that even the state-of-the-art cloud SDI does not possess.

Table 1: Some Well-Known Geospatial Big Data Analytics Tools Found in the Current Literature

S/No	Analytics tool	Author	Design / Context	Main Potential
1.	FogGIS	Barik *et al*. (2016).	Fog computing paradigm	Reduce latency and increase throughput by processing data near the body sensor network.
2.	IBM PAIRS	Lu *et al*. (2016)	IBM PAIRS offers an easy-touse platform for both rapid assembly and retrieval of geospatial datasets	Suitable for performing complex analytics, lowering time-to-discovery significantly by reducing the data curation and management burden
3.	Spatial Hadoop	Aji *et al*., (2013); Lenka *et al*. (2016)	A scalable, high-performance spatial data warehousing system	Supports multiple types of spatial queries on MapReduce through spatial partitioning, customisable spatial query engine RESQUE
4.	Cloud computing	Yang *et al*. (2017)	Cloud Geographic Information Systems (GIS) built a prototype using Intel Edison, an embedded microprocessor.	Potential for analysis, processing and transmission of geospatial data.
5.	SOA-FOG	Barik *et al.* (2017)	Fog computing paradigm	
6.	Mist GIS	Barik *et al*. (2015)	Mist computing paradigm	Reduce latency and increase throughput by processing data near the body sensor network.
7.	Map Reduce	Jo & Lee (2018)	Marmot	Handles complex and time-intensive queries involving spatial index.
8.	BigGIS	Yue & Jiang (2014)		
9.	GeoFog4Health	Barik *et al*. (2019)	Fog computing paradigm	
10.	CyberGIS-Jupyter	Yin *et al.* (2017)	CyberGIS capabilities	As a desirable outcome, dataintensive and scalable geospatial analytics
11.	GeoSpark; ApacheSPARK	Yu *et al.* (2015); Yu *et al*. (2019)	Spatial Resilient Distributed Datasets (RDDs)	provides a geometrical operations library that accesses Spatial Resilient Distributed Datasets (RDDs) to perform basic geometrical operations (e.g., Overlap, Intersect).

Aji *et al.* (2013) presented the *Hadoop-GIS*, a scalable and high-performance spatial data warehousing system for running geospatial big data on Hadoop and efficiently analysing and processing the geospatial big data. Yu *et al.* (2015) introduced *GeoSpark* as an in-memory clustercomputing framework for processing geospatial big data. *GeoSpark* provides a geometrical operations library that accesses spatially Resilient Distributed Datasets (RDDs) to perform basic geometrical operations (e.g. overlap, intersection). Among its various attributes, GeoSpark comprises three layers: Apache Spark, Spatial RDD, and Spatial Query Processing. Yu *et al.* (2019) discussed Apache Spark, highlighting the basic Spark functionalities, which it provides, but is not limited to, loading/storing data to disk to support spatial data types, indexes, and geometrical operations at a scale and regular RDD operations. Yu *et al.* (2019) conducted preliminary experiments to demonstrate that GeoSpark achieves better runtime performance than Hadoop-based programs (for example, SpatialHadoop). In a comparative investigation of SpatialHadoop and *GeoSpark*, Lenka *et al.* (2016) confirmed Yu *et al.'s view* on the superlative processing speed of the latter.

Other analytics tools are BigGIS, discussed in Yue & Jiang (2014), and IBM's Physical Analytics Integrated Data Repository and Services (PAIRS), presented by Lu et al. (2016). In principle,

IBMPAIRS is a geospatial big data service that contains many curated geospatial data from a vast public and private data repository and supports user-contributed data layers. *IBM-PAIRS* offers an easyto-use platform for both rapid assembly and retrieval of geospatial datasets or performing complex analytics, lowering time-to-discovery by reducing data curation and management burden. Jo and Lee (2018) developed the *Marmot*, a high-performance geospatial big-data processing system based on MapReduce. Marmot extended Hadoop at a low level to support seamless integration between spatial and non-spatial operations of a solid framework, thereby improving the performance of the geoprocessing workflow. Yin *et al*. (2017) proposed *CyberGIS-Jupyter*, an innovative cyberGIS framework for handling geospatial big data related to security and defence infrastructure.

These analytical tools have successfully addressed the challenges of geospatial big data. However, access to these tools and advanced skills to operate them are still vital issues to address, given that most tools are not open source and acquiring their licences might bear heavily on funds, which may be a challenge for DCs. Even when it is possible to buy these tools, personnel training still poses a significant challenge. This presents a critical challenge amidst the prospect of strengthening or complementing existing traditional land surveying methods using geospatial Big data analytics.

Dutch Water Management System The Netherlands has one of the world's most advanced water and flood management systems. Many authors, for example, Van Alphen (2016) and Van Buuren *et al*. (2016), acknowledge that the Netherlands' track record in flood and water management is due to the country's topographic milieu. Nearly half of the Dutch land areas are below level and prone to flooding, which makes a significant proportion of the population vulnerable to flooding. Having a history of flooding, Dutch authorities and people must strive to beat the odds of building resilient communities and mitigating losses due to flooding and other water issues. The country must understand the importance of geospatial big data in water and flood management systems to achieve these objectives. Traditional geospatial data such as elevation values, contours, and coordinates of points obtained from topographic surveying and levelling can be used to create topographic models such as digital terrain models (DEMs), DTMs (digital terrain models (DTMs), and DSMs (digital surface models (DSMs) to establish the foundation stage of flood hazard assessment and modelling. However, these are too simplified to meet the advanced expectations of the Netherlands's water and flood management. Dutch water management requires data on weather, tides, levee integrity, runoff, and water-related data, including precipitation measurements, current and historical maintenance data from sluices, pumping stations, locks, and dams, data regarding drinking water and wastewater, and urban drainage systems. This sequence of data represents the geospatial big data with which to process, retrieve, and share important information—with water agencies, the National Water Ministry (Rijkswaterstaat), local water authorities, research institutions, and private industry— towards water and flood management objectives, and upon which the coordination of efforts by the different stakeholders, and the Dutch government in particular, was essential, although problematic at some levels.

Scholten *et al*. (1998) and Busscher *et al.* (2019) acknowledge that this system provides clear insights into the prospects and challenges of geospatial big data for the Dutch water and flood management system but also highlights the dynamics of combined traditional surveying and geospatial big data analytics within the theory and practice of geoinformation. To address these challenges, the Dutch utilised the Digital Delta as a geospatial big-data analytics solution. This is part of the national "room for river programs, which offers capabilities for aggregating, integrating, storing, and analysing different data layers. Van Alphen (2016) argued that the Digital Delta data will also create an early flood warning system and will facilitate collaboration between the local water management and other external bodies, which will take part in integrating a large amount of real-time measurement data with weather information and running it against water system simulation models.

Dutch water and flood management offers some insights, which we summarise below.

1. Traditional land surveying is a crucial geospatial data source, but its weaknesses prevent it from meeting the expectations of today's geoinformation applications.

2. Geospatial big data offers a unique set of opportunities, including a variety of large, up-todate, online-friendly datasets that can meet the increasing demands of research politics, wider society, and several client-sensitive activities.

3. Despite the opportunities in geospatial big data, key issues confront end users in achieving various geoinformation objectives. For Dutch water and flood management, the challenge of data processing, analysis, sharing, and retrieval of important information that will instigate the participation of diverse stakeholders is an issue. Other issues in the current literature use geospatial big data for both developed societies and Dcs.

4. Dealing with the problems of geospatial big data requires an analytical tool. The digital delta was applied using Dutch water and flood management as a case study. This raises a major research issue for DCs in finding solutions to the current data paucity due to the nonutilisation of geospatial big data and analytics. What generic geospatial big data analytics programs will apply to the diversity of geoinformation applications in DCs requiring geospatial big data?

Conclusion

Traditional surveying, an agelong approach to geospatial data gathering, has limitations in the size of the data it can offer because of the cost of fieldwork, limitations placed on traditional analogue and semi-analytical instrumentation, error propagation, lack of modern skills, and technical capacity. This is in addition to the general lack of capacity to process geospatial data of exponential sizes, such as mosaics of hyperspectral and multispectral satellite images and point cloud images of LiDAR. Geospatial big data technology can solve these problems. Despite the inherent Big data potential, there is an issue in processing, storing, and sharing large amounts of data, which remains an active research issue. The application of artificial intelligence, the Internet of Things (IoT), and high-end engineering systems makes geospatial big data analytics a multivariate system and a major fancy of 21st-century sustainability across various human endeavours.

This study establishes a strong case for future research using Dutch water management experience. While it found various ways of optimising the potential of big data analytics in traditional land surveying, it also highlights the some challenges the DCs might face in realising the objectives of combined geospatial big data analytics and traditional surveying. These challenges include but are not limited to, the politics of DCs that subject sustainable development to uncertainties, lack of technical capacity, and limited funding to access big data across all geospatial data platforms.

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Theme D:
Maritime and Blue Economy, Land Management and Construction Economics

Factors Influencing Commercial Land Use Decisions in Port Harcourt, Nigeria

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Abstract

In view of commercial Land Use decision, the study examined the various factors that influence the choice of commercial land use in Port Harcourt, Rivers State. This paper explored qualitative and quantitative research methods to evaluate the decision-making criteria of property investors. The use of survey research design was employed which depended basically on the quasi-questionnaires, and site observation as instruments for data collection. Total population sampling technique was adopted in selecting the respondent which consists of property owners of commercial outlets in the Study Area. The study establishes the predominant Land use in the study area to be commercial Land Use. In the findings, five major factors (physical characteristics, Location, legal, Economic and Commercial agglomeration) were identified to influence commercial Land Use decision amongst others. However, the study recommended further studies to complement this study. (Keywords: Land Use, Commercial Land uses, influencing factors).

Keywords: Commercial Land Use, Decisions, Port Harcourt

Introduction

Land concepts are incomplete without including human societal development because a nation's foundation is land based. Land is the most readily and natural resource for social and economic development. The growth of a community and the area's economic activity takes place is reflected in land use (Kourtit, 2019; Goetz, Shortle, & Bergstrom, 2004). It could be viewed as the culmination of all plans, actions, and contributions made by individuals under a particular type of land cover. Orekan (2007) defines land use as management of land which involves the use of human intervention in a particular land cover type. Simply put, Land use is the categorization of land according to what can be constructed upon it and its intended use, as well as the way, means, or sequence in which land is utilised by individuals in a region for various objectives, such as for business objectives.

A plot of land designated for legal economic activity and business transactions is known as commercial land. It makes up the disproportionately biggest share of the entire area with higher economic worth. According to Adeniyi (1997), commercial land use includes, among other things, general and special markets, banks, petrol stations, supermarkets, and lodging facilities. According to Tucker (2017), a piece of land designated for business use is known as commercial land use which refers to the use of property for establishments, factories, parking lots, warehouses, and even homes that turn a profit.

Due to its social and economic feasibility in boosting economic developments and improving lifestyle, commercial land use has an undeniable relevance in any human settlement. According to Tucker (2017), one objective of commercial land use is to promote investment in both new and existing commercial development that complements current land uses in established regions in terms of scale, architectural style, intensity, and signage. Okeke (2020) and Onyebueke (1987) among others, maintained that the characteristics of neighbourhood land uses are similar to the incidence of commercial land use pattern.

According to Yang et'al (2016), The convenience of commercial service, which lowers travel expenses and promotes convenience, increases the value of residential real estate. The term "proximity effect" refers to these cumulatively beneficial benefits. As a result, several markets and supermarkets have been established in residential areas of the majority of Nigerian cities. The market's position is now determined more by a natural flow from the periphery to the middle, where infrastructure is abundant,

than by the master plan that already exists. Zhou et'al (2017) opined that in metropolitan regions, there is constant pressure on land for commercial purposes due to the rapid economic and social development. This was buttressed in Farooq (2019) where he stated that businesses eventually feel compelled to relocate into residential areas as a result of the multinucleated central business districts' inability to control the growth in economic activity within a city. This includes an increase in demand for commercial real estate, such as office space, shopping centres, and parking lots. Classical urban economic theories, however, corroborate this trend, stating that as economic activity increases over time, the areas nearest to the central districts will typically absorb the new activity, putting significant pressure on the demand for commercial land use and ultimately providing an incentive for residents to move into the residential areas (Gimba, Poopola & Garba, 2019).

The businesses are evidence of how profits are maximised as a result of the growing demand for commercial space and the central business district's inability to control the economy's rapid expansion (Amoah, Marful, Takyi, Amponsah and Poku-Boansi 2023). According to Offiong, Agbor & Umoh (2018) Promoting investment in both new and existing commercial development that is harmonious in scale, architectural style, intensity, and signage with the neighbouring land uses in established districts is one of the objectives of commercial land use. Toivonen and Viitanen (2016) highlighted how the commercial property market is intimately entwined with the local community because commercial buildings are subject to a variety of social, political, environmental, and cultural forces. The regular property market overviews feature a number of significant statistics, including supply and demand, vacancy rates, absorption volume, projected projects, economic indicators, and legal and tax issues.
Port Harcourt has continued to experience an increase in commercial properties. If not studied and controlled will lead to urban sprawl with residential neighbourhood tending towards the suburbs thereby increasing carbon emissions as travel distances for commuters to business areas will be increased as well. Insight from this research can aid a paradigm shift where land use policies can be realigned along various factors that influence land use decisions as well as prompt more investigations into factors affecting other land uses so as to gain a better understanding of real-life commercial land use location analysis thereby reducing travel distance to curb carbon emissions to mitigate climate change impacts. Policy documents in land use could be tailored towards densification from studies of this nature. And it also contributes to the body of existing knowledge on land uses and academics can critically analyse and develop on it. This study will also create an informed investment decision by investors. Literature has reviewed that study on factors influencing commercial land uses is sparse especially in the study area unlike residential land uses. It is on this background that the study seeks to analyse the factors influencing commercial land use decision in Port Harcourt using Woji Road of the Government Reserved Area (GRA) and Peter Odili as case study.

Factors Influencing Commercial Land Use Decision

For this study, commercial property is an incoming generating property used for business purpose. For many investors, real estate investing is the most reliable kind of investment. This has been ascribed to the substantial profits linked to land and landed property investments globally. Land investment, after all, provides a buffer against inflation (Turner, 2014). According to Nzomo (2011), it is the responsibility of investors in commercial real estate to guarantee that these assets are adequately and skillfully managed. This is so that investors can enjoy surplus income and make up for high purchase or development costs, which are typically compensated for by strong returns on commercial properties due to their capital-intensive nature. A brief analysis of the several factors influencing the choice of commercial land use reveals that each element has a plethora of co-factors that together influence the choice of commercial land use and related business premises. These factors do not consider carbon emissions and its impact on climate change.

Physical Characteristics: Commercial venture operators and business occupiers take into account

several physical aspects such as urban size, parking spaces, accessibility, weather, and environmental hygiene. In land use economics, the physical attributes of the location, including its moderate topography, have an impact on the amount of land required for a given activity (Chikwuado, Ibiam & Ezeudu, 2020; Hoover & Giarratani, 1984). However, in a rapidly urbanising environment where land is scarce, operators may find adverse topographical features appealing if they possess the technological ability to overcome the physical barrier to location selection. It suggests that despite the constraints placed on them by the topography of metropolitan regions marked by a lack of land and fierce rivalry for available space, operators may choose to optimise their land use decisions to benefit from both internal and external agglomeration economies. Recently, operators have realised that one of the elements influencing both their location decisions and the quality of urban living is the weather (Arnott & McMillen, 2006). Pleasant weather is usually associated with enjoyable shopping and commercial establishment visits. To combat the unfavourable tropical temperature conditions, the operator lowers the cost of air conditioning and provides related technologies. It has been proven that urban size influences the agglomeration of commercial land uses and the feasibility of land use decisions (Arnott & McMillen, 2006; Jacobs, 1969, Thorns, 2002). For instance, large, densely populated urban areas typically draw business owners, service providers, as well as prospective workers and job seekers. Businesses and commercial properties are more likely to be in areas with excellent sanitation and environmental quality (Wyatt, 2007 and Hoover & Giarratani, 1984). According to Carter and Vandell (2005), since parking lots draw customers, parking spaces are a standard need for commercial buildings such as retail centres. Customers will implicitly feel more comfortable visiting stores with plenty of parking spaces rather than risking their lives by parking on busy streets and highways. A survey conducted by Aguayo, et al (2007) indicated that distance to access roads, densities of the urban road system and urbanized area at various scales are among the predictors of urban growth pattern. In other studies, the most important consideration in business location decision is accessibility to customers, suppliers and business associates were the most important considerations in business location decision (Rahman & Kabir, 2019).

Location Factors: According to Smart, Gitman and Joehnk (2014), "The three most important factor in real estate value are location, location, and location". While there are other factors that influence value besides location, a property's investment potential is definitely enhanced by a prime location. The most important factor in every real estate decision is location. The market value and rental income of commercial real estate are influenced by its location. The rent for buildings in business centres is typically greater than that of structures outside of city centres.

This is merely because they are easily accessible by clients and typically have greater business potential. When choosing a location, having access to suppliers of support services and complementary businesses is important (Sivitanidou, 2014). The cost, accessibility, and availability of production are important aspects to take into account when choosing an office location because they directly affect your operating costs and, as a result, the purchasing power of that type of space (Jabar, Zailani & Irani, 2019; Fisher & Wu, 2009 and Dent & White, 1998). The choice of office location is heavily influenced by factors such as accessibility to financiers, investors, corporate headquarters, specialised services, and relevant government agencies. This will affect the business control and coordination costs (D'Arcy, McGough and Tsolacos, 2012). This means that the demand for office and other commercial space, as well as market rent, will be directly impacted by the choice of businesses for particular locations. Major trunk highways, public transport terminal accessibility, private vehicle accessibility, and closeness to other suburban centres will all affect office demand and rent in the appropriate amounts (Wheaton & Torto, 2018).

Market rent will be significantly impacted by the size of the market, its visibility to clients, the potential for business, and its proximity to rivals in related industries (Mills, 2012). Commercial property rent is closely correlated and influenced by the externalities of crime rates, pollution levels, traffic patterns,

and industry conditions in the vicinity. Office rental values are strongly impacted by market exposure and pooling demand, which is why similar activities in the same location tend to cluster together (Sivitanidou, 2014). The neighbourhood has an impact on a property's value. The property's marketability and value are significantly impacted by inadequate water, drainage, transportation, and electrical systems (Stephen, 2011).

Legal Factors (Government policy): Real estate properties are influenced by physical planning laws and regulations. They have the authority to assign land for specific uses, regulate changes in a building's use, for which planning approval is required and will not be granted unless the change is in line with local planning policy (Betts and Ely, 2015). In Nigeria, various statutory laws are enshrined to govern real estate activities and these laws are regulated through various institutions to ensure they are implemented. Town Planning Authority, Ministry of Lands, Works and Housing, Environmental Protection Agencies and Legislative Bodies respectively undertake regulatory measures that determine the uses of land. The way that property is developed at the federal, state, and local levels of government has a significant impact on how people use their land (Nwanekezie, 2009). These governmental entities take the required corrective or preventive actions to counteract the devastating outcomes of other forces in the use of land. Apart from the zoning and other town planning regulations, there are, according to Nwanekezie (2009) three other key laws in Nigeria viz, the Land Use Act Cap 2020 LFN, the Environmentat0l Impact Assessment (EIA), Decree 86 of 1992, and the Nigerian urban and Regional Planning Decree 88 of 1992. In the end, better development plans reflect the weight given to conflicting claims, which are typically decided by political objectives. The guiding principles and policies of the impacted public institutions are codified in the laws. However, the way the market behaves, and the distribution of building land based on market demand receive little to no attention (Murigu, 2015). The intensity of land use may also be restricted by planning, and any license is subject to additional limits imposed by building laws, which may override or restrict the planners' recommendations. Decisions about real estate (commercial land use) are influenced by these intricacies in planning regulations (Tony et al., 2016).

Economic factors: The prevailing economic condition of a region influences the decision to invest in a certain type of real estate investment, especially commercial real estate. Otiende (2014) points out that Current economic conditions and investment returns are influenced by a number of factors, including the rate of inflation, interest rates, taxes, commercial and industrial developments, wage levels, employment patterns, money, supply and demand, and money supply and demand. Stephen (2011) In the real estate industry, cash is required for in-site infrastructure, development, soft cost financing, and land acquisition. For any investor, having access to finance is crucial to preventing delays and incomplete projects, which are frequently seen after projects have already begun.
Since there are few sources of funding and the current lending institutions are unable to serve the bulk of middle-class earnings, access to financing is a critical factor in real estate development. The strict requirements Due to the impact of mortgage demand on low projects, there is a deficiency in housing supply compared to demand (Ventollo and Williamson, 2011). When borrowing becomes expensive, borrowers are unable to afford the kind of property they would otherwise be able to purchase. Interest rates have an impact on a real estate project's building cost, financing availability and cost, and overall financial sustainability. An equally significant factor in commercial land use decisions is the outcome of an investment evaluation, feasibility and viability study, or cost and benefit analysis. An analysis of a property's financial and legal situation based on research is called an investment assessment, often known as a feasibility and viability study. It has to do with a property's livability and financial returns (statutory potential). An investor's choice to pursue the most lucrative course of action is influenced by the investment's rate of return.

Commercial agglomeration: commercial usage of land Agglomeration is a spatial characteristic of the pattern and distribution of activities that are mutually dependent on one another in commercial land

uses (Ellison, Glaeser & Rose, 2004; Autor & Duggan, 2004). Agglomeration of commercial land use refers to the spatial organisation of several commercial activity types in an urban area in a clustered manner (Rosenthal & Strange, 2001).

The Study Area

The study area is Woji Road GRA Phase 2 and Peter Odili in Port Harcourt metropolis Rivers. Port Harcourt is located in the Niger Delta and bounded to the north by Ikwere, Etche and Omuma; east by Oyigbo, Tai, and Eleme, Part of which are in the metropolis; west by Emuoha; and south by Okrika and Degema Local Government Areas (figure 1.1). The city however lies approximately between longitude 6055I and 7055I E and latitude 4035I and 5010IN of the equator and on an elevation of 1.00 – 3.00m above sea level. The city area is 664sqkm with metropolitan area of 934sqkm and is linked to the outside world by land, sea and air. The rapid growth and urbanization of the city of Port Harcourt has been fueled by the massive influx of people from the surrounding hinterland to the city for job opportunities in various industries that sprang up as a result of the discovery of petroleum in the Niger Delta. Results of the 2006 population census put the metropolitan population at 1,255,387 and projected at 1,337,800 in 2009 (National Population Commission, 2006). The choice of Woji Road GRA Phase 2 and Peter Odili as case study is on the premise that Commercial land Use is predominant in the area.

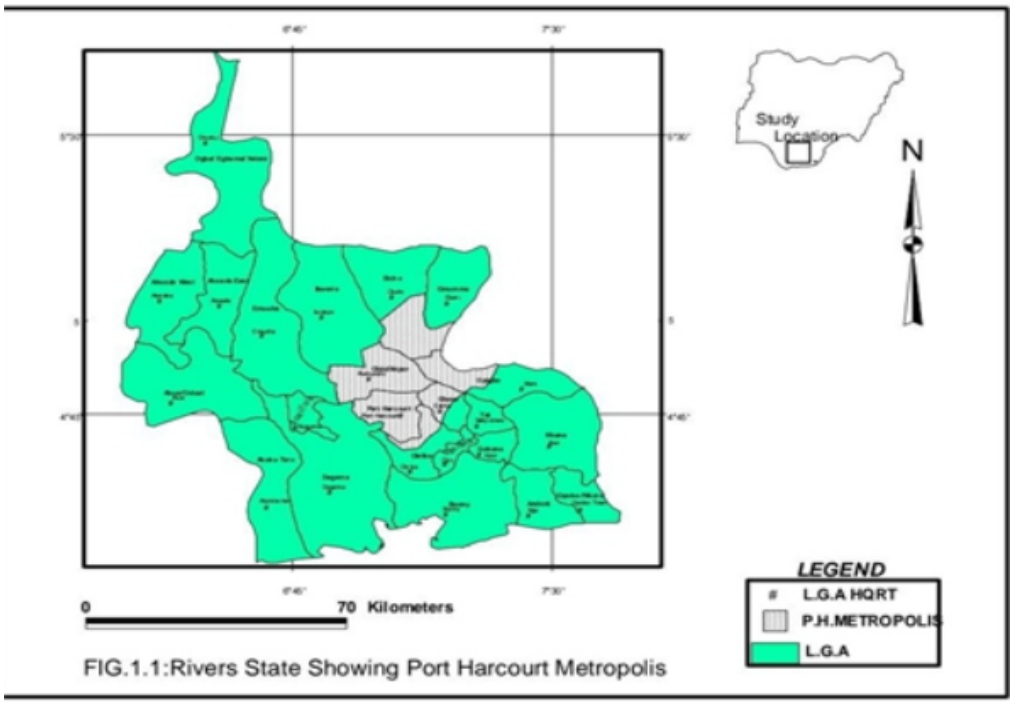

FIG.1.1:Rivers State Showing Port Harcourt Metropolis

The basis of the problem of commercial Land use decision in the study area is a number of factors affecting choice of locating commercial land use, has been on the increase in Port Harcourt especially the Woji Road New GRA Phase 2 and Peter Odili road.

Methodology

The researchers employed both primary and secondary data in this study. The primary data include observation and questionnaire The use of survey research design was employed in order to enhance the effective realization of the set goal. The researchers had employed the survey research because it involved the collection of data to accurately and objectively analyse the existing commercial land use in the study area. Besides, the survey research design was selected because the study involved both larger and small population, the distribution and interrelation between variables under investigation

(factors influencing commercial land use decisions). The survey research depended basically on quasi-questionnaires and observation as instruments for data collection. Observation was used to determine the prevailing land use and types of commercial properties in the study areas. A total of 212 open-ended questionnaire was administered to collect relevant information from commercial property owners in Woji Road GRA Phase 2 and Peter Odili Road for this study. However, 184 was returned which represents 86.79% of the total administered. The total population sampling technique which is a method of purposive sampling was adopted for the entire population which consists of owner of the existing commercial outlets in the Study Area. The technique was applied because the sample population was small, heterogeneous (different types of commercial uses) and the need to give each population unit the equal chance of being sampled.

Findings

The prevailing land use, types of commercial land use and factors influencing commercial land use in the study were identified.

Table 1: Prevailing Land Use (Dominant)

S/No.	Land uses	Woji Road		Peter Odili Road	
		Frequency	Percentage (%)	Frequency	Percentage (%)
1	Commercial	91	90.1	121	66.12
2	Residential	8	7.92	17	9.29
3	Undeveloped land (bare land)	1	0.99	35	19.13
4	Educational	1	0.99	8	4.37
5	Industrial			2	1.09
	Total	**101**	**100**	**183**	**100**

Field Survey May, 2024

The study reveals in table 1.1 that the various land use in the Woji road showing commercial land Use with 90.1%, Residential Land Use 7.92%, undeveloped Land 0.99%, Educational Land Use 0.99% while none was identified for industrial. For Peter Odili Road, the various land use shows that commercial land use as 66.12%, residential land use as 9.29%, Undeveloped land use as 19.13%, educational land use as 4.37% and industrial land use as 1.09%

Table 2: Types of Commercial Activities

S/No.	Commercial Land uses	Woji Road		Peter Odili Road	
		Frequency	Percentage	Frequency	Percentage
1	Supermarkets/ & Malls/lockup shops	44	48.35	87	71.90
2	Bars & Clubs	23	25.27	10	8.26
3	Eateries & Restaurants	9	9.89	9	7.44
4	Event centres	2	2.2	8	6.61
5	Financial institution	2	2.2	4	3.31
6	Hotels	3	3.3		
7	Offices	8	8.79		
8	Fashion outlets			3	2.48
	Total	**91**	**100**	**121**	**100**

Field Survey, May 2024

The commercial activities in Woji road as presented in Table 2 showed that Supermarkets/Malls/lock-up shops represented 43.35%, Bars/clubs represented 25.27%, Eateries/restaurants represented 9.89%, event centre represented 2.2%, financial institutions represented 2.2%, hotels represented 3.3%, Offices represented 8.87% while fashion outlets were not observed. While the commercial activities in Peter Odili road as presented in Table 2 showed that Supermarkets/Malls/lock-up shops represented 71.90%, Bars/clubs represented 8.26%, Eateries/restaurants represented 7.44%, event centre represented 6.61%, financial institutions represented 3.31%, hotels were not identified, Offices were not identified and fashion outlets represented 2.48%

Table 3: Identified Factors Influencing Commercial Land Use Decisions in the Study Areas

S/No.	Drivers	Respondents	% of 184
1	Location factors (traffic)	180	97.8%
2	Physical characteristics (Infrastructures)	128	69.6%
3	Legal factors (Government policy)	56	30.4%
4	Economic factors (Demand and trends, finance etc)	177	92.9%
5	Commercial agglomeration	42	10.42%
	Total	**403**	**100**

Field Survey May, 2024

The factor that drives the decision of commercial land use Investments as evident in Table 3 described that the sampled population were of the opinion that they considered all the above factors before locating their businesses in the study areas, but the degree of consideration varied. The table above shows that location factor consideration received 97.8%, physical characteristics is 69.6%, legal consideration received 30.4% while Economic factors received 92.9% and commercial agglomeration factors received 10.42%.

Discussion

The study revealed that the land uses in the area are commercial, residential, educational, and industrial. The dominant land use is commercial land use which takes up about 78% of the total land on average. The Woji road which had been in existence before the Peter Odili road has only one undeveloped land with no industrial use. On the other hand, the Peter Odili has more undeveloped land and very few industrial uses. The findings show that as more developments are carried out on the area, more commercial property will spring up as this is the preferred land use type in the location.

The predominant commercial land use for both areas is supermarkets/malls/shops. More of this use is found on the Peter Odili road since it is a connecting access from one area of the city to another area and has more ample spaces for parking. The woji road has more bars/clubs because it is a more secured area and more operational at night to create street parking for bar/club users at night. There are no hotels and offices along the Peter Odili road as against what is obtainable in the Woji area of Port Harcourt. This shows a variance in the choice of commercial land use (Offiong, Agbor & Umoh, 2018).

The major factor that influences commercial land use decision in the study area is location. Interaction with the respondents revealed that the access and traffic experienced in these areas has informed the decision of this use. Better traffic location can attract more investment and higher demand for Land. They noted that proximity of these areas to other uses creates a natural pull. When there is a growing demand in a Location, it encourages developer to start new commercial projects and there will exist an improved retail turn over thereby moving development into other surrounding areas and increasing built up areas (Biney & Boakye, 2021). Wang, Zeng, Wang, Gu & Chen (2024) noted that the continuation urban expansion has be attributed to creating a huge challenge for climate change

mitigation. This factor satisfies the findings of Ahn and Juraev (2023) where real-life contexts should be studied to gain insight into spatial patterns and factors that influence location of economic activities.

However, the second factor which is the economic indicators are equally important for commercial Land Use decision. Such factors include demand and prevailing market trends, general competitiveness, growth in rental rates, yield rates /rate of return, finances etc. Commercial properties within these areas yield more income as a result of demand. Physical characteristics in terms of infrastructure, good roads, parking space, good drainage as well as electricity is also a major contributory factor for commercial land use decisions in the study. The physical characteristics influences the demand for this use. The physical characteristics in this case for the property owners are infrastructure. Good access roads, regular electricity supply are the major infrastructure that influence their decision. To them, the topography terrain and so on has little or no impact in their choice of using the area for commercial purposes. The legal factors and commercial agglomeration contribute very little to this decision. For the legal factor, once they are able to settle planning regulators commercial activities can take place. These factors increase the value of commercial land uses (Abbas, Musa & Adefila, 2017).

Conclusion and Recommendations

There are many factors that may have an impact on the choice of commercial Land Use but however within our study, five major indicators were established to influence commercial Land Use decision, and these factors vary with their sub-factors. In the Study above, five major factors were identified to influence commercial Land Use decision in the Study Area, and these included their sub-factors. These five major factors were categories into: Physical characteristics which includes infrastructure, location factor, legal factors including government policy, Economic factors including demand and trends, finances etc, and lastly commercial agglomeration. These factors can be considered in policy decisions and property investment decisions specially to curb carbon emission as a way of mitigating climate change impacts.

We have learned from the study that the location of the property is not the only factor affecting the choice of commercial Land Use but economic activities which includes demand and the prevailing trends which are also among the major identified factors to consider before investing in commercial Land Use. However, Further studies is needed to validate this study. Policy reforms such as the use of densification in commercial land uses to reduce urban expansion and its attendant problems especially carbon emissions and climate change.

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An Assessment of Risk Factors and their Impact on the Overall Cost and Completion Time of Road Projects

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Abstract

Unforeseen or uncertain events and their exposure in a project are consequential or risky to effective project delivery. The importance of road infrastructure to the economic and social wellbeing of the community, state and nation though noteworthy, risk factors and their impact on road construction projects are a cause for concern. This study examines the inherent risk factors associated with road projects, their severity and influence on both the overall cost and duration of the project. Particularly, Rivers state, Nigeria, road projects were the primary focus. The survey research method was used for the study with data collected through a questionnaire distributed to professionals involved in road construction projects comprising highway engineers, cost engineers/Quantity surveyors, road Project Managers, road construction engineers, technicians and skilled workers within the Rivers State ministry of works and Transport. Through descriptive analysis of data, the findings of the study reveal notably that both financial and socio-political risks emerge as key determinants significantly impacting construction costs of road projects. Socio-political and technical risks also prove to be key determinants significantly impacting construction time of road projects. The study emphasises how different risk categories, such as technical, environmental, financial, socio-political and regulatory/external concerns, have a notable connection with project cost and time. The study concludes that there is a greater chance of project delays when these risk factors are present at higher levels, highlighting the importance of effective risk management techniques.

Keywords: Road Projects, Risk Factors, Impact, Cost and Time

Introduction

Consequences of unforeseen or uncertain events and its exposure in a project is risk. Project Management Institute (2016) defined risk as 'an uncertain event' or condition that, if it occurs, will have either a positive or negative effect on one or more of the project's objectives of cost, time, scope and quality. In a project generally, risk is considered via its chance, scope and direct effect of occurrence. Viewing these three dimensions of risk in two channels there is the probability of risk occurrence/impact of occurrence, and the range of risk occurrence/the impact of occurrence. Adams (2006) referred to the first as subjective risk and the second objective risk.

Worldwide, construction projects entail a variety of risks which can arise at any point in the construction project life cycle, from the design and development stage to the end. In construction projects, risks are inevitable and frequently result in overspending, lower project quality, delays in completion and impair teamwork. Road construction projects are by their very nature complicated, involving a number of parties, scarce resources, and uncertainties. In order to assure the effective completion of a project, road construction risk management is necessary as a methodical procedure that involves finding, analysing, evaluating, and minimising potential risks. Proactively addressing obstacles, reducing adverse effects, and optimising project results are all made possible by efficient risk management for project teams.

There are several instances of projects failing to meet deadlines, budgets, or quality standards because risk management strategies were not used in the project management process. Thus, the ability of each partner to manage risk would determine the success criteria of a construction project, which include timely completion, staying within the allocated budget, and attaining the necessary performance (Perera, 2009). All parties involved—clients, contractors, architects, quantity surveyors, engineers, investors, and financial institutions—face increased risk due to the increase in complexity of construction and engineering projects.

This study is unique in the sense that no known research in the area of risk factors and impact on road projects covering Rivers State of Nigeria has been carried out so far. Therefore, by identifying and assessing the risk factors influencing road projects in Rivers State, Nigeria, this study seeks to fill the identified vacuum in literature. The research area was chosen due to the significant amount of road developments in the area at the time of the investigation.

Aim of the Study

The study aims at assessing the risk factors and their impact on the overall cost and completion time of road projects in Rivers State, Nigeria, in order to enhance road projects' performance in terms of project duration and cost.

Objectives of the Study

The specific objectives are to:

1. Identify the various risk factors associated with road projects.
2. Determine the effect of risk factors on the cost of road projects in the study area.
3. Determine the effect of risk factors on completion time of road projects in the study area.

Literature Review

Road Project Risks

Public infrastructure, or physical facilities or structures in areas like transportation, energy, telecommunications, social services, and basic utilities, is one of the many aspects of government ventures or activities that support the country's economy (Beals, 2020). Thus, road infrastructure is a means of supporting successful economic activities. Road projects need careful planning and wellcoordinated implementation because they are capital-intensive with interwoven and complex activities that spell risks and uncertainties. It is desirable to understand and identify such risks as early as possible, so that suitable strategy action can be taken to control any likely negative effect. Generally, risks are expressed in terms of occurrence probability and its consequences, or impact on output of a project. For any event to be taken as a potential risk factor, it must have a probability of occurrence between 0 and 1, which explains to what extent the risk event is likely to occur. Road projects are exposed to various risks that can impact their successful delivery, budget, schedule, and safety, and understanding and managing such risks are crucial for ensuring the efficient development of transportation infrastructure. Dalal (2011), Akintoye and MacLeod (1997), indicated that road projects are exposed to diverse risks throughout their lifecycle. These risks are broadly classified into technical, financial, environmental, socio-political, regulatory and external factors.

Technical risks in road construction refer to uncertainties and challenges related to the engineering and construction aspects of the project. Examples are: design errors, construction method risk, material quality issues, geotechnical risks, use of new technologies, utility conflicts, complex intersections, road drainage, and construction quality control. **Financial risks** in road construction refer to uncertainties and potential events that can impact the project's budget, funding, and overall financial performance. Examples are: cost overruns, funding uncertainties, currency fluctuations, cost estimation errors.

Environmental risks in road construction refer to potential adverse impacts on the natural environment and ecosystems due to construction activities. Examples are: Habitat destruction and biodiversity loss, soil erosion and sedimentation, air pollution and greenhouse gas emissions, noise and vibration andwaste generation and disposal. **Socio-political risks** in road construction refer to uncertainties and challenges related to community engagement, public acceptance, and government policies. Examples are: community opposition and protests, stakeholder conflicts, land acquisition and resettlement, indigenous rights and cultural heritage, government policies and approvals.

Regulatory and external risks in road construction pertain to uncertainties and challenges arising from changes in government regulations, compliance requirements, and external 25 factors beyond the project's control. Examples are: changes in government policies, permitting and approval delays, economic and market fluctuations, natural disasters and extreme weather events, force majeure events.

Impact of Risks on Road Projects

Numerous studies have examined the impact of risks on road projects and have highlighted their potential consequences to be significant, affecting various aspects of the project's execution, performance, and outcomes. These impacts may include delays, cost overruns, safety hazards, and reduced quality. Addressing and mitigating these risks are essential for ensuring the successful completion of road projects. Here are some key impacts of risks on road projects: *Project Delays* - Risks such as unfavourable weather conditions, permitting delays, or unexpected site conditions can lead to project schedule disruptions and delays in road construction. *Cost Overruns* - Unforeseen events, changes in scope, or fluctuations in material and labour costs can lead to cost overruns in road projects, impacting the project's budget. *Safety Incidents* - Risks related to inadequate safety measures, equipment failure, or human error can result in accidents, injuries, and safety hazards during road construction. *Quality Issues* - Technical risks and inadequate quality control can lead to construction defects and compromised road quality, requiring additional corrective measures. *Stakeholder Dissatisfaction* - Social risks and conflicts with stakeholders can result in community opposition, protests, and dissatisfaction, affecting project acceptance and support. *Environmental Impact* - Failure to address environmental risks can lead to adverse impacts on the natural environment, including habitat destruction and pollution.

Empirical Literature

Leo-Olagbaye and Odeyinka (2020) carried out an assessment study of risk impact on road projects in Osun State, Nigeria. The findings showed that political and economic variables have a greater order of impact on scope creep and design difficulties, which are key risk concerns for road projects. It also illustrated how risk impact on time and cost performance of road projects might be modelled utilising important risk indicators. In the study using the survey method by Oluwajana, Ukoje, Okosun and Aje (2022) on the factors affecting time and cost performance of road construction projects in Nigeria, result of the study found that the key elements influencing the timely completion/performance of road building projects in Nigeria were inadequate equipment, inadequate managerial skills, project construction complexity, equipment failure, and shortage of materials. In contrast, inflation, imprecise estimates, dishonest business practices, inexperienced contractors, poor planning, and overdesign were the main factors affecting cost performance.

After looking at the risk response strategies used for large projects, Baker *et al.* (1999) came to the conclusion that the construction industry focuses nearly solely on lowering financial risk. Perera (2009) evaluated risk in civil engineering construction as well. They determined the contractual parties' risk duties to enhance their risk management techniques; however, their research was restricted to Sri Lankan road building.

Ammar, Abdel-Monem, and El-Dash (2022) carried out a survey to identify the most important variables influencing the cost overrun for road network development projects. The findings indicated that erroneous cost estimates, design modifications, quantity adjustments, variation orders, political meddling, inflation, specification changes, and changes in the work's scope are the primary causes of cost overruns. In their study towards identification of risk factors influencing time and cost of Highway construction projects in Malaysia, Bakri, Ab. Razak and Abd. Shukor (2021) used the survey method and found out that construction risks and financial risks are the most often occurring in highway projects. Service relocation, removal/ replacement of material and design changes were key factors influencing cost while permit approval, weather condition and low workers' productivity are key

influencers of project time.

Analysis of the questionnaire survey data collected and analysed by Anigbogu, Ahmad and Molwus (2019) showed that Inflation, fluctuation, exchange rate, changes in policies, variations, inaccurate cost estimates, and design changes were the 5 most significant causes of road construction projects' cost overruns in Federal Capital Territory (FCT) Abuja, Nigeria. LeoOlagbaye and Odeyinka (2018) evaluated risk factors and their effects on road projects. The study's findings showed that the risk factors that occur most frequently are scope changes, poor design, error and rework, design modifications, delays in receiving design details, and unanticipated unfavourable circumstances. Remarkably, according to the analysis's outcome, the risk factors that rank highest do not necessarily have the greatest impact - political as well as economic issues impact much more on the delivery of road projects in Nigeria.

Research Methodology

This study was undertaken within Rivers State, Nigeria. Data sets were collected from 65 participants, comprising highway engineers, cost engineers/Quantity surveyors, road Project Managers and road construction engineers and skilled workers through closed-ended structured questionnaires. However, 54 questionnaires were returned and validated for the study. Purposive sampling was used to select the respondents, allowing the researcher to get all relevant data. The questionnaire focused on collecting quality demographic information on issues relating to the research objectives which are: to identify and assess the risk factors inherent in road projects and to determine the effect of these risk factors on total cost and completion time of road construction projects in the study area.

The questionnaire was designed using a five-level Likert scale: (1) strongly disagree, (2) disagree, (3) neither agree nor disagree, (4) agree; (5) strongly agree. Descriptive analysis was used to produce results.

The response categories are in the order of Very High (VH) = 5, High (H) = 4, Moderate (M) = 3, Low (L) = 2 and Very Low (VL) = 1. All responses with mean value (x) between 1-2 taken as being very low, 2-2.49 as being low, 2.5-3.49 as being moderate, 3.5 – 4.49 as being high and 4.5 above as being very high.

Weighted Mean (x) is calculated as follows:

$$X = \frac{\Sigma R_1(VH)x5 + R_2(H)x4 + R_3(M)x3 + R_4(L)x2 + R_5(VL)x}{\Sigma R_T} \quad (1)$$

Where:

$\mathbf{R_{1\text{-}5}}$ - are the number of responses on each scale rating of Very high (VH), High (H), Moderate (M), Low (L) and Very low (VL).

$\mathbf{R_T}$ - is the total responses received (i.e. 54).

Data Presentation, Analysis and Discussion of Results

Following the administration and subsequent collection of responses, the following are the result and interpretation. Table 1 shows the administration of questionnaire and response rate calculated.

Table 1: Questionnaire Response Rate

Variable	Number of Respondents	Percentage (%)
Questionnaire returned	54	83.08%
Questionnaire not returned	11	16.92%
Total	**65**	**100**

As indicated in table 1**,** 65 questionnaires were administered to the various categories of respondents, 54 questionnaires were duly answered and returned. A total of 6 questionnaires were not returned. The total responses yielded the response rate of 83.08%. The entire respondents were residents of Port Harcourt, the capital city of Rivers State.

Table 2: Academic Qualifications

Qualification	OND	HND	B.Sc/B.Tech	M.Sc/M.Tech	Ph.D
Frequency	1	4	28	17	4
Percentage %	1.85	7.41	51.85	31.48	7.41

Table 2 shows that 50% of the respondents have a minimum of B.Sc/B.Tech degree in courses relevant to the construction industry.

Table 3: Category of Professionals

Professional Category	Frequency	Percentage (%)
Highway engineers	8	14.81
Cost engineers/ Quantity Surveyors	20	37.04
Road Project Managers	14	25.93
Road Construction Engineers	10	18.52
Skilled Workers	2	3.70
Total	**54**	**100**

From table 3, highway engineers have 14.81% responses, 37.04% of the respondents are cost engineers/ Quantity surveyors, 25.93% of the respondents are road project managers, 18.85% of the respondents are road construction engineers while 3.7% of the respondents are skilled workers. As indicated in the table, the majority of the respondents are Cost engineers/ Quantity Surveyors followed by project managers and construction engineers.

Table 4: Size of Road Construction Organization Worked with

Size of Organization	Frequency	Percentage (%)
Small size organization	5	9.26
Medium size organization	29	53.70
Large size organization	20	37.04
Total	**54**	**100**

Table 4 shows that 53.7% of the respondents worked in a medium size and 37.04% in large size organization that is related to road construction.

Table 5: Respondents Years of Experience

Years of Experience	Frequency	Percentage (%)
1-5 years	5	9.26
6-10 years	14	25.93
11-15 years	22	40.74
16 and above	13	24.07
Total	**54**	**100**

As indicated in table 5, 9.26% of the respondents have 1-5 years of experience, 25.93% have 6-10 years of experience, 40.74% have 11-15 years of experience and 24.07% have 16 and above years of experience. It is evident that the bulk respondents have above average experience.

Analysis of Risk Factors in Road Projects

Table 6: Mean Score ratings of respondent's responses on technical risk factor(s) in road projects.

S/N	Technical Risk factors in road Projects	VH	H	M	L	VL	X	Rank
a.	Design Errors	4	18	28	3	1	3.39	5
b.	Construction Method risk	11	16	21	6	0	3.59	2
c.	Materials quality issues	1	19	30	4	0	3.31	7
d.	Geotechnical Risks	3	39	8	4	0	3.76	1
e.	Complex Intersections	4	13	28	8	1	3.06	8
f	Use of New Technology	10	16	21	6	1	3.52	3
g.	Utility Conflicts	0	15	10	9	20	2.37	9
h	Road drainage	6	17	27	2	2	3.43	4
i	Construction quality control	20	6	8	11	9	3.32	6

Table 6 shows the mean score rating of respondents on the technical risk factors in road projects. The data in the table revealed that the most common technical risk factor inherent in road projects is Geotechnical Risks; rating (mean = 3.76). The second highest technical risk factor that was discovered from the findings to be inherent in road project is Construction method risk; rating (3.59), followed by use of new technology; rating (3.52) while other Technical risk factors, which includes Road drainage rating (Mean = 3.43), Design Errors, rating (3.39); Construction quality control, rating (mean = 3.32); Materials quality issues, rating (mean = 3.31) and Complex Intersections, rating (mean = 3.06) was found to have moderate inherent level in road projects in Rivers State.

Table 7: Mean Score Ratings of Respondent's Responses on Financial Risk Factor(s) in Road Projects

S/N	Financial Risk Factors in Road Projects	VH	H	M	L	VL	X	Rank
a.	Cost overruns	18	16	16	3	1	3.87	1
b.	Funding uncertainties	11	16	21	6	0	3.59	3
c.	Currency fluctuations	1	19	30	4	0	3.31	4
d.	Cost Estimation Accuracy	15	20	8	6	5	3.63	2

Table 7 shows the mean score rating of respondents on the financial risk factors in road projects. The data in the table revealed that the most common financial risk factor in road projects is cost overrun; rating (mean = 3.87). The second highest financial risk factor that was discovered from the findings to be inherent in road project is Cost Estimation Accuracy; rating (3.63), follows by funding uncertainties; rating (3.59) while other financial risk factors, which includes Currency fluctuation; rating (mean = 3.31) was found to have moderate inherent level in road projects in Rivers State.

Table 8: Mean Score Ratings of Responses on Environmental Risk Factors in Road Projects

S/N	Environmental Risk Factors in Road Projects	VH	H	M	L	VL	X	Rank
a.	Habitat Destruction and Biodiversity	28	11	10	3	2	4.11	1
b.	Soil Erosion and Sedimentation	16	11	21	6	0	3.69	3
c.	Air Pollution and Greenhouse Gas Emissions	1	19	30	4	0	3.31	5
d.	Noise And vibration	7	35	8	4	0	3.83	2
e.	Waste generation and Disposal	13	8	28	4	1	3.52	4

Table 8 shows the mean score rating of respondents on the Environmental risk factors in road projects. The data in the table revealed that the most common Environmental risk factor in road projects is Habitat Destruction and Biodiversity; rating (mean = 4.11). The second highest factor that was discovered from the findings to be inherent in road project is Noise and vibration; rating (3.83), followed by Soil Erosion and Sedimentation; rating (3.69) while other Environmental risk factors, which includes Waste generation and Disposal; rating (3.52) and Air Pollution and Greenhouse Gas Emissions, rating (3.31) was found to have moderate inherent level in road projects in Rivers State.

Table 9: Mean Score Ratings of Responses on Socio-Political Risk Factors in Road Projects

S/N	Socia-Political Risk factors in Road Projects	VH	H	M	L	VL	X	Rank
a.	Community Operation and protests	24	9	15	4	2	3.91	1
b.	Stakeholder Conflicts	14	10	26	3	1	3.61	2
c.	Land Acquisition and Resettlement	1	19	30	4	0	3.31	5
d.	Indigenous Rights and Cultural heritage	16	11	14	8	5	3.46	4
e.	Government Policies and Approvals	13	8	28	4	1	3.52	3

Table 9 shows the mean score rating of respondents on the Socio-Political Risk factors in road projects. The data in the table revealed that the most common Socio-Political Risk factor in road projects is Community Operation and protects; rating (mean = 3.91). The second highest factor that was discovered from the findings to be inherent in road project is Stakeholder Conflicts; rating (3.61), followed by Government Policies and Approvals; rating (3.52) while other Socio-Political Risk factor, which includes Indigenous Rights and Cultural heritage; rating (3.46) and Land Acquisition and Resettlement, rating (3.31) was found to have moderate inherent level in road projects in Rivers State.

Table 10: Mean Ratings of Responses on Regulatory and External Risk Factors in Road Projects

S/N	Regulatory and External Risk Factors in road Projects	VH	H	M	L	VL	X	Rank
a.	Changes in Government Policies	20	9	11	9	5	3.56	2
b.	Permitting and Approval delays	11	6	26	6	5	3.22	4
c.	Economic and Market Fluctuations	8	17	25	4	0	3.54	3
d.	Natural Disasters and Extreme weather events	21	12	13	5	3	3.80	1

Table 10 shows the mean score rating of respondents on the Regulatory and External risk factors in road projects. The data in the table revealed that the most common Regulatory and External risk factors in road projects are Natural Disasters and Extreme weather events; rating (mean = 3,80). The second highest factor that was discovered from the findings to be inherent in road project is Changes in Government Policies; rating (3.56), followed by Economic and Market Fluctuations; rating (3.54) while other Regulatory and External risk factors, which includes Permitting and Approval delays; rating (3.22) was found to have moderate inherent level in road projects in Rivers State.

Summary Analysis of Group Risk Factor(s) in Road Projects

Table 11: Mean Score Ratings of Respondent's Responses on the Group Risk Factor(s) Inherent in Road Projects

Risk Factors in Road Projects	VH	H	M	L	VL	X	Rank
Technical Risks	2	19	29	3	1	3.33	4
Financial Risks	5	18	24	6	1	3.37	2
Environmental Risks	1	19	30	4	0	3.31	3
Socio-political Risks	3	39	8	4	0	3.76	1
Regulatory and External Risks	0	16	29	9	0	3.13	5

Table 11 shows the mean score rating of respondents on the group risk factor(s) inherent in road projects. The data in the table revealed that the most common risk factor inherent in road projects is Socio-political risks; rating (3.76). This risk factor was found to have high inherent level in road projects, while other risk factors, which includes Financial risks; rating (3.37), Technical Risks; rating (3.33), Environmental Risks; rating (3.31) and Regulatory/External risks rating (3.13) was found to have moderate inherent level in road projects in Rivers State.

Summary Analysis of Individual Risk Factor(S) in Road Projects (Without Respect to Group)

Table 12: Mean Score Ratings of Respondent's Responses on the Individual Risk Factor(s) Inherent in Road Projects

S/N	Risk Group	Risk factors in road Projects	X (Mean Score Rating	Ranking
1.	Environmental	Habitat Destruction and Biodiversity	4.11	1
2.	Socia-Political	Community Operation and protests	3.91	2
3.	Financial	Cost overruns	3.87	3
4.	Regulatory and External	Natural Disasters and Extreme weather events	3.80	4
5.	Technical	Geotechnical Risks	3.76	5

Table 12 shows the mean score rating of respondents on the individual risk factor(s) (without respect to group) inherent in road projects. The data in the table revealed that the most common risk factor inherent in road projects is Habitat Destruction and Biodiversity risks (Environmental risk group); rating (4.11). This risk factor was found be the highest inherent in road projects, while other risk factors, which includes Community Operation and protests risks (Socia-Political risk group); rating (3.91) and Cost overruns risks (Financial risk group); rating (3.87), are the second and third.

Analysis of the Effects (impact) of Risk Factors on the Construction Cost of Road Projects
Table 13: Mean Score Ratings of Respondent's Responses on the Effects (Impact) of Group Risk Factors on the Construction Cost of Road Projects

Risk Factors in Road Projects	VH	H	M	L	VL	X	Rank
Technical Risks	2	25	21	4	2	3.39	3
Financial Risks	8	24	17	5	0	3.65	1
Environmental Risks	0	18	30	6	0	3.22	4
Socio-political Risks	2	35	9	8	0	3.57	2
Regulatory and External Risks	0	18	20	16	0	3.04	5

Table 13 shows the mean score rating of respondents on the impact (effect) of risk factor(s) on the construction cost of road projects. The impact is a positive one, meaning that initial construction cost is overrun. The data in the table revealed that Financial risks and Socio-political risks; rating (3.65 and 3.57) were found to have high impact on the construction cost of road projects. Other risk factors which include Technical risks; rating (3.39), Environmental risks; rating (3.22) and Regulatory/External risks; rating (3.04) were found to have moderate impact on the cost of road projects in Rivers State.

Analysis of the Effects (Impact) of Risk Factors on the Completion Time of Road Projects
Table 14: Mean Score Ratings of Respondent's Responses on the Effects (Impact) of Group Risk Factors on the Completion Time of Road Projects

Risk Factors in Road Projects	VH	H	M	L	VL	X	Rank
Technical Risks	7	28	15	2	2	3.67	2
Financial Risks	5	26	20	3	0	3.61	3
Environmental Risks	1	22	24	7	0	3.31	5
Socio-political Risks	3	38	10	3	0	3.76	1
Regulatory and External Risks	6	25	18	4	1	3.57	4

Table 14 shows the mean score rating of respondents on the impact (effect) of group risk factor(s) on the completion time of road projects. The impact is a positive one, meaning that initially planned construction duration is exceeded. The data in the table revealed that Socio-political, Technical, and Financial risks, ratings (3.76, 3.67, and 3.61) were found to have high impact on the completion time of road projects. Other risk factors which include Regulatory/External and Environmental risks; rating (3.57 and 3.31) was found to have moderate impact on the completion time of road projects in Rivers State.

Overall Findings

The data analysis revealed that road projects face a wide range of risks, including technical, financial, environmental, socio-political, regulatory and external factors. Most common risk factors inherent in road projects in Rivers State were revealed to be **socio-political risks** which include: community operation and protests, stakeholder's conflicts, land acquisition/resettlements, indigenous rights/cultural heritage, government policies and approvals. Socio-political risk risks were found to be highly inherent (always likely to occur or has higher probability of occurrence) in road projects in the study area.

The study also revealed that the risk factor that has the highest effect (impact) on the construction cost of road projects in Rivers State is **financial risk** factors which include: Cost overruns, funding

uncertainties, currency fluctuations, cost estimation accuracy etc. and Socio-Political risk factors which includes; Community operation and protests, stakeholder's conflicts, land acquisition/resettlements, indigenous rights/cultural heritage, government policies and approvals etc.

The factor with the highest impact on the construction completion time of road projects in the study area was found to be **socio-political risk factors** which include: Community operation and protests, stakeholder's conflicts, land acquisition/resettlements, indigenous rights/cultural heritage, government policies and approvals. This is followed by *technical risk* factors which includes; design error, construction method risk, materials quality issues, geotechnical risks, use of new technology, utility conflicts, complex intersections and construction quality control etc. Third in the line was *financial risk* factors which include: change in government policies, permitting and approval delays, economic and market fluctuations, natural disasters, extreme weather events etc., were revealed to have high impact on construction cost.

Conclusion and Recommendations

As seen from the data analysis, discussion and findings in this chapter it is thus concluded that the risk factors inherent in road projects in Rivers State are Socio-political risks. Financial and Sociopolitical risks also, are the risk factors that can highly negatively impact the construction cost of road projects in Port Harcourt. Furthermore, the project duration (completion time) depends on the level of Socio-political, technical and financial risk factors involved in the project. Thus, the higher the level of these risks' factors, the higher the likelihood or probability of not completing the project within the specified time frame and vice versa. On the basis of individual risks without respect to risk groups, Habitat Destruction and Biodiversity, Community Operation and protests and Cost overruns are risks top on the chart.

The recommendations here are aimed at addressing the identified challenges and improve the effectiveness of risk assessment and management in road construction projects. By implementing these recommendations, project stakeholders can enhance their ability to proactively identify analysis and respond to risks that will ultimately lead to improved project success and the successful delivery of road infrastructure projects. Hence, the following recommendations are proposed for enhancing risk management.

1. Foster a culture of risk awareness and engagement: It is essential to foster a culture of risk awareness and engagement among project stakeholders. This involves promoting open communication and collaboration among all parties involved in the road project, including training sessions that can help stakeholders understand the importance of proactive risk identification and analysis, encouraging them to actively participate in risk management activities.
2. Socio-political laxities which include; community operation and protests, stakeholder's conflicts, land acquisition/resettlements, indigenous rights/cultural heritage, government policies and approvals, should be carefully managed by government as much as possible as these form major risk factors to effective road construction in Rivers State. Government and road project contractors should also ensure that financial activities of road construction are planned and managed properly as financial risk is the second prominent risk factor from the findings of this study. These two factors, financial, followed by socio-political, are also the major factors in negatively affecting the overall cost of road projects.
3. Technical risk factors which include design error, construction method risk, materials quality issues, geotechnical risks, use of new technology, utility conflicts, complex intersections, road drainage and construction quality control, should be notably managed by the road construction technical team as these negatively affect the completion time of road projects.
4. Considering individual risks without respect to risk groups, road construction experts should note the positive impacts of Habitat Destruction and Biodiversity, Community Operation and protests and Cost overruns risks on road projects and plan and manage them decisively.

5. Develop comprehensive risk register: To effectively manage risks in road projects, it is crucial to develop comprehensive risk registers that encompass all potential risk categories and their respective response plans. The risk register should be regularly updated and shared with all relevant stakeholders. This proactive approach will enable project teams to be well-prepared to address emerging risks and make informed decisions throughout the project lifecycle.
6. Conduct regular risk assessment and monitoring: To stay ahead of potential risks, projects teams should conduct regular risk assessments and monitoring. This allows project managers to identify emerging risks promptly and implement appropriate risk response strategies. Regular update to risk registers and risk profiles ensure that the risk management process remains relevant and effective throughout the project lifecycle.
7. Strengthen collaboration and communication: Effective risk management relies on strong collaboration and communication among project stakeholders. Project managers should establish clear channels of communication to facilitate the sharing of risk-related information and updates. Regular meetings and progress reviews can help identify potential risks early and foster a collective understanding of risk management goals and strategies.

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Conceptual Review of the Application of Geomatics Techniques in Environmental Management

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Abstract

The increasing occurrence of environmental-related issues (such as geo-hazards dynamics, desertification, deforestation, wind and soil erosion, flooding, land degradation through oil spills, water, and air pollution, etc. are of great concern to managers of the environment. The mechanism for the management, protection, preservation, and upgrading of the delicate environmental structure is an issue of global concern that requires the collaborative effort of all environmental stakeholders, and the integration of different environmental management techniques and instrumentation. The application of Geomatics techniques has brought to the fore this critical component of environmental management capabilities. Geospatial and Geological data, Digital maps, and terrain models are critical resources and of uttermost importance in the proper management and protection of the built environment. These modern technological applications such as Global Navigation Satellite Systems (GNSS), Geospatial Information System (GIS), and Remote Sensing has proved to be a veritable tool in the management and studies of these critical menace of environmental conditions. The thrust of this research therefore is to highlight specific environmental problems and the conceptual review of the application of modern techniques of geomatics in the study and management of these environmental challenges. We relied on the theoretical and operational framework of some of these modern surveying technologies such as Global Positioning System (GPS), GIS, and Remote Sensing for environmental change detection, assessment, protection, and management. The conceptual exposition of these phenomena demonstrates the indispensable application of Geomatics techniques in environmental management. The need to have the required National Geodetic infrastructure and continuous mapping of our environment will remain imperative and critical for sustainable environmental management for national development.

Keywords: Geospatial Data, Remote Sensing, GPS, GIS, Environmental Management

Introduction

The environment provides all life support systems with air, water, and land as well as the materials for fulfilling all development aspirations of man. As in most countries of the word, the environmental condition of Nigeria currently presents a grim litany of woes (Hart, 2008). The environment has different meanings or connotations and is often used in different ways by different disciplines. However, it suffices to say that it has physical, social, cultural, and even technological dimensions. Therefore, the environment can be seen to be the total of all surroundings of living organisms, including natural forces and other living things, which provide conditions for development and growth as well as danger and damage. The environment constitutes the complex interaction of physical, social, cultural, economic, and aesthetic which affect individuals and communities and ultimately determine their form, character, relationship, and survival (Ayeni, 2001; Bassey, 2003).

The Oxford Advanced Learner's English Dictionary defines environment as conditions, circumstances, affecting people's lives. It is the complex of physical, chemical, and biotic factors that act upon an organism or an ecological community and ultimately determine its form and survival (Encyclopedia Britannica, vol. 4). In his view, Haggat (1975) defines environment as the total of all conditions that surround man at any point in time on the surface of the earth. Schultz (2005), defined the environment as the sum of all external conditions affecting the life, development, and survival of an organism. For a given system, the environment is the set of all objects, a change in whose attributes are changed by the behavior of the system. The environment is, therefore, not static and can be considered to be an integration of some systems. Any interface with any part of the system affects the entire system

and the system responds to it (Eugene, 2007). Mapping the environment has always been an intricate exercise in the face of its changing nature and attributes through climate change, geodynamical phenomena, and human and anthropogenic activities with emerging challenges in methodology, instrumentation, and skill gap required (Hart, *et al.,* 2019).

Environmental management is not, as the phrase could suggest the management of the environment as such, but rather the management of the interaction by the modern human societies with, and impact upon the environment. According to (Uchegbu, 2002), "Environmental management is the process of putting together those items of an environmental nature where man exists so that man's penetration and exploitation do not have adverse effects on the environment". The process of environmental management involves the systematic data collection premised on unique data analysis to depict attribute changes with respect to time. Geomatics techniques include the use of various tools, equipment, processes, and methods to collect, analyze, and visualize spatial data related to the environment and its associated changes. Geospatial and geological data, digital maps, and terrain models are critical resources and of uttermost importance in the proper management and protection of the built environment. Modern surveying technologies have made it imperative for its compliance by geomatics experts, this is due to its versatility and ability to integrate and manipulate large volumes of geospatial data from various sources and formats. These modern technological applications such as GNSS, GIS, and Remote Sensing have proved to be a veritable tool in the management and studies of these critical menace of environmental conditions.

National Environmental Problem

Every state of the Nigerian federation suffers from one form of environmental problem or the other in varying degrees. The northern part of the country is blown away by the wind erosion while the southern part is inundated with soil erosion and flooding. Wind erosion can be quite severe in states such as Sokoto, Zamfara, Kebbi, Kastina, Kano, Jigawa, Borno, and Yoba. Farmlands become inundated by drifting dunes that bury young crops. Roads, huts, and public buildings may be completely buried by active dunes rising sometimes up to 12 meters high (Hart, 2008). Similarly, soil erosion and flooding adversely impact the southern and eastern states of the country with great economic burden on the populace. A brief review of some of the environmental problems associated with states of Nigeria.

Desertification and Drought: Desertification entails the formation and expansion of degraded areas of soil and vegetation cover in arid, semi-arid, and seasonally dry areas, caused by climatic variations and human activities (Wright & Nebel, 2002). It involves denuding and degrading a once fertile land, initiating a desert-producing cycle that feeds on itself, and causing long-term changes in the soil, climate, and biota of an area (Cunningham & Cunningham, 2006). Population pressure, overgrazing and the continuous exploitation of marginal lands have aggravated drought and desertification. Nigeria is presently losing about 315,000 square kilometers of its land mass to the desert which is advancing southward at the rate of 0.6 kilometers per year (Ibrahim *et al.,* 2022). According to a recent survey by the Center for Arid zones studies in Nigeria, desertification is by far the most pressing environmental problem in the northern state of Niger Republic border (Haruna & Bukar, 2010). Entire villages and major access roads have been buried under sand dunes in the northern portions of Katsina, Jigawa, and Borno states. With about 55 percent of its land under siege from desert encroachment, Borno state which suffered from a protracted fifteenyear drought in 1972-1978, is one of the most threatened land areas of Nigeria (Ibrahim, et al 2022). Perhaps more spectacular, and of grave consequence are the persistent droughts which, many times, have resulted in famines in the northern part of the country. During the drought of 1972-1973 for instance, about 300,000 animals died and farm yields dropped by up to 60% (Haruna & Bukar 2010, Ibrahim *et al.,* 2022).

Land Degradation: Land degradation is one of the worst environmental problems facing many people worldwide. Over 40 million are affected in Nigeria. This has led to food shortages and health problems in Nigeria (Uchegbu, 2002). Land degradation involves a wide array of natural and human-induced factors affecting the productivity of land. These factors can exist in various non-unique and complex

combinations of different environmental settings, making detection and monitoring of land degradation an often-difficult undertaking. In other to reduce its rates of encroachment, this phenomenon should be assessed and qualified to identify the causes, processes, and factors leading to land degradation. In Nigeria, land degradation mainly results from the issues of deforestation, accelerated soil erosion, declining soil fertility, the increased incidence of flooding, soil and water pollution and contamination, and oil spillage, (Hart & Basil, 2018).

Erosion: Gully erosion is particularly severe in Abia, Imo, Anambra, Enugu, Ondo, Edo, Enugu, Ondo, Edo, Ebonyi, Kogi, Adamawa, Delta, Jigawa and Gombe States. Anambra and Enugu state alone have over 50 active gully complexes, with some extending over 100 meters long, and 20 meters wide. A geospatial baseline Assessment of the impact of Gully erosion and Geological changes in selected locations of the South East Region of Nigeria reveals that the total area of 6.969 Hectares and 22.485 hectares of land has been claimed by gully erosion in Nkpor and Obosi town in Anambra State (Hart and Basil, 2018). Coastal and Marine erosion and subsidence occur particularly in the coastal areas of Ogun, Ondo, Delta, Rivers, Bayelsa, Akwa Ibom, and Cross River States. The most significant case of coastal erosion and flooding is the overflow of the bar beach of the Atlantic Ocean now a regular feature since 1990, threatening the prime property areas of the Ahmadu Bellow Way, Victoria Island, Lagos (Hart, 2008).

Figure 1: Impact on Geological Changes in Ire-Obosi, Anambra State, Nigeria
Source: Hart & Basil, 2018

Deforestation: Forest clearance on a massive scale for agricultural development, urban growth, industrial expansion, and general pressure from increasing population have reduced the extent, diversity, and stability of Nigeria's forests. According to an estimate by the Food and Agricultural Organization (FAO 1983), Nigeria through circles of exploitation and husbandry, destroys rain forestation efforts of about 25% hectors a year and refurbishes about 4% of the loss. This constant deforestation attitude has caused the extinction of plants and animals in Nigeria (Uchegbu, 2002). Many of our cities are turning into concrete jungles where plants are no longer used for home landscaping. High-rise buildings and other commercial centers have displaced areas earlier earmarked as low-density residential areas in Ikoyi and Victoria Island. The new federal capital territory at Abuja is a pathetic example of this development where the rich and natural vegetation is being systematically depleted as a result of increasing human pressure. The rampant bush burning is threatening the growth of trees and wildlife species and reducing the ecological and diversity of the area.

Flooding: Flooding occurs throughout Nigeria in three main forms: coastal flooding, river flooding, and urban flooding. Coastal flooding occurs in the low-lying belts of mangrove and fresh water swamps along the coast. River flooding occurs in the flood plains of the larger rivers, while sudden, short-lived flash floods are associated with rivers in the land areas where sudden heavy rains can change them into destructive torrents within a short period. Urban flooding occurs in towns located on flat or low-lying terrain especially where little or no provision has been made for surface draining, or where existing drainage has been blocked with municipal waste, refuse and eroded soil sediments. Extensive urban flooding is a phenomenon of every rainy session in Lagos, Maiduguri, Aba, Warri, Benin and Ibadan. Virtually every Nigerian is vulnerable to disasters, natural or man-made. Every rainy season, wind gusts arising from tropical storms claims lives and property worth millions of Naira across the country. Flash floods from torrential rains wash away thousands of hectares of farmland. Dam bursts are common following such floods. In August 1988 for instance, 142 people died, 18,000 houses were destroyed and 14,000 farmers were swept away when the Bagauda Dam collapsed following a flash flood. Urban flooding such as the Ogunpa disaster which claimed over 200 lives and damaged property worth millions of Nigeria in Ibadan, are common occurrences (Hart, 2008). In recent years (2012, 2018, 2022), states in the northcentral regions and south-south states of the country have been affected by flooding due to increased intensity of rainfall and water discharge from various dams upstream.

Plate 1: Floods at Federal Road Safety Corps, Aba Road and Winners Church at Rukpokwu
Source: Authors

Modern Application of Geomatics in the Study and Management of the Environment

Surveying and mapping are traditionally concerned with the science and art of obtaining information about the relative position of points and spatial objects on, above, or below the surface of the earth or the sea; representing them in a usable format, charts, and maps (Atilola, 1994). This art of mapping is done by the Geomatics Specialist (the Surveyor). The Surveyor is concerned in knowing what (Object/s) is where (space) and when (time) using a field-based or an object-based concept of reality or real world" (Kufoniyi, 1997). The International Federation of Surveyors (FIG) by its latest definition defines "A surveyor as a professional person with the academic qualification and technical expertise to conduct one or more, of the following activities; to determine, measure and represent land, three-dimensional objects, point-fields and trajectories (on, above or below the surface of the earth or the sea), to assemble and interpret land and geographically (Spatially) related information, to use that information for the planning and efficient administration of the land, the sea, and any structure thereon; and to conduct research into the above practices and to develop them" (FIG, 2004 as in Fajemirokun, 2011).

Digital technology has changed the scope and mode of operation of the surveyors. As more intelligence is being built into geomatics equipment, most of the tedious and time-consuming data collection and analysis are now achieved easily. Consequently, geomatics techniques have provided an attractive

platform for the timeous provision of spatiotemporal information on the phenomena of study for the optimal use of allied professionals in the environment (Atilola, 2010). With the capabilities of the geomatics techniques and approaches to the practice of surveying and mapping, the role of a surveyor has been shifted from that of data collection to information management; from Land Surveying to Geomatics. Geomatics therefore is defined as a systemic, multidisciplinary, integrated approach to selecting the instruments and appropriate techniques for collecting, storing, integrating, modeling, analyzing, retrieving at will, transforming, displaying, and distributing spatially georeferenced data from different sources with well-defined accuracy characteristics, continuity and in a digital format (Mario, 2009). The traditional land surveyors have developed their skill in the management of geodata and he is now referred to as the
"Geomatician".

Geospatial information in whatever form is the sine qua non for development, and it has been confirmed that the best-mapped parts of the world are the most developed. Therefore, there can't be any meaningful development in any nation without adequate and up-to-date surveying (i.e. mapping). Most of the nations of the world have taken advantage of the recent developments in technological advances to produce much-needed maps both static and dynamic for optimal environmental management (Kassim, 1998).

Recent developments in computer capabilities, digital technology, and surveying instrumentation have revolutionized surveying and mapping practices, in a way that has never been seen before. Of particular interest are the developments of modern surveying equipment which are of great innovative design (Ndukwe, 2001). The major digital surveying technology and instrumentations systems used for the acquisition of geospatial data include but are not limited to the following;

1. Global Navigation Satellite Systems and Geospatial Information System
2. Remote Sensing and Digital Photogrammetry using Drone Technology
3. Total, Smart Stations, Robotics Equipment
4. Inertial Surveying System and Dead Reckonings
5. Digital Levels and
6. Laser-Based Surveying Instruments
7. Light Detection and Ranging (LiDAR) and high-resolution satellite imagery

Application of Global Navigation Satellite System and Geospatial Information System in Environmental Monitoring

Global Navigation satellite system is the generic name for a group of independent, although interoperable satellite navigation systems including the United States Global Positioning System (GPS), the Russian Federation Global Navigational Satellite System (GLONASS), Chinese Beidou satellite system, and the European Galileo satellite system, also included in the satellite navigation family are regional satellite systems such as the Japanese Quasi-Zenith satellite system, and the India regional satellite system (Hofmann-Wellenhof, Lichtenegger, and Walse, 2008). GNSS is a satellite-based positioning, navigation, and timing system that provides accurate 4-D information, anywhere, under any weather conditions (Ahmed El-Rabbany, 2002; Alfred, Lev, and Dmitry, 2015). Geospatial Information System (GIS) is a computerized system for capturing, storing, querying, analyzing, and displaying geospatial data (location-based data) (Chang, 2018). The interoperability of GNSS and GIS has proven to be a veritable tool in the real-time monitoring of environmental changes; resulting in accurate measurement, monitoring, and management of the natural environment. The ubiquitous application of GNSS and GIS for environmental management has given birth to a new field of "Environmental Geodesy" (Awange and Kiema, 2013), which can be argued as a branch of geodesy that applies geodetic techniques to monitor the environment and provide information that contributes towards effective management of the environment by supporting appropriate decision making. This is true since the primary task of geodesy is the measurement of the earth's surface parameter, and the temporal variation in this parameter as a function of time (Torge, muller, and Pail, 2023). Exhaustive treatment can be found in several geodetic literatures including e.g. (Blewitt, 2007; Awange and

Kiema, 2013; Yehuda and Diego, 2016; Jeff, 2017; Elgered and Wickert, 2017; Awange, 2018). The applications of GNSS/GIS in environmental management are further highlighted.

Atmospheric Sensing

GNSS signal propagated through the atmosphere is affected by signal refraction due to the ionosphere and the troposphere (Jonathan et al., 2016; Ogaja, 2022) as described in Figure 2. Although the keen interest of geodesists is in the estimation of ionosphere and tropospheric delay only to eliminate them to obtain accurate positions, meteorologists and environmental geodesists use these ionospheric and tropospheric delays for weather forecasting, climate studies (e.g., sea, land, and ice level changes), hazards predictions and early warning systems (Awange, 2018). The troposphere region extends about 50km from the earth's surface, it is divided into two components, the dry and the wet component. The dry component is a function of temperature, pressure, and humidity; the wet component is mainly a function of water vapor (Langley, 1998; El-Rabbany, 2002; Alfred, Lev, and Dmitry, 2015).

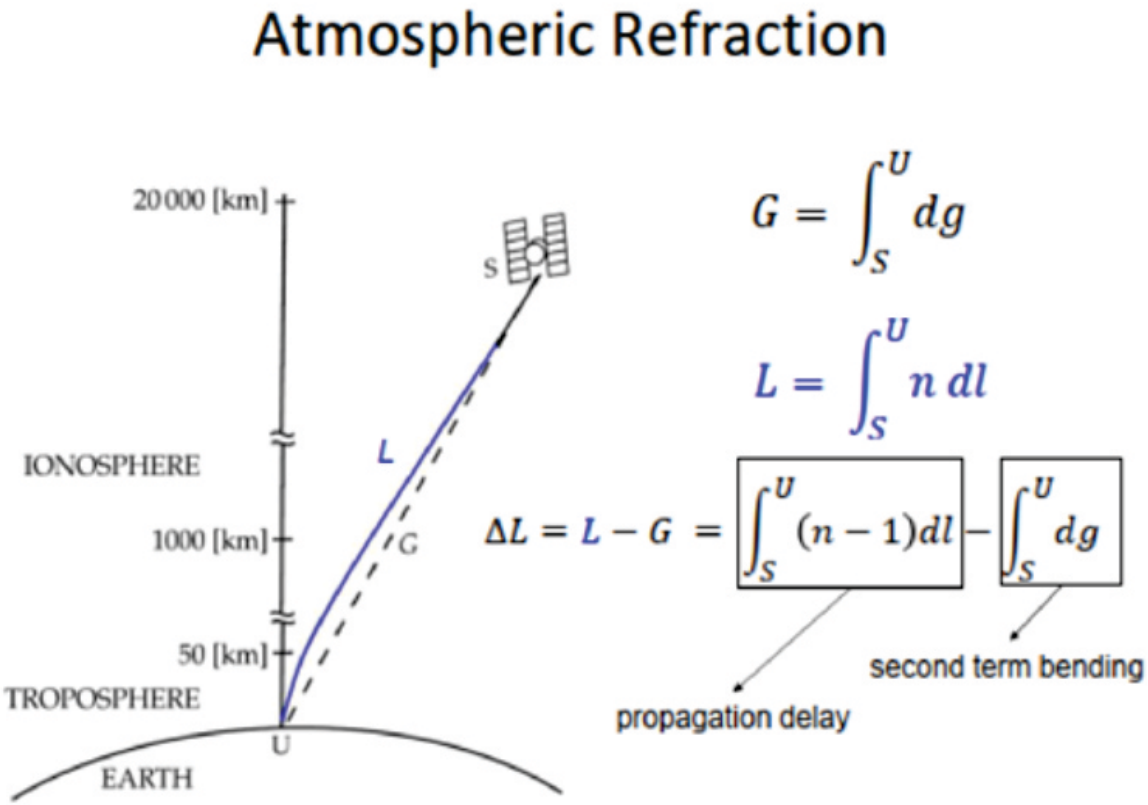

Figure 2: Atmospheric Refraction on GNSS Signal

Where G is the true geometric range between the ground antenna and the satellite antenna, given by the integration along the signal part taking into consideration the refractive index n according to Snell's law

Rapid changes in integrated water vapor (IWV) are often associated with high humidity conditions linked to extreme weather events such as thunderstorms. Extreme weather events such as these are typically difficult to predict and track under traditional operational meteorological observing systems and can potentially cause great damage and risk to life. GNSS metrology which is the application of GNSS techniques in the measurement and mapping of the spatio-temporal change of the earth's atmosphere has found great application in improving Numeric Weather Prediction Models (NWPM), via the assimilation of GNSS-derived precipitable water vapor in real-time. Hence, via GNSS

techniques, the real-time spatiotemporal changes of the earth's atmosphere can be now-casted and forecasted, a critical support for the early warning systems, particularly in the equatorial region characterized by extreme weather conditions. GNSS signal is also deployed in monitoring the earth's atmosphere's ionosphere using the linear combination of dual frequency GNSS receiver.

The ionospheric region extends from 50km to 1000km above the earth's surface. The ionospheric refraction is modeled as a function of the electronic density represented by the total electronic content (TEC) (Hofmann-Wellenhof, Lichtenegger, and Walse, 2008). The TEC is a function of solar activities, diurnal and seasonal variations, and geomagnetic storms resulting in the ionization of positive charge ions in the atmosphere.

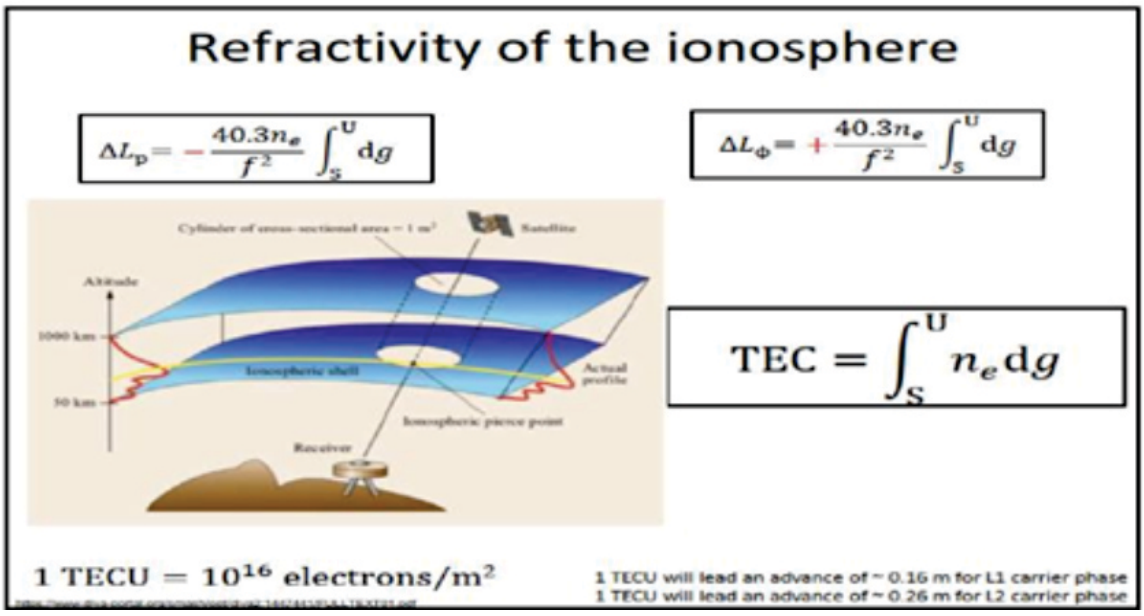

Figure 3: Refractivity of the Ionosphere

The responses of the Nigerian low-latitude ionosphere to geomagnetic storms of the ascending and maximum phase of the solar cycle 24 carried out by Oyeyemi et al. (2024) reveal that during the periods of investigation, the Nigerian ionosphere record marked TEC variations around 11001700LT with the highest value between 1400LT and 1600LT, and a minimum diurnal variation at 0600LT. The study recorded an increase in the TEC over the Nigerian Ionosphere to a maximum value at 1400-1600LT which was attributed to a corresponding increase in solar extreme ultraviolet (EUV) ionization. Indeed, the equatorial regions including Nigeria have experienced the solar maximum with increasing heat that defiles cooling systems. Geodetic and geomatics techniques can be used to sense the earth's atmosphere for efficient environmental management as shown in figure 3.

Geodynamic Monitoring

GNSS systems have been used for decades to monitor the geophysical responses of the earth. Coordinate velocity derivable from the time series of GNSS observation has been used to investigate the natural response of the earth induced by various geophysical signals. (Dong *et al.,* 2002; Klos *et al.,* 2016; Ma *et al.,* 2016; Peng *et al.,* 2018). Geophysical signal resulting from the earth mass redistribution including hydrological mass loading (Alexandre Michel, 2021), tidal loading (Ait-Lakbir *et al.,* 2023; Penna *et al.,* 2015; Thomas *et al.,* 2008), atmospheric and nontidal loading (Antokoletz *et al.,* 2023; Männel *et al.,* 2023; Williams & Penna, 2011), sea level variations (Li *et al.,* 2023), tectonic plate motion (Vardic, 2021), and post-glacial rebounds (Montillet & Bos, 2020).

Quantifying and modeling time series velocity and associated noise either at the local or global scale helps to better understand the underlying process, which in turn helps to mitigate the impact of natural hazards that can lead to the loss of lives and infrastructures. Normally, a standard trajectory linear model is fitted to the GNSS observations as given in equation (1) and described in Figure (4)

The conventional Least Squares (LS) fitting by the method of observation is usually applied to GNSS time series via a model including linear and periodic terms at a time as

$$y(t_i) = y_0 + vt_i + \sum_{k=1}^{q} a_k \sin(w_k t_i) + b_k \cos(w_k t_i) + \sum_{k=1}^{n} J_k H(t_i - t_{jk}) + e_i$$

In the above equation, $y(t_i)$ ($i = 1, 2, 3, 4, \ldots N$) is the position at epoch t_i in year, y_0 is the station position, v is the linear velocity, a_k, and b_k are the amplitude of the periodic signal which are model using the sine and cosine function. For a time, series with annual and semi-annual signals $q = 2$. The offset term due to either the receiver antenna failure, earthquake human intervention is modelled as $\sum_{k=1}^{n} J_K H(t_i - t_{jk})$, where n is the number of offsets, H is the Heaviside step function J_k is the magnitude change in the position time series at epoch t_{jk}. The measurement errors (noise) is given as e_i.

The linearize model for equation (1) can be written as;

$$y = A\hat{X} + \hat{V} \quad (2)$$

The solution to equation (2) can be given as;

$$\hat{X} = (A^T P A)^{-1}(A^T P y) \quad (3)$$

In equation (3), $\hat{X} = [y_o \; v \; a_{k1} \; b_{k1} \; a_{k2} \; b_{k2}]^T$, Where y is the matrix of observation, A is the Jacobian matrix (Design matrix) containing be partial differential of the observation with respect to the unknown parameter $(\hat{X})$, $\hat{V}$ is the vector of residuals which contains the noise term and P is the covariance matrix of the observation.

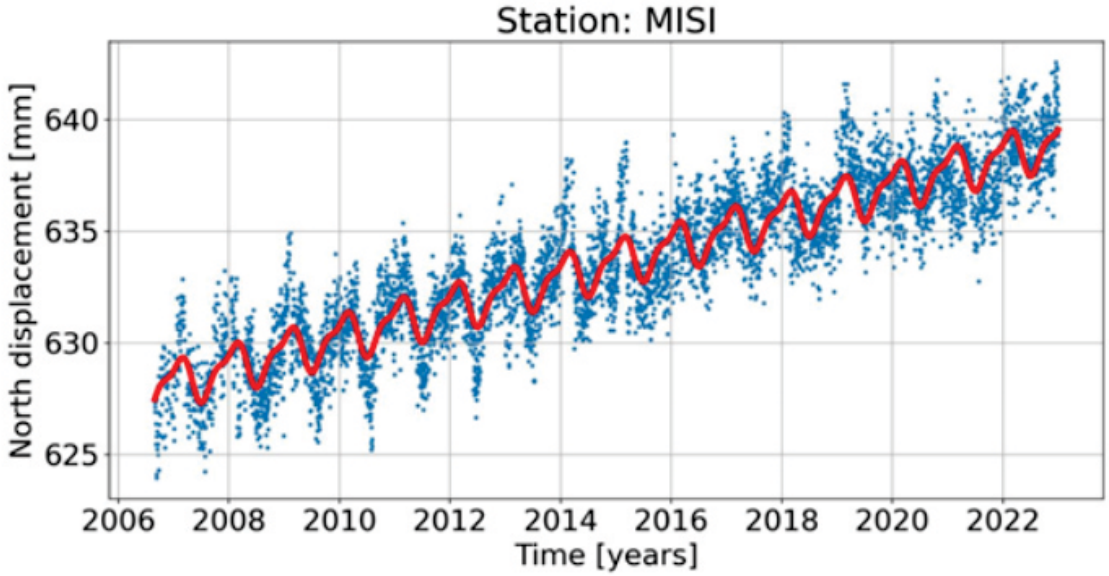

Figure 4: Coordinate time series of IGS GNSS station (MISI), the parameters describing the linear trends and periodic signal and associated degree of uncertainties can be determined using a functional model, and a stochastic model via the method of least squares.

Biodiversity: Anthropogenic pressure on the earth's environment has caused substantial alterations to regional biodiversity. Quantifying these losses and changes allows protective mechanisms to be developed and enforced in an attempt to preserve these genetic resources (Hart, 2008). GPS and GIS have been widely used in this field because of its real time capabilities and its integrated data collection, analysis, and reporting functionality. This systems and tools have been proven to be an extremely powerful tool in raising public awareness about preserving the earth's natural biodiversity. This is manifest in the disappearances of Wetlands within our urban spaces.

Impact Assessment: GPS and GIS improve the process for assessing the effect of change on a location's resources, natural or manmade. Using GIS gives you the ability to measure areas, calculate rate of change, visualized changes over time and report share findings in real time. Post event assessment are important, but perhaps more critical to communities is the use of GIS to model the potential impacts that planned and unplanned events and activities will have on an area. Planning and development processes involve multiple stages before the proposed land use change can be implemented. Impact assessment is an integral part of the process when considering manmade development and associated environmental sustainability.

Pollution Management: Pollution has been defined as the contamination of soil, water or the atmosphere by the discharge of harmful substance (Uchegbu, 2002; Richard, James, 2006). Pollution occurs overtime, and this process has been successfully retreaded by individuals and organizations employing GIS. GIS is used at all stages of the pollution management. Before pollution has occurred, avoidance and prevention management benefits from GIS. Pollution prediction can be strengthened by assessing combination of data, identifying potential risks, and prioritizing potential pollution scenarios. Once pollution has occurred, the planning and response can be facilitated by GIS. after the event, cleanup programs and monitoring are organized through GIS.

Hazard and Risk Analysis: mitigating the effects of natural hazards and providing potential risk analysis for communities is a common application are of GPS and GIS. This subject, perhaps more than any other, demonstrates the ability of GIS to create shared resources among varying professional disciplines. Documenting know hazards, for example, geological faults or mine workings, has many applications beyond the environmental industry. Developers and insurance companies frequently use such information in their business models. It is accepted that certain area is more prone to specific types of natural hazards, and the combine technology of GIS and GPS has proven to be a robust management tool.

Waste Management: there are few processes that create a useful product without a residual that is nonbeneficial. The management of such waste, whether industrial, agricultural, or domestic, must limit the potential harmful effects it may have on the environment. Waste management entails three basic operations- waste removal, waste treatment, and, ultimately, waste storage. Each step has an inherent geographic aspect, best managed in a GIS environment. Planning waste collection along the most efficient route while still considering public opinion is a simple function using the combined technology of GPS and GIS. Planning the location of facilities for treatment and disposal is also possible within a GIS environment.

Geomatics Techniques in Groundwater Sustainable Management

According to Papatheodorou, Evangelidid, and NTouros (2017), Groundwater sustainability must consider three basic aspects: (i) exploration, to define resource availability; (ii) protection, which is a combination of prevention and remediation activities, and (iii) management, which includes balancing demand to availability by regulating consumption using legislation and law enforcement, to ensure sustainable management of the resource.

Groundwater Exploration: Groundwater aquifers are developed both in coarse sediments (alluvial) and in rock formations. Although groundwater is easily detected and abstracted in alluvial formations, there is the necessity of defining Ground Water recharge zones, which should be protected in order to prevent surface pollution and dispersion of the pollutants in the rest of the aquifers. Identification of Ground Water recharge sources can be through the use of Remote Sensing and Geographic Information Systems for complementing research with ancillary data. The use of ancillary data including the hydrologic network, rainfall data, effective infiltration coefficients, land use and more, in order to define zones of high Ground Water potential, even in theoretically impermeable rock formations, made feasible through Geographic Information Systems (GIS) has also been thoroughly investigated. Recent studies suggest that in hard, theoretically impermeable rocks, tracing fractures through Remote Sensing techniques is the key to successful groundwater investigation in such areas (Tweed, Leblanc, Webb & Lubczynski, 2009).

Groundwater Protection: Groundwater quality can be adversely affected by a series of factors related to human activities and to the respective pollution sources. Fertilizers, pesticides, herbicides, insecticides from agriculture, chemicals and heavy metals from the industry, and landfills, and seawater are among those factors. Most of these factors are introduced to GW from the ground surface, thus GW's vulnerability to surface pollution, combined with the location of potentially hazardous installations can provide a measure of the GW Risk to pollution. Reliable and accurate GW Risk assessment can support decisions regarding both land use and GW management which can be considered as very effective preventive measures. Reliability and accuracy of risk assessment outputs is closely related to the respective data attributes taking into consideration the scale of implementation which, in this case should be great enough to display the spatial variability of the important influencing parameters; indicatively, 1:25 000–1:100 000 for risk assessment at regional scales and 1:5000–1:25 000 for assessment at local scales.

Groundwater Management; including a continuous monitoring of important Ground Water quantitative and qualitative parameters, can be strongly supported be a Ground Water Information System. The design of a such a system must be based upon a conceptual model which requires understanding the existing conditions and problems for any specific site including the hydrogeologic regime, the land use, the potential contaminants per location according to land uses, vulnerability maps and risks assessed, Ground Water demands, consumption and recharge rates and of course all the parameters related to the dynamic, physical and chemical attributes of groundwater.

Figure 2: A Picture of the Gully Data Acquisition Exercise
Source: Hart & Basil, 2018

National Geodetic Infrastructure for Environmental Management and Sustainable Development

Modern global geodetic infrastructure was developed over the past several decades primarily to support activities in the scientific and military communities. Nevertheless, the physical computational, and organizational infrastructure developed for these communities now support a wide range of applications. Like roads and highways that facilitate interstate commerce, the geodetic infrastructure provides significant benefits to society by enabling an astonishing array of activities and innovations, including autonomous navigation, precision agriculture, civil surveying, early warning systems for hazards, and improved floodplain mapping.

Conclusion

In view of recent development in the capability of instrumentation and techniques required in management of the environment, geomatics techniques become an indispensable tool. With geospatial information at the core, a substantial number of geodetic basis and different views on the current state of the environment and the associated potential natural disasters and their effects can be simulated. As we incorporate the use of Geospatial Information Technologies such as Satellite Remote Sensing, UAV, LIDAR, GNSS in monitoring the frontline locations, the resultant consequence is to generate credible information and guide decision making to achieve sustainable national, regional and local development. The increasing effect and diverse environmental challenges in Nigeria have continued to threaten the attainment of food security, socioeconomic issues and other important sustainable development goals in the affected states. Great attention should be given to the application of Geospatial/Geodetic approaches and their technologies due to their economics and high speed of digital data production. Furthermore, it is suitable for applications in a number of risky situations where rapid response is required. A great advantage has also been achieved through the ability to use it in inaccessible areas.

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The Impact of Property Conversion on Residential Environment (The Case of D/line, Port Harcourt), Rivers State

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Abstract

The aim of this study is to assess the effect of property conversion from residential to commercial use in D/line Port Harcourt. To identify the residential properties converted to commercial in D/Line Port Harcourt, examine the value of the residential and commercial properties in D/line Port Harcourt, Identify the problems and prospects of conversion of residential buildings to other uses. The study therefore had to rely on community key informants to track the residential buildings conversion in D/line and ascertained the challenges of building conversion in the study area. Furthermore, the study interviewed 15 key informants (drawn from relevant government agencies). The questionnaires administered to them were structured to help ascertain nature of and reasons for residential buildings conversion and household questionnaires administered to 76 households in the study area. The study found that, there were series of residential building conversion from residential to commercial uses Poor maintenance as well as lack of government interest in the Neighbourhoods has led to a general depreciation of the Neighbourhoods. The study therefore recommended that Government should through her MDAs, pay attention to the uncontrolled residential housing conversion in D/line, Port Harcourt to ensure compliance with government regulations. There should be strict compliance with the government regulation on residential density and building conversions to maintain serenity of our residential neighbourhoods. Government should deliberate impose high charges on converted buildings. This will indirectly discourage any further conversion and serious fine on the unauthorised converted once. this would drastically reduce the rate of residential buildings conversion in D/line Port Harcourt and as well control the cost of rent in the neighbourhood.

Keyword: Property Conversion, Residential, Commercial, Neighbourhood, Land Use

Introduction

The conversion of housing structure to other uses significantly changes the urban appearance, not only physically but also socially and economically. The resulting changes will ultimately create both positive and negative impacts. In addition to increased property values, impacts include incompatible land uses, high traffic congestion (pedestrian and auto environments, and increased burden on social services). and infrastructure). According to Spedding (1998), the function of building maintenance/conversion is to maintain facilities and buildings in optimal conditions so that the intended functions are satisfactorily performed. This developmental assessment technique commonly used in practice has been criticized for its simplifying assumptions (Darlow, 1990).

Conversion can be defined as modernizing a building or changing its original use or form. The conversion process may be legal or illegal depending on the planning and arrangements for that development. Conversion can also refer to the modification of existing structures. It involves carrying out works to improve existing buildings and convert existing buildings if it is estimated that the capitalized value of the additional profits will exceed the costs of the modifications. (Okunola *et al.,* 2012).

Conversion of residential structure to other uses alters the urban scene dramatically not only physically but also socially and economically. The evolution resulting there from end to make both positive and adverse consequences. Apart from raising the property value, the effects include the juxtaposition of

incompatible land uses heavy traffic congestion (pedestrian and vehicular environmental and increased burden on social and infrastructural services. According to Spedding, (1998), the function of building maintenance/conversion is to keep the facilities and the building in optimum conditions so that the intended functions are performed satisfactorily. This development appraisal technique generally employed in practice had been criticized on the basis of the simplifying assumptions (Darlow, 1990). Conversion transformation likewise alludes to the idea of redevelopment, which includes obliterating or wrecking a current design on a plot of land and remaking the construction for high thickness than the past. This might include a difference in use simultaneously (Okunola *et al*., 2012).

The problem of homelessness, as observed in the Nigerian housing policy of 2006 is more in the urban centres than rural areas. One of the factors responsible for this situation is the nature of physical development of housing which includes building and rebuilding activities and conversion of use of buildings especially in old areas of the towns in the developing world. Building use conversion is the change in the use of a building from the purpose for which it was originally used or intended to be used. Change of use of buildings from residential to other uses has increased in Port Harcourt in recent years in areas which predominantly have been used for residential purposes. These residential areas have over the years maintained the housing stock, providing the residential needs of the people, especially as it cuts across all residential densities. Residential buildings of varying types adorn these areas and accommodate not only the indigenous population but also immigrants from other cities and nations of the world. The buildings are gradually being converted to commercial and institutional uses wholly or partially. The houses are now used for shops, stores, restaurants, tailoring workshops, churches, offices, and so on. In most of these streets, the frontal rooms of buildings are converted and, in some cases, extensions made, converting valuable residential spaces to commercial use.

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Several theories have been propounded by earlier scholars on land use, development, management and control. Verburg *et al.,* (2004) in their attempt to appraise the patterns of land use conversions and its determinants in the Netherlands advocated for the understanding of the multifarious interactions that exist between man and his physical environment. Egbenta, (2009) validated the postulation of economic theory premised on the idea that economic activities expansion absorb other abutting land uses through space competition and ability to pay higher rent (bid rent theory).

Qina *et al.* (2016) concluded that bearing in mind the specific land uses, Wingo's (1961) rent the theory of the totality of the relationship by Wingo assesses and incorporated the specific land uses attributes that exists between the components and its surrounding environment in land offer prices. This study is hinged on economic theories validated by Egbenta (2009). The identified conversion factors that was tested were gotten from previous literature on land use.

Conversion in the use for which a property or land is intended, zoned or approved for has become a common phenomenon in most Nigerian cities. Fabiyi (2006) viewed land or property use change as the reflections or the indirect consequences of economic growth through which the structure and functioning of the ecosystem have been in one way or the other altered. Abiodun *et al.* (2011) observed that the degree of land use conversions varies with the time under consideration as well as with the geographical locations. Ogungbemi (2012) examined factors influencing change in use and its attendant problems. The study posited that land use conversion is induced by varieties of factors among which are economic, demographic, institutional, infrastructural, environmental attributes, and sociological factors. Ankeli (2007) argued that investors expected returns on the available use options (which could be financial, social or otherwise) often serves as the determiner for land use conversions. These studies were not specific on any of the influencing factors. Olujimi (2010) however, asserted that the negative effect of the factors of land use conversions damage the interest of investors, thus subsequently discouraging investment potentials and initiatives in the subsector. Olarewaju (2016) examined the spatio - environmental dimension of residential land use change along Taiwo road, Ilorin and discovered a statistically significant variation in residential property values. Olarewaju (2016) failed to specify the value type, hence there exist gap that need to fill. Iroham *et al.* (2013) assessed the trend in rental values of commercial properties in commercial hub of Akure. The study revealed that converted office spaces with the highest rental values have better investment fund recoupment potentials. The study failed to report the cause(s) of conversion. It is in an attempt to fill the observed gaps, determine the influence of property use conversion factors on rental values in the study area that this study test the conversion factors reported by Ogungbemi (2012).

Study Area

Port Harcourt City Local Government Area is one of the area councils that make up the Port Harcourt Metropolis, and one of the twenty- three local Government areas in Rivers State. It is an economic beehive (centre) in the Niger Delta area of Nigeria. The Local Government area covers 100km^2 and a population of 538,558 Persons (National Population Commission, NPC 2006), and has its headquarters at Old Port Harcourt Township (Ajie & Dienye, 2014). The 1975 Port Harcourt City Master plan which covered both Port Harcourt City Area Council and Obio/Akpor shows that Port Harcourt Local Government Area Council has a total of 100km^2 landmass out of which about 45% (17.3km^2) of it is wetland area (Visigah, 2017).Port Harcourt City Local Government Area is bounded by Obio/Akpor to the North, Okrika to the South (See Fig. 1.1). It is located within latitudes 4^{0}5'11" and 5^{o}15'45" North and longitudes 6^{o}22'25" and 8^{o}05'12" East (Ajie & Dienye, 2014). **(Fig. 1).**

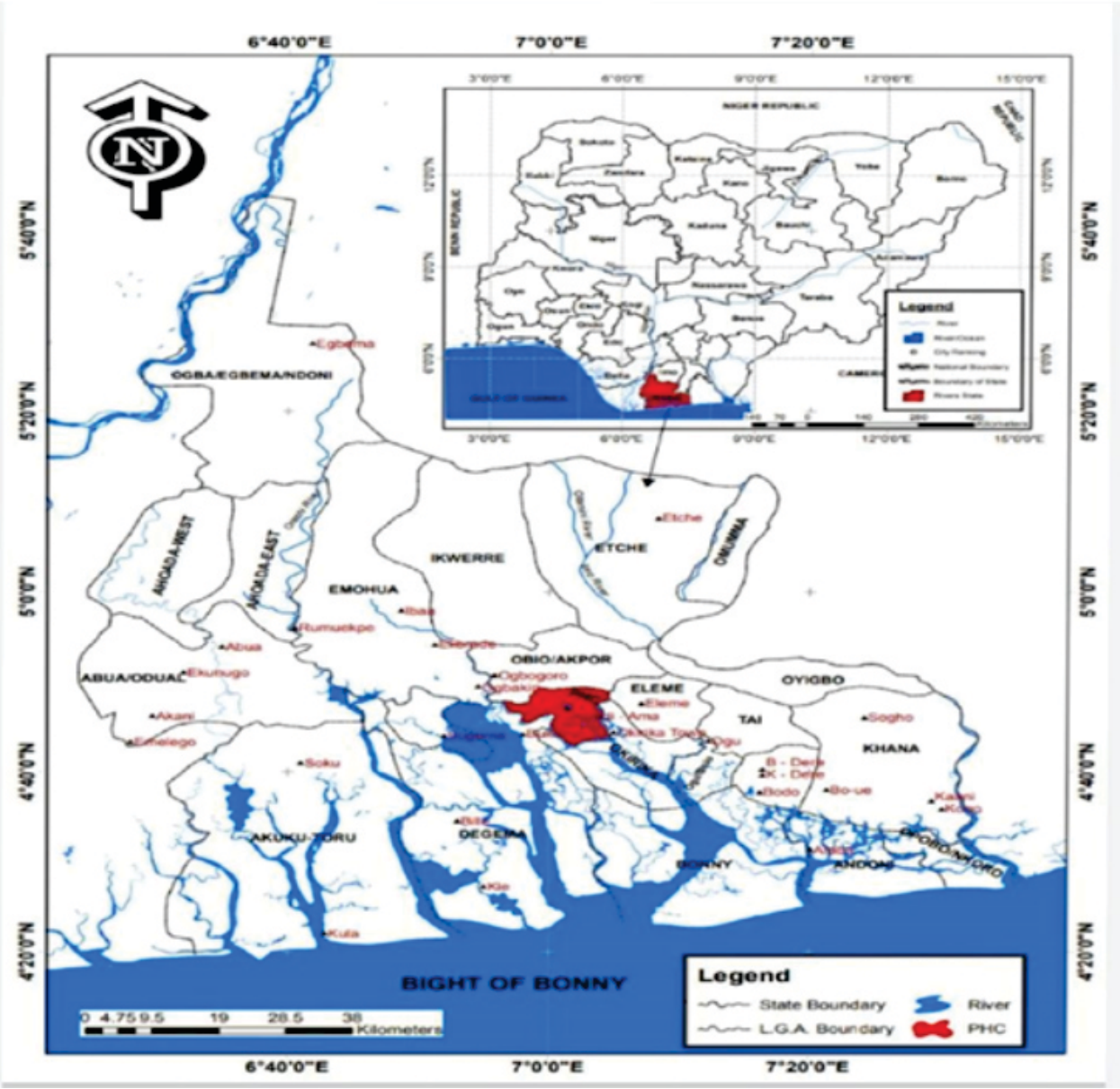

Fig. 1: Map of Rivers State showing Port Harcourt City LGA
Source: GIS Lab, URP Dept, RSU, 2023

The growth of D/Line in both absolute and relative terms has been accompanied by the expansion of existing built-up areas and the emergence of new and identifiably "urban? settlements. The choice of D/line was due to the fact that the area is classified as a medium class resident whose development was captured in the Master Plan of Post Harcourt prepared in 1975, by Specialists Konsult, a Swedish planning firm. Figure 2 is a map showing the study area.

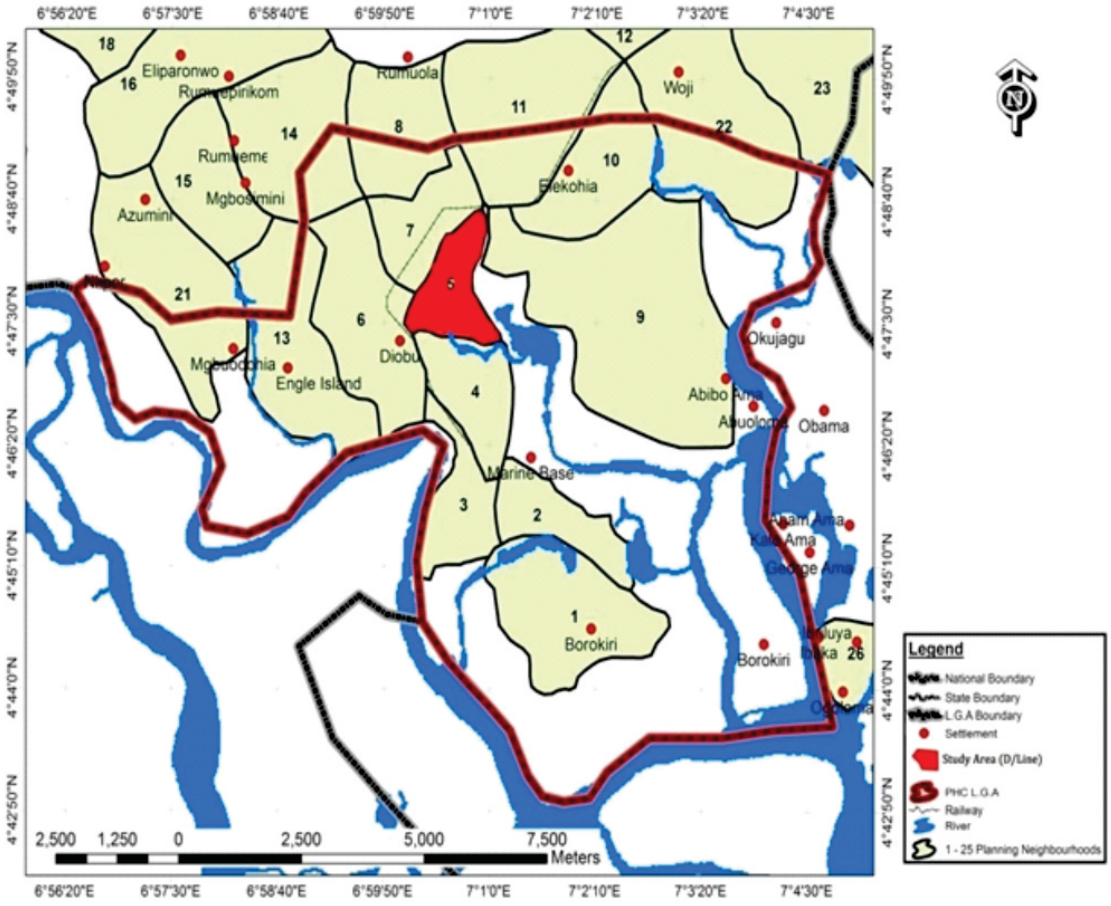

Fig. 2: Map of Port Harcourt City L.G.A Showing Study Area
Source: GIS Lab, URP Dept, RSU, 2023

Methodology

This study adopted the descriptive survey research design; this research design was preferred because it is used primarily to conduct quantitative research and gather data that is easy to analyze statistically and can provide qualitative data that will helped describe and understand the research subject. And data for this work was gathered from two major sources namely, primary and secondary sources of data. The researcher considers this design appropriate for this study since it intends to collect data from Tenants, Property Agents and Developers, regulatory authorities, Neighbourhoods Surveyors and Valuers and other associated professional in the built environment operating in that vicinity or in the study area.

The population of the study neighbourhoods from the 1991 population result was 21,377 and projected to 2023 which gave us 43,415 at 6.5% growth rate in urban areas in Nigeria (NPC 2006). The study employed mixed method approach with stratified simple random sampling techniques and key informant interviews for data collection. Primary data was obtained from residents of the selected neighbourhoods, government officials and experts through interviews, physical observations and photographs to characterize the nature and extent of conversion of the residential buildings to commercial.

The study selects 100 respondents (household heads) from the available residential buildings in the study area for sampling. To derive the sample size, the study applied Yamane formula with 10 percent level of precession which gave us approximately 100 questionnaires. A simple random technique was employed to choose the respondents for interview. Furthermore, key informant interviews for staff of

the Rivers State Ministry of Urban Development and Physical Planning, Port Harcourt City Council, and other allied professionals e.g Neighbourhoods Surveyors and Valuers/ experts in the built environment.

Review of Previous Studies

The term 'conversion' emerges as a pivotal concept. Conversion in real estate encapsulates the transformation of property from one type of use to another, signifying a strategic move that can significantly influence the property's value and appeal in the market. An understanding of conversion is essential not only for real estate professionals but also for investors, property owners, and tenants, as it can manifest in various forms such as repurposing a commercial space into residential dwellings or vice versa. Nina Sheridan (2024).

Building conversion is the process in which a property undergoes a change in its use or function. The meaning of conversion in real estate is multifaceted, encompassing both the legal and strategic aspects. Legally, it involves the unauthorized use of property by someone who initially had lawful possession, while strategically, it signifies the alteration of an existing building's structure or use to better align with current market demand or to enhance the property's value. Nina Sheridan (2024).

Nwachukwu (2008) did a research on the impact of housing conversion on residential land use development in Nigerian Cities; A case study of Enugu Metropolis. The high incidence of housing conversion is one of the major problems confronting Nigerian cities. While property owners' clamour for such conversions which they see as venues for maximizing rents, experts view housing conversion as an aberration. Some experts have attributed housing shortages in Nigerian cities to residential housing conversion other have blamed it on high rent, inadequate housing supply etc. these views were investigated in this study using Enugu Metropolis as the case study. Egbenta (2009) carried out a research on the analysis of residential land use changes in Enugu Urban from 1997 to 2008. The study shows that the sudden change in residential land use to commercial use in Enugu Urban is to maximize optimum returns from the land.

This finding is a signal to property developers and investors to utilize. The study suggests that there should be legal framework on conversion and advices that rational developers should be aware of the implication of business cycles in that demand for new buildings are highly sensitive to short term output changes. Kalu, Alozie, Oti and Onyennah (2017) carried out a research on the effects of residential land use change to other land uses in Enugu Metropolis. The study analysed the effects of change in residential land uses in Enugu Metropolis. 150 copies of questionnaires were purposively and randomly distributed to the major residential areas and individuals in Enugu Metropolis. Chi-square analysis was used to test the hypothesis, the findings made showed that land use change from residential to other land uses affect the physical environment (soil, air, and water quality) lack of government planning agency to implement its planning policy in the area is the major factor that causes this land use change, commercial activities contributed more to the land use changes. This works dwells extensively on the effects of residential land use change to other land uses in Enugu Metropolis while this research lays emphasis on the effects of building use conversion on property values in Enugu Urban between the periods 2011 to 2021.

Result and Discussion

The result shows that there were significantly more male than female. Male respondents accounted for 82% and female accounted for 18% of the distribution. This is not surprising, given that there are more males in the civil service than female and males are head of their households, as per unofficial information. Married respondents accounted for 72% of respondents (table 1). This is normal, because marital status could be considered as one of the considerations for eligibility for allocation of government housing, an unofficial information has it that, the neighbourhood of D/line was allocated

by government. It makes sense to consider the married first, before the single, as the need for shelter would be more severe for the married. This shows that most heads of household are earning far above the minimum wage and fall within the high earning class in the society. This finding agrees with Lekwotet al,2012, in which he opined that "the housing programs did not make any improvement on the housing situation of the urban poor as it benefited only a few civil servants". The current minimum wage in Nigeria is N30,000 per month. Respondents who earn less than N100,000 were about 5.2%. Most residents claimed to have lived in the Neighbourhoods for "15 – 20 years", representing 45% of respondents. Some others claimed to have lived for "6 – 10 years", accounting for 17% of the distribution.

Table 1 Percentage Distribution of Marital Status of Respondents

S/N	Status	N	%
1	Married	55	55
2	Separated	6	7.9
3	Widowed	11	14.5
4	Single/never married	4	5.3
Total		**76**	**100**

Source: Researchers' Field Survey, 2023

Over (45%) of the residential properties in D/line have been converted to commercial and institutional uses. Which has contributed to densifying the neighborhood and therefore attracting more commercial related activities, and reduction of residential properties which also, affect the cost of rent based on high demand for residential properties.

Plate 1: General Outlook of the Neighbourhoods
Source: Researchers' Field Survey, 2023

Respondents were not satisfied with the cost of rent, as (74%), said is about high which could be the result of building conversion from residential properties to commercial uses and properties value at D/line placed at an average of N27,000,000 per flat. However, respondents were "Dissatisfied" on amount of money spent on rent annually this account for (70.8%) respectively. Respondents were asked about their general satisfaction with the neighbourhood. The modal response was "Dissatisfied", accounting for 49% (Fig. 3)

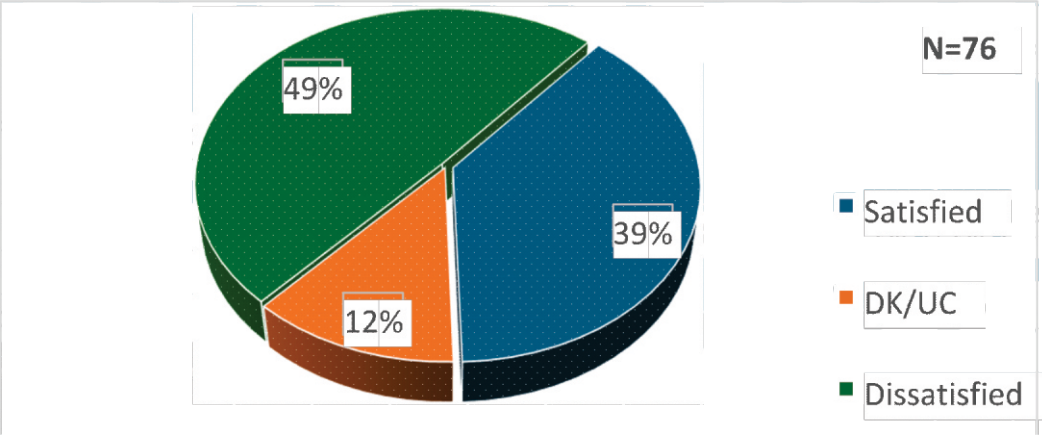

Fig. 3: Percentage Distribution of Respondents' General Satisfaction with Neighbourhoods
Source Researchers' Field Survey, 2023

Data in this study revealed a lot of inadequacies in residential properties conversion in D/line Port Harcourt. For example, in the study area, there are zero control to development. The neighbourhood also lacks ancillary facilities to make the neighbourhood more liveable and affordable such as public schools, and health facilities. See table 2. Residents have to walk for kilometres to access some services. There is also the issue of units being too close together. Buildings were designed in such a way that households can hear conversations from their units and have a lot of direct interaction, thereby making privacy a luxury. Parking is also a major challenge in the neighbourhood of D/line, given that residents have to park on the roadsides within the neighbourhood.

Table 2: Distance from Respondents Dwelling to Some Basic Facilities

S/N	Facility	More than 2 Km	1 – 2Km	Less than 1Km	Total
1	Elementary School (N=76)	0	67.1	32.9	**100**
2	Police Station (N=76)	0	64.5	35.5	**100**
3	Hospital /Clinic(N=76)	0	55.3	44.7	**100**
4	Shopping Area/Market(N=76)	0	51.3	47.8	**100**
5	Recreational Playground(N=76)	0	82.9	17.1	**100**
6	Church(N=76)	0	48.7	51.3	**100**
7	Mosque(N=76)	0	71.2	28.8	**100**
8	Secondary School (N=76)	0	68.4	31.6	**100**

Source: Researchers's Field Survey, 2023

Conclusion and Recommendations

In conclusion, this study revealed a lot of inadequacies in housing conversion in D/Line with reference to the residential buildings. Topmost is the rate of commercial and institutional activities emanating rapidly with no control and the space where the Neighbourhoods is situated. The conversions are made in buildings so tightly built without consideration for privacy of households, no parking space, ancillary facilities were basically absent. In terms of satisfaction with Neighbourhoods, respondents seemed to be dissatisfied (over 49%).

Poor maintenance as well as lack of government interest in the Neighbourhoods has led to a general depreciation of the Neighbourhoods. The conversion of the buildings didn't take convenience and comfort of residents into consideration. Affordability is another thing; most respondents were of the high-income level. The mid-income who should reside in the neighbourhood are gradually chased-out due to high cost of rent. The older respondents and those with relatively high monthly income expressed satisfaction with Neighbourhoods.

The following recommendations were derived from this study: Government should through her MDAs, pay attention to the uncontrolled residential housing conversion in D/line, Port Harcourt to ensure compliance with government regulations. There should be strict compliance with the government regulation on residential density and building conversions to maintain serenity of our residential neighbourhoods. Government should deliberate impose high charges on converted buildings. This will indirectly discourage any further conversion and serious fine on the unauthorised converted once. this would drastically reduce the rate of residential buildings conversion in D/line Port Harcourt and as well control the cost of rent in the neighbourhood.

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Exploring the Prospects of Public Market Development as a Panacea for National Economic Growth in Niger-Delta Region, Nigeria

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Abstract

Public market development holds significant potential for national economic growth. The resource-rich but economically challenged Niger-Delta exemplifies how improved infrastructure can drive regional and national progress, where economic disparities had not been addressed contributing to broader development goals. This study employs a mixed-method approach, administering 239 questionnaires with a 76.7% response rate (188 retrieved). Utilizing a pragmatic philosophy and explanatory case study in the NigerDelta, surveys and interviews were conducted in three ultra-modern markets. Data were analyzed using frequency tabulation, percentages, mean, and relative importance index (RII). The study identified significant challenges in public market infrastructure, including governance issues, financial constraints, logistical problems, and health, safety, and environmental concerns, impacting market efficiency and economic contributions. Despite these challenges, developing public markets offers substantial economic and social benefits, such as stimulating local economic activities, generating employment, increasing household income, enhancing market efficiency, boosting government revenue, supporting small enterprises, promoting local production, and fostering innovation. Conclusively, collaborative efforts between government, private investors, and local communities are essential for sustainable development. This research offers a blueprint for using public markets to drive inclusive growth and stability in resourcerich, underdeveloped regions like the Niger-Delta.

Keywords: Infrastructure, Economic Growth, Public Markets, Sustainable Development, Niger-Delta

Introduction

The Niger-Delta region of Nigeria, known for its abundant natural resources, particularly crude oil, is paradoxically characterized by significant economic challenges and underdevelopment. Despite its wealth in resources, the region struggles with high levels of poverty, unemployment, and environmental degradation, leading to a complex socio-economic landscape (UNDP, 2006). These issues necessitate a strategic approach to fostering sustainable development, and one potential avenue is the development of public markets. According to (Nkpite, Ihuah and Ogbonda, 2024a), public markets, traditionally seen as centers for economic activities, trade, and social interaction, play a critical role in local and national economies. They serve as hubs for small and medium-sized enterprises (SMEs), providing a platform for local entrepreneurs to access wider markets and for consumers to obtain diverse goods and services. This function is particularly relevant in the Niger-Delta, where many communities rely on informal trade and agriculture as primary sources of livelihood (Akinola, 2018). Economic theories and empirical studies suggest that the development of public markets can stimulate economic growth by enhancing trade, generating employment, and fostering entrepreneurship (Fafchamps, 2004). By improving infrastructure, market accessibility, and regulatory frameworks, public markets can facilitate more efficient distribution of goods, reduce transaction costs, and increase market participation. This can lead to higher productivity and income levels, thereby contributing to overall economic growth (World Bank, 2019).

In the context of the Niger-Delta, the prospects of public market development as a panacea for economic growth are particularly convincing. The region's strategic location, coupled with its rich agricultural potential, offers a unique opportunity to develop robust market systems that can drive

regional and national economic progress. However, the current state of public markets in the NigerDelta is underdeveloped, characterized by poor infrastructure, inadequate regulation, and limited access to financial services. The underutilization of public markets faces significant barriers for local producers and traders accessing wider markets, resulting in suboptimal economic outcomes (Oyedele, 2012). As the traditional economic interventions have often fallen short of addressing the multi-faceted challenges of the Niger-Delta. Public markets, which serve as hubs for local trade and entrepreneurship, present a promising avenue for such strategies. Moreover, the lack of organized markets limits the ability to generate employment and stimulate local economies, exacerbating poverty and economic disenfranchisement (Adetayo, 2018). There is a critical need for innovative and sustainable economic strategies that can harness the region's intrinsic strengths by developing public markets.

Furthermore, the establishment of well-organized public markets can help mitigate some of the socio-economic issues in the region by providing stable employment opportunities and fostering community cohesion (Ekpo, 2004). The Nigerian government and various development agencies have recognized the potential of market development in their policy frameworks. Initiatives aimed at improving market infrastructure, providing financial support to traders, and enhancing market governance have been proposed as part of broader economic development strategies (Nigerian Ministry of Budget and National Planning, 2017). However, the success of these initiatives depends on comprehensive planning, effective implementation, and the active participation of local communities. Therefore, exploring the prospects of public market development in the NigerDelta Region is not only timely but also critical for devising sustainable economic strategies that can uplift the region and contribute to Nigeria's overall economic growth.

Statement of the Problem

The Niger-Delta region of Nigeria, despite its vast natural resources and significant contributions to the national economy; there remains plagued by severe socio-economic challenges. High levels of poverty, unemployment, and environmental degradation are pervasive, undermining the region's potential for sustainable development (UNDP, 2006). The reliance on crude oil as the primary economic driver has not translated into broad-based economic prosperity for the region's inhabitants, leading to widespread disenchantment and socio-political unrest. It is observed that the current state of public markets in the Niger-Delta is underdeveloped, characterized by poor infrastructure, inadequate regulation, and limited access to financial services. Yet, the traditional economic interventions have often fallen short of addressing the multi-faceted challenges of the Niger-Delta. There is a critical need for innovative and sustainable economic strategies that can harness the region's intrinsic strengths. Public markets, which serve as hubs for local trade and entrepreneurship, present a promising avenue for such strategies. (Akinola, 2018).

The underutilization of public markets in the Niger-Delta impedes their potential to drive economic growth. Without robust public markets, local producers and traders face significant barriers in accessing wider markets, resulting in suboptimal economic outcomes. Moreover, the lack of organized markets limits the ability to generate employment and stimulate local economies, exacerbating poverty and economic disenfranchisement (Rebelo, Santos and Silva, 2016). Given the strategic importance of public markets in fostering economic development, there is a pressing need to explore their potential in the Niger-Delta context. The underutilization of public markets in the Niger-Delta may be traceable to inadequate infrastructure hindering efficient trade and commerce, due to poor market governance and lack of regulatory frameworks contributing to inefficiencies and market distortions with limited financial services for traders and market participants that restrict economic activities and growth potential, and challenges reduce market accessibility, affecting both traders and consumers. With the above assertion, this study therefore investigates the prospects of public market development as a panacea for national economic growth in the Niger-Delta, Nigeria.

Aim and Objectives of the Study

This study aims to critically investigate the prospects as a solution for national economic advancement in the Niger-Delta Region, Nigeria. The following specific objectives are to:

iv. Assess the primary challenges hindering the effective functioning of public markets for economic growth in the study area.
v. Identify potential benefits of public market development driving sustainable economic growth in the study area.
vi. Provide evidence-based recommendations for policymakers and stakeholders on the strategic development of public markets to drive sustainable economic growth.

Research Questions

The study had two objectives, which were addressed through the following research questions:

iii. What are the primary challenges hindering the effective functioning of public markets for economic growth in the study area?
iv. What are the potential benefits of public market development that drive sustainable economic growth in the study area?

Significance of the Study

This study on exploring the prospects of public market development as a panacea for national economic growth in the Niger-Delta Region, Nigeria, holds significant implications for various stakeholders, policy makers, and researchers. The study on national economic growth is poised to generate valuable insights that can inform policies, empower communities, advance academic knowledge, and contribute to achieving sustainable development goals. By addressing the significance of market infrastructure and governance in fostering economic prosperity and community well-being, this study aims to make a meaningful impact on regional development efforts in Nigeria. The findings of this study will address issues that are essential for unlocking the potential of national economic growth in the Niger-Delta. Understanding the potential of public market development as a catalyst for economic growth is crucial for policymakers and government agencies. By identifying key factors that hinder or promote market efficiency and economic productivity, this study can inform strategic interventions to stimulate local economies, create employment opportunities, and enhance income generation within the Niger-Delta Region. Furthermore, the findings of this study can contribute to evidence-based policy formulation and implementation at local, regional, and national levels. Recommendations derived from the study can guide policymakers in developing effective regulatory frameworks, infrastructure investments, and economic strategies aimed at maximizing the socio-economic benefits of public market development while addressing existing challenges. This statement emphasizes the broader implications and contributions of the study on public market development in the Niger-Delta Region, Nigeria, highlighting its relevance to economic development, community empowerment, policy formulation, academic discourse, and sustainable development goals.

Scope of the Study

This study focuses on purpose-built public markets in Rivers, Bayelsa, and Delta States within the Niger-Delta Region. It includes markets built, owned, or operated by State or Local Governments. The selected markets are New Town Ultra-Modern Market in Port Harcourt, Rivers State; Swali Ultra-Modern Market in Yenegoa, Bayelsa State; and Uvwie Ultra-Modern Market in Effurum Warri, Delta State. The research involves 1,964 respondents: 1,882 end-users of lockup shops, 40 market administrators, 30 visitors/community members, and 12 government officials, identified during a pilot study. The focus on ultra-modern public market infrastructure addresses a gap in existing studies, which predominantly examine office environments. While ideally, the study would cover all public markets in the Niger-Delta Region, it is limited to the specified ultra-modern markets. New Town Market is located at Latitude 4.7578 and Longitude 7.03079, along Creek Road/Harold Wilson Drive

and Bishop Johnson Street and King Jaja Street in Port Harcourt, Rivers State. Swali Market is at coordinates 4°55'29"N and 6°15'45.6"E, situated at 853 Melford Okilo Road, Opolo, Yenegoa in Bayelsa State. Uvwie Market is at 5°33'0"N and 5°46'0"E, along Alegbo/Ugbolokposo Road, Effurum Warri in Delta State. Public market development supports local economies, livelihoods, and trade activities. Understanding its operational challenges and benefits is crucial for sustaining economic growth and prosperity in the region.

Literature Review

Public Market Development and National Economic Growth

According to Nkpite, Ihuah and Ogbonda (2024a), public markets play a crucial role in the economic development of nations, serving as hubs for trade, entrepreneurship, and community interaction. As the investments in market infrastructure and governance can contribute to broader economic outcomes. This review studies explore the relationship between public market development and national economic growth as detailed below.

Economic Contribution of Public Markets: Public markets contribute significantly to national economies by fostering economic activities and generating employment (Nkpite, et.al., 2024b). Akinola (2018) emphasizes that well-developed public markets provide opportunities for smallscale entrepreneurs to access markets, promote local production, and stimulate economic diversification. These markets serve as platforms for income generation and poverty reduction, particularly in developing regions where informal economies thrive. Fafchamps (2004) underscores that efficient market systems reduce transaction costs, improve market accessibility, and enhance the efficiency of goods distribution. These improvements contribute to increased productivity and competitiveness, thereby bolstering economic growth at the national level (Nkpite & Ekenta, 2021). The economic benefits of public markets extend beyond direct market activities to include multiplier effects in related sectors such as transportation, agriculture, and services.

Infrastructure Investment and Market Efficiency: Investments in market infrastructure are critical for enhancing market efficiency and stimulating economic growth (Rebelo, Santos & Silva, 2016). Ekpo (2004) discusses how improvements in market facilities, such as sanitation, security, and transportation infrastructure, can attract more traders and customers. Enhanced market infrastructure not only improves the trading environment but also supports local businesses by reducing operational costs and increasing profitability. The World Bank (2019) highlights that strategic investments in market infrastructure can lead to significant improvements in market functionality and economic performance. These investments include upgrading physical facilities, implementing technology solutions for market management, and ensuring sustainable environmental practices (Nkpite and Ekenta, 2021). Such initiatives not only enhance market operations but also contribute to broader economic goals, including job creation and income generation.

Governance and Regulatory Frameworks: Effective governance and regulatory frameworks are essential for the sustainable development of public markets and their contribution to national economic growth (Nkpite *et.al.,* 2024b). Akinola (2018) argues that transparent and accountable market governance systems promote fair competition, reduce market distortions, and improve investor confidence. Clear regulations and enforcement mechanisms ensure market stability and protect the rights of traders and consumers alike. According to the Nigerian Ministry of Budget and National Planning (2017), enhancing market governance is a key component of national economic strategies. The Economic Recovery and Growth Plan (ERGP) emphasizes the importance of regulatory reforms to streamline market operations, remove barriers to market entry, and foster a conducive business environment. These reforms are crucial for unlocking the full economic potential of public markets and integrating informal economies into formal economic structures.

Social and Environmental Impacts: Public market development not only contributes to economic growth but also has significant social and environmental impacts (Nkpite *et.al.,* 2024a). Akinola (2018) notes that vibrant public markets promote social cohesion by providing spaces for cultural exchange, community interaction, and collective identity formation. These markets serve as social hubs where diverse groups converge, fostering social integration and mutual understanding. However, Ekpo (2004) warns that rapid market development can also lead to environmental challenges such as increased waste generation and resource depletion. Sustainable market development strategies, including waste management initiatives and green infrastructure investments (Nkpite & Ekenta, 2021), are essential to mitigate these environmental impacts and promote eco-friendly market practices.

Operational Challenges and Opportunities for Public Market Development

Public markets in the Nigeria face a myriad of challenges that hinder their development potential, they also present significant opportunities for economic growth and community development (Nkpite, et.al., 2024b). The specific challenges and opportunities associated with public market development are here highlighted with key insights and recommendations for policymakers and stakeholders.

Challenges in Public Market Development

Infrastructure Deficiencies: Odozi and Akinola (2018) states that one of the primary challenges facing public market development in the Nigeria is inadequate infrastructure. Nnodim (2018); Holodny (2015) underscores that many markets lack basic amenities such as proper sanitation facilities, electricity, storage facilities, and reliable transportation infrastructure. These deficiencies not only affect market operations but also deter traders and customers, leading to reduced economic activities and potential revenue loss (Nkpite *et.al.,* 2024a). Ekpo (2004) further elaborates on the impact of poor infrastructure on market efficiency, noting that inadequate facilities increase transaction costs, limit market accessibility, and hinder the growth of marketbased enterprises. Addressing infrastructure gaps is crucial for enhancing market functionality and attracting investments that can drive economic growth in the region.

Governance and Regulatory Issues: Effective governance and regulatory frameworks are essential for the sustainable development of public markets (Nkpite, et.al., 2024b). However, Akinola (2018) highlights that governance in many Nigerian markets is characterized by weak enforcement of regulations, corruption, and lack of transparency. These issues create uncertainties for market participants, undermine investor confidence, and contribute to market inefficiencies. Ekpo (2004) emphasizes the need for strengthened regulatory oversight to ensure fair competition, protect consumer rights, and promote market integrity. Clear and consistent regulatory frameworks are necessary to streamline market operations, remove barriers to entry, and foster a conducive business environment that supports market growth and development.

Opportunities for Public Market Development

Economic Stimulus and Employment Generation: Despite the challenges, public market development in the Nigeria presents significant opportunities for economic stimulus and employment generation (Nkpite, et.al., 2024a). Akinola (2018) argues that well-planned market development initiatives can create numerous job opportunities for local residents, particularly in sectors such as retail, logistics, and services. These markets serve as platforms for small-scale entrepreneurs to access markets, promote local production, and stimulate economic diversification. Fafchamps (2004) underscores that efficient market systems reduce transaction costs, improve market accessibility, and enhance the efficiency of goods distribution. These improvements contribute to increased productivity and competitiveness, thereby bolstering economic growth at the local and national levels.

Social Cohesion and Community Development: Public markets are not only economic hubs but also

social spaces that foster community interaction, cultural exchange, and collective identity formation (Nkpite *et.al.,* 2024b). Akinola (2018) highlights that vibrant markets promote social cohesion by providing opportunities for diverse groups to converge, interact, and build relationships. These interactions strengthen community bonds, enhance social capital, and contribute to overall community well-being (Nkpite & Ekenta, 2021). Moreover, public markets can serve as platforms for promoting inclusive growth and empowerment, particularly for women and marginalized groups. Investments in market infrastructure and support services can empower these groups economically, improve their livelihoods, and promote gender equality within market communities (Nnodim, 2018; Holodny, 2015).

Public Market Development as a Panacea for Economic Growth

Public markets are pivotal to economic growth in both developing and developed economies, serving as critical nodes for trade, entrepreneurship, and community development (Odozi and Akinola, 2018). It is important to explore key insights into its impacts, challenges, and policy implications on the role of public market development as a catalyst for economic growth.

Economic Contributions of Public Markets: Public markets play a significant role in stimulating economic activities and fostering local economic development (Nkpite *et.al.,* 2024a). Akinola (2018) emphasizes that vibrant public markets create employment opportunities, support smallscale enterprises, and promote local production. These markets serve as platforms for economic transactions, generating income for traders, service providers, and suppliers within the market ecosystem. Fafchamps (2004) underscores that efficient market systems reduce transaction costs, improve market accessibility, and enhance the efficiency of goods distribution. By facilitating trade and commerce, public markets contribute to increased productivity, competitiveness, and overall economic output (Holodny, 2015). This economic multiplier effect extends beyond market boundaries, benefiting related sectors such as transportation, agriculture, and tourism.

Infrastructure and Market Efficiency: Investments in market infrastructure are crucial for enhancing market efficiency and supporting economic growth (Nkpite *et.al.,* 2024a). Ekpo (2004) considers how improvements in market facilities, including sanitation, security, and transportation infrastructure, can attract more traders and customers. Enhanced infrastructure not only improves the trading environment but also reduces operational costs, increases market participation, and boosts local economic activities. The World Bank (2019) pointed out that strategic investments in market infrastructure can lead to significant improvements in market functionality and economic performance. These investments include upgrading physical facilities, implementing technology solutions for market management, and ensuring sustainable environmental practices. Such initiatives are essential for maximizing the economic benefits of public markets and integrating informal economies into formal economic structures.

Governance and Regulatory Frameworks: Odozi and Akinola (2018) opine that effective governance and regulatory frameworks are critical for the sustainable development of public markets and their contribution to economic growth. Akinola (2018) argues that transparent and accountable market governance systems promote fair competition, reduce market distortions, and improve investor confidence. Clear regulations and enforcement mechanisms ensure market stability and protect the rights of traders and consumers, fostering a conducive business environment (Nkpite *et.al.,* 2024a). The Nigerian Ministry of Budget and National Planning (2017) emphasizes the importance of regulatory reforms in enhancing market governance and promoting economic growth. The Economic Recovery and Growth Plan (ERGP) outlines strategies to streamline market operations, remove barriers to market entry, and foster a competitive market environment. These reforms are essential for unlocking the full economic potential of public markets and driving sustainable economic growth.

Social and Environmental Impacts: Public markets contribute not only to economic growth but also to social cohesion and environmental sustainability (Odozi & Akinola, 2018). Akinola (2018) notes that markets serve as social hubs where community members interact, exchange cultural knowledge, and build social networks. These interactions strengthen community bonds, enhance social capital, and contribute to overall community well-being. However, rapid market development can also pose environmental challenges such as increased waste generation and resource depletion (Nnodim, 2018; Holodny, 2015). Sustainable market development strategies, including waste management initiatives and green infrastructure investments, are essential to mitigate these impacts and promote eco-friendly market practices (Nkpite *et.al.,* 2024b).

Comparative studies offer valuable insights into how improvements in market infrastructure can transform economic outcomes. For example, a study by the World Bank (2019) on market infrastructure in Sub-Saharan Africa demonstrates that investments in basic amenities such as sanitation, electricity, and secure trading spaces can lead to significant improvements in market efficiency and economic performance. Applying these lessons to the Niger-Delta context, targeted infrastructure development could similarly enhance the functionality and economic contributions of public markets in the region. In the Niger-Delta context, little or none of these studies have been conducted on public market development's role in economic growth. Ekpo (2004) Nkpite and Ekenta (2021) addresses broad economic development and policy challenges in Nigeria but does not consider public market development in regional growth. Fafchamps (2004) discovers market institutions and economic performance, yet overlooks public market development in Nigeria's socio-economic context. The UNDP (2006) report focuses on human development indicators and broader issues, missing microeconomic aspects of public market development in the Niger-Delta. The Nigerian Ministry of Budget and National Planning (2017) details a national economic recovery plan without exploring public market impacts on the Niger-Delta. Odozi and Akinola (2018) and Akinola (2018) analyze regional policies but do not specifically address public markets' role in economic growth. World Bank (2019) reports provide a macro perspective, ignoring public market development. This study aims to fill these gaps by analyzing public market development's role in economic growth, examining socio-economic impacts on local communities, and offering policy recommendations for the Niger-Delta, enhancing regional economic strategies and providing actionable insights for policymakers.

Research Methodology

This study focuses on three selected public markets in the Niger-Delta Region: New Town UltraModern Market in Port Harcourt, Rivers State; Swali Ultra-Modern Market in Yenegoa, Bayelsa State; and Uvwie Ultra-Modern Market in Effurum Warri, Delta State. These urban markets were chosen for their economic significance and representativeness. Employing a mixed-methods case study approach, the research integrates both qualitative and quantitative data through questionnaire surveys and personal interviews, as advocated by Creswell and Plano Clark (2018). The target population includes market administrators, vendors, government officials, and community leaders from the selected states, providing diverse insights into market development. A pilot survey identified a total population of 239 respondents, who were randomly selected for data collection. This comprehensive data gathering achieved a representative response rate of 76.7%. Quantitative data were analyzed using frequency tabulation, percentages, mean, and the relative importance index (RII), while qualitative data underwent content and thematic analysis. The integration of quantitative and qualitative data will facilitate evidence-based policy recommendations and strategies to enhance market infrastructure, governance frameworks, and socio-economic benefits for local communities. This robust mixed-method approach ensures a detailed investigation of the operational challenges and benefits associated with public market development, ultimately driving sustainable economic growth in the Niger-Delta Region, Nigeria.

Results and Discussion

Condition of Components of Public Market Infrastructure

Table 1 shows the condition of components of public market infrastructure hindering national economic growth in the Niger-Delta Region. The majority of responses were less than average with <3.00 mean score reflecting the very poor state of market infrastructure components: sanitary facilities, waste management systems, electricity and water supply, drainage systems, storage and cold chain facilities, parking and transportation, and poor premises cleanliness. Also, the components of lockup shops &stalls and security and safety measures were rated (>3.00) fair, which is the average mean score. This implies that all the components of public market infrastructures as listed in Table 1 is not greater than average (>3.00) and are dilapidated and little or no attention been paid to maintenance management, except in situations where deliberate force was applied to rectify defects by the Market Traders Association.

During interview; more than 50% of the respondents agree that infrastructure deficiencies in many public markets in the Niger-Delta suffer from inadequate infrastructure, hindering efficient trade and commerce. As the components of existing public market infrastructure lacks the potentials of driving sustainable economic growth due to infrastructure deficiencies, governance issues, and financial barriers.

Table 1: Condition of Components of Public Market Infrastructure

Condition of Components	Weigh: N= 188					∑fx	∑fx/∑f	Decision
	VG	G	F	P	VP			
Lockup shops &stalls		42	40	36	37	35	587	3.122	Fair
Sanitary Facilities		36	36	36	38	42	550	2.925	Poor
Waste management systems		34	34	37	39	44	539	2.867	Poor
Security and safety measures		40	39	37	36	36	575	3.060	Fair
Electricity and water Supply		30	36	38	38	46	530	2.819	Poor
Drainage systems		36	35	37	40	40	511	2.718	Poor
Storage and Cold Chain Facilities		36	35	37	38	42	549	2.920	Poor
Parking and Transportation		35	32	36	46	39	537	2.856	Poor
Premises cleanliness		34	34	37	43	40	543	2.888	Poor

Legend: <2.00= Very Poor, >2.00= Poor, <3.00= Fair, >3.00= Good, & <4.50 =Very Good. Note: ∑f = Number of values; ∑fx = Sum of Values; ∑fx/∑f = Sum of Values divided by Number of values (mean).

Source: Authors' Field Surve y, 2024

Current State of Public Market Infrastructure

Figure 1 shows that 40% of the rated public market infrastructure conditions are very poor, 22% agree to be poor, 16% indicated that the infrastructure conditions are fair, while 12% as good. However, 10% rated the conditions of the public market infrastructure as excellent. This infers that the general conditions of public market infrastructure are poor. Consistent with earlier studies of Akinola (2018); Ekpo (2004); the findings provided a comprehensive overview of the dilapidated condition of many market facilities, including inadequate stalls, poor sanitation, lack of waste management systems, and insufficient security measures. These conditions not only deter traders and customers but also pose significant health risks, impacting the overall functionality and attractiveness of these markets. This study has demonstrated that the impact of poor infrastructure on market efficiency and trader profitability is high. The findings discovers that many markets lack basic amenities such as clean water, electricity, and proper drainage systems. These deficiencies result in unfavorable trading conditions,

reduce market hours, and increase the cost of doing business, thereby limiting the economic potential of these markets. It also indicated that the absence of reliable infrastructure in markets increases transaction costs and reduces the overall efficiency of goods distribution. This inefficiency translates to higher prices for consumers and lower profit margins for traders, undermining the economic viability of market activities.

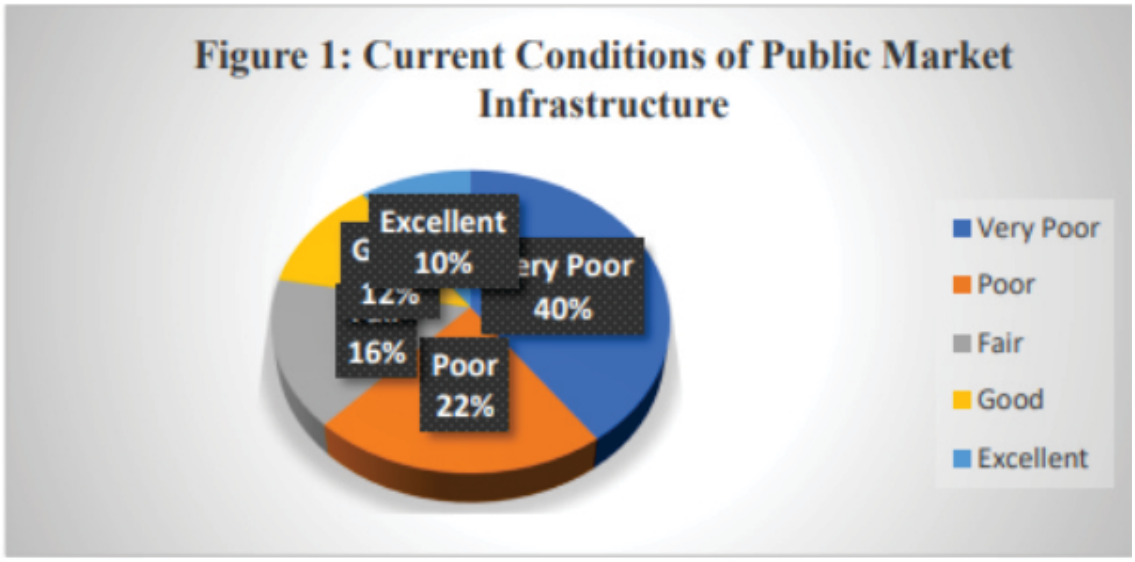

Figure 1: Current State of Public Market Infrastructure

Operational Challenges of Developing Public Markets

Table 2 shows the operational challenges of developing public market infrastructure hindering national economic growth in the Niger-Delta Region. The response rate of >3.00 mean score/RII>0.60 in Table 2 reveals the operational challenges at which public market development are hindered from national economic growth that are most important. Table 2 shows the respondents' responses with their rating/ranking. However, most of the respondents agreed upon all of the items presented under the variable, meaning that all the items listed under as the operational challenges of developing public market infrastructure hindering national economic growth were indicated as being used and the highly-rated once since the mean or RII of every item range from >3.00 mean scores or RII>0.60. This shows the consensus that the respondents hold towards governance issues, financial constraints, logistical problems, health and safety concerns, and environmental concerns as operational challenges affecting public markets efficiency and economic contributions. This study finding aligned with earlier studies of Fafchamps (2004); Ekpo (2004); Akinola (2018); Odozi and Akinola (2018) suggests that enhancing access to finance through microcredit schemes and financial literacy programs can empower traders and stimulate market growth. Additionally, improving transportation and storage infrastructure can mitigate logistical inefficiencies, while robust waste management systems can address health and environmental concerns. Therefore, effective implementation of new strategies is essential for overcoming the operational hurdles faced by public markets.

This study has identified also the pervasive situation in the public markets are logistical challenges such as poor transportation infrastructure, inadequate storage facilities, and inefficient supply chains that significantly impede market operations. Many markets lack proper roads, making it difficult for traders to transport goods efficiently. Many markets lack proper roads, making it difficult for traders to transport goods efficiently. Moreover, inadequate storage facilities lead to high levels of waste, particularly for perishable goods. These logistical problems result in increased transaction costs and delays, reducing the competitiveness of market traders. Similar issue has occurred due to poor

sanitation and waste management are common problems, creating unhygienic conditions that deter customers and pose health risks to traders and consumers alike. These health and environmental issues have also significantly posed operational challenges in Niger-Delta public markets. The absence of proper sanitation facilities and ineffective waste disposal systems are major concerns that need urgent attention to improve market conditions. The study has shown that beyond infrastructure, public markets in the Niger-Delta also face significant operational challenges that affect their efficiency and economic contributions. Key among these are governance issues, financial constraints, logistical problems, and health and environmental concerns. Addressing these infrastructural and operational challenges requires a multifaceted approach involving infrastructure investment, regulatory reforms, and financial inclusion initiatives.

Table 2: Operational Challenges of Developing Public Markets

Operational Challenges	Weigh: N= 188					∑fx	∑fx/∑f	RII	Rank
	5	4	3	2	1				
Governance issues	40	39	38	37	34	578	3.07	0.614	2nd
Financial constraints	37	37	40	37	37	564	3.00	0.600	4th
Logistical problems	43	38	36	36	35	582	3.09	0.618	1st
Health and safety concerns	37	37	40	37	37	564	3.00	0.600	4th
Environmental concerns	38	38	38	38	36	568	3.02	0.604	3rd

Legend: <3.00= Disagree, >3.00= Agree. Note: ∑f = Number of values; ∑fx = Sum of Values; ∑fx/∑f = Sum of Values divided by Number of values (mean). and RII = relative importance index.

Source: Authors' Field Investigation. 2024

During interview, more than 50% of the respondents agree that investments in market infrastructure and market-oriented policies stimulate economic activities within and around the markets, fostering local entrepreneurship and job creation. These economic activities contribute to poverty reduction and economic empowerment, especially among women and youth who constitute a significant portion of market participants. Moreso, improved market infrastructure enhances market efficiency, reduces transaction costs, and increases market participation, thereby boosting economic productivity and competitiveness at the local level.

One of the key informants stated that:
'Market activities also contribute to the preservation and promotion of local cultures and traditions: it serves as social hubs where community members converge, interact, and engage in cultural exchange'.

It suggests that public markets foster social cohesion by providing spaces for social interaction, networking, and community solidarity. These interactions strengthen social bonds, build trust among community members, and promote collective identity formation. Public markets often showcase diverse cultural practices through food, crafts, music, and other cultural expressions, enhancing cultural diversity and mutual understanding among different ethnic groups within the Niger-Delta Region.

Prospects of Developing Public Markets

Figure 2 indicates that 45% of the respondents agree of economic benefit being one the prospects of developing public markets, 37% agree to view that the prospects of developing public markets is for social benefits, 18% being of environmental benefits. neutral, 15% being high and !0% being very high. From the Figure it can be seen that the prospects of developing public markets include economic, social and environmental benefits. It implies that these potential benefits, Nigeria can leverage public market development as a key driver of sustainable economic growth, fostering a more resilient, inclusive, and prosperous economy.

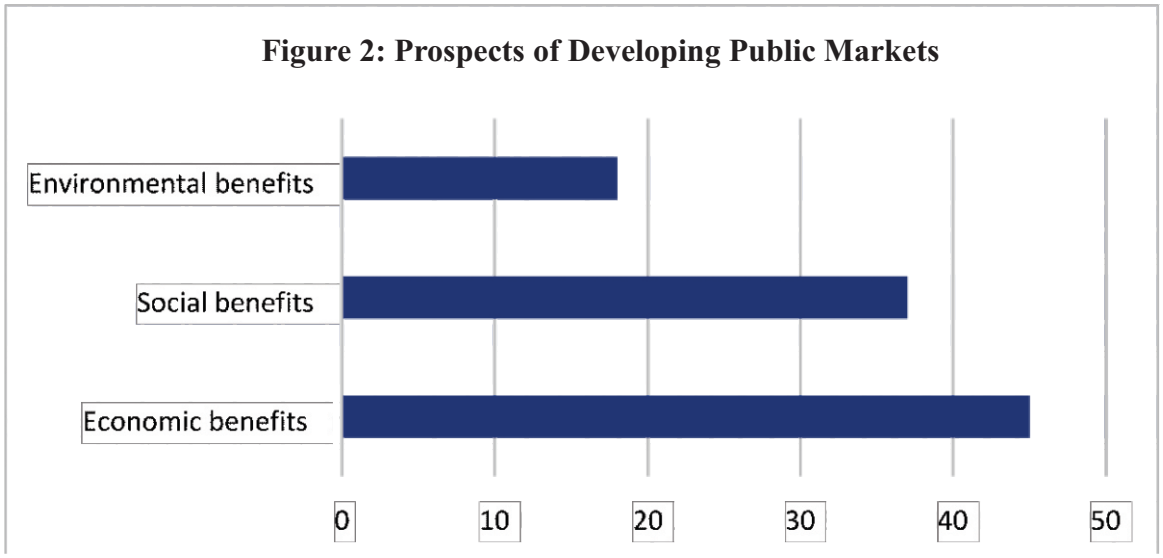

Figure 2: Prospects of Developing Public Markets

Potential Economic and Social Benefits of Developing Public Markets

Table 3 shows the potential of economic and social benefits of developing public markets in NigerDelta Region. As shown in Table 3; more than half of the respondents with RII>0.60 identified stimulate stable and localized economic activities, generate employment, generate employment, increase household income, enhance local economic development, improve market efficiency, enhanced government revenue, increased productivity and competitiveness, support small-scale enterprises, promote local production, and support innovation as the economic benefits of public market development. Similarly, as shown in Table 3; more than half of the respondents with RII>0.60 identified social benefits of public market development include to foster community interaction, preserve cultural heritage, promote inclusive economic participation, enhance civic engagement, improve consumer choice, affordability, and overall welfare, and provide spaces for urban growth. This study finding affirmed the studies of Fafchamps (2004); (Ekpo (2004) Akinola (2018); and World Bank (2019) which emphasizes that efficient market systems reduce transaction costs, improve market accessibility, and enhance the efficiency of goods distribution. By facilitating trade and commerce, public markets contribute to increased productivity, competitiveness, and overall economic output. This economic multiplier effect extends beyond market boundaries, benefiting related sectors such as transportation, agriculture, and tourism. The study has demonstrated that public markets play a significant role in stimulating economic activities and fostering local economic development. And any vibrant public markets create employment opportunities, support small-scale enterprises, and promote local production. These markets serve as platforms for economic transactions, generating income for traders, service providers, and suppliers within the market ecosystem. Still, the study identified public markets as not only contributing to economic growth, but also to social cohesion and environmental sustainability. It should be noted that markets serve as social hubs where community members interact, exchange cultural knowledge, and build social networks. These interactions strengthen community bonds, enhance social capital, and contribute to overall community well-being. Nevertheless, rapid market development can also pose environmental challenges such as increased waste generation and resource depletion. Sustainable market development strategies, including waste management initiatives and green infrastructure investments, are essential to mitigate these impacts and promote eco-friendly market practices. Evidence in this study explained the transformative potential of public market development as a panacea for economic growth. By stimulating economic activities, creating employment opportunities, enhancing market efficiency, and fostering social cohesion, public markets contribute significantly to local and national economic development. Strategic investments in market

infrastructure, coupled with effective governance and regulatory frameworks, are essential for harnessing the full economic and social benefits of public markets. Policymakers and stakeholders must prioritize sustainable market development practices to ensure inclusive growth, environmental sustainability, and long-term economic prosperity.

Table 3: Potential Economic and Social Benefits of Developing Public Markets

Potential Economic and Social Benefits	Weigh: N= 188					∑fx	∑fx/∑f	RII	Rank
	5	4	3	2	1				
Economic Benefits									
Stimulate stable and localized economic activities	50	38	35	35	30	607	3.23	0.646	1st
Generate employment	38	42	38	37	35	581	3.09	0.618	6th
Generate household income	47	38	35	35	33	595	3.16	0.633	2nd
Enhance local economic development	44	39	37	34	34	589	3.13	0.626	4th
Improve market efficiency	44	37	37	36	34	585	3.11	0.622	5th
Enhanced Government Revenue	46	39	35	33	35	593	3.15	0.630	3rd
Increased productivity and competitiveness	38	37	42	36	35	571	3.04	0.608	7th
Support small-scale enterprises	40	37	40	35	36	576	3.06	0.613	8th
Promote local production	40	40	35	36	37	574	3.05	0.610	9th
Support innovation.	38	37	42	36	35	571	3.04	0.608	10th
Social Benefits									
Foster community interaction,	50	38	35	35	30	607	3.23	0.646	1st
Preserve cultural heritage	47	38	35	35	33	595	3.16	0.633	2nd
Promote inclusive economic participation	46	39	35	33	35	593	3.15	0.630	3rd
Support healthy lifestyles	44	39	37	34	34	589	3.13	0.626	4th
Enhance civic engagement.	44	37	37	36	34	585	3.11	0.622	5th
Provide spaces for urban growth	43	38	36	36	35	582	3.09	0.618	6th
Improve consumer choice, affordability, and overall welfare	40	39	38	37	34	578	3.07	0.614	7th

Legend: <3.00= Disagree, >3.00= Agree. Note: ∑f = Number of values; ∑fx = Sum of Values; ∑fx/∑f = Sum of Values divided by Number of values (mean). and RII = relative importance index.

Source: Authors' Field Survey, 2024

Conclusion

The study established that there are several challenges hampering effective functioning of public market development, pivotal for stimulating economic growth. These recurrent operational challenges stemmed from infrastructure deficiency, regulatory and bureaucratic hurdles, security concerns, access to finance, technological gaps, market information asymmetry, and political instability. Moreover, sustainable market development practices can ensure that economic gains are balanced with social inclusiveness and environmental stewardship, contributing to long-term economic resilience and prosperity. Addressing infrastructure deficiencies, strengthening governance frameworks, and leveraging market opportunities are essential for unlocking the full economic and social potential of public markets in the region. Still, prioritizing infrastructure investment, strengthening governance frameworks, supporting economic empowerment initiatives, integrating technology, promoting sustainability, and implementing robust monitoring mechanisms, public markets in the Niger-Delta

Region can realize their potential as engines of economic growth, cultural preservation, and community development.

Furthermore, the study underscores the dual benefits associated with public market development in the Niger-Delta. These opportunities driving sustainable economic growth include enhanced market accessibility and trade, employment generation, economic diversification, increased agricultural productivity. boost to small and medium-sized enterprises (SMEs), technology integration and innovation, enhanced revenue generation for government, improved food security, promotion of regional and international trade, community development and social cohesion. The study accentuates the transformative potential of public market development as a panacea for economic growth. The study findings align with criticism that by capitalizing on these opportunities, Nigeria can create a more vibrant and sustainable economy, leveraging public market development as a catalyst for broad-based economic growth and development. As these transformative potentials of public market development stimulates economic activities by creating employment opportunities, with enhanced market efficiency through fostering social cohesion; public markets contribute significantly to local and national economic development. Strategic investments in market infrastructure, coupled with supportive policies and governance frameworks, are essential for harnessing these benefits and ensuring sustainable economic growth and development in communities where public markets operate. However, realizing these benefits requires addressing the governance, financial, and logistical challenges that currently impede market efficiency. Targeted interventions and effective policy implementation are essential for leveraging the full potential of public markets to drive sustainable economic and social development in the Niger-Delta.

Recommendations

The effective functioning and potential benefits of public market development in Nigeria, pivotal for stimulating economic growth. It is imperative to ensure that public market operations are unhindered to smoothened the potential benefits of public market development in order to drive sustainable economic growth. The following suggestions are meant to drive sustainable economic growth through public market development. These suggestions include:

i. Investment in infrastructure is crucial to enhance the functionality and attractiveness of public markets: by improving sanitation facilities, water supply, and waste management systems to meet hygiene standards, upgrade market facilities for operational efficiency facilitate easy access for vendors and customers, thereby increasing market footfall and economic activity
ii. Effective governance and regulatory frameworks are essential to foster transparency, accountability, and market efficiency: with clear policies and guidelines for market administration, ensure equitable distribution of market benefits, and protect the rights of market stakeholders.
iii. Supporting economic empowerment initiatives will strengthen market resilience and contribute to local economic growth: access to credit facilities for market vendors empower vendors with essential skills for market competitiveness and sustainability.
iv. Harnessing technology can enhance market efficiency, customer engagement, and operational management; leveraging on technology for business growth and customer service enhancement.
v. Promote sustainable practices to mitigate environmental impact and ensure long-term market viability through effective waste management and energy-efficiency.
vi. Establish a robust monitoring and evaluation framework to track progress, measure impact, and guide future interventions: to address concerns, and continuously improve market management and service delivery.

Institutionalizing these recommendations can significantly enhance sustainable economic growth through public market development requiring the commitment of all public market stakeholders. As implementing these recommendations will require collaborative efforts from government agencies, market associations, private sector partners, and community stakeholders in Niger-DeltaRegion, Nigeria.

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Theme E:
The Built Environment, Climate Change and Environmental Sustainability

Assessment of Urban Boundary Layer Heat Index Rate in Port Harcourt

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Abstract

This study examined the heat index rate of an Urban centre in Port Harcourt. A 1-year hourly air temperature and relative humidity data from January 2023 to March 2024 was sourced from NASA's MERRA-2 Satellite at 0.5 x 0.625° resolution and analysed using the NOAA's Weather Service Heat Index Model. Results showed that 19.8%, 44.9%, 34.4% and 1% of the assessed diurnal data indicated stable (<=25); moderate caution (26-31 °C); extreme caution (32-38 °C) and danger (39-46 °C) levels of heat stress. A comparative analysis of January to March 2023 and for 2024 showed that there was increased heat wave from 4 to 16%, 3 to 15 % and 8 to 27 % in 2024 from 2023 for the specified respective months. Specifically, the days: 11 and 21 and 11, 28-29 of February and March 2024 respectively showed an extreme caution/danger levels of heat wave all through the diurnal hours including period of dawn as the heat index ranged from 32 to 39 °C. In March 2024, the average period for extreme caution was from 7:00 am to 9:00 pm while the average time period for the whole data reviewed was from 9:00 am to 4:00 pm. The main rainy months of July to September had a reduced heat wave index of moderate caution due to the effect of maritime air mass within and outside the study environment. The trends of these increased heat waves most especially from January to March 2024 will enhance dehydration, heat rashes, measles, heat stroke and increased susceptibility to unfriendly health situations particularly for infants and elderly if adequate measures are not taken to lessen the negative impacts. Urban dwellers in Port Harcourt are advised to moderate energetic activity during maximum heat periods and stay hydrated as well as, where possible, stay in air conditioned/ventilated domains as a way of limiting heat stress/stroke. Infants and elderly should be well aerated coupled with wearing light clothing to decrease effects of high ambient temperature. Government at various levels should engaged in public awareness drives and coaching of her citizens on the hazards linked with heat stress and the adequate adaptation measures to ease negative impacts.

Keywords: Port Harcourt, Heat index, Air temperature, Relative humidity, Heat stroke, Adaptation

Introduction

Dangerous urban heat waves which causes heat stress is one of the most persistent climate risks globally and is aggravated by a warming climate as well as modifications of urban domains. It is noted that over 5,000 global deaths occur annually due to heat stress (Rennie *et al.,* 2021). It was also emphasised that 30% of the global human population is now at risk of exposure to increased heat conditions surpassing harmful thresholds, and this percentage will increase to 48% and 74% by 2100 respectively with increasing greenhouse gas emissions. Edokpa and Nwaerema (2019) highlighted that urban micro-climatic situations are intensely modified by energy fluxes driven by different composite physical and chemical processes. The development of urban environment and the associated anthropogenic activities has a considerable influence on the atmospheric boundary layer. The heat that radiates from the urban planetary layer is being driven by both mechanical and thermal turbulence depending on the one that is dominance. While thermal turbulence is created from the surface layer exchanges with solar energy, mechanical turbulence is mainly generated from surface roughness creating a wind shear and this limit free flow of air. Limaye *et al.,* (2018) observed that intense heat and impact on the biotic environment are aggravated by high levels of relative humidity leading to heat related fatalities most especially for vulnerable humans such as infants and the elderly. Raymond *et al.,* (2020) noted that when atmospheric humidity is high, there is amplified limitation to the evaporation of sweats from the human body. This condition restricts the cooling of the body especially during exposure to intense heat and exhaustive tasks.

Port Harcourt, a coastal city with less than 60km from the Atlantic Ocean experiences high humidity all through the year, and in recent times has witnessed an unusual heat wave both during the day and night

periods. This heat effect is largely due to the effect of global warming and persistent black carbon emissions choking the lower atmosphere (Ede & Edokpa, 2017). Also, the continuous terrain modifications due to the City's hub as a center for oil and gas businesses, increasing population and other numerous anthropogenic activities contributes to city's increased heat island. Agu and Ikwuka (2021) disclosed that increasing city population will amplify the rise of temperature as energy utilization increases intensifying rate of heat discharges into the environment. Teodoreanu (2016) stated that a vital ability of the human body is the homoeothermic which is maintaining a constant internal body temperature at 37.5^{0}C. This system is attained by thermoregulation mechanisms. This is a process whereby the human body generates heat in a low temperature environment and releases heat to the outside during high temperature situation via sweating which lead to evaporative cooling. This system which is termed thermal comfort varies depending on geographical location with boundaries for Europe as: 14 – 20.6 ^{0}C, USA: 20.2 – 26.7 ^{0}C and Tropical regions: 23.3 – 29.4 ^{0}C for relative humidity between 30 – 70 %.

Material and Methods

Study Area

Port Harcourt is situated within Latitudes 4^o 45^l – 4^{o}60^l N and Longitudes 6^o 55^l – 7^{o}56^l E (Figure 1). The area is situated in the Nigeria's wet climate zone classified under Koppen's '*Am*' tropical monsoon climate. The area which is roughly 60 km from the Ocean exposes it to the influence of continentality and this boost both the effects of mechanical and thermal turbulence on the city boundary layer atmosphere (Edokpa and Nwaereman, 2019). The moist maritime air mass from the Atlantic Ocean and the dry continental air mass from the Saharan desert control the area's climate system during the wet and dry season. Though, the major dominance of the rainfall bearing maritime air mass exceeds 75 %. The city experiences a low diurnal temperature variation due to the humid atmosphere all through the year and this impacts the cloud cover pattern of the area.

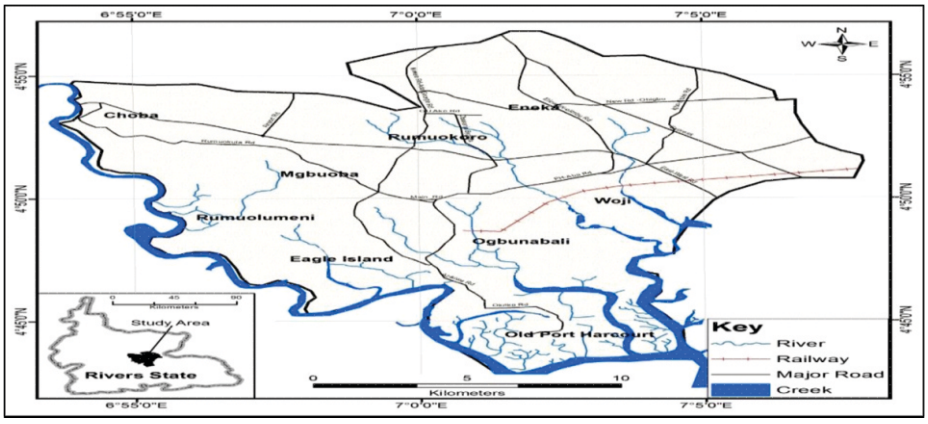

Figure 1: Map of Port Harcourt

Material Methods

A 1-year hourly air temperature and relative humidity data from January 2023 to March 2024 was sourced from NASA's MERRA-2 Satellite at 0.5 x 0.625^o resolution and analysed using the NOAA's National Weather Service (NWS) Heat Index Model. The heat index formula is based upon the temperature and relative humidity to indicate the air temperature perceived by the human body. The heat index formula (NWS, 2024) is expressed as:

$$HI = c_1 + c_2T + c_3R + c_4TR + c_5T^2 + c_6R^2 + c_7T^2R + c_8TR^2 + c_9T^2R^2$$

where,

- HI denotes the heat index in degrees Fahrenheit

- R denotes the relative humidity
- T refers to the temperature in °F, and 'C's are constants given by:
- $c_1 = -42.379$
- $c_2 = 2.04901523$
- $c_3 = 10.14333127$
- $c_4 = -0.22475541$
- $c_5 = -6.83783 \times 10^{-3}$ $c_6 = -5.481717 \times 10^{-2}$
- $c_7 = 1.22874 \times 10^{-3}$
- $c_8 = 8.5282 \times 10^{-4}$
- $c_9 = -1.99 \times 10^{-6}$

A program was written in Micro Soft Excel to analyse and convert temperature data from degree Celsius to degree Fahrenheit given the heat index equation.

Results and Discussion

The Table 1 shows the percentage summary heat index (HI) for Port Harcourt for the periods under review. Results showed that 19.8% 44.9%, 34.4% and 1% of the assessed diurnal data indicated stable (<=25); moderate caution (26-31 °C); extreme caution (32-38 °C) and danger (39-46 °C) levels of heat stress.

Table 1: Percentage Summary of Heat Index (HI) for Port Harcourt from January 2023 to March 2024

Key Index	Range	Percentage HI (%)	Health Impact
Stable	<=25	19.8	No thermal stress
Moderate caution	26-31 °C	44.9	Fatigue is possible with prolonged exposure and activity. Continuing activity could result in heat cramp
Extreme caution	32-38 °C	34.4	Heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke
Danger	39-46 °C	1.0	Heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity

A comparative analysis of January to March 2023 and for 2024 as shown in Figures 2 – 4, showed that there was increased heat wave from 4 to 16%, 3 to 15 % and 8 to 27 % in 2024 from 2023 for the specified respective months. Specifically, the days: 19 and 21 and 11, 28-29 of February and March 2024 respectively showed an extreme caution/danger levels of heat wave all through the diurnal hours including period of dawn as the heat index ranged from 32 to 39 °C (Figures 5 and 6). In March 2024, the average period for extreme caution was from 7:00 am to 9:00 pm while the average time period for the whole data reviewed was from 9:00 am to 4:00 pm. The main rainy months of July to September had a reduced heat wave index of moderate caution due to the effect of maritime air mass within and outside the study environment. Both the moderate and extreme caution constituted about 79%. The prevalent warning heat trend will impact stressfully on the lives of the city inhabitants if adequate precautionary measures are not taken to mitigate the impacts. The over 70% humid condition Port Harcourt boundary layer with the average typical low wind speeds of 1 – 3m/s (Edokpa, 2018) will greatly limit the ability of air to carry moisture from one surface to another.

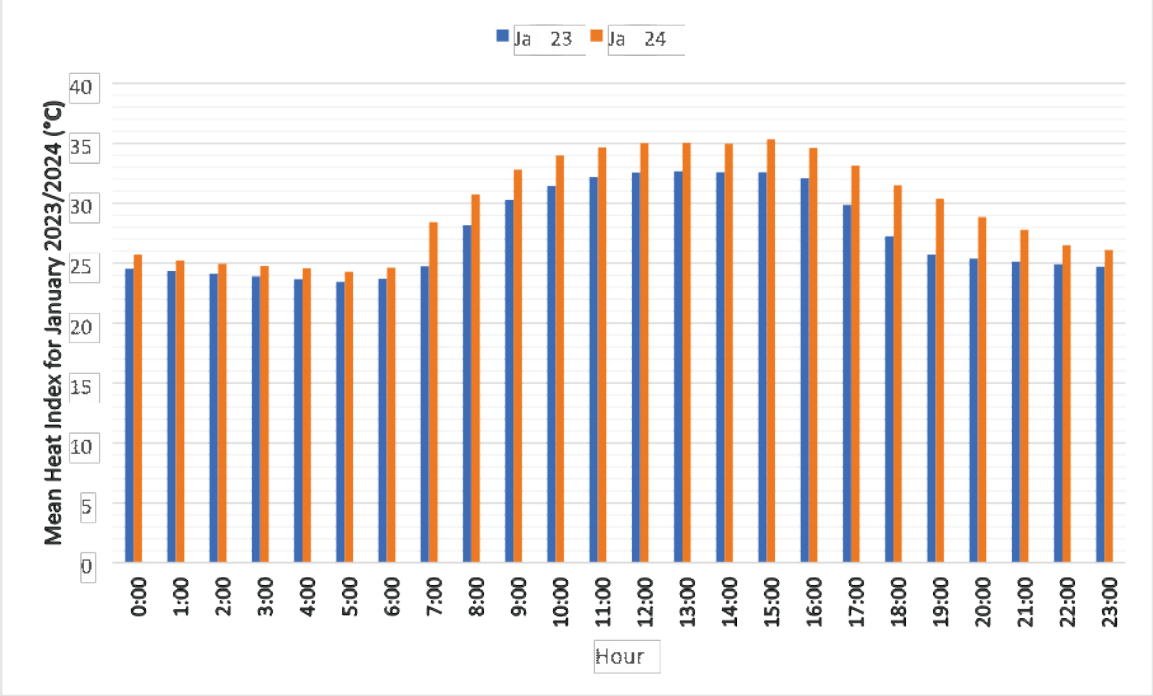

Figure 2: Mean HI Comparison for January 2023 and 2024

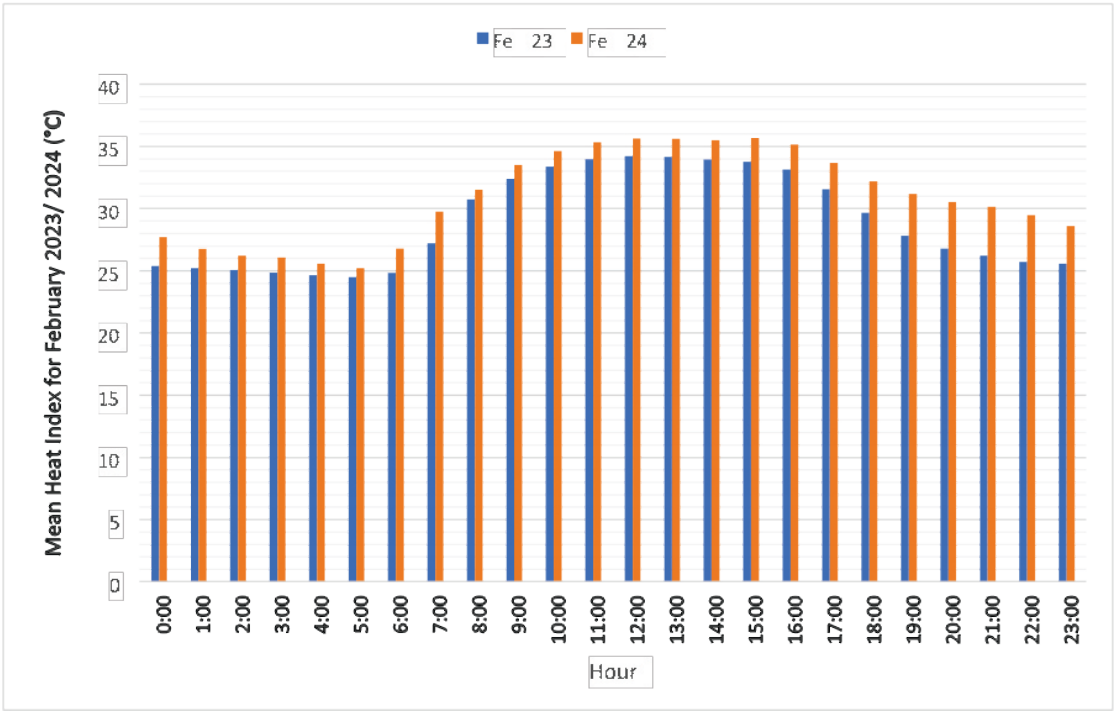

Figure 3: Mean HI Comparison for February 2023 and 2024

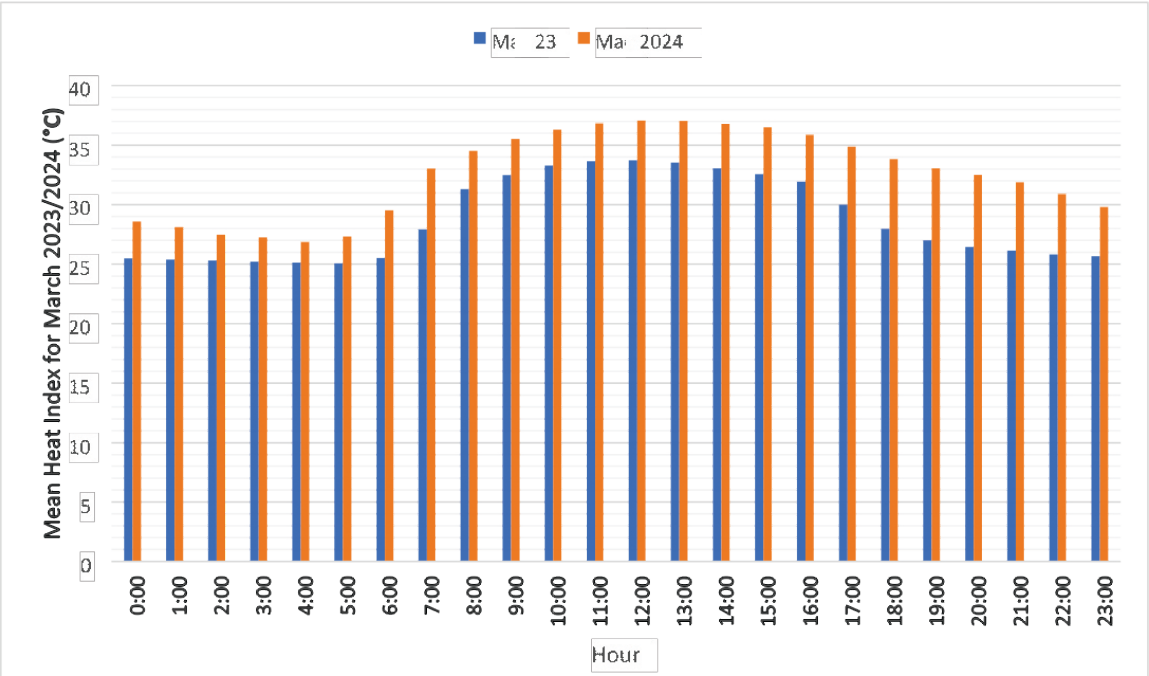

Figure 4: Mean HI Comparison for March 2023 and 2024

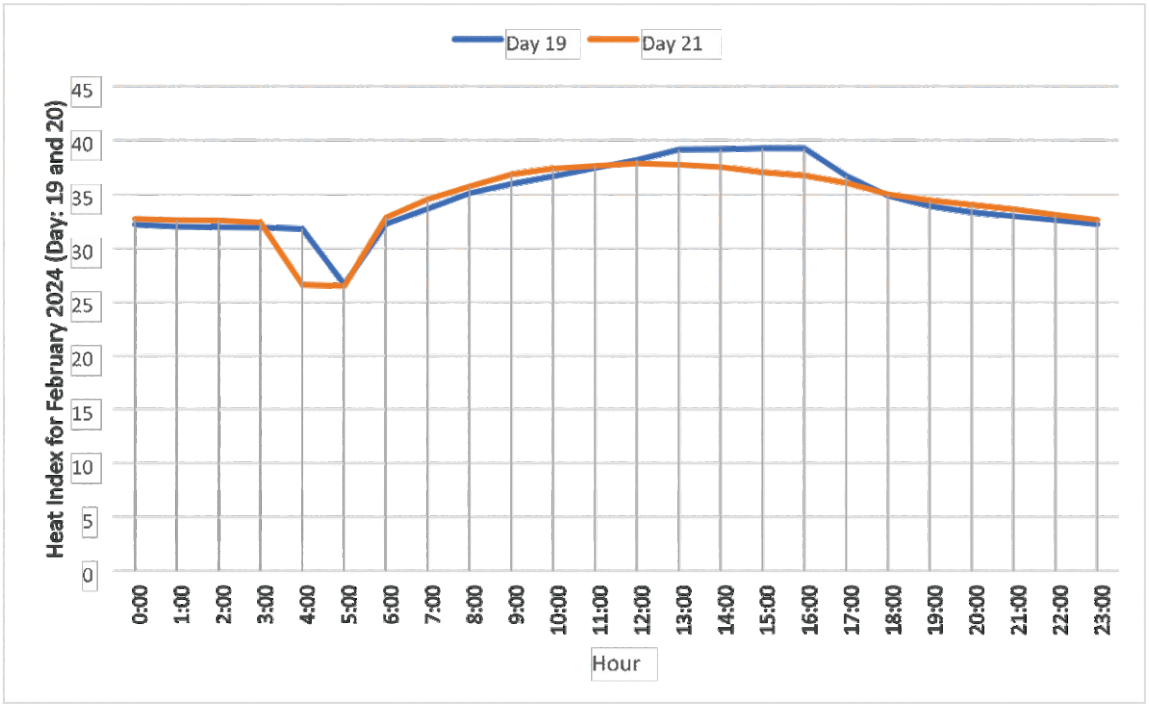

Figure 5: HI for Day 19 and 21 of February 2024

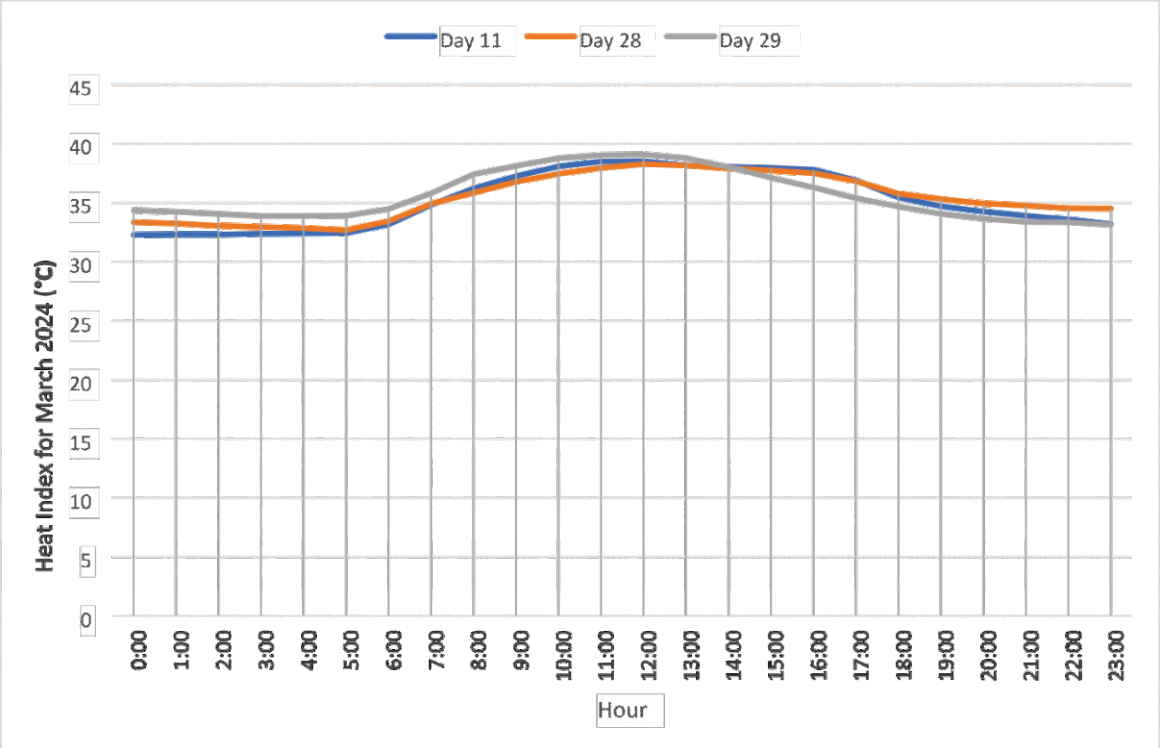

Figure 6: HI for Day 11, 28 and 29 of March 2024

Edokpa and Nwaerema (2019) observed that the heat island experienced in Port Harcourt boundary layer especially during the period of dawn, is strongly linked to the black soot emissions which emanates from the illegal refining of petroleum crude. During the periods of dawn, the city's boundary layer atmosphere is very stable where vertical motion is hindered, hence the lower atmosphere incapable of dispersing pollutants. It has been emphasised that a vigorous El Niño period that started in the middle of 2023 is pushing up temperatures globally even further. All through El Niño period, there is a spread of warm water across the surface of the Pacific Ocean towards South America. This very extensive area of warm water transfers massive ocean heat into the atmosphere which distorts the global atmospheric circulatory system, hence, causing surface temperatures to rise. The tropics are mostly affected during this period with persistent and unavoidable heat waves (Scientific Report, 2024).

The Nigerian Meteorological Agency (NiMET) in a weather warning early second quarter of 2024 says that if safety precautions are not taken, Nigerians in Abuja, Kano, and many other northern states are likely to suffer heat strokes due to the scorching heat waves (Anoliefoh, 2024). According to the Agency, residents of these states might suffer extreme heat, which would make them prone to heat-induced conditions. NiMET grouped the 36 states into 5 categories: Normal, Caution, Extreme Caution, Danger and Extreme Danger based on the degree of heat waves anticipated. Abuja, Kano, Sokoto, Kebbi, Katsina, Adamawa, Gombe, Bauchi, Taraba, Niger, Zamfara, Nasarawa, Jigawa, Benue, Kwara and Kogi states were classified under extreme danger, and inhabitants were advised to take precautionary steps as they were likely to experience heat. Furthermore, NiMET also cautioned the Niger Delta states to be ready for increased heat waves, though the likelihood of heat stroke is less expected compared to states in the extreme danger level. Early 2024, NiMET, projected that temperatures would hit 41°C in the north and 39°C in the south on some days between March and May. An hourly analysis of the HI for the month of March 2024 in Port Harcourt is shown on Table 2.

Table 2: HI Range in March 2024

HI Range (^{0}C)	No of Hours (744 Hours)
< "26"	39
> "31"	548
> "35"	245
> "37"	93
> "38"	41

The HI range for March 2024 for the entire hours reviewed showed that values greater than 31 ^{0}C occurred for 548 hours out of the total 744 hours in March. This constitutes an average of 73.7 % (Figure 7) indicating extreme caution level during the said Month. The danger level occurred for 41 hours constituting 5.5 %. The number of hours for the normal periods was 39 constituting about 5.2 %. The extreme caution/danger HI dominance in March 2024 showed that heat exhaustion which could result in heat stroke would impact on vulnerable dwellers such as infants and elderly in the city if necessary, precautions were not taken.

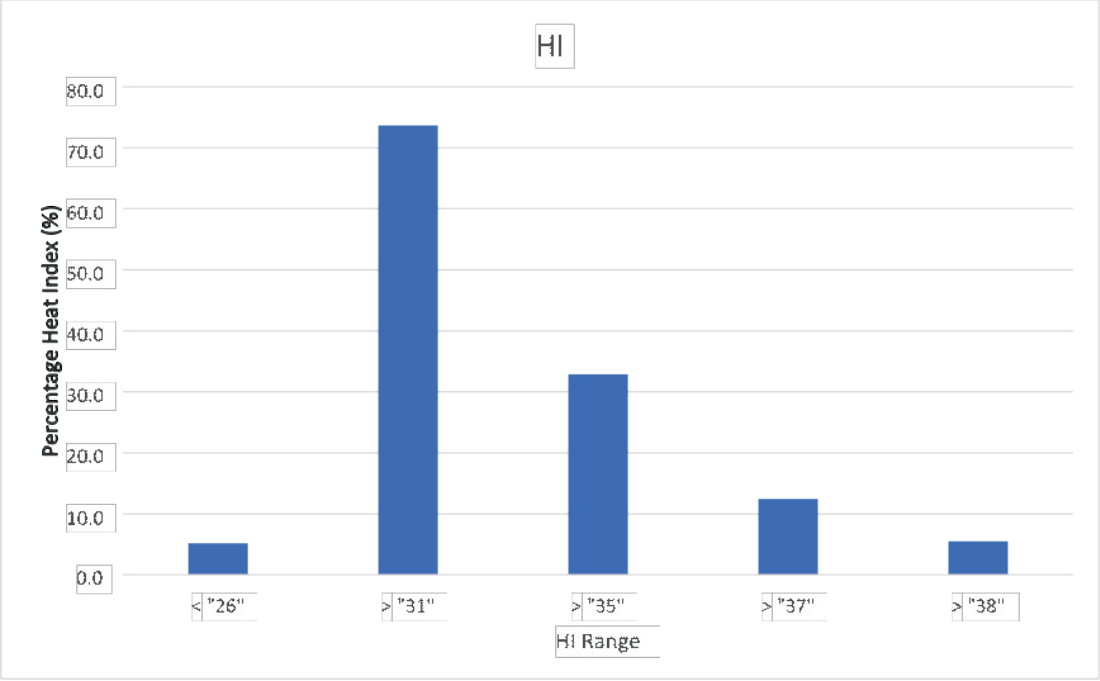

Figure 7: Percentage HI Range for March 2024

Kauda *et al.,* (2023) disclosed that high heat wave can cause a rise in core body temperature and heart rate subsequently leading to heat stress, heat stroke and in extreme situations, death. It was emphasised that individuals with heart illnesses, obesity, or respiratory conditions are more vulnerable to heat stress. The impacts of heat stress on human health are increased dehydration, fatigue, respiratory anomalies, skin ailments, mental stress etc. A continuous exposure to heat stress with activities engenders organ failure and death. It is also noted that economic constraints can limit access to cooling/convenient systems that alleviate the impacts of heat stress. The recent hike in electricity tariff in Nigeria has shown that adjustment in electricity usage for the average individual is a must if one must cope with the current economic challenges. This situation unsettles vulnerable city dwellers and creates illogical behavioural conditions unsuitable for progressive work tasks.

Conclusion

The recent increased in heat wave in Port Harcourt have shown that the comfort index for the city is at its very low ebb, most especially for inhabitants disadvantaged economically and health-wise. This is because disadvantaged city dwellers experience thermal discomfort both indoors and outdoors. The evidence gathered in this study showed that there was an increase in heat wave by 4-27% within January-March 2024 from January-March 2023. It was noted that extreme caution/danger levels dominated the month of March by 73% including night periods and could be detrimental to vulnerable dwellers where adequate precautionary measures are not taken. It is recommended for adaptation and mitigation of urban heat increases, afforestation within the city should be encouraged policy makers should develop and encourage the use of alternative energy to reduce the combustion of hydrocarbon and subsequent emissions of greenhouse gasses. Also, awareness and enlightenment should be created on the effect of urban heat wave and measures for reducing negative effects. Government must empower her populace by creating economic viable conditions that promotes comfort and sustainability.

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Oil Exploitation and Conflicts in The Niger Delta Area: Cause and Effect

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Abstract

This study examines the origins and impacts of oil-related conflicts in the Niger Delta, Nigeria, where oil exploitation has led to significant environmental and social disruptions. The research explores the interplay between oil wealth, environmental degradation, and local discontent, which have resulted in sustained conflict within the region. Utilizing historical data and contemporary accounts, the study highlights the roles of multinational oil corporations, the Nigerian government, local communities, and militant groups in the ongoing disputes. Findings indicate that despite Nigeria's vast oil wealth, the local population in the Niger Delta experiences high levels of poverty and environmental harm due to inadequate governance, corruption, and inefficient wealth distribution. This research also explores the environmental impacts of oil exploitation, such as oil spills and gas flaring, which contribute to the degradation of the Niger Delta and exacerbate conflicts. The study underscores the paradox of resource wealth leading to socio-economic challenges, aligning with the resource curse theory. Recommendations focus on implementing stricter environmental protections, enhancing community engagement, and improving transparency and governance to mitigate conflict and promote sustainable development in the Niger Delta. This study contributes to understanding the complex dynamics at play in resource-rich regions and provides insights into addressing resource-related conflicts globally.

Keywords: Oil Exploitation, Conflicts, Cause and Effect, Niger Delta

Introduction

Nigeria is enriched with natural resources such as coal, iron ore, gas, crude oil etc. (Ejibunu and Tuschl, 2006). According to Ebegbulem et al. (2013), the exploration of crude oil can be traced back to when a German company started looking for crude oil in Nigeria in 1908. The Nigerian Bitumen Corporation also began searching for oil in this period in the western part of the country. The Shell Petroleum Development Company however continued with this search and discovered oil firstly in Oloibiri, a community in the Delta Area in 1956 (Ebegbulem et al., 2013) and in 1958, discovered oil in commercial quantity in the same community of about 5100 barrels per day (Akhakpe, 2012; Ebegbulem *et al.,* 2013). According to the Nigerian National Petroleum Corporation (NNPC), Nigeria is the largest oil producing country in Africa and is ranked 6th in the world with the maximum production capacity of 2.5million barrels per day with a reserve of crude oil that stands at 28.2 billion barrels (NNPC, 2015).

The oil industry has been continuously dominated by foreign multi-national companies like Agip, Shell, ELF and Chevron, which represent the five big multi-national companies in the area and they have taken up key roles in determining the trends in the industry over the years. Their activities have resulted in both positive and negative impacts on the country and the Niger Delta Area over the years such as wealth generation, oil pollution characterized by contamination of streams and rivers, destruction and biodiversity loss (Ejibunu and Tuschl, 2006). This chapter aims to give a brief description of the Niger Delta Area and a background on the origin of oil exploitation in Nigeria and the Niger Delta Region.

The Niger Delta

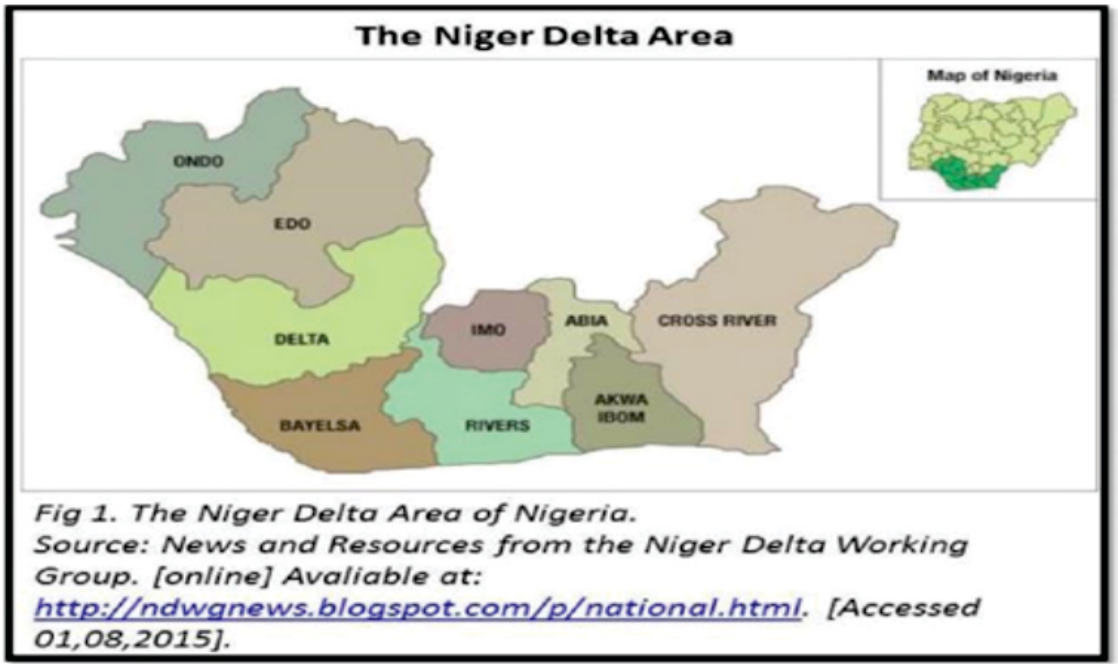

Fig. 1: The Niger Delta Area

"Nine states" make up the Niger Delta Area of Southern Nigeria which consists of: Abia, AkwaIbom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo and Rivers State shown in Fig. 1. According to the 2006 Nigerian Population and Housing census, the Niger Delta area is made up of about 21,044,081million people who make up about 15.9% of Nigeria's population (NPC, 2010). With about 40 ethnic nationalities spread over about 6000 communities with about 1500 of them as host to both local and multinational oil companies (Kadafa, 2012; Agho & Uyigue, 2007).

The Niger Delta represents the second largest delta amongst the deltas in the world with its coastline covering over 450 kilometres ending at the entrance of the Imo River. It is found on the "Atlantic coast of southern Nigeria*"* at the area where the "River Niger*"* splits into different branches (Ayodele, 2010: 110). The resources from this area are oil and gas which accounts for over 90% of the total value of exports of the country (Akhakpe, 2012; Agho & Uyigue, 2007: 5; Ejibunu and Tuschl, 2006; Ebegbulem et al., 2013). Fig. 2 below shows the oil fields available in the Niger Delta region. And shows how an oil resource is distributed among the Niger Delta states.

Fig 2: Oil Fields in the Niger Delta Region

Source: Stratfor Global Intelligence, 2015

The Niger delta has over 5 200 oil wells and produces crude oil that amount to over 2.5 million barrels daily that flows through about 275 flow stations being exported at ten terminals. Oil and gas pipeline installations in the area cover over 7000km, which aid in crude oil transportation to the rest of Nigeria (Ayodele, 2010; Kadafa, 2012). Although Nigeria has four refineries in the country, Nigeria remains a major crude oil exporting country in Africa due to consistent breakdowns and lack of maintenance from the Nigerian government. For example, the performance of the Port Harcourt refinery has been consistently poor for decades with its production only rising above 50% on 4 occasions. From 1993 to 1998, the refinery has been "plagued by technical malfunctions and breakdowns", and has suffered a major short down since 2002. This also applies to the other three refineries in Nigeria (Mbendi, 2016).

The production of crude in this region is largely dominated by Transnational oil companies like Chevron, Texaco, Royal Dutch Shell, Exxon Mobil, Total and Agip who operate a joint venture with the Nigerian Government through the National Petroleum Corporation (NNPC) and its subsidiaries in which the Federal government owns in average, about 60% of its equity shares **(**SDN, 2015; World Bank, 2008; Okumagba, 2012). The activities of oil exploration have resulted in social and environmental costs to the Niger Delta people and have led to the degradation of the environment through oil spillage and gas flaring. This is because little or no regard is given to the development of the people and the environment on whose land the oil is acquired. Oil spillage has continuously been one of the major sources of environmental degradation and pollution in the Niger Delta environment. A continuous blast and discharge of harmful effluents into rivers, and other sources of water, loss of marine life and the loss of bio-diversity are common occurrences in the area (Agho and Uyigue, 2007; Akhakpe, 2012; Ogu, 2006).

All this has led to the grievances from the Niger Delta people that the proceeds that comes from the production of crude oil are not used to develop their region and people who suffer from the degradation caused by the exploitation and production of crude oil (Agho and Uyigue, 2007; Oyefusi, 2007; Ogu, 2006). This study is significant because it explores the relationship of oil exploitation, its impacts in the environment and conflicts in the Niger Delta and also explores the different types of conflicts and the understanding of the relationships between them, its causes and effects in the Niger Delta Area. This study is significant in that it highlights the contradiction of the wealth and mystery that natural resources in the region create development in the Niger Delta region of Nigeria.

Objective of the Study

i. To explore the underlying causes of oil conflicts and the effect of oil exploitation and conflicts in the Niger Delta Area.

Research Question

i. What are the underlying causes of oil conflicts and the effect of oil exploitation and conflicts in the Niger Delta Area?

Methods

This is qualitative research that is explorative and seeks to explore conflicts that are linked to oil exploitation in the Niger Delta region, in order to identify the interaction and intersection with environmental degradation in the area. This study made use of only secondary data through a desktop review which involves an extensive literature search, review and synthesis of material relevant to oil exploitation and oil conflicts in the Niger Delta Area (Tellis, 1997 and Yin, 1994). Data and information were drawn internally through the extensive use of library materials and externally through extraction from online databases like Web of Science, Science Direct, Sage Premier Online, Research Channel Africa, African Portal, Ebsco Host and World Newspaper Archive; collation of newspapers, reports, Nigerian Government publications, statistical releases, conference material and presentations, etc. that

relate to the objective and research question of this study. These databases provided me with a pool of information that helped in the understanding of the different conflicts in the Niger Delta, the root causes and in exploring the interrelationship between oil exploitation, environmental degradation and the conflicts the Nigeria Delta region has been experiencing over the years.

Case Study Research

This is a qualitative approach to research that enables the exploration of a subject within its context using a pull of data sources (Baxter and Jack, 2008). This type of research ensures that the topic of research is not explored from one point of view; rather it uses variety of lenses which allows for multiple facets of a particular phenomenon to be revealed and understood (Baxter and Jack, 2008). It also seeks to ensure that the topic of interest is well explored, and that the essence of the phenomenon is revealed. The type of case study research used in this study is the Exploratory Case Study. An exploratory case study was used because it helps in seeking answers to question that attempts to explain a presumed causal links in real life interventions in complex situations like that of the Niger Delta Oil Conflicts (Yin, 1995; 2003).

Literature Review

The History of Oil Exploitation in Nigeria

Oil exploitation in Nigeria started in 1958 with the discovery of oil in large quantity by the British Shell Corporation in Oloibiri, a community in Bayelsa State in the Delta Region (Ejibunu & Tuschl, 2006; Agho & Uyigue, 2007; Akhakpe, 2012). Following this discovery, the rights to explore and exploit oil were extended and given to other multi-national corporations like Total, Chevron, Mobil, etc. This discovery displaced agricultural activities as a major contributor to the growth of the Nigerian economy. Over 90 per cent of the economic wealth of the nation today comes from oil produced from the Niger Delta area, which amounts to millions of barrels of crude oil daily (Ebegbulem *et al.,* 2013).

Although crude oil which is the backbone of the Nigerian economy all comes from the Niger Delta, the region is ranked among regions that are greatly marginalized in Nigeria. The Niger Delta people are mostly without electricity, lack basic water to drink, experience high level of poverty and live far below levels of subsistence (Ebegbulem et al., 2013). The predominant occupation for the Niger Delta rural population is farming and fishing. The rural people therefore engage in fishing and farming activities as a means of supplementing their diet and income. However, forests, farmlands, rivers and streams are continuously being destroyed. The level of poverty in the NigerDelta is made worse by high living cost and lack of basic necessities. (Akhakpe, 2012).

The Effects of Oil Exploitation in the Niger Delta

The effects of oil exploitation in the Niger Delta can be seen in environmental impacts and social impacts experienced. The environmental problems like oil spillage and gas flaring, have impacted on the environment through the contamination of streams and other water bodies, oil spills, flaring of gas, deforestation and loss of bio-diversity, disposal of untreated waste, etc. and social problems like social and economic underdevelopment, poverty, communal conflicts and conflicts between multi-national companies and the communities, etc. (Achi, 2003).

Oil spillage has been identified as a major source of pollution of the environment in the Niger Delta. The continuous blast and discharge of harmful effluents into rivers, and other sources of water are common occurrences in the area. Kadafa, (2012); Agho and Uyigue, (2007) notes that, over the period of 50 years, the estimated number of oil spillage in this area accounts for about 1.5 million tons of crude. A lot of these oil spillages occurred on land, swamp and off shore environment (Kadafa, 2012). An average of 221 oil spillages per year were recorded by The Shell Petroleum Development Company (SPDC) since 1989 in the areas it operates in, which accounts for over 7350 barrels annually with impacts such as loss of vegetation, contaminated streams and rivers, etc. (Kadafa, 2012).

Oil Conflicts in the Niger Delta

The rate of natural resource export, especially the wealth from nature has been linked to conflicts and the onset of civil wars. This wars and conflicts are strongly linked to the struggle for gaining control over such resources therefore increasing the risk to violence and conflicts (Ikelegbe, 2005). Development Economists at the beginning of the 1950s, proposed "according to the Staple theory of growth that natural resource abundance would help developing states to overcome their capital shortfalls and provide revenues for their governments to provide public goods and lift citizens out of the doldrums of poverty.*"* A lot of research in the 1990s however shows, that there is a link between "resource-abundance and a number of socio-economic problems.*"* (Oyefusi, 2007).

This is because; the abundance of natural resources has also been accompanied by poverty and great inequality in a country, slow growth, corruption of political institutions and importantly the risk of conflicts (Collier & Hoeffler, 2001; Gravin & Hausmann, 1988; Lane & Tornell, 1999; Oyefusi, 2007; Sachs & Warner, 1995; Ross 2004b; Ross, 1999, 2001). Also, the link between resource led conflicts and the collapse of economies has been established (Collier *et al.,* 2003; Skaperdas 1992; Deininger, 2003; Oyefusi, 2007). Moreover, it has been indicated that amongst all the natural resources, crude oil has proven to have a highest tendency to lead to conflicts because of the huge revenue it generates and the extent to which governments and national economies depend on oil (Collier & Hoeffler, 2005; Fearon & Laiton, 2005; Oyefusi, 2007).

Inequality and Conflicts in the Niger Delta

Although Nigeria has made some significant progress economically and politically in the past years, a large proportion of its population still live in poverty. World Bank (2005; 2007) and DFID, (2005) indicate that over 70 million people in Nigeria live below US$1 per day. UNDP 2006 reports that the number of Nigerian citizens that live below the poverty line accounts for 54% of the Nigerian population. Also, the UNDP (2006) indicate that Nigeria is characterised by poor Human Development Index of (0.448), ranking 159 out of 177 countries (Higgins, 2009). The level of inequality in Nigeria is high and also on the increase, poverty and inequality in Nigeria is highly concentrated in certain regions and as such there are huge regional disparities of poverty and inequality. The National Bureau of Statistics (2005) and Higgins (2009) indicates that poverty is highly concentrated in the Northern and Southern region of Nigeria. The increase in oil wealth in Nigeria has not led to an increase in the standard of living. It has been argued that the rise in poverty and inequality in Nigeria corresponds with the discovery and export of crude oil (Higgins, 2009).

Comparing oil revenue and GDP of Nigeria in 1965 and 2000 shows that oil revenue in 1965 was US$33 per capita and GDP per capita was US$245 and in 2000, when oil revenue was US$325 per capita, GDP per capita remained at this level as in 1965. Although the Niger Delta region is responsible for sustaining the economy of the Nigerian federation, there is a huge disconnect between the income generated and the human development of the Niger Delta. An analysis carried out by the UNDP (2006:15) shows that poverty incidence in the Niger Delta increased between the period of 1980 and 2004. It went further to state that the Human development index of the Niger Delta is 0.564 which is slightly higher than that of Nigeria which is 0.448. when compared to other oil producing regions and countries with similar oil and gas reserves like "Venezuela (0.772) and Indonesia (0.697)", Nigeria and indeed the Niger Delta are far below the ladder of Human development.

The Behaviouralist Perspective on the Resource Curse

The Behaviouralist perspective draws from the work of political and economic theorists who proposes that the abundance of natural resources can lead to different types of irrational and emotional behaviour from political elites which in turn results in institutional deterioration and poor economic policy making. Literature indicate that boom in resource revenue creates shortsightedness and over-

exuberance in political elites and produces tendencies that countries will become optimistic which might lead to excessive spending from the government. Also, oil boom can create wishful thinking among policy makers in countries that are rich in oil and so, lead to policies that are not proactive, well thought through and realistic (Andrew, 2006).

For the Niger Delta Area and Nigeria, the dependence on oil revenue has led to short-sighted and excessive spending by the government and among political elites. The budgets of the oil producing states of Nigeria are huge with little or no substantial development and improvement in the daily lives of citizens. In 2008, Rivers State alone spent N367 billion which amounts to over $3 billion excluding budgets at the local government councils. Despite this huge budget, this spending has not been transformed into higher standard of living and improved amenities. They have only been mere wishes that have raised the hopes of citizens with little or no results (Niger Delta Citizens and Budget Platform, 2009).

Table 1: Budget Highlights for the Niger Delta States in 2008

States	Total Budgets (2008)
Akwa-Ibom	N153. 525 billion
Bayelsa	N180.1billion
Delta	N150.574 billion
Rivers	N377.081 billion

Source: Niger Delta Citizens and Budget Platform, 2009

Foreign Policy

Oil has been at the centre of foreign policy and international relations since the second half of the 20th century. This has been illustrated by "The Suez Crisis in 1956, the 1973 Arab oil embargo, the consequences of the Iran-Iraq War in 1980, and the two Gulf Wars in 1990 and 2003". Countries that depend on export of oil (developing countries like Nigeria) are concerned with securing, maintaining sustainable access to oil at lower prices, while countries that export oil (developing countries) are concerned with the desire to maintain prices, revenue generated and market share. "This relationship between importing states and Organisation of Petroleum Exporting Countries (OPEC) states has been highly strategic and political*"* (Bromley *et al.,* 2006: 4). The countries that make up OPEC are able to collectively bargain for prices and the level of production. The politics of oil has therefore become a "strategic game with strong implications for foreign policy*."* Developing countries like Venezuela and Libya have used the presence of resource abundance (oil) in their country to avow authority in world politics through what is referred to as "petro-nationalism." The system of quotas and collective bargaining practiced by OPEC has empowered a lot of the member countries to "leverage political capital in other areas through their strategic significance as supply or transit routes*"* (Bromley *et al.,* 2006). Developed countries and more powerful states like China, United States and France uses diplomatic relations and military power most times as a way to ensure that they gain and maintain energy security for example the foreign policy of the "United States during and after the Cold War in

the Middle-East, parts of Latin America and, increasingly, the Caucuses and Central Asia has been consistently linked to the political economy of oil*"* (Bromley *et al.,* 2006).

Oil Conflicts in the Niger Delta

History of Conflicts in the Niger Delta Region

In order to understand the nature and characteristics of the Niger Delta conflicts, there is need to understand the forces that define these conflicts by looking briefly at an overview of the Niger Delta history of oil conflicts. Oil conflicts in the Niger Delta started in the mid-1960s after oil was found in a community in the then Rivers State in commercial quantity and after Nigeria's independence. The Niger Delta conflicts started with the beginning of the "Isaac Adaka Boro Revolution*"* of mid-1960s (Anugwom, 2011). In the modern struggle of the Niger Delta people, Ken Saro-Wiwa can be regarded as the face of the Niger Deltans who is against oil companies and the Nigerian government for the degradation of the Niger Delta environment, the social and economic marginalization of the Niger Delta people. Ken Saro-Wiwa took the struggle of the Niger Delta people beyond just a mere political struggle led by what is regarded as a "disgruntled ragtag army of youths*"* to a more popular and well-articulated and focused struggle for emancipation in the end of the 1980s to the beginning of 1990s (Anugwom, 2011).

The Ogoni Movement of 1990

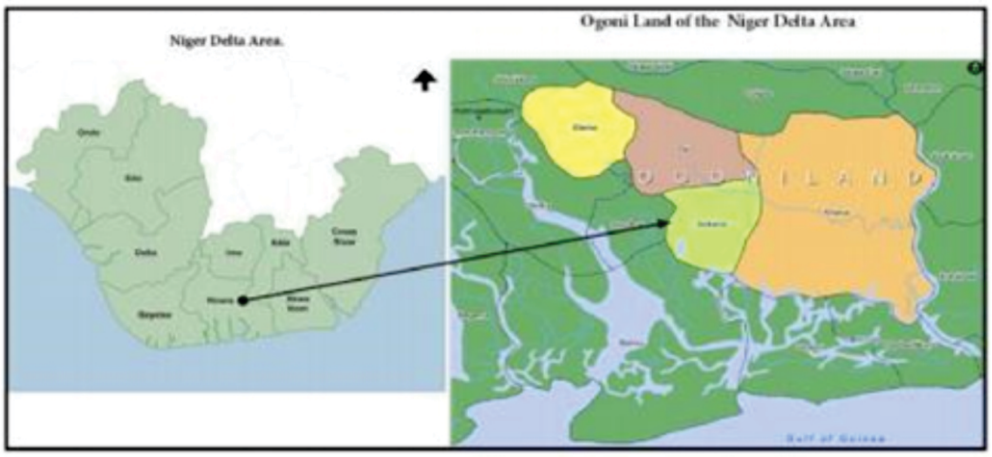

Fig. 4. Ogoni land of the Niger Delta Area. Sources: http://www.pinfoundation.org/who-we-are/where-we-work/; http://www.geocurrents.info/news-map/self-rule-and-environmental-crisis-in-ogoniland. Accessed [19 September, 2015].

The Shell Corporation started operating in the Niger delta area since? The discovery of oil in 1958. However, the conflicts over oil in Ogoni land a tribe in Rivers State of the Niger Delta Region started in 1970 when the chiefs of the Ogoni people for the first time wrote a petition against the activities of Shell Corporation in their land to the local Military Governor stating that the activities of Shell Corporation in the Niger Delta and especially in Ogoni land was "seriously threatening the well-being, and even the very lives" of the people of Ogoni (Remember SaroWiwa, 2015: 1). Prior to this petition, there was a major explosion at an oilfield in Bomu in Ogoni land. This explosion lasted for three days with a lot of pollution and damage caused to the environment. Mangroves and other resources obtained from the seascape are destroyed during oil spills for example mangroves produce fuel woods that are highly caloric and this is used by the people to support their energy needs. More so, mangroves are naturally productive ecosystem that serves as a habitat for many biodiversity, the mangroves serve as a breeding ground for many fish stock which the people depend on for livelihood and they inhabit the mangroves during their larva stage of development. Acknowledging how dependent the people are on the environment for livelihood, the Centre for Environment, Human Rights and Development (CEHRD) (2008), indicated that oil spillage will largely undermine food security in the community where they occur. By the 1980s; many other communities began the crusade and protest against the

activists of oil companies in the Niger Delta. One of such protests is the petition wrote by the Iko people to Shell demanding that compensations and restitution should be made for their right to clean water, air and a liveable environment where a good livelihood can be achieved (Remember Saro-Wiwa, 2015).

The Ogoni Bill of Rights was signed by Ogoni elders in August 1990. The bill called for the control of Ogoni affairs by Ogoni people politically, the control and the use of economic resources derived from Ogoni land for the development of the Ogoni area and the direct and adequate representation of the rights of the Ogoni people in all Federal institutions protecting their environment from more degradation. That same year, the Movement for the Survival of the Ogoni People (MOSOP), which is a non-violent group, was launched (Remember Saro-Wiwa, 2015).

Ken Saro-Wiwa is a key player in the birth of the "Movement for the Survival of the Ogoni People (MOSOP)" and the prominent "Ogoni Bill of Rights" that was brought before the Nigerian government in 1990. Ken Saro-Wiwa who is an author and a businessman in the 1990s sought the help of international community and started travelling often to the United States and Europe seeking support for the plight of his people (Remember Saro-Wiwa, 2015). By August 1991, the Ogoni Bill of Rights was amended that empowered MOSOP to be able to make appeal to the international community for help in their struggle since they have not received and reply from the Federal government (Remember Saro-Wiwa, 2015). The United Nations Working Group on Indigenous Peoples was addressed by Saro-Wiwa in July 1992 in Geneva, stating "I speak on behalf of the Ogoni people. You will forgive me if I am somewhat emotional about this matter. I am Ogoni … Petroleum was discovered in Ogoni in 1958 and since then an estimated 100 billion dollars' worth of oil and gas has been carted away from Ogoni land. In return for this the Ogoni people have received nothing" (Remember SaroWiwa, 2015).

The Ogoni Bill of Rights was tendered at the conference as evidence along with a book authored by Ken Saro-Wiwa titled "Genocide in Nigeria: The Ogoni Tragedy." In the book, Ken SaroWiwa wrote about the oppression and deprivation the Ogoni people and the Niger Delta people are experiencing and how they have been helpless watching multinational companies and the Nigerian government exploiting their resources and destroying their environment constantly and destroying their livelihood without any substantial development in the region. Ken Saro-Wiwa went ahead to write about the double standard of the Shell Corporation in Nigeria compared to its Operation in European countries and accused Shell of racism and the federal government of genocide (Remember Saro-Wiwa, 2015). The demands of the Ogoni people were presented to the Federal Government through the Nigerian National Petroleum Corporation (NNPC) and oil companies operating in Ogoni land including Chevron and Shell Corporation demanding that compensations and royalties be paid to the Ogoni people or quit their land in 30 days (Remember Saro-Wiwa, 2015).

At the expiration of the 30 days, what has been regarded as the largest demonstration ever in Niger Delta against oil companies took place. On the January 4, 1993, about 300 000 Ogoni people were mobilised in the celebration of the Ogoni day with a peaceful protest against the activities of oil companies on their land that has destroyed their environment. "We have woken up to find our lands devastated by agents of death called oil companies. Our atmosphere has been 39 totally polluted, our lands degraded, our waters contaminated, our trees poisoned, so much so that our flora and fauna have virtually disappeared" one of the Ogoni leader addressed the crowd and declared the 4th of January as the Ogoni Day (Remember Saro-Wiwa, 2015). Knowing the risks involved in the struggle, Ken Saro-Wiwa gave all he had to the struggle as a peaceful advocate. Ken Saro-Wiwa and eight other leaders of the Ogoni people died after being detained and charged by the military government for conspiracy. After the death of these nine Ogoni leaders, the struggle translated into a violent struggle involving youth militias from the region in a combat with the Nigerian armed forces (Anugwom, 2011). During this period, a lot of lives was lost and many fled from their homes with about 5 400 refugees reported by the United Nations High Commissioner (Pavšič, 2012).

The Kaiama Declaration of 1998

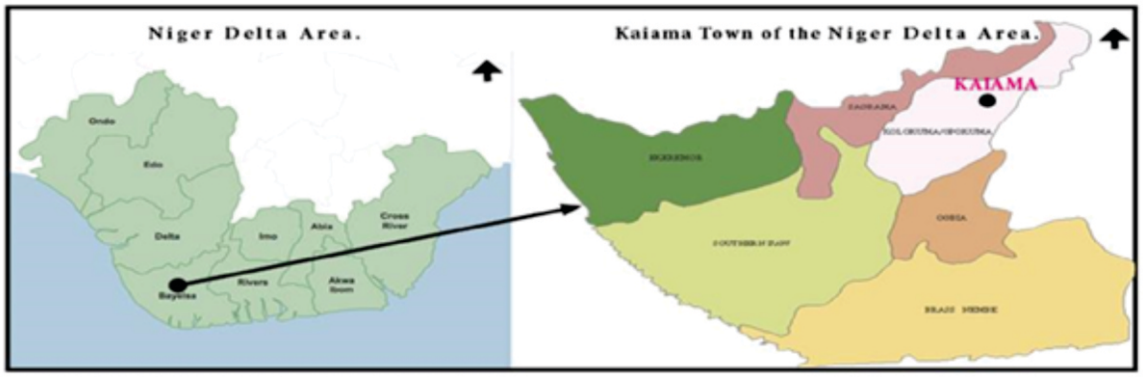

Fig. 4: Kaiama Town of the Niger Delta Area

After the death of General Sani Abacha in June 1988, who during his administration suppressed MOSOP protests, General Abdulsalami Abubakar came into power as the new military head of state and released a lot of prisoners and began the process to restore a civilian government back to Nigeria. This improvement gave activists in the Niger Delta area an opportunity to make a case and placed demand on the incoming civilian government to address their problems because the administration of General Abdulsalami Abubakar created the atmosphere that gave room and respect for the freedom of expression and association. The Ijaw people were the most vocal of all the tribes as the fourth largest ethnic group in Nigeria and the occupants of most of the lands where oil is produced in the riverine, and dryland areas of Rivers, Bayelsa and Delta States of Niger Delta (Courson, 2009; Human Rights Watch, 1999).

The Ijaw youth Council (IYC) was formed on December 11, 1998 in Kaiama during a youth meeting. The IYC adopted the Kaiama declaration that represented the political crisis over the struggle for the control of oil resources in the Niger Delta and maintaining that the reason why the Niger Delta environment is being continuously destroyed by oil companies and the Federal government is because the Ijaw people do not have any form of control of their land and resources from their land (Human Rights Watch, 1999). Niger Delta people is no longer recognized by the IYC (Human Rights Watch, 1999). These resolutions were set to be implemented from December 30 1998 by youth in all communities, especially in the Ijaw clans of the Niger Delta area. Oil companies were threatened and ordered to leave the region by that date in order to avoid being caught unaware by youth from the region, stating their displeasure with how their environment has been destroyed with gas flaring, blow-outs, oil spills and being addressed as terrorists and labelled as saboteurs (Human Rights Watch, 1999).

The Odi Massacre of 1999

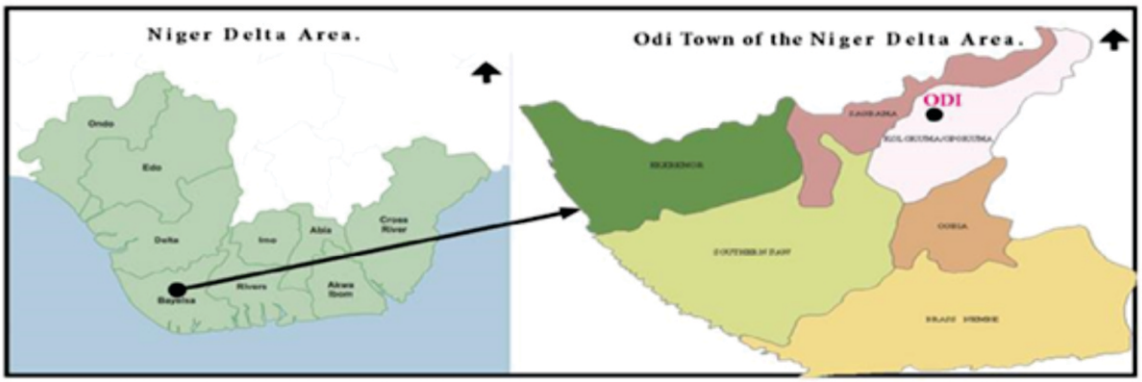

Fig.5: Odi Town of the Niger Delta Area

This massacre took place on the 20 of November, 1999in Odi, a community in Ijaw land of Bayelsa State months into Olusegun Obasanjo's administration as a civilian president of the Republic of Nigeria. This massacre was a military raid in response to the kidnap and killing of 12 policemen by a criminal youth gang in the area Odi community (Anugwom, 2011). The Human Rights Watch of 1999 revealed that dozens of defenceless civilians including women and children were killed by the soldiers sent by the Nigerian Government by order to Odi. It was reported that there was large scale killing and arson by the military force to a level that the community was left with only three buildings ("a bank, the Anglican Church, and the health centre*"*) standing in the town at the end of the massacre (Anugwom, 2011). Few days after the operation of the military in Odi, the government deployed soldiers in response to a protest in Choba community of Rivers State to disperse protesters at the gate of a subsidiary of an American pipeline construction company Wilbros Nigeria Ltd. It was reported by community members that four people were killed by the soldiers and a large number of woman raped. Photographs captured during the event shows Nigerian soldiers raping women. The Federal government however, out rightly denied its deployment of soldiers and the rapes reported. And no one was ever held to account for the crimes against women and the Niger Delta people (Ekine, 2013 and Ransome-Kuti, nd).

Militancy- Militia Youth Groups

Along with these events, popular and strong militia youth leaders like "Asari-Dokubo, Tom Polo, Ateke Tom, Boy Loaf" amongst others emerged who organised their fellow youths as soldiers under the platforms of the "Niger Delta Defence Force (NDDF), Niger Delta Vigilante (NDV), Niger Delta Patriotic Force (NDPF), Egbesu Boys of Africa (EBA)" amongst others who have strongly kept the cause alive and have been committed to the struggle and all the violence experienced in the late 1990s. One of the most popular and influential militia groups is the "Niger Delta Peoples Volunteer Force (NDPVF)," is headed by Asari Dokubo is regarded as being dominant at the beginning of 2000s and launched the violent and well-known Operation Locust Feast in 2004 that targets the workers of Transnational oil corporations in the region (Anugwom, 2011).

Another militia group with high prominence is MEND which sprang from the NDPVF at the end of 2005 with a goal "to destroy the ability of the Nigerian government to export oil." At the inception of this group, they placed two demands on the Nigerian Government as a condition to stop its plan to bomb oil facilities that belong to the Nigerian government and oil companies and the kidnap of oil workers as a means to see that they gain control over oil resources in the Niger Delta; the release of Asari Dokubo and Diepreye Alamieyeseiya a former governor of Bayelsa State arrested and on trial for money laundering and corruption. This request is an indication that youth militia groups have political support from highly placed politicians in the region and establishes the claims that these militia groups were used as political mercenaries in the 1999 general elections (Omotola, 2009). This two people are regarded to be key players in the struggle for the control of resources in the region in the late 1990s and early 2000s (Anugwom, 2011). The activities of these militia groups include stealing, refining and selling of crude oil which is known as oil bunkering in the Niger Delta. They have been the masterminds behind kidnaps of oil company workers, expatriates and top executives of the government and ransom taking.

Causes of Oil Conflicts in the Niger Delta

The Structure of the Federal Government

The structure of the administration in Nigeria has gone through some change since after independence in 1960. In 1960, Nigeria was made up of three regions which are dominated by the Hausas, Yorubas and Igbos the three major ethnic groups. In 1966, a federation of twelve states was established; the Niger Delta Region and its ethnicities were offered some level of autonomy because two states Rivers and Bendel states were created in the Region. Subsequently, more states have been created over the years. The Local Government Area (LGA) was created as one of the sphere of government in 1979 by

the military government with an initial number of 300 LGAs (Francis *et al.,* 2011).

Nigeria is currently made up of 36 states and 774 Local Governments of which 9 states and 185 LGAs make up the Niger Delta Area. Yet, the level of autonomy the Federal Government inherited from their military predecessors has remained. The Federal Government is structured in a way that makes the centre strong while the periphery weak. When the civilian rule was brought back in 1999, it came with more autonomy. (Francis, 2008; Francis *et al.,* 2011).

The "hybrid centralized/federal political structure of the country still remains*"* and this has led to tension between the state and the centre that still rely on resources and decisions made at the federal level. Also because the political economy of oil continues to shape the system of federation practiced in Nigeria, and the way oil revenue is being allocated from the national government. This has given rise to tensions between the National Government and the people of the Niger Delta (Francis, 2008 and Francis *et al.,* 2011). In practice, the States and local authorities have the responsibility to carry out all public functions except "defence, the police, external relations, and customs." Despite this huge responsibility on the State governments and Local governments, they still remain fiscally dependent on the National Government (Francis *et al.,* 2011). Also, the 1999 Constitution limits the autonomy of the State and Local government because it prevents other levels of government having legislation that contradicts the National legislation. The concentration of too much power at the centre has increased "ethno-regional competition*"* in the country and for the Niger Delta Region; it has resulted to the sense of dependency and marginalisation (Francis *et al.,* 2011).

Existing Systems of Neo-Patrimonialism and Corruption.

One way to look at the conflicts in the Niger Delta is to relate it to the neo-patrimonial school of thought that illustrates how corruption, conflicts and poor governance has been rationalised within the African social, cultural and historical environment. This school looks into how political and administrative disorder has been used by political elites in Africa to weaken the state in favour of their personal interest in ways that has led to the failure of the state and conflicts (Chabal & Daloz 1999; 2006; Obi, 2009).

Bayart, Ellis and Hibou (1998) and Obi (2009), also made a connection between oil conflicts in the Niger Delta and the activities of political elites that "criminalize the state, subvert it and enrich themselves*."* Combining the weak, personalised state and patrimonial politics, creates a context for a context for misrule, corruption, state failure or collapse and conflicts over the state, power (Obi, 2009).

Neo-patrimonialism also links to personal ties and networks of power. In the Nigerian System, family, communal ties, ethnicity and religion has been used as basis for and access to power and resources, political mobilisation and the political relations of inclusion and exclusion. The conflicts in the Niger Delta Region has also been explained in connection to the existing communal, ethnic terms that determines access to oil resources, power and blames the conflicts on the failure of the state and grievances have been based on injustice and insecurity (Obi, 2009).

The collapse of the state, corruption and the patrimonial political networks all produces and nurtures the feeling of violence and injustice. The struggle for oil resources and corruption has been identified as the main causes of conflict in the Niger Delta (Obi, 2009). This is because the patrimonial system of political god- fathers that exists in the Nigerian system makes it difficult for the government to manage conflicts and also makes room for high levels of corruption and rentseeking. It is indicated that the bureaucracy was created as a means to reward clients politically and economically and this has been one factor responsible for the failure in the delivery of public services in the Niger Delta Area (Francis, 2008).

In the Niger Delta Region, extended family or clan structures, headed by traditional chiefs form the

basis for group identification. Traditional authorities are custodian of group assets like "land and fishing grounds." These traditional socio-political organisations were incorporated during the colonial rule through the "system of indirect rule" where traditional chiefs were used to administer the country by colonial leaders (Francis *et al.,* 2011). This system was adopted by oil companies upon their arrival in the Niger Delta Region. Traditional chiefs and preferred community elites were used as the middlemen in community relations. This traditional patrimonial system placed resources and powers in the hands of a selected few who are less accountable to the people. These systems still make up the social and economic life of the Niger Delta communities and the quest for oil assets and rents (Francis *et al.,* 2011).

Land Decrees

Right from the agricultural period to the period of industrialisation, land remains essentially valuable to mankind and so, the well-being of the Niger Delta people. Land represents a "source of wealth" to its owners and is represents the "mother of all properties." This implies that the existence of the Niger Delta people is dependent on land. Looking at the usefulness and importance of land to development of societies and the well-being of man, it is not out of place that generally every individual want to be able to take on and own a parcel of land in a bid to meet the various goals for which land is needed for (Rasak, 2011: iii). The Nigerian government, during and after the colonial period and put in place laws to regulate how land is used and administered as a way of ensuring that land is acquired and used appropriately for development of the country (Rasak, 2011).

Before the advent of colonisation, customary laws in place were used to regulate the administration and use of land in Nigeria. The customary laws vary in every locality due to the diverse customs and ethnicity that exist in Nigeria. As a result, the existence of multiple land laws administered in different regions before the "Land Use Act of 1978" (Rasak, 2011). The multiplicity of land laws makes it difficult to administer land in different parts of the country and brought about problems of land tenure. Also, problems with land racketeering and speculation, exorbitant compensations demanded by landowners from government whenever land is acquired for development (Rasak, 2011).

This made it difficult for individuals and the government to acquire land for development purposes. Problems of land acquisition and availability of land for the development of the project was identified as one of the stumbling block to the implementation of the second development plan of 1975-1980. The Nigerian government introduced the Land Use Act of 1978 that confers the right and ownership of land on the government as an intervention to the monopolies of land by land owners (Rasak, 2011).

In the Niger Delta, the question; "whose land?" constitutes a major factor behind conflicts over the exploitation of oil resources in the region. This is a question in which the government, multi- national corporations and the community groups always differ in their response to. The Niger Delta Region represents an example of this kind of clash of perspective in regards to land ownership and control especially when it comes to oil resources. It is also the question that determines how much landowners and communities received as compensation for the expropriation of land for oil exploitation activities (Apkan, 2005; nd: 1).

The Key Players in the Niger Delta Struggle

1. **Oil Companies:** Community development policies of the 18 oil companies operating the Niger Delta area have evolved to emphasise the involvement of communities. However, this has not been successful because community development plans in the Niger Delta remains unplanned and short sighted and the people are not engaged during projects to design projects that will meet the needs of the people and to have substantial and sustainable benefits on the people (Francis, 2008)
2. **Militant groups:** Given the injustice of not benefiting from their own resources yet having to

face the negative consequences of extraction, a variety of militant groups have emerged. Many are political in nature though use violent tactics to demand greater local control, more transparent management of oil revenues and adequate compensation to those affected by oil extraction. Other groups have taken advantage of the situation to operate as criminal gangs resorting to activities such as kidnapping foreign oil workers for ransom, oil theft, etc. The two groups are not water-tight categories and lines between them often blur (Francis, 2008).

3. **Communities:** People of the Delta feel powerless, distrust leaders and are frustrated as they cannot legitimately benefit from the oil resources. Conflict occurs both among and within communities over access to oil company development projects. Being designated as a host community comes with benefits; this has led to jealousy and fighting among communities and on disputes over boundaries (Francis, 2008).

Conclusion

It is important to note that the failure of the Nigerian government to translate oil wealth into sustainable development in the Niger Delta area constitutes a major source of grievance in the Niger Delta. Issues of poor governance, lack of institutional capacity, the feeling of marginalisation, corruption and lack of political accountability especially on how oil revenue been spent is fundamental to the conflicts in the Niger Delta. Corruption in the Niger Delta region and in Nigeria have created and encouraged rent-seeking activities which have manifested in the form of oil theft, bunkering and political thuggery where political elites hire the expertise of youth militia groups for the purpose of election and as such these groups develop strong political links and funding for their activities in the Niger Delta Region (Anugwom, 2011; Omotola, 2009). Adequately explain the political cycle, when is it perpetuated?

The high level of degradation and pollution experienced in the Niger Delta and the continuous neglect from the Nigerian Government towards the development of the region has resulted in conflicts which have manifested in the form of illegal oil markets, hostage taking and kidnapping of expatriates and oil company workers in the region. The rise of youth militia groups under the umbrella of MEND, NDVF, Egbesu Boys, etc. led by youth leaders like Asari Dokubo, Tom Polo, et al. and disruption of activities of oil production, physical combat and cross-fire between the Nigerian military and Niger Delta youth militia groups, hijacking of offshore and onshore oil vessels and deaths in the region (Aghalino, 2001).

Furthermore, the conflicts and the problems of underdevelopment in the Niger Delta are linked to the neglect from oil companies who claim their obligation were paying of royalty and taxes to the Nigerian Government and not concerned with developing the region together with the corrupt practices of governmental and political bureaucrats and personnel that continuously misspend huge oil revenue (Isidiho & Mohammad, 2015).

It has been argued that the position of the multinational companies might have legitimate claim in that, their legal responsibilities and obligations may be to the Government and not to the communities. However, the failure of the state in delivering equitable and adequate distribution of resources and deliver rapid and sustainable development in the Niger Delta and the provision of effective security of property and lives puts oil companies on pressure to appraise communities where they operate as a way of ensuring the smooth operation and security of their properties and staff. Countries like Asia and Malaysia where crude oil is mined by multinational companies indicate that oil companies are only liable to the government and not to the communities (Isidiho & Mohammad, 2015).

Recommendations

Land-Use Management and Environmental Protection

The increased need for food security, the dangers of oil exploitation to the environment and the implications of environmental degradation nationally and internationally in issues relating to climate change, the need to protect the natural environment and achieve economic growth at the same, and the

need to resolve conflicts in the Niger Delta, promote and achieve development represents some of the challenges experienced in the Niger Delta and makes Land use planning important (GIZ, 2012). Land use planning is one of the ways through which the above mentioned concerns can be met. Land use management emphasises the negotiation of future use of land and resources by all relevant stakeholders for the public benefit (GIZ, 2012; Samper, nd).

The continuous struggle and conflicts over oil resources and land in the Niger Delta and the need to adapt land use to global discourses like climate change, sustainability, and the high levels of income and power inequality, enhances the role of land use planning and makes it more significant in the Niger Delta region (GIZ, 2012). This is because; land use planning has become a central prerequisite for any spatial development over the years and focuses on ecological, economic and social sustainability. Also, land use planning promotes a development approach that helps in preventing land use conflicts, it helps to put in place measures that will promote the physical and ecological environment, the protection of natural resources, helps to preserve and ensure the productivity of land and creates a balance economically, ecologically and socially (Sustainability) (GIZ, 2012).

According to GTZ (1995:7), *"*Land use planning creates the preconditions required to achieve a type of land use that is environmentally sustainable, socially just and desirable and economically sound. It thereby activates social processes of decision making and consensus building concerning the utilization and protection of private, communal or public areas." The essence of land use planning is to create a balance among competing land uses by all stakeholders (people who use or are affected by changes in land use) and the identification of such uses in which consensus has been reached or achieved with the main of promoting and achieving sustainability. To be able to achieve sustainable growth and manage the conflicts in the Niger Delta, the land use planning system in Nigeria should embrace and extend its contents to adapt and capture the needs of all stakeholders in relation to oil production and crude oil exploitation in the Niger Delta (GIZ, 2012; Samper, nd).

One of the problems identified with land decrees in Nigeria is that although land resources now belong to the Federal Government according to the Land Use Act of 1978, the act does not set the procedure for compensation for appropriation of land and for the effect of oil exploitation on the environment. Before the introduction of the land use act of 1978, land transfer fees or rents were received by land owners directly from oil companies for land acquisition. This however, does not apply any more according to the Land use act. These revenues are now being received by the government and its officials who are mainly made up of the political elites (Emuedo & Abam, 2015).

Also, the Land Use Act according to "Section 28*"* empowered state Government with the power *to "*revoke the right of occupancy to any land for reasons of overriding public interest*"*. In regard to oil activities, the most significant development following the introduction of the Land Use Act is its implication for compensation for land in the Niger Delta. This further creates rent seeking opportunity and an avenue that have contributed to the corruption and poor governance (Emuedo & Abam, 2015). Establishing guidelines for compensation for the appropriation of land, environmental damage and activities of oil companies in the Niger Delta area will be one way of addressing the conflicts in the Niger Delta region. (Apkan, 2005; Rasak, 2011).

More so, the introduction of "stringent measures" against oil companies that will not adhere to EIA procedures stipulated by the Environmental Impacts Assessment Decree No. 86 of 1992 of the Federal Republic of Nigeria and the National Policy on the Environment of 1999 should be enforced. These measures were put in place to mitigate and preserve the environment and in ensuring that oil companies carry out their social responsibilities to their host communities and the adequate compensation of host communities for oil spills and other environmental damaged caused as a result of their activities should be strictly adhered to and be enforced by the Ministry of Environment,

National Emergency Management Agency (NEMA) and the Department of Petroleum Resources (DPR) (Idowu, 2012).

Other recommendations include diversifying the Nigerian economy through the introduction and development of other sectors of the economy like building of agro processing industries for agricultural products like cocoa, groundnut, hides and skin and palm oil. This will help to diversify the economy and will reduce the pressure of the exploitation of crude oil as a necessity for economic growth. One of the major factors behind the Niger Delta conflicts is the dependence of the Nigerian Government on crude oil exploitation since the 1970s for economic growth. Other sectors and resources that Nigeria is blessed has been gradually abandoned for crude oil production which has led to the over-exploitation of crude oil and increase in environmental impacts and subsequently conflicts, which have adverse effects on the Niger Delta area and the national economy (Iniaghe *et al,* 2013; Ransome-Kuti, nd).

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Towards Climate Adaptation and Mitigation in Port Harcourt: The Socioeconomic Characteristics of Building Occupants Relative to Flood Risk Adaptation Measures

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Abstract

Perennial flooding within Port Harcourt, Nigeria is a climate induced disaster with catastrophic human and property loss consequences. A common assertion in the literature is that socio-economic parameters strongly underlie the technical dimensions of disaster preparedness. This study socioeconomically characterizes the uptake of flood mitigation adaptation measures in residential buildings relative to the level of flood exposure in Port Harcourt and whether a typology of households deploying similar adaptation measures can be identified. It further investigates whether relationships exist between the socio-economic characteristics of building occupants and the uptake of flood risk mitigation adaptation measures. An analysis of data collated for 407 residential properties/occupants was carried out using multiple analytical techniques including descriptive cross tabulation analysis, a two-stage exploratory cluster analysis and Chisquare analysis. The cross tabulated socioeconomic data depicts a direct association between the building occupant's income and their levels of educational attainment, and an inverse association between the level of flooding and the duration of residence of the building occupants**.** Based on the exploratory data analysis, two clusters of household respondents are evident: cluster-1 and cluster-2, predominantly determined by predictor differences in monthly income, educational status, ownership status, and duration of residence. Relationships were also found to exist between a number of building occupants' socio-economic characteristics and the uptake of adaptation measures. The ownership status of the properties, income level, and educational level of the building occupants exhibit significant relationships with the uptake of structural adaptation measures, while gender disparity mostly impacted the pattern of uptake of non-structural adaptation measures. This study outcome provides empirical evidence, which reinforces the assertion that socio-economic factors play a critical role in the adaptive capacity of individuals to undertake climatic adaptation/mitigation measures in response to flood disasters, and can serve as a starting point for catalytic change.

Keywords: Climate Adaptation; Flood Risk Mitigation; Residential Buildings; Socioeconomic Characteristics

Introduction

Literature, suggests that adaptive responses to flood risk are highly differentiated, irrespective of experiencing similar disaster risks (Yamin, 2005). There are differences in residents/occupiers characteristics and factors that can significantly affect the capacity of individuals to proactively undertake property-level adaptive measures in response to disaster risk (Ahmad & Afzal, 2020; Amadi, 2023). Research on disaster resilience thus combines different socioeconomic perspectives on resilience. From these perspectives, an eclectic range of studies has contributed to the resilience debate (Steinfuhrer & Kuhlicke, 2007; Walker & Burningham, 2011; Fuchs *et al.,* 2017; Ahmad & Afzal, 2020). A common thread in these studies is that socio-economic parameters strongly underlie the technical dimensions of disaster preparedness. Empirical evidence, such as was provided by Ahmad and Afzal, (2020) based on a study conducted in Pakistan, revealed that socioeconomic factors play a critical role in the adaptive capacity of individuals. In common usage are socioeconomic indicators such as gender, age, income, and educational status. It was revealed that the use of socio-economic factors as explanatory variables in flood risk adaptive responses, may show bidirectional relationships, which may vary in tandem with the contextual and locational peculiarities of the study area.

Port Harcourt is a metropolitan city located in the coastal lowlands of southern Nigeria and lies within the flood plain of the River Niger. Coupled with rainfall all through the year, with heavy downpours

between April and October, the water table frequently rises to exceedingly high levels. Flash flooding, particularly during heavy rainfall is thus a predominant cause of temporary human displacement and property loss in Port Harcourt (Amadi & Adeniyi, 2023). The flooding pattern has recurred over the years and the consequences follow a repetitive spatial scale of impact on buildings (Gerald-Ugwu *et al.,* 2019). The general populace thus perceives flooding in Port Harcourt as a natural consequence of the combination of climatic and geo-factors, which they must live with. This is given the well-established interaction between climate, landforms, and geology (Johnson et al., 2021).

A range of studies have however countered this perception, describing the non-natural causes of flooding in Port Harcourt metropolis (Jumbo and Wizor, 2020; Johnson *et al.,* 2021). In these studies, it has been re-emphasized that other than hydro-meteorological and geologic factors, anthropogenic factors such as inadequate and blocked drainage network, lack of land use planning and urbanization have exacerbated the flooding problem in Port Harcourt. Urbanisation due to rural-urban migration has led to rapid population increase whereby the demand for land has led to ad-hoc development and building on swamplands and floodplains, violating land use/planning laws. Typically, Abam (2016) recounted how hitherto, the swamps in the coastal lowlands of the Niger Delta used to support little or no population. The combination of these natural and anthropogenic factors has led to flash floods in Port Harcourt, which often occur after prolonged periods of intense rainfall, causing a rapid rise in water levels, with high flow velocities that cause mass destruction and damage to properties (Johnson *et al.,* 2021).

Building codes aimed at reducing vulnerability in buildings and guidelines for flood disaster mitigation are well established in developing countries such as the United Kingdom and the United States, where the Department for Environment, Food and Rural Affairs (DEFRA, 2008) and the Federal Emergency Management Agency (FEMA, 2014) respectively, have issued institutional guidelines for mitigating the impact of floods at property level. These regulations among other things specify the siting of buildings, types/classification of buildings, minimum elevations for the lowest floor, building access, design requirements (including structural, electrical and mechanical considerations), construction procedure, materials for the construction (flood-resistant and resilient materials), materials for retrofitting (Amadi, 2024). In developing countries such as on the Asian continent, building codes for climatic adaptation necessary to mitigate the impact of flood is relatively new and still emerging compared to developed countries in the northern hemisphere (UN ESCAP, 2012). Typically the Indian government through the National Centre for People's Action in Disaster Preparedness (NCPDP) in 2008 published the "Manual on Hazard Resistant Construction in India," aimed at reducing vulnerability in buildings. In Nigeria, which has a similar humid tropical climate as India, although there is a national building code, it is not specific to flood risk adaptation, but rather outlines the general structural, fire and other safety requirements of buildings (Onugba et al., 2022). It is thus imperative that the integration of climatic disaster mitigation measures, particularly against floods in building codes is achieved, and a series of good practices for building adaptation in Port Harcourt is outlined and documented.

Several recent studies including Oladokun and Proverbs (2016*)*, Adebimpe et al. (2018), Wariebi and Tonye (2018), Gerald-Ugwu *et al.* (2019), Onugba *et al.* (2022) and Amadi (2024) have thus espoused the need to establish and enforce building codes and provide manual/guidelines for building and infrastructural development bespoke to the climatic conditions of areas prone to flooding in Nigeria. Wariebi and Tonye (2018) reported that in the swampy terrain of the Bayelsa State, located in deltaic wetland of southern Nigeria, efforts are been made in this direction, with the government of specifying that house foundation has to be a minimum of 1.0 to 1.6m above ground level. Enlightening and sensitizing building occupants in flood prone areas of Port Harcourt, Nigeria, should therefore be a pivotal anchor in the process of achieving flood resilience, Property owners in Port Harcourt

metropolis thus need to be aware of the significant role of adaptation measures in fostering disaster resilience as part of their property management agenda in preserving asset values. All stakeholders must therefore be encouraged to take decisive actions to minimize flood risk, and be aware of the nomenclature of property level flood risk adaptation options available to them.

However, a starting point for such catalytic change is understanding the socio-economic nomenclature of Port Harcourt, and whether the current flood risk adaptation responses by building occupants are in tandem with the differential levels of uptake of flood risk adaptation measures. This requires that the pattern of socio-economic characteristics, adaptive tendencies and typology of property occupants, which will ultimately define the flood resilience status of different floodprone areas/locations in Port Harcourt, are systematically understood. Against this backdrop, this study seeks to determine the socio-economic characteristics of households residing in flood-prone areas of Port Harcourt, identify whether there is a typology of households deploying similar adaptation measures, and investigate significant relationships between the uptake of adaptation measures and residents' socio-economic characteristics.

Flood Risk Adaptation Measures in Residential Buildings

Preventive features to help reduce flood threats in building design are key highlights in the property management versus disaster resilience literature (Kreibich *et al.,* 2011; 2015). These preventive features diminish the impact of flood disasters. Attems et al (2019) classified such preventive features into five subgroups: avoidance of flood discharge; wet flood-proofing; dry flood-proofing; barriers, and other emergency mitigation measures. Jeroen and Aertsa (2020) identified three main subgroups of flood risk adaptation measures in property management- the elevation of the building to prevent flooding, dry-flood proofing to prevent flood water from entering the building, and wetflood proofing to allow water to enter the building but minimizing damage. Avoidance of flood discharge is achievable via landscape design, drainage for surficial water, design shape of a building or elevation of a building via raising the ground floor level or buildings on elevated areas (Attems *et al,* 2019). Wet-proofing measures include flood-adapted interior, situating important rooms at higher levels, pumping to remove water using sump pumps and providing floor drain standpipes. FEMA (2014) however recommends that since wet flood-proofing allows floodwaters to enter a building, they are most appropriate for basements or other non-living areas. Dry-proofing measures seek to prevent water entry and are achievable by sealing building openings, sealing cellars with waterproof concrete or bitumen, and using door guards using stop logs and window guards. Permanent and/or mobile barriers can stop the intrusion of water into individual structures. Barriers can be free-standing barriers such as stop logs, flood walls and external flood doors. Barriers can also be erected as emergency measures using permeable mediums such as sandbags or impermeable box walls. Other mitigation measures range from the installation of back-flow valves in building plumbing and drainage systems to elevated podiums for parking spaces to protect vehicles from flood damage etc.

Table 1 presents a summary of different building adaptation measures, synthesized from the literature, listing, and grouping structural and non-structural measures, necessary for climatic adaptation by occupants of residential properties, to mitigate the impact of flooding and achieve resilience at property level.

Table 1: Flood Mitigation Measures and Resilience Indicators in Buildings

Mitigation Type	Mitigation Measure	Resilience Indicator	Literature Source
Inherent Resilience (Structural Adaptation)	Landscape design	Properties with green landscape	Oladokun et al. (2017); Adebimpe et al. (2018); Adegun (2021)
	Building Type	Households occupying more than one floor or in multi-storey buildings	Oladokun et al. (2017); Adebimpe et al. (2021)
	Elevation	Households living in elevated houses/elevated land	Attems et al., (2020); (Adegun, (2021)
	Floor Type	Households living in houses with concrete floors	Oladokun et al. (2017); Adebimpe et al. (2021)
	Floor Finishes	Households living in houses with screeded/ceramic tiled floors	Oladokun et al. (2017); Adebimpe et al. (2021)
	Wall Type	Households living in houses with block walls.	Oladokun et al. (2017); Adebimpe (2018) Adebimpe et al. (2021)
	Wall finishes	Households living in houses with water-repellant wall finishes (plastered and painted with matt or silk/tiled).	Oladokun et al. (2017); Adebimpe et al. (2021)
	Electrical Installation	Households living in houses with electrical sockets raised at a higher level.	Oladokun et al. (2017); Adebimpe et al. (2021)
Supportive Attributes (Semi-Structural Adaptation)	Additional Barriers to water entry	Households with additional water barriers such as window seals, door guards, and using sandbags/demountable barriers/embankments	Attems et al., (2020); Adegun (2021)
	Backup storage	Households with backup space for storing watersensitive items.	Oladokun et al. (2017); Adebimpe et al. (2021)
	Flood Adapted interior	Households that repositioned water-sensitive furniture/appliances, removed wallpapers, and rugs	Koerth et al., (2014; Attems et al., (2020);
	Backup power/ energy Source	Households with backup power (Generators, solar batteries, inverters, solar panels)	Oladokun et al. (2017); Adebimpe et al. (2021)
	Flood water removing Systems	Households with pumps, dryers, or other rapid water removal mechanisms.	Oladokun et al. (2017); Attems et al., (2020); Adebimpe et al. (2021)
Residents' Capacity (Non-Structural Adaptation)	Economic Capacity	Households with savings/funds reserve/insurance policy	Koerth et al., (2014); Oladokun et al. (2017);
	Flood Awareness behavior	Households with pre-flood awareness behavior-Listening to/keeping up with weather reports, collective effort, storing phone numbers, storing important documents, clearing gutters, having a plan of where to temporarily evacuate to.	Koerth et al., (2014); Isunju (2016) Adegun, (2021)
	Technical Capacity	Households with technical knowledge/free access to technicians, having technical tools/emergency kits, knowledge about how to switch off electricity supply	Oladokun et al. (2017); Adebimpe et al. (2021)
	Social capacity	Households with membership in supportive social networks	Oladokun et al. (2017); Adebimpe et al. (2021); Adegun, (2021)

Method of Study

Sampling Framework and Data Collection

Residential properties are the unit of analysis, and the geographic spread of Port Harcourt metropolis, Nigeria defines the spatial extent/boundary of investigation. Therefore, all data collection efforts were directed to the households which occupy residential buildings in Port Harcourt, Nigeria. Port Harcourt metropolis comprises the current Port Harcourt Local Government Area (LGA) as well as Obio-Akpor LGA. As Figure 1 shows, these two LGAs together define the spatial extent of the study.

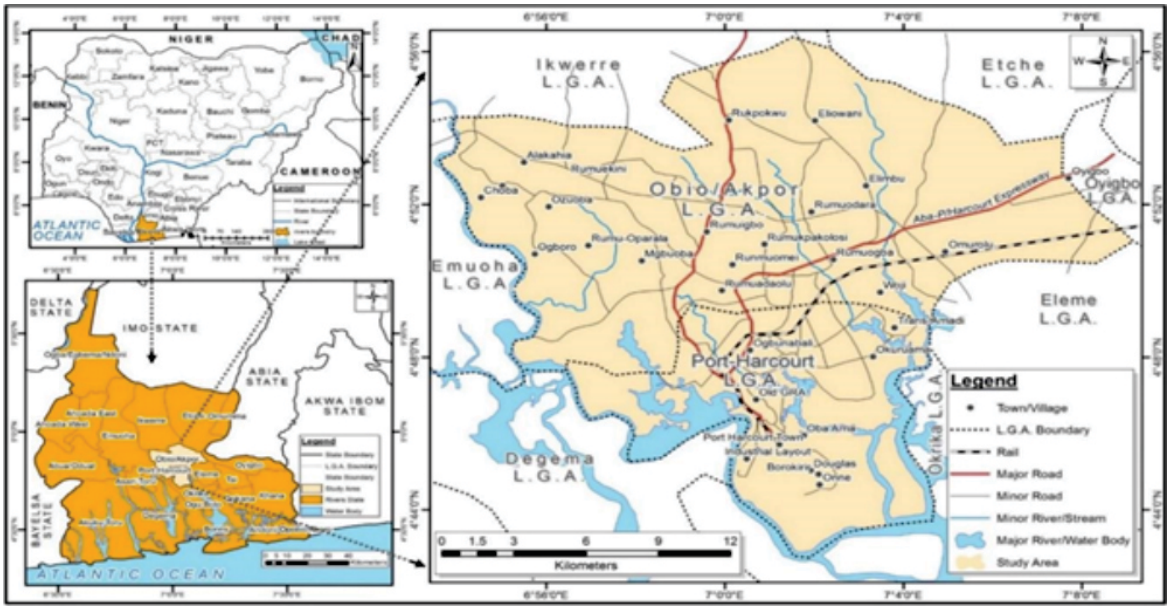


Figure 1: Map of Rivers State Showing the Study Area

The target of the analysis is to investigate the nomenclature of the socioeconomic clusters of residents relative to the uptake of flood risk adaptation measures in residential buildings. To identify areas prone to flooding, the study relied on previous research on flooding patterns in Port Harcourt. This is because there was no readily available flood map of Port Harcourt, from institutional sources. Previous research has delineated Port Harcourt according to the risk, exposure, and vulnerability to flooding (Akukwe & Obodo, 2015; Wizor & Mpigi, 2020; Johnson *et al.,* 2021). Wizor and Mpigi (2020) delineated Port Harcourt metropolis into 3three zones: low (20 -40cm; 200 – 400 m), moderate (41-80cm; 401 – 600 m), and high (above80cm; Above 600 m), based on the depth of inundation and extent of floodwater. Wizor and Mpigi (2020) further identified 25 spatially dispersed areas in Port Harcourt that are prone to high, moderate, and low flooding.

Table 3: Flood Prone Areas in Port Harcourt

S/No	Street/Area	Northings	Eastings	Flooding Classification
1	Abanna Street, Old GRA	4.785583	7.022028	Low
2	Hon. Attah Close, Peter Odili Road	4.793833	7.05075	Low
3	L.K. Anga Road, Off Peter Odili Road	4.801917	7.047389	Low
4	Hilltop Road, Amadi-Kalagbo	4.823806	7.023444	Low
5	Uyo Street, Rumumasi	4.838444	7.017583	Low
6	Omerelu Street, GRA Phase 11	4.839583	7.005639	Low
7	Akwaka Street, Rumuodomaya	4.880281	6.994285	Low
8	Peter Odili Road	4.804861	7.045556	Low
9	Omachi Road, Rumuodomaya	4.875247	6.999777	Moderate
10	Salem Close, Off Ada George Road	4.855444	6.979556	Moderate

11	Obiwali Road, Rumuigbo	4.858639	6.986944	Moderate
12	Diamond Valley Estate	4.796222	7.046083	Moderate
13	Zion Street, Rumuodomaya	4.881607	6.993837	Moderate
14	Odani Road, Elelenwo	4.840208	7.073506	Moderate
15	Evelyn‘s Close, GRA Phase 11	4.8195	7.006917	Moderate
16	Horsefall Street, Old GRA	4.786017	7.001000	Moderate
17	Alalibo Road, Old GRA	4.794083	7.019917	Moderate
18	Nkpolu Road 1, Rumuigbo	4.853346	6.986527	High
19	Eneka Town	4.878167	7.029514	High
20	NTA/Apara Link Road	4.854637	6.983774	High
21	Rotimi Amaechi Drive, GRA Phase 11	4.821278	6.000972	High
22	Kenka Road, Off Mgbuoba Road	4.856194	6.980361	High
23	Abacha Road, GRA Phase 11	4.823778	7.003361	High
24	Orubo Close, Peter Odili Road	4.797111	7.052361	High
25	BuePearl Street, Peter Odili Road	4.794083	7.019917	High

Based on Table 3, for each of the 25 areas, the study set out to sample 20 residential properties, with only one household respondent per property. This study adopted Wizor and Mpigi (2020) classification as a basis for the sampling framework, and for achieving stratification. Households situated in these areas were thus purposively sampled, in line with the study objectives. Questionnaires were used as the instrument for data collection. Five hundred questionnaires were thus sent out to potential respondents. The questionnaires were hand-delivered, as opposed to postal questionnaires. A response rate of 81.4% was achieved

Data Analysis Approach

Data analysis of the questionnaire responses was carried out using descriptive, exploratory, and inferential statistics. The analysis begins by reporting the socioeconomic characteristics of the residents of flood prone areas descriptively in tables. Descriptive statistics via cross tabulated frequency counts are used to relay the information gathered on the respondents' socio-economic characteristics, in order to establish their locational distribution relative to flooding levels. The socioeconomic characteristics/ demographic information of the building occupants such as age, gender, income, educational level, duration of residence and ownership status of the occupants of buildings located in the 25 flood prone areas sampled. The descriptive analysis also reports information about the characteristics of the residential buildings sampled, in terms of the housing type, type of accommodation and use. The descriptive analysis thus centers on reporting information on building occupants socioeconomic demographics, property description and the locational variability of the socio-economic characteristics of the occupants of buildings located in flood prone areas of Port Harcourt.

Exploratory statistics are also used to explore the data on adaptation measures for any form of discernible patterns relative to the typology of households. An analysis of households implementing similar adaptive strategies is explored via cluster analysis of the data. Cluster analysis is a visual statistical technique that is used to systematically classify data, such that internal homogeneity and external heterogeneity are attained (Guha *et al.* 2000). The study thus investigates whether there are clusters of similar households relative to their uptake of resilience measures. Due to the size of the data set, and its categorical nature, a 2-step clustering approach is used. Primary clusters were generated using residents' socio-economic characteristics, while the adaptation measures were subsequently used as evaluation fields. This is as opposed to using the k-means method of clustering which necessitates that the number of clusters is known apriori and is more suitable for continuous data (Huang, 1998). Also due to the large data set, the use of hierarchical clustering may be limited. The Schwarz Bayesian Criterion is used as the algorithm for clustering (Huang, 1997).

For the inferential analysis, necessary to draw conclusions, the Chi-Square analysis approach is used. Chi-square is a statistical technique suitable for investigating relationships between variables for grouped or categorical data. It is amenable for use in analyzing data collated in nominal scales, which are typically non-numeric. Using Chi-Square analysis, statistical independence/associations are sought between the level of uptake of different categories of property level adaptation and the socio-economic characteristics of households. Chi-Square analysis was thus carried out to test the following hypothesis:

Ho: There are no significant relationships between the uptake of resilience measures and residents' socio-economic characteristics.

H1: There are significant relationships between the uptake of resilience measures and residents' socio-economic characteristics.

Results and Discussion of Findings
Descriptive Analysis
Property Description
Table 1 is the property description showing the various types of properties sampled at the different location, showing the housing type, accommodation type and building use, further cross-tabulated according to the levels of flooding. As Table 1 show, all the properties, are privately owned.

Table 1: Property Types and uses

Flooding level				Count	Column N %
	low flood	Housing Type	Private	111	100.0%
			Public	0	0.0%
	moderate flood	Housing Type	Private	144	100.0%
			Public	0	0.0%
	high flood	Housing Type	Private	152	100.0%
			Public	0	0.0%
Flooding level	low flood	Accommodation Type	Rooms	18	16.2%
			Terraced	47	42.3%
			Semi-detached	20	18.0%
			Detached	26	23.4%
	moderate flood	Accommodation Type	Rooms	4	2.8%
			Terraced	36	25.0%
			Semi-detached	59	41.0%
			Detached	45	31.3%
	high flood	Accommodation Type	Rooms	2	1.3%
			Terraced	41	27.0%
			Semi-detached	70	46.1%
			Detached	39	25.7%
Flooding level	low flood	Building Use	Purely Residential	60	54.1%
			Mixed Uses	51	45.9%
	moderate flood	Building Use	Purely Residential	48	33.3%
			Mixed Uses	96	66.7%
	high flood	Building Use	Purely Residential	70	46.7%
			Mixed Uses	80	53.3%

The accommodation types found in the various locations are rooms, terraced houses, semidetached and detached houses. In the low-flood areas, terraced houses are the most common accommodation type, while in the moderate and high-flood areas, semi-detached houses are more common. The buildings across of locations are of mixed and purely residential use.

Building Occupants' Socioeconomic Characteristics

Table 2 shows the building occupants' socioeconomic characteristics, in terms of their gender, age, monthly income, highest educational level. As Table 2 shows, 58% of the sampled occupants are male, while 42% are female. The highest percentage of the building occupants are within the 41 to 60 years age bracket. The monthly income of the responds varied, from below N30,000, which is the current minimum wage in Nigeria, to above N200,000. A higher percentage of the respondents however earn between N100,000 to N200,000. The cross tabulation also shows that building occupants who earned below the minimum wage had the least educational attainment, and mostly had no formal education. For building occupants earning the N31,000-N100,000 income bracket, majority had primary education as their highest educational level, while most of those earning between N100,000 to N200,000 had secondary education. The highest level of educational attainment is possessed by building occupants earning above N200,000. The cross tabulated data thus reveal a clear direct association between the building occupants' income and their levels of educational attainment.

Table 2: Socioeconomic Demographics of Building Occupants

				Count	%
Gender	Male			236	58.0%
	Female			171	42.0%
Age (years)	18 – 25			20	4.9%
	26 – 40			122	30.0%
	41 -60			183	45.0%
	Above 60			82	20.1%
Monthly Income (Naira)	Below 30,000	Highest educational level	No formal Education	4	50.0%
			Primary	2	25.0%
			Secondary	2	25.0%
			Tertiary	0	0.0%
	31,000-100,000	Highest educational level	No formal Education	9	9.4%
			Primary	52	54.2%
			Secondary	34	35.4%
			Tertiary	1	1.0%
	101,000-200,000	Highest educational level	No formal Education	2	1.1%
			Primary	24	13.6%
			Secondary	121	68.8%
			Tertiary	29	16.5%

Table 3 is data on the building occupants' duration of residence and ownership status, further cross tabulated according to the levels of flooding experienced at the respective locations. As shown in Table 3, most of the building occupants have resided at their current locations for less than five years. The longest duration of residence (above 20 years) is evident for two properties in the low flood areas and for one property in the moderate flood area. Properties in the high flood areas had no building occupant residing up to 20 years. The pattern of the data, depicts an inverse association between the level of flooding and the duration of residence of the building occupants. Table 3: Duration of Residence and Ownership Status

Table 3: Duration of Residence and Ownership Status

				Count	Column N %
Flooding level	low flood	Duration of Residence (Years)	0-5	75	67.6%
			6-10	22	19.8%
			11-15	10	9.0%
			16-20	2	1.8%
			Above 20	2	1.8%
	moderate flood	Duration of Residence (Years)	0-5	114	79.2%
			6-10	24	16.7%
			11-15	4	2.8%
			16-20	1	0.7%
			Above 20	1	0.7%

	high flood	Duration of Residence (Years)	0-5	124	81.6%
			6-10	24	15.8%
			11-15	3	2.0%
			16-20	1	0.7%
			Above 20	0	0.0%
Flooding level	low flood	Ownership Status	tenant	86	77.5%
			Owner	25	22.5%
	moderate flood	Ownership Status	tenant	122	84.7%
			Owner	22	15.3%
	high flood	Ownership Status	tenant	132	86.8%
			Owner	20	13.2%

In terms of ownership status, Table 3 shows that most of the building occupants in the sampled properties are tenants. The high- flood areas have the most tenant occupied properties, followed by the moderate flood areas and then the low flood areas. Owner-occupied properties are minimal compared the number of tenants occupied properties, with the highest number (25) evident in the low-flood areas and the least in the high flood areas. It would appear that the ratio of tenant to owner occupied properties is highest in the high flood area, which may imply that most of the tenants are unaware of the flood risk status of the locations of the buildings.

Exploratory Analysis

Cluster Analysis of Socio-Economic Typology

A two-stage cluster analysis is carried out to investigate whether a typology of households deploying similar adaptation measures can be identified. Figure 2 shows the generated household clusters and the colour-coded importance of the predictor socio-economic parameters used in cluster formation.

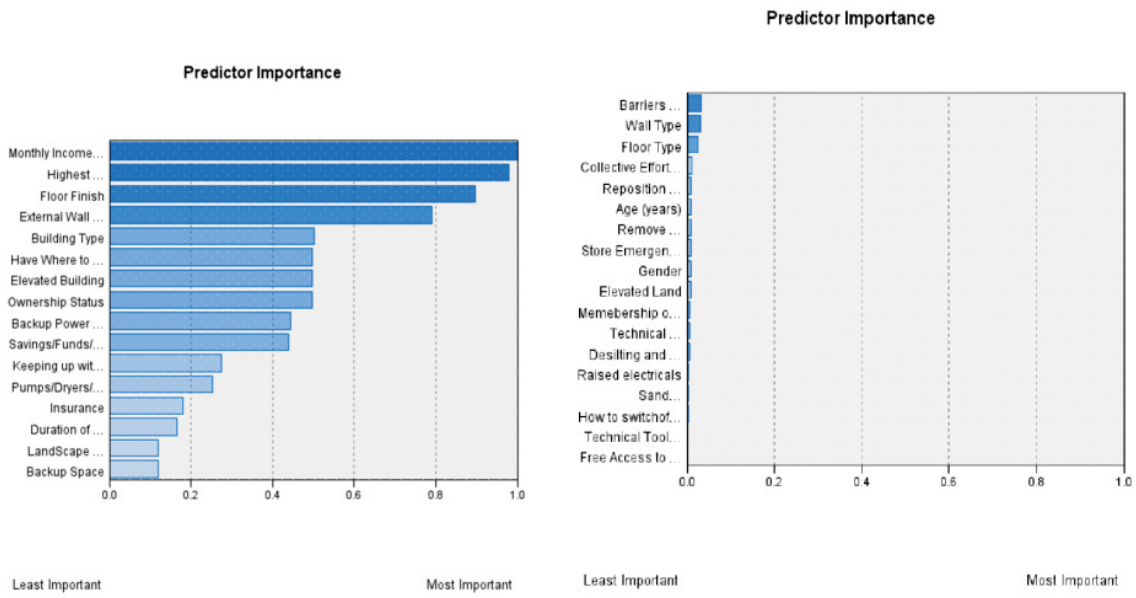
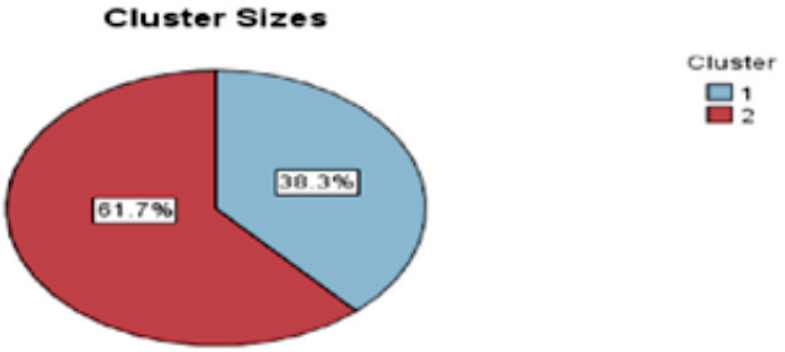


Figure 2: Predictor Importance of Adaptation Measures

As Figure 3 shows, two clusters of household respondents are evident: cluster-1 and cluster-2, predominantly determined by predictor differences in monthly income, educational status, ownership status, and duration of residence.



Size of Smallest Cluster	156 (38.3%)
Size of Largest Cluster	251 (61.7%)
Ratio of Sizes: Largest Cluster to Smallest Cluster	1.61

Figure 3: Cluster Formation and Sizes

Figure 4 is a visual comparison of the contributory powers of the socioeconomic characteristics of households in the formation of the Cluster-1 and Cluster-2. It shows that for cluster 1, ownership status and duration of residence of the building occupants had the most contributory power in cluster 1, while for Cluster-2, monthly income and educational qualification had the highest contributory powers in cluster formation.

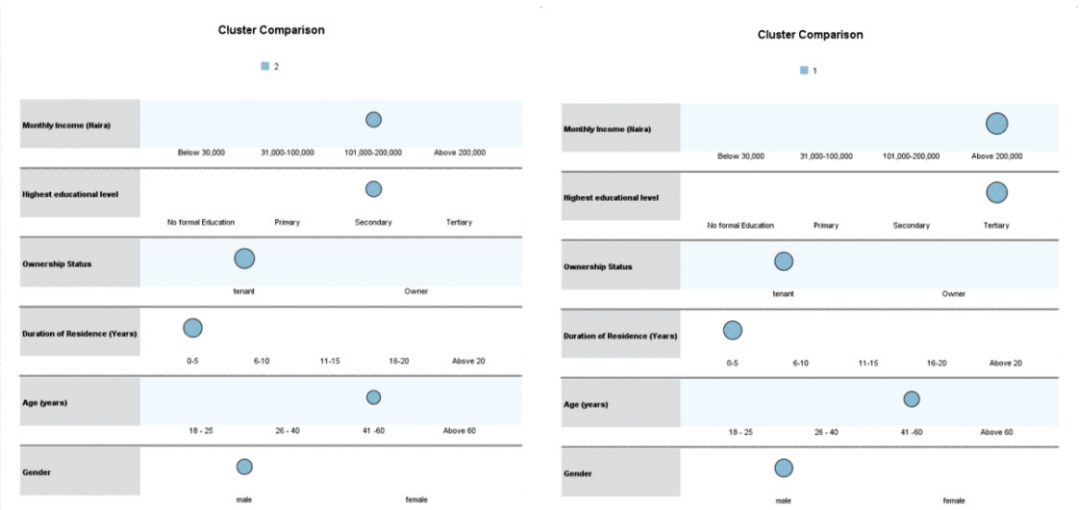


Figure 4: Cluster Comparison

Figure 5 is the socioeconomic characterization of the clusters formed. It shows that age and gender had minimal impact on the cluster formation. Cluster-1 accounts for 38.3% of the respondents, while cluster-2 accounts for 61.7% of the respondents.

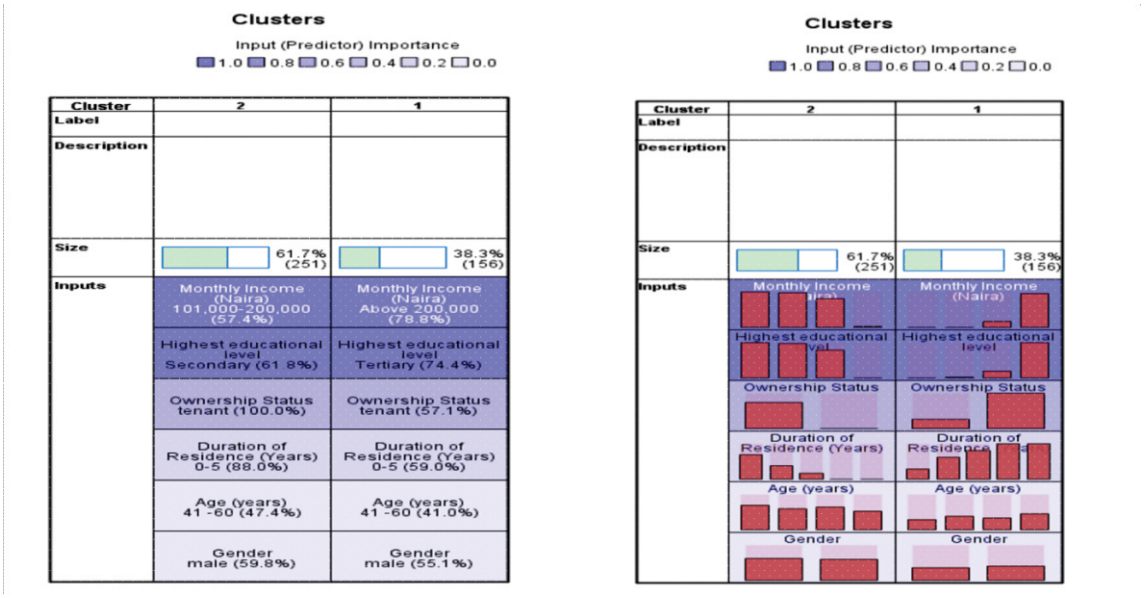


Figure 5: Socioeconomic Characterization of Clusters

Residents in cluster 1 are mostly high-income earners (above N200, 000) and have attained tertiary education, 57.1% are tenants, and 59% have resided at their places of residence for a maximum of five years. Residents in Cluster 2 are mostly middle-income earners (between N101, 000-200,000), have attained secondary education, are all tenants, and have resided at their places of residence for no more than five years.

Cell Distribution of Socioeconomic Clusters

This section of the cluster analysis further analyses the individual cell distribution of the socioeconomic clusters according the inputs. The cell distribution of monthly income in the clusters (Figure 6) shows that in cluster-2 the lowest percentage of residents earn above N200,000, while the highest percentage of residents earn between N101,000 to 200,000. While for cluster-1 appears to have household respondents who are of a higher income bracket, earning mostly above N200, 000 monthly.

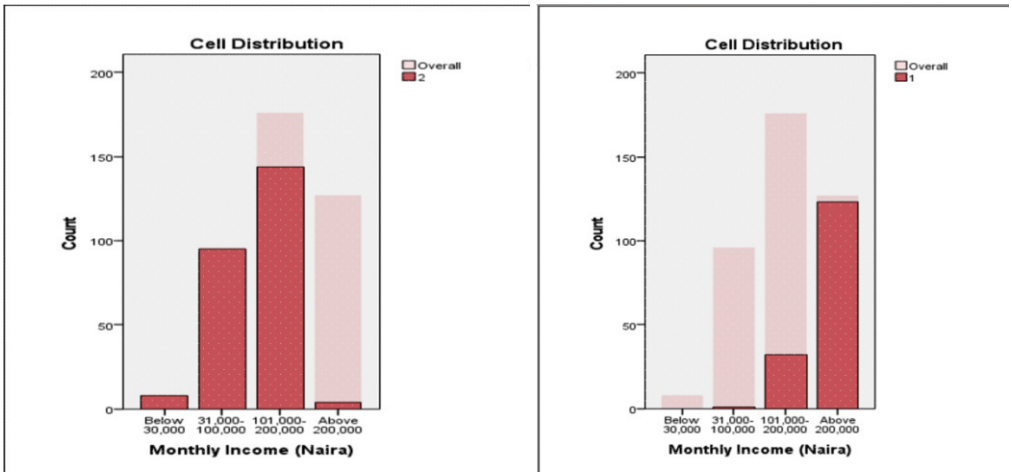


Figure 6: Cell Distribution of Monthly Income

Figure 7 shows the cell distribution of the highest educational qualification in the two clusters. Cluster-2 comprises mostly respondents with lesser educational qualifications. The highest educational qualification of residents in this cluster is secondary education, which also accounts for the greatest percentage of the residents, while the least number have no formal education. For Cluster-2, most of the residents have tertiary education while the rest have secondary education.

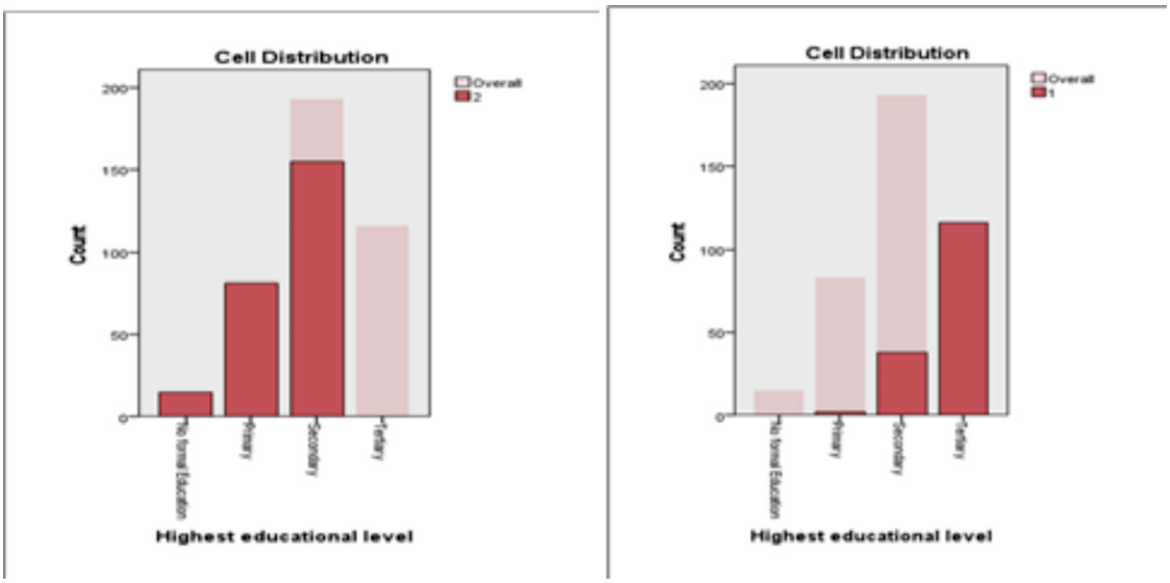


Figure 7: Cell Distribution of Highest Educational Qualification

Figure 8 shows the cell distribution in terms of ownership status in the clusters. As Figure 8 shows, respondents in cluster-2 are all tenants, while cluster-1 is comprised of a mix of tenants and owners. Respondents with ownership status in cluster-1 are however lesser than the tenants.

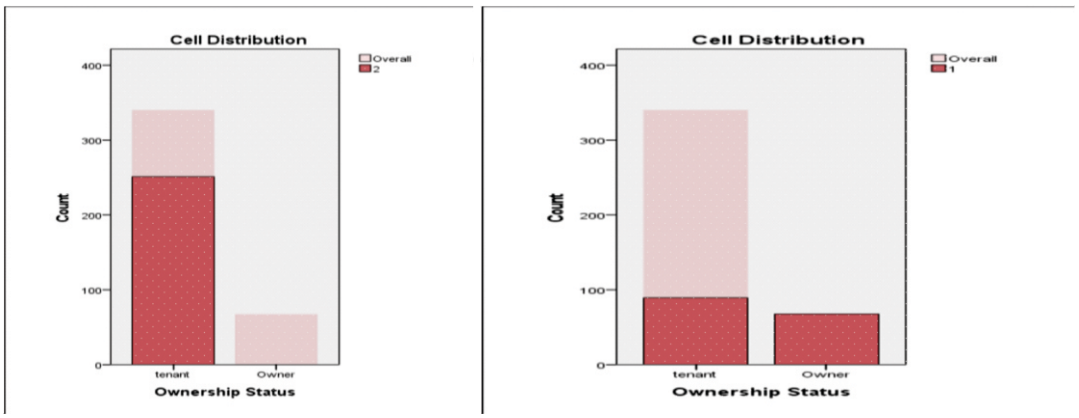


Figure 8: Cell Distribution of Ownership Status in Clusters

Figure 9 shows the cell distribution of clusters in terms of the respondents' duration of residence. For cluster-2, a distinctly highest percentage of the respondents have resided at the properties for lesser than five years. Some of the residents in cluster-2 had however resided at the property for between 6 to 10 years, while the least number of respondents had stayed longer than 10 years, up to 15 years. Similar to cluster-2, the majority of households in Cluster-1 had resided at the properties for less than 5 years. However, for cluster-1, the percentage of respondents that had resided at their properties beyond 5 years is proportionally higher than those in cluster-2.
Respondents with a duration of residence of up to 20 years and above were evident in cluster-1.

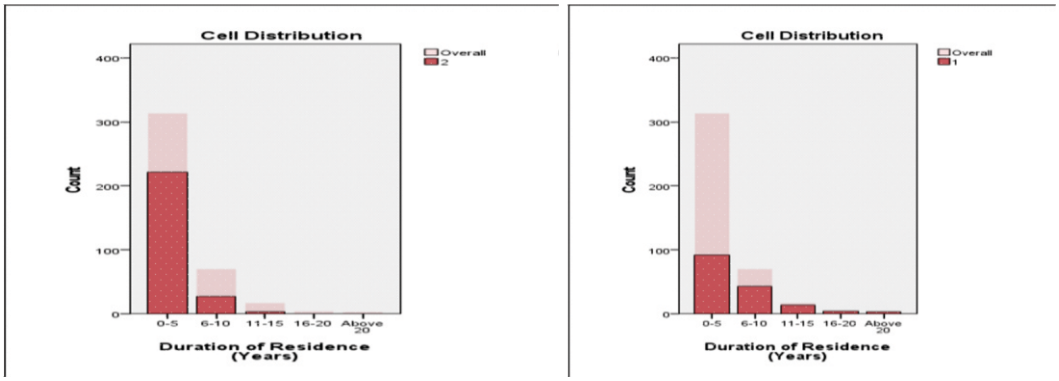


Figure 9: Cell Distribution of Duration of Residence

Figure 10 shows the age range of respondents in clusters 1 and 2. For both clusters, the highest percentage of the respondents were between 41 to 60 years. This is followed by respondents within the 26 to 40 years age bracket. Respondents above 60 years appear to be evenly distributed between the two clusters, while respondents within the least age bracket (18 to 25 years) appear to be more in cluster-2.

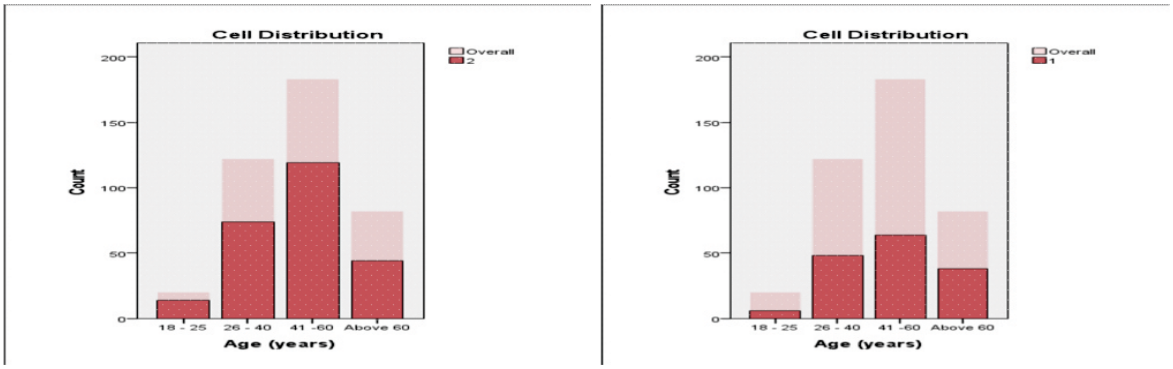


Figure 10: Cell Distribution of Age

Figure 11 shows the cell distribution of the clusters in terms of gender. In both clusters 1 and 2, males are relatively more represented than females. The disparity in gender representation however is more discernible in cluster-2.

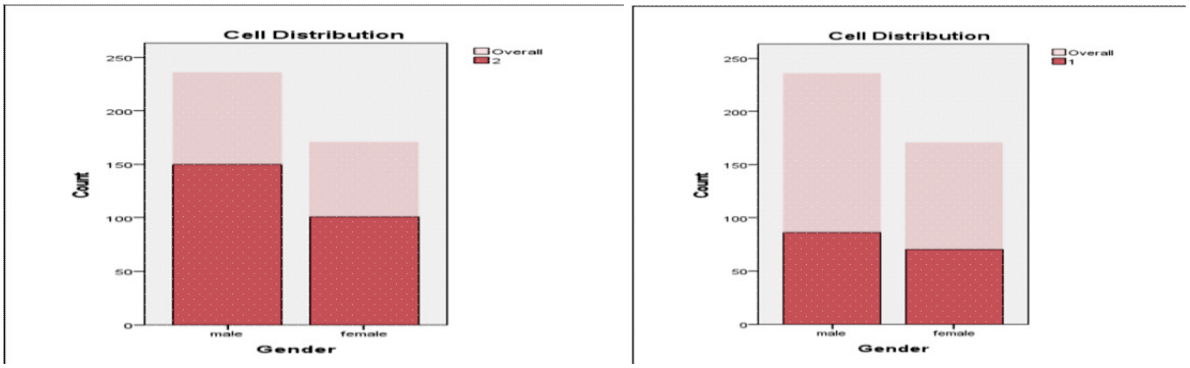


Figure 11: Cell Distribution of Gender in Clusters

Summarily, the analysis shows that each of the socio-economic characteristics of the households contributes disparately in the cluster formation, by virtue of the differences in their contributory powers in cell distribution.

Inferential Analysis: Chi-Square Tests for Significant Relationships

Table 4 is a concise summary of the chi-square analysis outputs carried out to investigate whether there are significant relationships between the uptake of resilience measures and residents' socioeconomic/housing characteristics.

Table 4: Chi- Square Analysis Summary

Adaptation Measure		Gender	Age	HEL	Income	DOR	OS
Structural Measures	Landscape design	X	X	*	*	X	*
	Building Type	X	X	*	*	X	*
	Elevation	X	X	X	X	X	*
	Floor Type	X	X	X	X	X	X
	Floor Finishes	X	X	*	*	X	*
	Wall Type	X	X	X	X	X	X
	External Wall finishes	X	X	*	*	X	*
	Electrical Installation	X	X	X	X	X	*
Supportive Measures	Window seals/door guards	X	X	X	X	X	X
	Sandbags/demountable barriers	*	X	X	X	*	X
	Backup storage	X	X	*	*	X	X
	Repositioned water sensitive furniture/appliances	X	X	X	X	X	X
	Removed wall papers and rugs	X	X	X	X	*	X
	Backup power	X	X	*	*	X	*
	Flood water removing systems	X	X	X	X	*	*
Non-Structural Measures	Savings/funds reserve	X	*	*	*	X	*
	Insurance policy	X	X	X	X	X	X
	keeping up with weather reports	X	X	*	X	*	X
	Collective effort	*	X	X	X	*	*
	Storing phone numbers	X	X	X	X	X	X
	Storing important documents	X	X	X	X	X	X
	Clearing gutters,	*	X	X	X	*	*
	Evacuation Plan	X	X	X	X	X	X
	Technical knowledge	*	X	*	*	*	*
	Free access to technicians	X	X	X	X	X	X
	Technical tools/emergency kit	*	X	X	X	*	*
	knowledge to switch off electricity supply	*	X	X	X	X	X
	Membership of supportive social network	*	X	X	X	X	X

*Significant relationship X- No Significant relationship

The summaries of the Chi-square analysis outputs show that the primary factors that exhibit significant relationships with the uptake of structural adaptation features are ownership status, income level, and educational level. This is not unexpected as the responsibility for the initial design and subsequent retrofitting of structures primarily lies with property owners. In terms of the uptake of supportive measures, there were no discernible patterns in its relationship with residents' characteristics. However, there were significant relationships between the availability of backup storage and backup power with increasing income and educational level. The level of adoption of non-structural measures shows significant relationships with some resident characteristics. Gender displayed the highest number (6) of significant correlations with nonstructural measures, while age had the least number (1).

Conclusion

The study outcome provides a descriptive snapshot, which socioeconomically characterizes the nature

flood risk adaptation behavior of building occupants within context of Port Harcourt. The cross tabulated socioeconomic data depicts direct and inverse associations between the building occupants socioeconomic characteristics, which vary relative to the level of flooding and the duration of residence of the building occupants**.** The study further shows that each of the socioeconomic characteristics of the households contributes disparately in the cluster formation, by virtue of the differences in their contributory powers in cell distribution. The Chi-square analysis shows the existence of significant relationships between the uptake of adaptation measures and socioeconomic parameters. The differences in residents/occupier socioeconomic characteristics therefore significantly affect the capacity of individuals to proactively undertake property-level adaptive measures in response to disaster risk. The empirical evidence provided in this study thus shows that socio-economic factors play a critical role in the adaptive capacity of individuals in Port Harcourt, to undertake climatic adaptation and mitigation measures in response to flooding experienced in Port Harcourt. The socioeconomic nomenclature of building occupants uncovered in this study, can be useful for designing risk communication tools for targeted household types, as a basis to ensure that the information dissemination requirement for different households with differing flood adaptation inclinations is addressed.

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Climate Change Awareness and Adaptation Strategies of Cassava Farmers in Etche, Rivers State

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Abstract

Climate change is mainly induced by anthropogenic activities such as lumbering and deforestation, unsustainable agricultural practices, burning of fossil fuels and land use changes. This study assessed climate change awareness and adaptation strategies of cassava farmers in Etche, Rivers State. The data for the study was derived from the secondary and primary sources. Secondary data includes rainfall, windspeed, relative humidity and surface air temperature values for a period of thirty-five years (1982-2017) retrieved from NIMET operated meteorological stations. Primary data was obtained through questionnaire responses of cassava farmers in the study location. The purposive sampling technique was used to select the communities. Data on the perception of climate change and variability and its impact on cassava farmers were collected using a well-structured questionnaire distributed to 398 cassava farmers purposively selected in the sampled communities. Results revealed that rainfall increased by 3.76mm per annum, temperature increased by 0.043°C per annum, relative humidity decreased by 0.057% per annum and windspeed also decreased by 0.028 m/s per annum. Results also revealed that 241 respondents representing 60.6% of the total respondents observed long term changes in climatic parameters in their communities and 157 respondents representing 39.4% of the total respondents did not observe long term changes in climatic parameters in their communities. Questionnaire analysis also revealed that 291 respondents representing 73.1% of the total respondents opined that climate change and variability had impact on cassava yield and 107 respondents representing 26.9% of the total respondents opined that climate change and variability had no impact on cassava yield in their communities. The socioeconomic impacts of climate change and variability revealed reduced crop yield (28.9%), land degradation (13.1%), reduced household income (25.1%), destruction of flora/fauna (12.6%) and loss of arable land (20.4%). The study therefore recommends the planting of different crop varieties and periodic pest control as the adaptation strategy to climate variability.

Keywords: Climate Change, Awareness, Adaptation Strategies, Cassava Farmers

Introduction

Climate change implies the variation and departure from the temperature, precipitation and wind over a geographical location for a period of time usually over 30 years. Weather is not static and changes within seconds and minutes. When this change is witnessed over a long period of time, climate change is said to have taken place (Leichenko & O'Brien, 2019). There are scientific evidences of climate change all over the world and the discourse has changed significantly from the availability of scientific proof to the extent of impact of climate change which is induced by anthropogenic activities such as lumbering and deforestation, unsustainable agricultural practices, burning of fossil fuels, land use changes etc. (Ajuang *et al*., 2016).

The ever-fluctuating climate is attributed to the emission of greenhouse gases (GHG) into the atmosphere leading to increased temperature and a shift in the amount and distribution of rainfall. These fluctuations in climatic parameters have had very significant impact on humans and on the ecosystem. These impacts include flooding, drought, desertification, land, water and air degradation, extreme storms, insect and disease outbreaks, forest fires and global warming (IPCC, 2022).

However, climate change does not usually present negative impacts as cooler regions are witnessing a

warming effect which may be suitable for agricultural productivity. For instance, grain production is expected to increase in high latitude regions. Moreover, the stable storage of harvested grains is efficient in dry or cold weather as it increases the harvested grain humidity and rising temperatures increase up to 32°C is suitable for increased yield of corn, soybeans and cotton (Rosenzweig *et al*., 2014). On the other hand, increased temperature in a tropical climate negatively affects agricultural productivity exposing crops to pest attacks, micro-organisms, and diseases (Owusu *et al.,* 2020). In Nigeria, studies have shown that the intensity of drought in northern Nigeria and flooding in southern Nigeria is expected to increase which will subsequently impact on agricultural productivity (Ekanem & Nwagbara, 2010). Cassava (Manihot esculenta) is a perennial dicotyledonous tuber crop which is prevalent in sub-Saharan Africa but origins have been traced to Brazil. Aside from been an vital source of carbohydrates, cassava play pivotal roles in tackling food shortages and providing a source of revenue and income for rural farmers (Rahman & Awerije, 2016).

Etche (the study area) is popular for the cultivation, harvesting and processing of cassava and its products. In every part of Etche, cassava is not only cultivated at subsistence level but to supply to other parts of the state and also to neighbouring states like Imo and Abia States. It is the massive production of cassava and other agricultural farm produce that earned Etche the name as the food basket of the state (Anyanwu & Iyagba, 2009). The vulnerability of cassava to climate change in the study area is dependent on the magnitude and extent of erratic rainfall which has disrupted agricultural activities to a large extent as farmers are no longer able to know when to cultivate the crops for optimal yield. Moreso, flooding cause by increased rainfall frequency have washed away cultivated cassava stems while extreme temperature is expected to increase the incidence of pest invasion and crop diseases. (Akpenpuun & Busari, 2018). Although there is a plethora of studies of the impact of climate on agricultural productivity (Owusu *et al*., 2020; Mbanasor *et al*., 2015; Olarenwaju, 2010; Schlenker & Roberts, 2009), literature on climate vulnerability and adaptation strategies of cassava farmers in Etche, Rivers State is scanty. It is on this premise that this study was conceived to fill the literature lacuna that hitherto existed.

Materials and Methods

The study was undertaken in Etche, Rivers State which is located at the North-Eastern part of Rivers State, Nigeria. It lies within latitude $4^0$45'N – $5^0$17'N and longitude $6^0$55'E – $7^0$17'E. The study area covers about 641.28km^2. It is bounded to the north by Imo State, to the east by the Imo River, to the south by Obio/Akpor and Oyigbo and to the west by Ikwerre L.G.A. Etche enjoys the tropical hot monsoon climate because of its latitudinal position. Heavy rainfall and high temperature all the year round is a one of the unique characteristics of the tropical monsoon climate. The mean annual rainfall of the area is about 3450mm with temperature ranging between 25.4^{0}C – 29.6^{0}C with high humidity of up to 90% during the wet season. (Nwankwoala & Nwaogu, 2009).

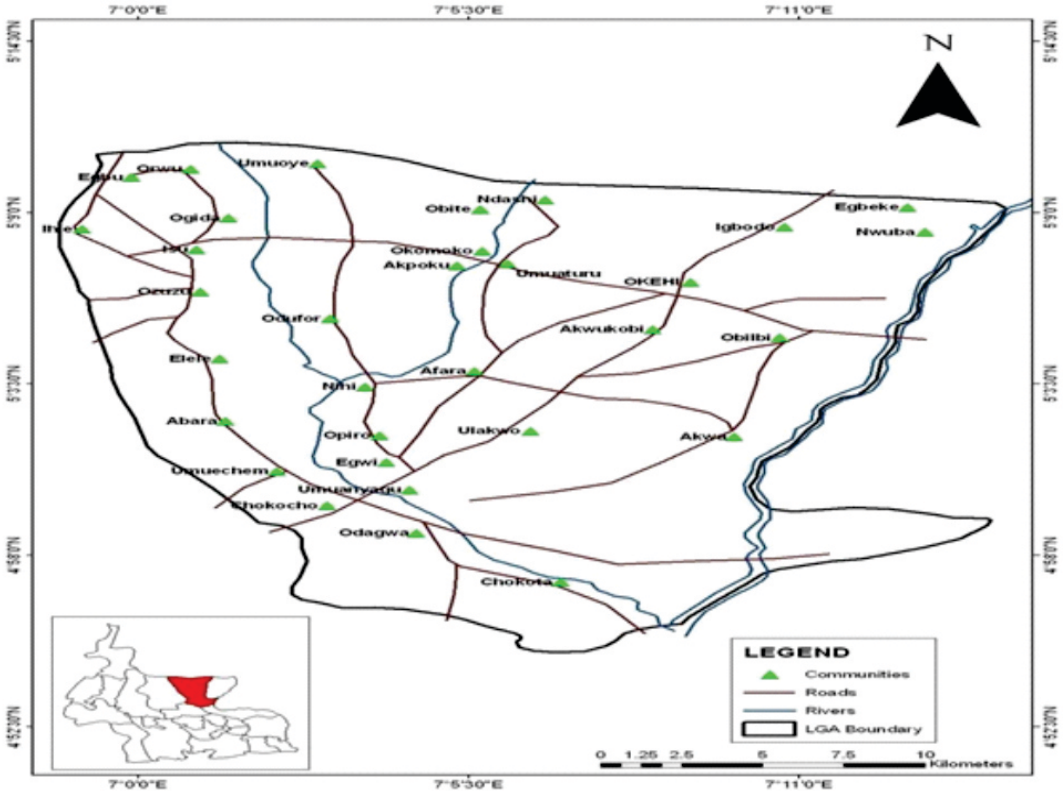

Figure 1: Map of Etche Showing Communities
Source: Chiaka *et al*., 2013

The data for the study was derived from the secondary and primary sources. Secondary data was obtained from materials which have been previously documented and that relates to the study. Such documents include related research reports in the field of study from journals, textbooks and magazines. The data includes those from all the NIMET operated meteorological stations in the study area. They are rainfall, windspeed, relative humidity and surface air temperature values for a period of thirty-five years (1982-2017). These data were obtained from the records in the daily weather register at the meteorological stations in the selected cities in the study area. The primary data was obtained through questionnaire responses of cassava farmers in the study location. The purposive sampling technique was used to select the communities sampled in Etche, Rivers State. The inclusion criteria are the population of cassava farmers and ease of accessibility. The population of selected communities is shown in table 1 below.

Table 1: Population of Selected Communities

S/No	Communities	1991 Census Population	1996 Projected Population	2024 Projected Population
1	Afara	8,061	9,540	24,709
2	Umuokenyi, Egwi	7,217	8,541	22,121
3	Egbu	5,767	6,825	17,677
4	Okehi I	4,892	5,790	14,996
5	Odufor	4,349	5,147	13,331
	Total	**30,286**	**35,843**	**92,834**

Source: National Population Commission, 1991 Census

From the population of the selected communities the total population of 42,662 was obtained. Finally, to achieve a manageable sample size from the total population, the Taro Yamane (196 7) formula was applied to arrive at a cumulative sample size of 396 respondents for this study. The formula is expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

Where

n = sample size required
N = total population
1 = constant
e = $(0.05)^2$ error margin

$$n = \frac{92,834}{1 + 92,834\ (0.05)^2}$$

n = 398.2 (Approx. 398)

For adequate distribution of questionnaires to the sample strata, the proportional allocation method was applied. The purposive sampling technique was also used to distribute the questionnaires to cassava farmers in each selected community.

The information on the perception of climate change and variability and its impact on cassava farmers were collected using a well-structured questionnaire. The test-retest method was adopted to test the reliability of the research instrument. The Cronbach Alpha reliability coefficient of 0.787, is indicative that the questionnaire used is reliable.

Result Presentation

Annual trend of temperature, relative humidity, windspeed and rainfall

Figure 2 shows the annual total rainfall in the study location. The analysis of rainfall reveals that rainfall was on the increase by 3.76mm. As displayed in Figure 2 the least square line shows that rainfall was increasing in the duration studied.

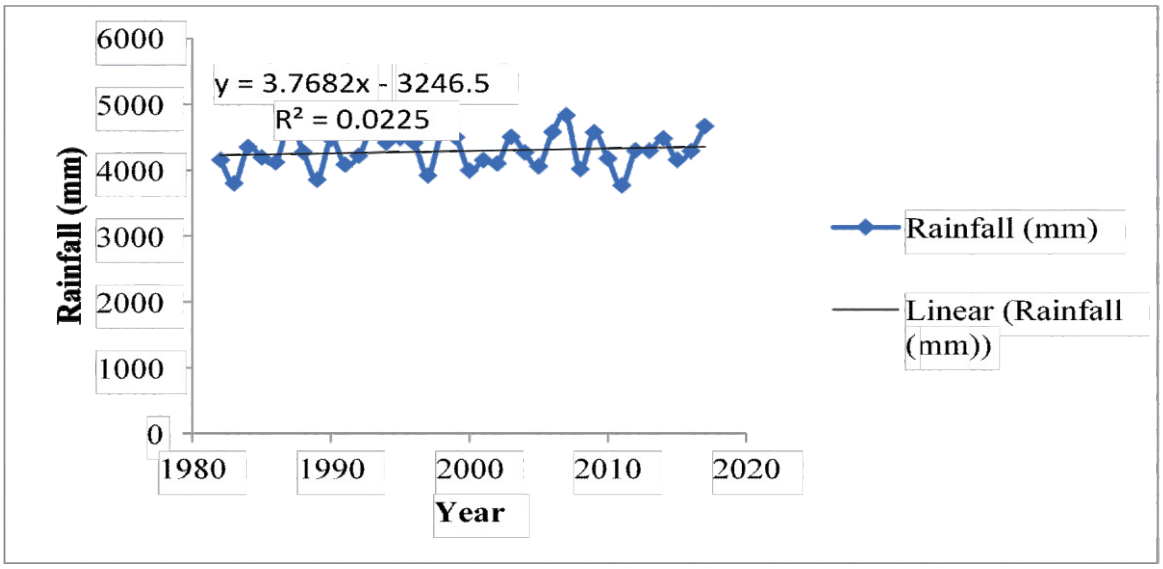

Figure 2: Total Annual Rainfall for Etche, Rivers State

Figure 3 shows the mean annual temperature in the study location. The trend analysis of temperature revealed that temperature was on the increase and there was an increase in temperature per annum by 0.043oC.

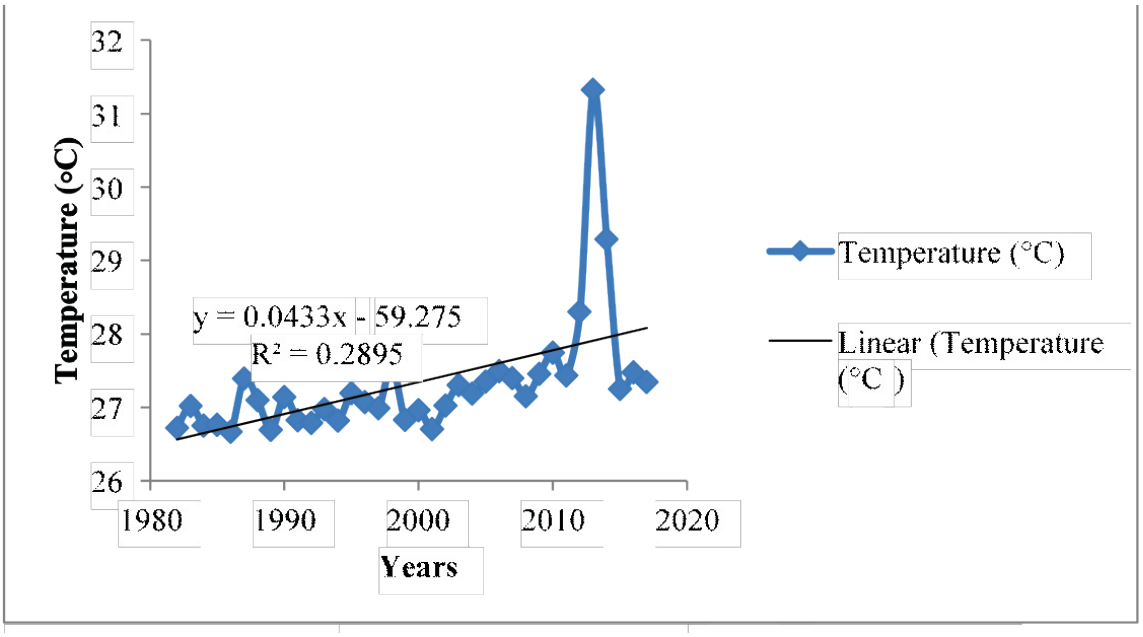

Figure 3: Mean Annual Temperature for Etche, Rivers State

Figure 4 shows the relative humidity in the study location. The trend analysis of relative humidityfor the period under study shows that relative humidity was on the decrease by 0.057% per annum.

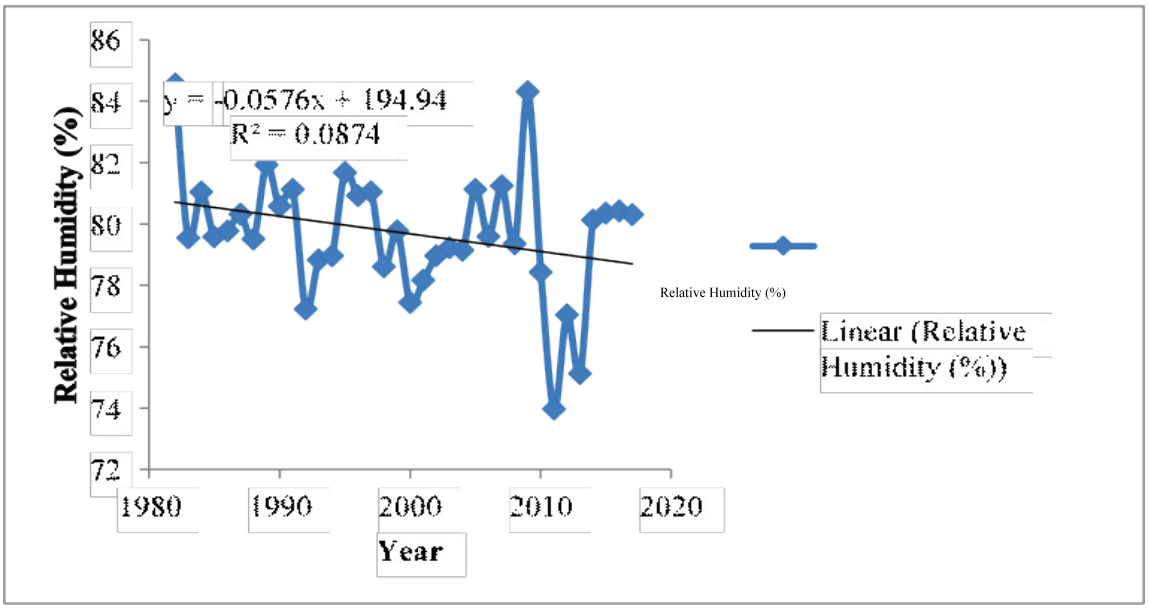

Figure 4: Mean Annual Relative Humidity for Etche, Rivers State

Figure 5 shows the windspeed in the study area. The analysis of windspeed reveals that windspeed was on the decrease by 0.028 m/s per annum.

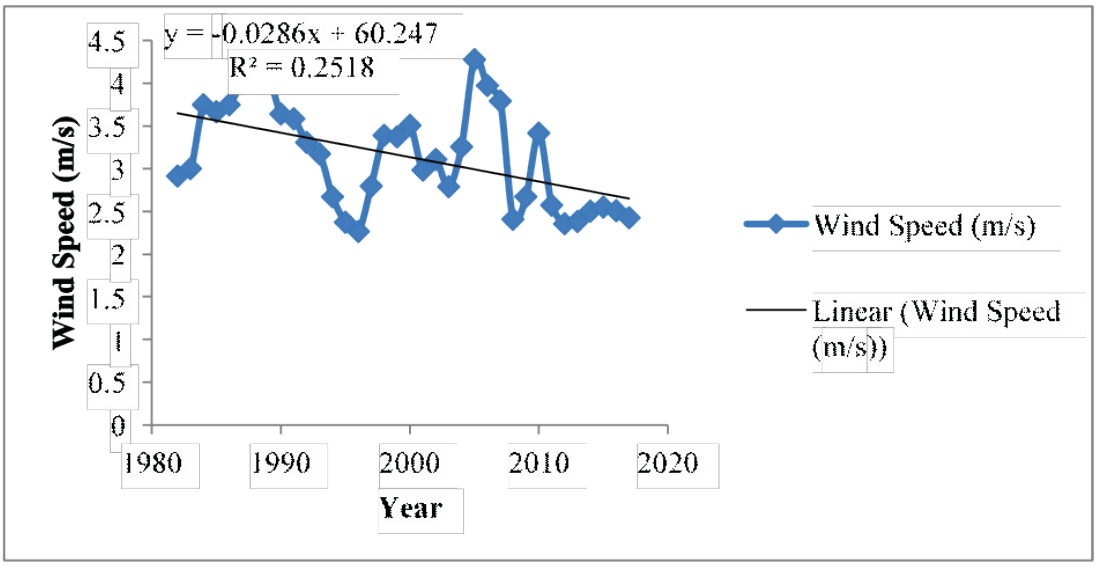

Figure 5: Mean Annual Wind Speed in Etche, Rivers State

Awareness and Perceived Effects of Climate Change on Cassava Yield

(i) Socio-economic Characteristics of Respondents

Table 2 shows the socio-demographic characteristics of respondents. The distribution of sampled respondents from the questionnaires analyzed shows that 26.6% of the respondents were within the ages of 21-30 years, 27.1% were within the ages of 31-40 years, 35.4% were within the ages of 41-50 years and 10.8% were within the ages of 50 and above. Furthermore, questionnaire analysis revealed that 57.8% of the respondents were males and 42.2% of the respondents were females. In the analysis of the marital status of respondents, it was revealed that 36.2% of the respondents were single and 46.5% were married. The percentages of divorced and widowed respondents were 4.5% and 12.8% respectively. From the questionnaire analyzed, it shows that 21.1% of the respondents had no formal education. 41.7% had primary school education, 30.4% had secondary education and 6.8% had tertiary education. Questionnaire analysis also revealed that 13.3% of the respondents were had 1-5 years of farming experience, 27.9% of the respondents had 6-10 years of farming experience, 26.9% of the respondents had 11-15 years of farming experience and 31.9% of the respondents had above 15 years of farming experience. The questionnaire analysis on monthly income from farming revealed that 41.0% of the respondents generated a monthly income of less than N50,000, 27.1% of the respondents generated a monthly income of N50,000- N100,000, 17.6% of the respondents generated a monthly income of N101,000- N150,000 and 14.3% of the respondents generated a monthly income of N150,000 and above.

Table 2: Socio-demographic Characteristics of Respondents

Variables	Frequency(n=398)	Percent (%)
Age(years)		
21- 30	106	26.6
31-40	108	27.1
41-50	141	35.4
>50	43	10.8

Variables	Frequency(n=398)	Percent (%)
Gender		
Male	230	57.8
Female	168	42.2
Marital Status		
Single	144	36.2
Married	185	46.5
Divorced	18	4.5
Widowed	51	12.8
Level of education		
None	84	21.1
Primary	166	41.7
Secondary	121	30.4
Tertiary	27	6.8
Years of farming experience		
1-5 years	53	13.3
6 – 10 years	111	27.9
11-15 years	107	26.9
> 15 years	127	31.9
Monthly Income from farming		
< N50,000	163	41.0
N50,000- N100,000	108	27.1
N101- N150,000	70	17.6
>N150,000	57	14.3

(i) Awareness about climate change and variability

Figure 6 presents the analysis of questionnaire responses on the awareness about climate change and variability. The results revealed that 268 respondents representing 67.3% of the total respondents were aware about climate change and variability and 130 respondents representing 32.7% of the total respondents were not aware of climate change and variability.

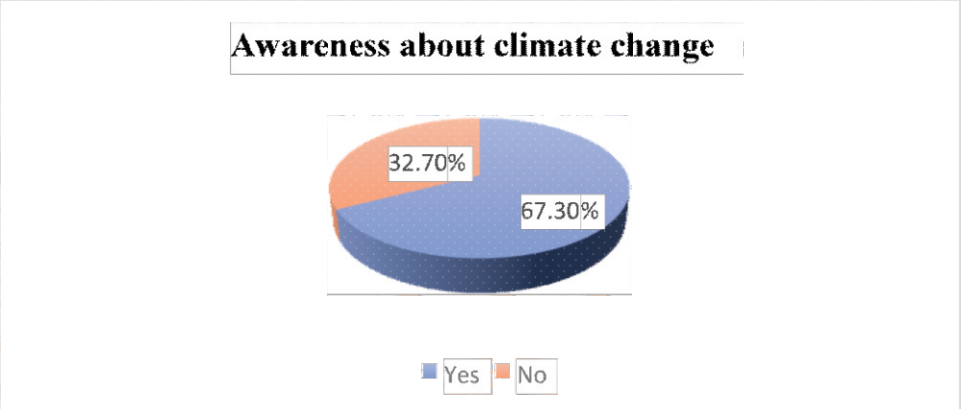

Figure 6: Awareness About Climate Change and Variability

(iii) Observation of long-term changes in climatic parameters

Figure 7 presents the analysis of questionnaire responses on the observation of long-term changes in climatic parameters. The results revealed that 241 respondents representing 60.6% of the total respondents observed long term changes in climatic parameters in their communities and respondents representing 39.4% of the total respondents did not observe long term changes in climatic parameters in their communities.

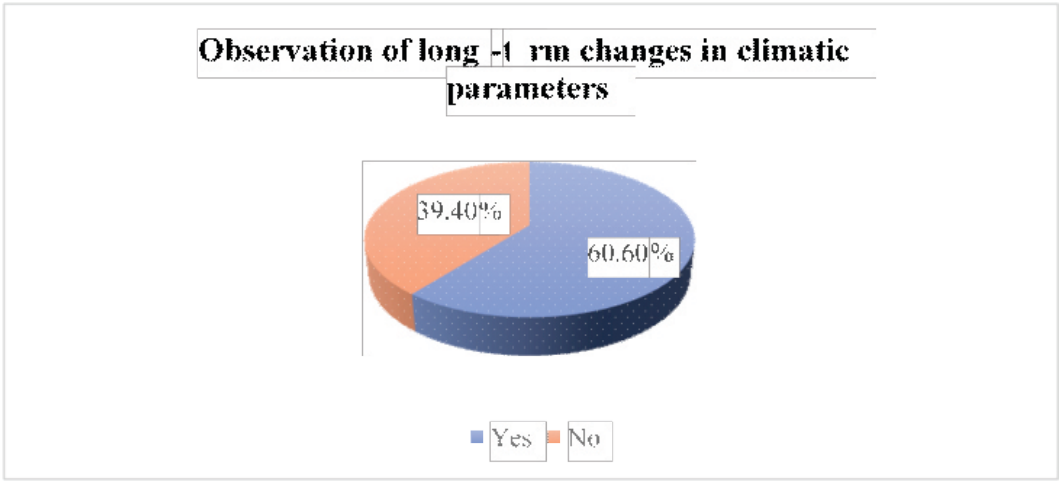

Figure 7: Observation of Long-Term Changes in Climatic Parameters

(iv) Impact of Climate Change and Variability On Cassava Yield

Figure 8 presents the analysis of questionnaire responses on the impact of climate change and variability on cassava yield. The results revealed that 291 respondents representing 73.1% of the total respondents opined that climate change and variability had impact on cassava yield and 107 respondents representing 26.9% of the total respondents opined that climate change and variability had no impact on cassava yield in their communities.

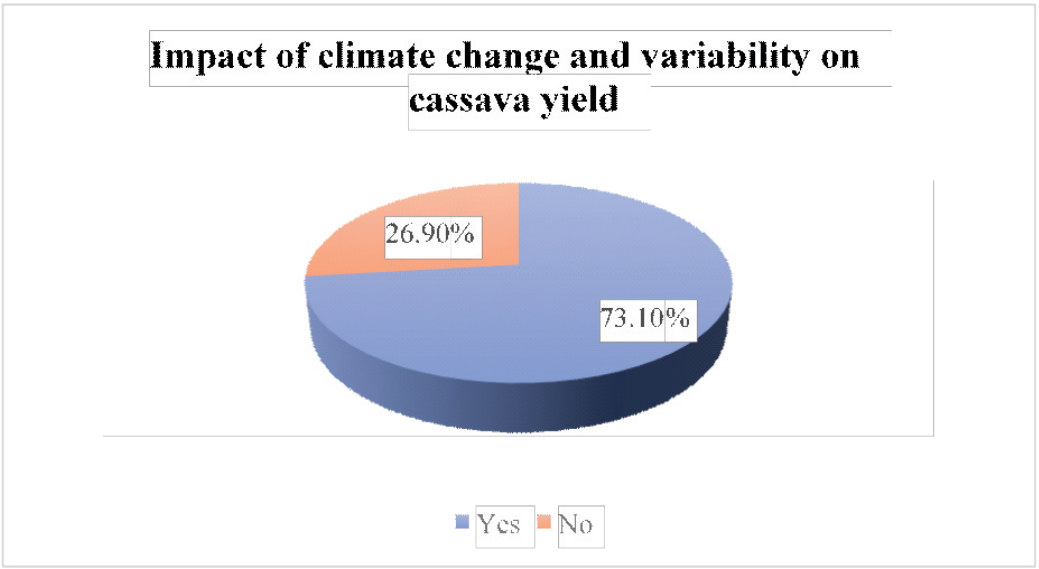

Figure 8: Impact of Climate Change and Variability on Cassava Yield

(i) Extent of Impact of Climate Change and Variability on Cassava Yield

Figure 9 presents the analysis of questionnaire responses on the extent of impact of climate change and variability on cassava yield. The results revealed that 34 respondents representing

8.5% of the total respondents opined that climate change and variability had no impact on cassava yield, 80 respondents representing 20.1% of the total respondents opined that climate change and variability had low impact on cassava yield, 100 respondents representing 25.1% of the total respondents opined that climate change and variability had medium impact on cassava yield and 184 respondents representing 48.2% of the total respondents opined that climate change and variability had high impact on cassava yield in their communities.

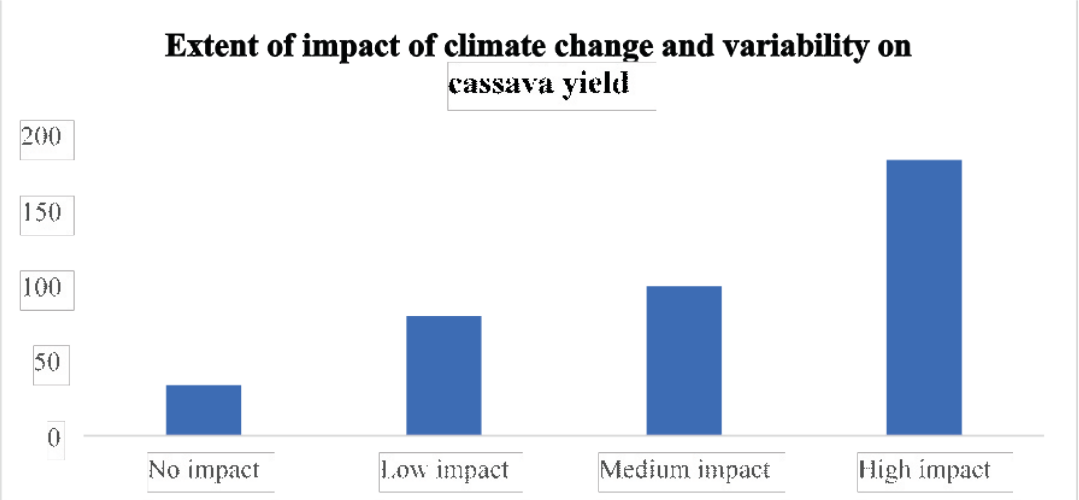

Figure 9: Impact of Climate Change and Variability On Cassava Yield

(i) Climate Change Extreme Events Affecting Cassava Yield

Figure 10 presents the analysis of questionnaire responses on the climate change events affecting cassava yield. The results revealed that 178 respondents representing 44.7% of the total respondents opined that flooding is the climate change extreme event affecting cassava yield, 39 respondents representing 9.8% of the total respondents opined that drought is the climate change extreme event affecting cassava yield, 121 respondents representing 30.4% of the total respondents opined that crop disease is the climate change extreme event affecting cassava yield and 60 respondents representing 15.1% of the total respondents opined that forest fire is the climate change extreme event affecting cassava yield.

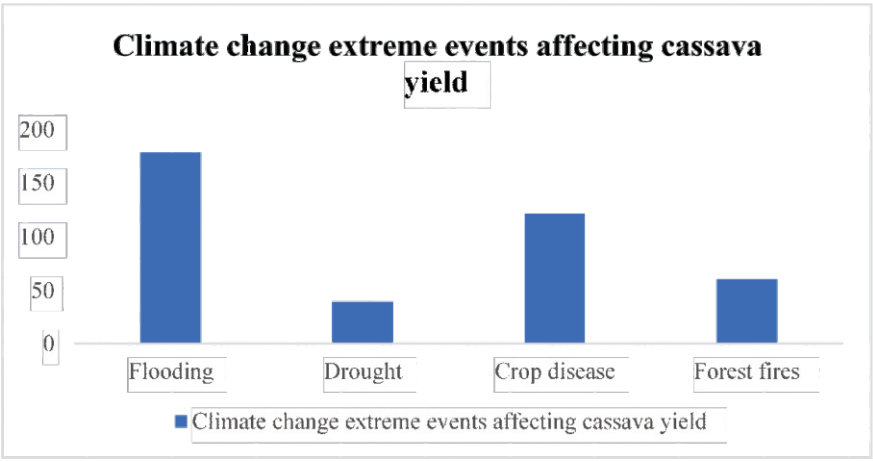

Figure 10: Climate Change Extreme Events Affecting Cassava Yield

(i) Socioeconomic impacts of climate variability on cassava farmers

Figure 11 presents the analysis of questionnaire responses on the socioeconomic impacts of climate variability on cassava farmers. The results revealed that 115 respondents representing 28.9% of the total respondents opined that climatic variability led to reduced crop yield, 52 respondents representing 13.1% of the total respondents opined that climatic variability led to land degradation, 100 respondents representing 25.1% of the total respondents opined that climatic variability led to reduced household income, 50 respondents representing 12.6% of the total respondents opined that climatic variability led to destruction of flora/fauna, 81 respondents representing 20.4% of the total respondents opined that climatic variability led to loss of arable land.

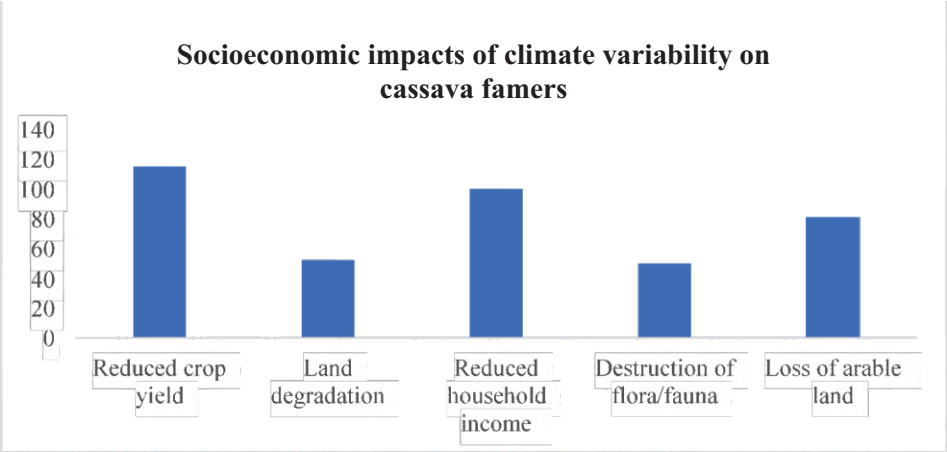

Figure 11: Climate Change Extreme Events Affecting Cassava Yield

Adaptation strategies to climate change and variability

Fig 12 presents the analysis of questionnaire responses on adaptation strategies of cassava farmers to climate variability. The results revealed that 30 respondents representing 7.5% of the total respondents noted that they used increased irrigation as the adaptation strategy to climate variability, 32 respondents representing 8.0% of the total respondents noted that the use of drought resistant crops was their adaptation strategy to climate variability, 55 respondents representing 13.8% of the total respondents noted the planting of different crop varieties as the adaptation strategy to climate variability, 65 respondents representing 16.3% of the total respondents noted the use of agro-forestry as the adaptation strategy to climate variability, 60 respondents representing 15.1% of the total respondents noted that soil and water conservation was the adaptation strategy to climate variability, 112 respondents representing 28.1% of the total respondents noted that regular fumigation against pest attack was the adaptation strategy to climate variability while 44 respondents representing 11.1% of the total respondents did not have adaptation strategies to climate change and variability.

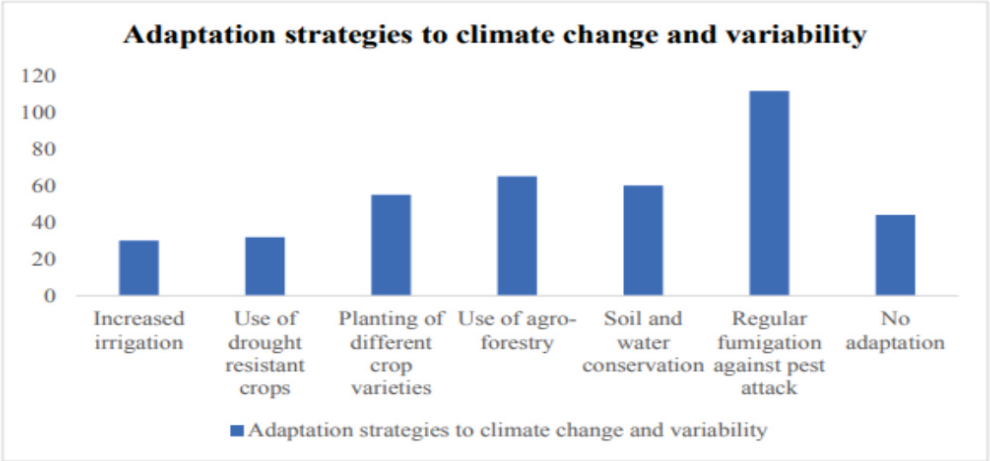

Figure 12: Adaptation Strategies to Climate Change and Variability

Discussion of Results

The findings of this research revealed increasing rainfall, increasing temperature, decreasing relative humidity and decreasing windspeed in the study area. This finding adds to the plethora of researches which affirmed that climate change is taking place. The finding of this study is synonymous with the findings of Oyerinde (2021) who in their separate study on the analysis of decadal rainfall and temperature trend in Warri, Nigeria revealed increasing trend of rainfall and temperature.

Research finding revealed that majority of cassava farmers in the study location were aware of climate change and variability and had observed long term changes in climate change and variability within their communities. The finding of this study also revealed that climate change impacted on cassava yield. The farmers perceived that climate change had high impact on cassava yield. The finding of this study is synonymous with the findings of Owusu *et al.* (2020) and Akpenpuun & Busari, (2018) who discovered in their separate research that climate change had significant impacts on crop yield.

The findings of this research revealed that the major climate change extreme event affecting cassava yield in the study area was flooding and crop disease. This is attributed to the erratic and more frequent rains witnessed presently. Moreso, the increased temperature is responsible for the increase in the incidence of crop disease and pest attack. This research finding is in tandem to the findings of Okoye *et al.* (2023) and Schlenker & Roberts, (2009) who noted in their separate study that temperature rise led to increased pest attack which subsequently affects crop yield.

The research findings also revealed that the socioeconomic impacts of climate change and variability on cassava farmers include reduced crop yield, reduced household income, loss of arable land for agricultural activities and destruction of flora/fauna. Furthermore, the study also revealed that the cassava farmers in the study area had adopted adaptation strategies to cushion the vagaries of climate change and variability. The adaptation strategies include increase irrigation, use of drought resistant crops, planting of different crop varieties and regular fumigation against pest attack and crop diseases. The finding of this study is in tandem to the findings of Anarah *et al.* (2023) who in their separate study on perceived effects of climate variability on cassava production among small scale farmers in Anambra State noted that climate variability led to reduced crop yield and a decline in the income of farmers.

Conclusion

The study was able to establish evidences of climatic change and variability in the study area. Increasing rainfall and surface air temperature was witnessed in the study area within the period under study. Furthermore, the research was able to establish that climate change and variability had significant impacts on cassava yield. Similarly, climate change and variability had significant socioeconomic impacts on cassava farmers in the study area. The study therefore recommends the planting of different crop varieties and periodic pest control as the adaptation strategy to climate variability.

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Review of Artificial Intelligence for Geoinformatics

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Abstract

Artificial intelligence (AI) is rapidly transforming the field of Geoinformatics, which is the science of collecting, managing, and analyzing spatial data. AI is being used to automate tasks, improve accuracy, and enable new applications in Geoinformatics. Geospatial Artificial intelligence (GeoAI) benefits from a perfect storm of trends: the availability of many new sources of data, from remote sensing, social media, and sensor networks; access to almost unlimited resources of computational power; and the emergence of powerful new methods of data analysis and machine learning. one of the most significant impacts of AI in Geoinformatics is in the area of data processing and analysis. AI can be used to automate the processing of large amounts of geospatial data, which can lead to improved accuracy and efficiency in tasks such as land surveying, cartography, and environmental monitoring. This paper covers Geospatial Artificial Intelligence (GeoAI), which is the integration of geospatial studies, and AI machine (deep) learning and knowledge graph technologies. This paper provides an overview of GeoAI, covering important concepts, methods, models, and technologies. It explores applications in environmental observation, social sensing, and Spatiotemporal image detection. The impact of AI on Geoinformatics is still in its early stages, but it has the potential to be transformative. AI is already being used in a variety of Geoinformatics applications, and its use is only going to increase in the future.

Keywords: Geoinformatics; Artificial Intelligence (AI); Machine Learning; AI Methodology and AI Applications

Introduction

Artificial intelligence (AI) mimics human brain to develop more advanced algorithms. AI, including Machine Learning (ML) and Deep Learning (DL), revolutionizes data analysis (Paolanti and Frontoni, 2020). ML focuses on learning from data, evolving into DL to manage multimedia big data and geomatics data complexities. DL improves capabilities and adapts to challenges (LeCun *et al.,* 2015). Geoinformatics automates processing and managing 2D or 3D information. It's a multidisciplinary approach enabling collection, storage, integration, modelling, and analysis of georeferenced data digitally with accuracy. Surveying disciplines like geodesy, photogrammetry, and remote sensing, tightly linked to representation disciplines like cartography. GeoInformatics data is collected from various systems, resulting in a wealth of geospatial information. The acquisition techniques yield data types like images, trajectories, and point clouds. Algorithms for data processing primarily use manual or semi-automatic methods due to automation challenges. The processed data is organized, managed, visualized, and stored in a GIS or databases. Analyzing this big data requires specialized computational approaches such as ML and DL (LeCun et al., 2015). AI identifies relevant patterns and trends within the data.

Geospatial artificial intelligence (GeoAI) combines geography and AI to create intelligent programs mirroring human perception of the environment and spatial reasoning, exploring geographic phenomena, and understanding human-environment interactions and Earth systems (Li, 2020). GeoAI's growth is driven by AI advancements, geospatial big data, and improved computing hardware. New advancements in AI, including large language models and other foundational models, are continuously emerging. GeoAI, which combines geospatial studies with deep learning and knowledge graph technologies, is an area of research gaining prominence. This paper provides an

overview of the fundamental concepts, methods, models, and technologies in AI in Geoinformatics, as well as its various applications.

Origins of Artificial Intelligence (AI)

The convergence of AI and geographic studies has a rich history, evident in works by Smith (1984). Prior to the recent surge in deep learning research by LeCun, et al. (2015), significant AI progress was made in the 1950s and 1960s (Buchanan, 2005); artificial neural networks (ANN), heuristic search, expert systems, neuro-computing, and artificial life were prominent in the 1980s; genetic programming, fuzzy logics, and hybrid intelligent systems emerged in the 1990s; and ontology and web semantics integration for geographic information retrieval (GIR) advanced in the 2000s, all impacting the themes of GeoAI. GeoAI advancements focus on the vital role spatial data plays in AI models. Geographic location connects diverse datasets used to train AI. AI can address geographical issues more effectively than traditional methods. Unresolved challenges can be tackled with AI. Geographers and computer scientists contribute to developing models and GIS data pipelines through publications like Hu *et al.* (2019b) and Janowicz *et al.* (2020).

Artificial Intelligence (AI) Principles and GeoAI

The geographic world's complexity led to advanced techniques to find patterns and processes. Some used place-based methods like Geographically Weighted Regression, permitting explanations to vary across space and time. Others explored sets of models, rather than fixed hypotheses, as shown by Openshaw's geographical analysis machines. This approach, known as the Fourth Paradigm, focuses on letting data guide model selection (Openshaw & Openshaw, 1997). Openshaw was an early advocate of the term artificial intelligence, with his insights captured in a book appropriately titled and published in 1997 (Openshaw & Openshaw, 1997). Similarly, Dobson began exploring the concept of automated geography in 1983 (Dobson, 1983), with both he and Openshaw emphasizing the increasing role of computers in research. Today, these ideas have become mainstream in the geographic sciences, Albeit with a key distinction. While Dobson and Openshaw were experts in domain-specific geographic analysis techniques, modern machine learning methods do not draw from any specific domain science. Instead, they apply universal approaches that are applicable across various subjects.

In GeoAI, developing techniques integrating geography principles like spatial dependence, spatial heterogeneity, and scaling is crucial. While these principles apply across domains, advancements like the Diffusion-Convolutional Neural Networks (DCNN) - represent a model designed specifically for graph-structured data - that draw from brain function and pattern recognition concepts. Moving from classical physics models to complex neural networks may seem paradoxical but reflects similar mechanistic principles. DCNN in image analysis embodies spatial dependence, seen in Tobler's First Law of Geography. The shift in geographic science framework from Newtonian to neural networks brought a fundamental change and Science typically focused on explanation and understanding over description and prediction. Data science and machine learning's success in prediction has led to efforts to derive understanding and replicability. Search and classification within digital archives can contribute to science driven by GeoAI. But they fall short of the ultimate aims of explanation and understanding and might be seen as hypothesisgenerating rather than hypothesis-confirming.

Artificial Intelligence (AI) Methods

Machine Learning

Machine learning (ML) involves computational algorithms to extract knowledge from data sources. A computer program learns from experience (E) in relation to tasks (T) and performance measure (P), improving performance with experience. ML methods are supervised and unsupervised learning techniques classified.

Supervised Learning
Supervised learning involves datasets with features and labels for each input. These methods are parametric, non-parametric, or a mixture of both. Parametric methods fit data to a complex function for predictions, while non-parametric methods don't make assumptions. It's a popular area in machine learning due to its effectiveness in training machines with labeled data, preferred over unsupervised learning for regression or classification tasks depending on the needs. Satellite imagery is valuable in the geospatial field, assisting in regression and classification tasks. Classifying objects in satellite images is a classification problem, while estimating quantities is a regression task.

Unsupervised Learning
Unsupervised learning algorithms analyze datasets to uncover properties and structures without using labelled information. The goal is to identify natural patterns in the data for detecting key patterns and grouping. Unsupervised learning allows machines to learn independently, without relying on labelled data. Tasks can be clustering or association problems. Clustering techniques identify patterns and similarities in data. Unsupervised learning helps understand complex datasets and extract insights. The algorithm categorizes data into forms, grouping similar images for easier retrieval. In unsupervised learning, solving association problems means identifying key features and understanding rules and meanings of groups.

Artificial Neural Networks
Artificial neural networks (ANNs) evolve from training machines in 1940s-1960s to deep learning in 2006. ANNs simulate human brain functions offering learning proof through practical examples. ANNs started as linear models mapping input to output values. The model learns weights for a linear model to identify categories. It can distinguish between categories by the linear function's result (positive or negative). The weights need manual adjustments for accurate predictions. In the 1950s, the perceptron introduced an algorithm to learn weights linking inputs to classes. Stochastic gradient descent adapted to adjust model weights. Neural networks draw on a neuron model inspired by neuroscience (Goodfellow *et al.,* 2016).

Deep Learning
Deep learning (DL) uses artificial neural networks to create autonomous machine learning algorithms for supervised and unsupervised tasks. Inspired by artificial neural network structure and function, DL involves deep neural networks with multiple layers of data transformation instead of traditional single-layer neural networks. These hierarchically organized layers nonlinearly map information signals to abstract representations (Goodfellow *et al.,* 2016). The training process involves using large datasets to train algorithms to find patterns and make predictions on new data. Deep learning (DL) method shows scalable predictive performance with more data and computation, surpassing traditional machine learning that support vector machines. A DL algorithm identifies buildings in satellite images by training with labeled examples and optimizing model weights to recognize image features such as edges, shapes, colors, and spatial context.

Reinforcement Learning
Reinforcement learning (RL) is a branch of AI significant in geospatial applications. RL is autonomous and uses a self-teaching framework, learning through actions by maximizing a reward function in a specific environment. Learning is incremental, involving dynamic interaction to make decisions. RL is a more general form of learning compared to supervised or unsupervised methods. RL algorithms are expected to perform well in uncertain real-world scenarios by learning from experience rather than training data.

Hypothesis Space
The characteristics of the hypothesis space, e.g. dimensionality, representational capacity, local

optima, define it (Duch and Mandziuk, 2007). Learning complexity increases due to the curse of dimensionality, where the hypothesis space size grows exponentially with dimensions (Duch and Mandziuk, 2007). The hypothesis space's representational capacity is based on the expressive power, richness, and flexibility of the function space learnable by an algorithm. Searching all hypotheses, whether from continuous or discrete spaces, may be impractical. Learning methods use heuristics to explore the local Euclidean search space (Mitchell 1997). When discussing object recognition in satellite images, the hypothesis space is seen as a functional view. Task is framed as a function-fitting issue, with image pixels as inputs and recognizing objects as outputs. The form can vary in complexity but must be easy to evaluate. Optimization algorithms are used to find optimal values in this function space, leading to a predictive function for identifying objects in new test images. Model-based approach can be applied for object recognition, where objects are represented using an ontology, allowing knowledge extraction through logic and probability reasoning, aiding inference and prediction on test cases.

Transfer Learning

Transfer learning (TL) is a methodology in machine learning where models developed for one task are adapted for a different task. It includes learning features from a source domain with labeled data and applying them to a target domain with fewer samples. By fine-tuning models and reusing feature knowledge, performance can improve in the target domain. This is common in deep learning; transferring knowledge from Task A to Task B. Gerrand et al. (2017) view this as a way to initialize weights for tasks with limited data.

Geospatial Artificial Intelligence: Algorithms and Models

The uncertainty in location, spatial heterogeneity, and dependence, along with other spatial characteristics in geographic information, make spatial thinking and the use of spatial concepts crucial in developing spatially explicit AI models. To use a spatially explicit model effectively, it must pass one of the four spatial tests as outlined by (Goodchild, 2001) and (Janowicz et al., 2020): (1) invariance test, (2) representation test, (3) formulation test, or (4) outcome test. Models that incorporate spatial contexts outperform traditional non-spatial machine learning models in tasks like image classification, geographic knowledge graph summarization, and solving geographic question-answering problems.

Spatial Representation Learning

Spatial representation learning (SRL) utilizes deep neural networks (DNNs) to encode and feature various types of spatial data such as points, polylines, polygons, graphs, etc. SRL, as a subset of spatially explicit artificial intelligence, stands as a distinctive area of research that sets apart GeoAI endeavours and underscores the unique hurdles in developing AI models tailored to geospatial data.

Spatial Prediction and Interpolation

Spatial prediction involves estimating values of unknown geographic variables using either known values or through multivariate analysis. This practice is commonly utilized in Geographic Information Systems (GIS), where spatial interpolation methods like Inverse Distance Weighting (IDW) and Triangulated Irregular Network (TIN) are employed. Recent advancements in the field include the integration of machine learning and deep learning techniques, such as leveraging conditional generative adversarial neural networks (CGANN) for spatial interpolation (Zhu, et al. 2020). Additionally, spatial prediction has been used in diverse applications like predicting activity locations from mobile data (Li *et al.,* 2019), classifying GPS noise levels to improve distance estimation accuracy using convolutional neural networks (Murphy, et al. 2017), and implementing traffic sign recognition.

Generative Adversarial Networks (GAN)

The utilization of deep learning in cartographic design and map style transfer offers significant benefits

in automating the detection and extraction of map features, symbols, and texts, as well as in cartographic generalization (Feng *et al.,* 2019). This technology, specifically generative adversarial networks (GAN), can be further expanded to assist cartographers in deconstructing key stylistic elements that define the unique aesthetics of existing designs, thereby enhancing future cartographic creations. Additionally, maintaining the topological accuracy of geographic features and employing separate pattern recognition models for map symbols and texts are essential for achieving optimal results. Ultimately, the integration of artificial intelligence with cartographic design has the potential to either fully or partially automates the map generalization process, revolutionizing the field.

Deep Learning for Earth Observation

Recent studies have shown that combining spatial and temporal features derived from remote sensing data with deep learning models can enhance our understanding of data-driven earth system science and physical processes. This integration is especially beneficial for various Earth observation applications, such as land cover and land use analysis. One popular deep learning architecture used for this purpose is the convolutional neural network (CNN or ConvNet), which is designed to learn patterns directly from data. CNNs excel in recognizing objects, classes, and categories in images, particularly in three dimensions.

GeoAI for Social Sensing

Social sensing data enriches remote sensing data by uncovering human dynamics and socioeconomic traits through a variety of sources such as mobile phone data, taxi GPS trajectories, location-based social networks, and social media. This process involves generating complex semantic data signatures encompassing spatial, temporal, and thematic elements, as defined in Janowicz et al. (2019). The study of social sensing often revolves around the concept of place, including the analysis of place attributes within geographic settings (Zhu *et al.,* 2020) and the identification of human emotions in different locations based on facial expressions (Kang *et al.,* 2019).

With the advancement of data drive-by sensors, computer vision, and deep learning techniques, street-level images have become a valuable new data source for analyzing physical and social environments. This includes tasks such as estimating demographic information about neighborhoods (Gebru *et al.,* 2017), gaining insights into how humans perceive different locations through semantically segmented scene elements (Zhang *et al.,* 2018), and exploring the relationship between street green and blue spaces and geriatric depression (Helbich *et al.,* 2019). The emergence of geospatial big data has opened up new opportunities for social sensing. One area of interest is the fusion of multiple geospatial datasets with deep learning techniques. This includes the fusion of remote sensing data and social sensing data to recognize urban functional regions (Cao *et al.,* 2020), combining street view images with social media check-ins to uncover hidden locations (Zhang *et al.,* 2020), and utilizing street view images along with OpenStreetMap data for analyzing street frontages.

Geospatial Semantics and Text Analysis for Geographic Data

Digital Gazetteers serve as comprehensive dictionaries of geo-referenced locations, while geo-text data analysis plays a crucial role in various aspects of geographic information retrieval (GIR), spatial-temporal knowledge organization, and data-driven semantics research. These gazetteer databases are typically maintained by authoritative agencies. Recently, there has been a growing focus on extraction and integration techniques aimed at automatically gathering geographic information from spatiotemporal linked data and volunteered geographic information sources (as highlighted in studies by Janowicz *et al.,* 2019 and Gao *et al.,* 2017). Key steps in the processing of geo-text data analysis include place name disambiguation, toponym matching, and footprint extraction.

Different methods such as topic modeling, rule-based matching, machine learning, and deep learning have been suggested for processing geo-text data (Wang *et al.,* 2020). Recent studies by Hu *et al.,*

(2019) show that advanced uses of geospatial semantics involve analyzing the context of physical locations and emotions expressed in user reviews. Another key aspect highlighted by Scheider *et al.,* (2019) is the conversion of natural language queries into GIS tools and functions. Furthermore, the utilization of deep learning methods on social media text data is on the rise for the extraction of situational awareness information at varying geographical resolutions amidst natural disasters.

Applications

Leveraging GeoAI for the Digitalization of Historical Maps

The exploration focuses on advanced AI techniques and technologies used to analyze historical maps, extracting valuable data, insights, and knowledge. These maps depict both natural and manmade elements of past landscapes. Over the past ten years, a significant number of maps have been converted into digital formats and made readily available to the public.

AI for Transportation with Spatiotemporal Focus

AI utilizing location data to predict traffic variables, using reinforcement learning to optimize traffic networks, and employing computer vision in the observation of intricate urban landscapes. Spatiotemporal data suggests potential avenues for future research in Spatiotemporal AI within the realm of transportation.

Utilizing GeoAI for Image Processing

Deep learning has excelled in the field of computer vision, enabling computers to process visual data effectively. This technology is especially beneficial for GIS as the rapid production of satellite, aerial, and drone imagery surpasses traditional analysis capabilities. Key computer vision tasks for GIS include image classification, object detection, semantic segmentation, and instance segmentation. Object detection is crucial for computers to identify objects within an image and determine their precise locations. This task plays a critical role in Geographic Information Systems (GIS) by analyzing satellite, aerial, or drone imagery, pinpointing objects, and mapping them out. This capability is particularly valuable for National Mapping and Cadastral Agencies (NMCAs) focused on change detection and extracting features.

In the realm of GIS, semantic segmentation involves classifying each pixel in an image into a specific category. This technology is particularly useful for tasks such as land-cover classification and extracting road networks from satellite imagery. Another segmentation method, known as instance segmentation, offers a more detailed approach to object detection by accurately delineating the boundaries of individual objects within an image. This technique is beneficial for enhancing base maps by incorporating features like building footprints or generating 3D structures from lidar data.

Data Mining

Data Mining, also referred to as knowledge discovery in data, involves the exploration and extraction of valuable patterns from extensive data sets (Hu *et al.,* 2019). The process entails the utilization of various machine learning techniques, such as recommendation algorithms, association, clustering, and numeric predictions, in batch processing. By incorporating advanced mathematical algorithms from artificial intelligence and machine learning, data mining enhances conventional database applications by identifying previously unidentified correlations within diverse and extensive datasets. Data mining encompasses several key features, such as predicting patterns automatically through trend and behavior analysis, linking input and output based on probable outcomes, generating decision-focused information, extracting insights from extensive data sets for analysis, and identifying clusters by uncovering groups of facts that were previously unknown. When applied in GIS applications, these functions are tailored to spatial data, aiming to uncover correlations and incorporate geographical information, thereby justifying the term "spatial data mining".

Resources for Development in GeoAI

Various tools, libraries, and frameworks play a crucial role in modern GeoAI, utilizing coding programming to enhance capabilities. Some key examples include:

i. Scikit-learn: This library offers efficient machine learning tools for tasks such as classification, regression, clustering, and dimension reduction, among others. Implemented in Python, it also provides data preprocessing and model evaluation metrics.
ii. PyTorch: Designed as a computational framework for building machine and deep learning models in Python, PyTorch is widely utilized in the field.
iii. Tensorflow: Another powerful computational framework, Tensorflow is tailored for developing machine and deep learning models, offering extensive capabilities for AI applications.
iv. Keras: Renowned for its high-level neural network API in Python, Keras is popular among beginners in machine and deep learning due to its user-friendly interface and ease of learning.
v. Hugging Face: This prominent AI community is dedicated to developing and deploying cutting-edge models like generative pre-trained transformers using open-source technology in machine and deep learning.
vi. Google Earth Engine: A vast repository of satellite imagery data, Google Earth Engine is a valuable resource for various geoAI applications.

Two computational platforms are available for creating machine learning models, analyzing data, and accessing educational resources. Google Colab offers a user-friendly web-based interface for seamless development, while CyberGISX specializes in providing open educational resources like Jupyter Notebooks for computationally intensive and reproducible geospatial analytics. Both platforms leverage cloud computing technology and CyberGIS middleware to facilitate efficient collaboration on advanced workflows

Conclusion and Recommendations

This paper provides an overview of fundamental concepts, methods, models, and technologies of GeoAI and their applications. The impact of AI on Geoinformatics is promising, with potential benefits including improved accuracy, efficiency, new applications, and job creation. However, there are challenges to overcome such as limited availability of extensive datasets and the need for specialized expertise. The integration of artificial intelligence and GIS technologies in Geoinformatics faces obstacles that need to be addressed to fully harness its potential. However, the benefits of this integration are significant, particularly in data processing & prediction and exposure modeling for environmental research. This includes the ability to handle large quantities of spatial and temporal data, increased computational efficiency, and the flexibility to adapt algorithms to suit spatial processes. Additionally, this approach is scalable and can be applied to model various environmental variables or exposures in different geographic areas. Artificial intelligence technology is transforming the discovery of geographical insights, particularly in fields like urban dynamics modelling & expansion analysis, geostatistics predictions & modelling, and hyperspectral image analysis. As the development of GeoAI transitions from code-based tools to codeless cloud platforms, I strongly recommend curriculum review of programmes with AI specialized expertise within the Geoinformatics field.

Integration of Clean Mechanisms in Recovery of Environmental Pollutants

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Abstract

The study investigates the innovative integration of 1-propyl-3-methylimidazolium bromide (propyIMIMBr) ionic liquid in the extraction of anthracene and fluoranthene. The experimental research involved synthesising the propyIMIMBr ionic liquid and conducting solubility tests at preset temperatures for fluoranthene (74°C) and anthracene (140°C), respectively. The recovery process included a two-step extraction for the propyIMIMBr ionic liquid using methanol and 1-butanol; fluoranthene using 2-butanol and tetrachloroethylene; and anthracene using methanol and 2-butanol. The findings revealed a successful recovery of fluoranthene and the ionic liquid, providing reassurance about the effectiveness of the research. However, anthracene retrieval remained challenging due to its finer particle size, underscoring the complexity of the study and the need for innovative solutions. Subsequent Fourier Transform Infrared (FTIR) spectroscopy analysis revealed residual anthracene in the recovered ionic liquid and fluoranthene. A secondary extraction using 1-butanol and tetrachloroethylene successfully recovered anthracene, albeit in low yield. This outcome demonstrates the potential for selective extraction with reduced solvent usage, offering a promising outlook for the future of environmental management and inspiring confidence in the research's potential impact.

Keywords: Anthracene, Fluoranthene, Ionic Liquid, Pollutants, Reuse and Recovery, Toxicity

Introduction

Most polycyclic aromatic compounds (PAHs) emanate from human activities (Amirdivani et al., 2019) and are identified as a major source of their presence in the environment. As these pollutants increase through various mediums, including incomplete combustion, diverse treatment solutions for recovering these pollutants have emerged (Patel et al., 2020). Restoring the environment to its natural state is a drive towards sustainable solutions. Environmental pollutants have challenged scientists to explore integrating clean mechanisms or recovery processes in their research design and environmental management strategies (Nazeer et al., 2016). This study, which investigates the selective extraction of anthracene and fluoranthene and the potential to separate them from the environment, is a significant step towards a more sustainable solution in environmental management.

Industrialisation is a critical environmental threat to sustainable development. It thus requires an assessment of each stage to identify waste streams that can be segregated to integrate resource recovery options that can value the chemical industry (Ogwu, 2022). PAHs, commonly found in oil and gas wastes, are lethal to aquatic life and can reduce oxygen and light penetration, disturbing the food chains (Alaidaroos, 2023). Prolonged exposure to such environmental pollutants can also impact the human body, mainly respiratory, cardiovascular and neural health (Shetty et al., 2023). The findings from this study proffer novel solutions for tackling environmental pollutants in the PAH category, such as anthracene and fluoranthene, thus challenging scientists to explore the potential of ionic liquids in their research and the tenacity to attain effective outcomes through collaboration.

Adaptation of Waste Hierarchy in Material Recovery

The waste hierarchical structure serves as a framework to inform decision-making processes concerning waste management systems at both local and national levels (Lazarevic et al., 2010). The enhancement of waste management strategies focuses mainly on integrating technological advancements such as liquid-liquid extraction and robust regulatory frameworks. Despite variations in drivers, global decision-making can be informed by adopting best practices in material recovery

strategies, such as using ionic liquids and promising organic solvents (Lingaitiene & Burinskiene, 2024). An enhanced sustainability-focused waste management strategy emphasises prioritising recovery (Wang & Tester, 2023), an environmentally conscientious practice that substantially mitigates adverse health and environmental repercussions (Khan & Kaneesamkandi, 2013). Recovery of hazardous waste components can reduce a nation's reliance on raw materials while yielding financial advantages (Ostad-Ali-Askari, 2022).

Policy Implications of Hazardous Wastes in the Environment

Standards, policies, and regulatory frameworks are vital in facilitating effective, sustainable practices that curtail environmental pollution's long-term impacts. These include the rapidly growing United States Zero-Waste Initiatives in Nigeria, the United Nations Sustainable Development Goals, and the European Union's Waste Framework Directive (Dada *et al.,* 2024). The novel use of ionic liquids proffers a new route for separating aromatic compounds from the environment and has prospects in resource reuse applications (Berthod & Armstrong, 2021).

Materials and Methods

Solubility tests were conducted under prescribed conditions, with 0.2g of anthracene and fluoranthene stirred with 2g of propyIMIMBr at 74°C for 20 minutes. Two extraction methods were adopted in the study. The selective extraction process comprised different solvents based on their solubility results. Thus, methanol and 2-butanol were used for the first extraction; afterwards, 1-butanol and tetrachloroethylene were used. The membrane filtration method was used during the separation process. Afterwards, the mixture was evaporated under vacuum and gradually ramped up from 40-60°C for approximately 1 hour and 45 minutes. The recovered substances were characterised using FTIR spectroscopy (Table 1).

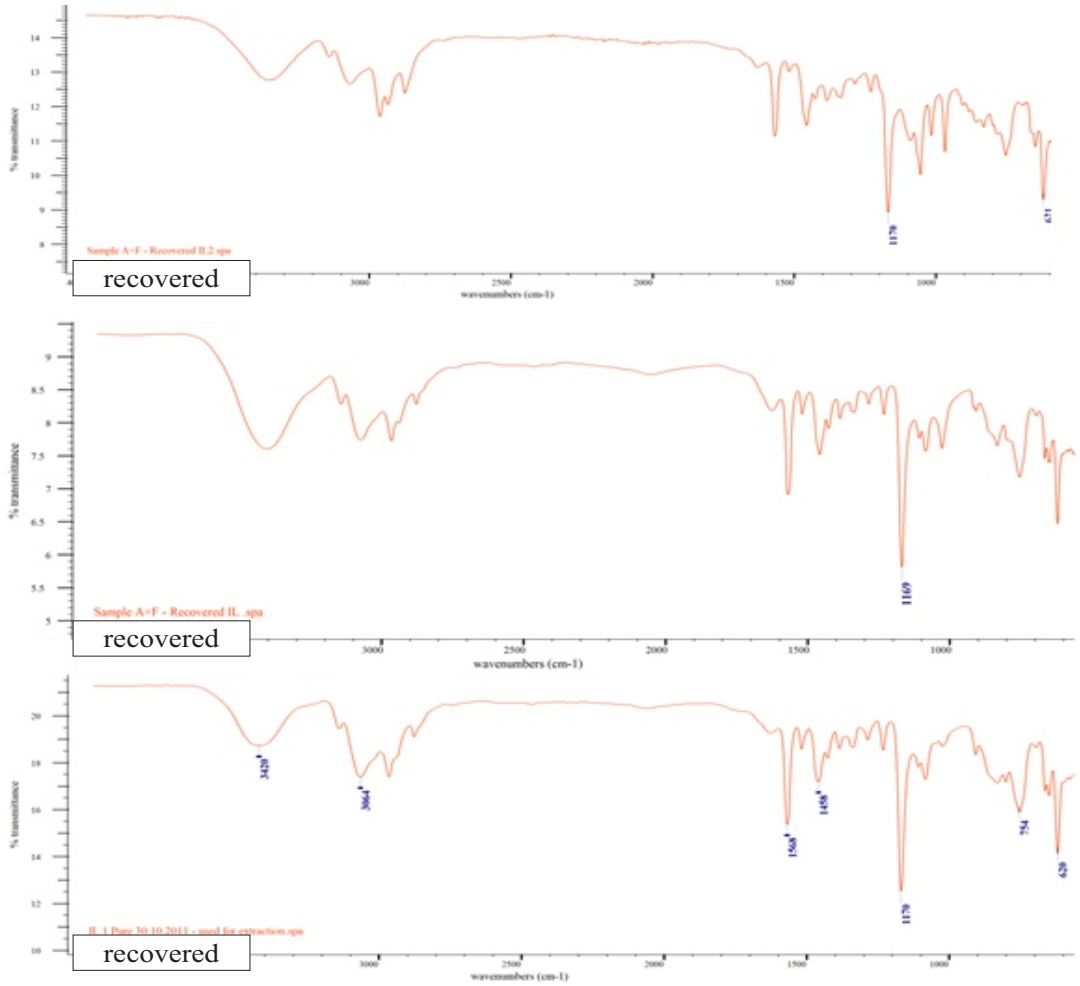
Results

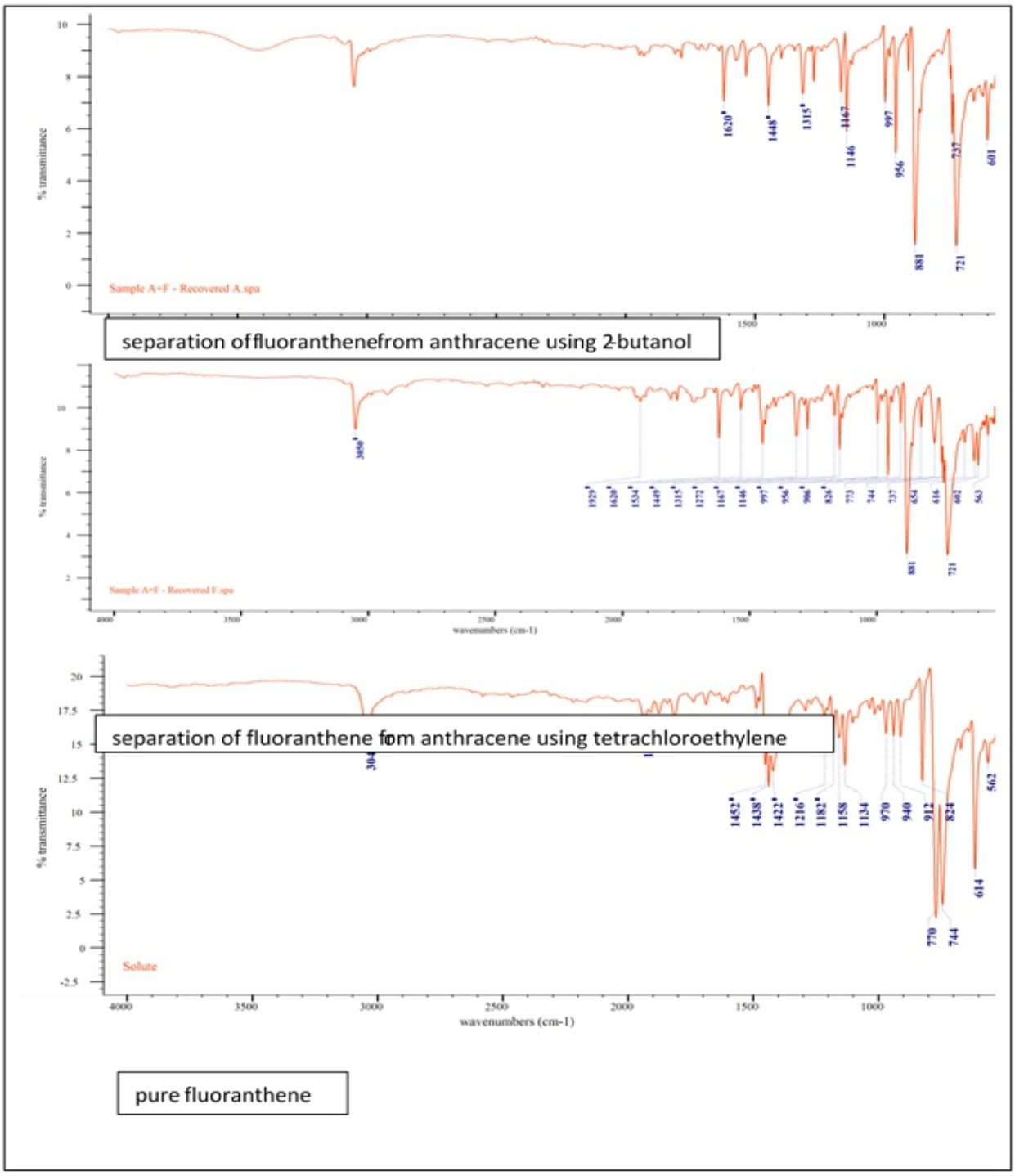
Fluoranthene solubility was observed at 74°C, while anthracene required 140°C in propyIMIMBr. The first extraction method resulted in the recovery of ionic liquid and fluoranthene (**(Figure 1)** in high yields, but anthracene could not be recovered due to its fine particle size. FTIR analysis revealed residual anthracene in the recovered ionic liquid and fluoranthene mixture (**Figure 2**). A second extraction method using 1-butanol and tetrachloroethylene successfully recovered anthracene, albeit in low yield, with spectral characteristics matching the reference spectrum (**Figure 3**). The ionic liquid recovered in high yield using 1-butanol is consistent with the reference spectrum shown in **Figure 1**.

Table 1: Extraction of Anthracene and Fluoranthene from PropyIMIMBr Mix

Component mix	Condition	Separation	Recovery
IL, anthracene and fluoranthene mixture	IL – 2g Anthracene – 0.5g Fluoranthene – 0.5g Heating – 74°C Stirring – 1000rpm Duration – 20min Filter paper-0.22µm	a. Add methanol to the test tube and shake (decant aqueous layer, leaving residual anthracene and fluoranthene in a test b. tube). Transfer the ionic liquidmethanol mixture to a membrane filtration apparatus (remove traces of anthracene and fluoranthene). c. Residual anthracene and fluoranthene in the test tube and filter paper are washed with 2-butanol to get fluoranthene into the solution, leaving anthracene.	- Ionic liquid-methanol mixture: Transfer the mixture to the rotary evaporator globe and run it at 60°C, spin it at 9 rpm, and wait for 1 hr 45 min until a dry residue is obtained. - Fluoranthene-2-butanol mixture: Transfer the mixture to the rotary evaporator globe and run it at 60°C, spinning at 9 rpm for 1 hr 45 min, until a dry residue is obtained.

Component mix	Condition	Separation	Recovery
IL, anthracene and fluoranthene mixture	IL – 2g Anthracene – 0.5g Fluoranthene – 0.5g Heating – 74°C Stirring – 1000rpm Duration – 20min Filter paper- 0.45µm	a. Add 1-butanol to the test tube containing the ILanthracene-fluoranthene mixture and b. shake. Decant (ionic liquid-1butanol mixture) into an empty beaker and quantitatively transfer to a membrane filtration apparatus (using a glass rod) to remove traces of anthracene or c. fluoranthene. Using the membrane filtration, tetrachloroethylene solvent gets fluoranthene into the solution (precipitating through the vacuum flask), leaving anthracene on the filter paper.	- Ionic liquid-1-butanol mixture: Transfer the mixture to the rotary evaporator globe and run it at 60°C. Spin it at 9 rpm and wait 1 hr 45 min until a dry residue is obtained. - Fluoranthene—Tetrachloroethylene mixture: Transfer the mixture to the rotary evaporator globe and run it at 60°C. Spin it at 9 rpm, and wait 1 hr 45 min until a dry residue is obtained.

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Sample A+F - Recovered F.spa
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wavenumbers (cm-1)
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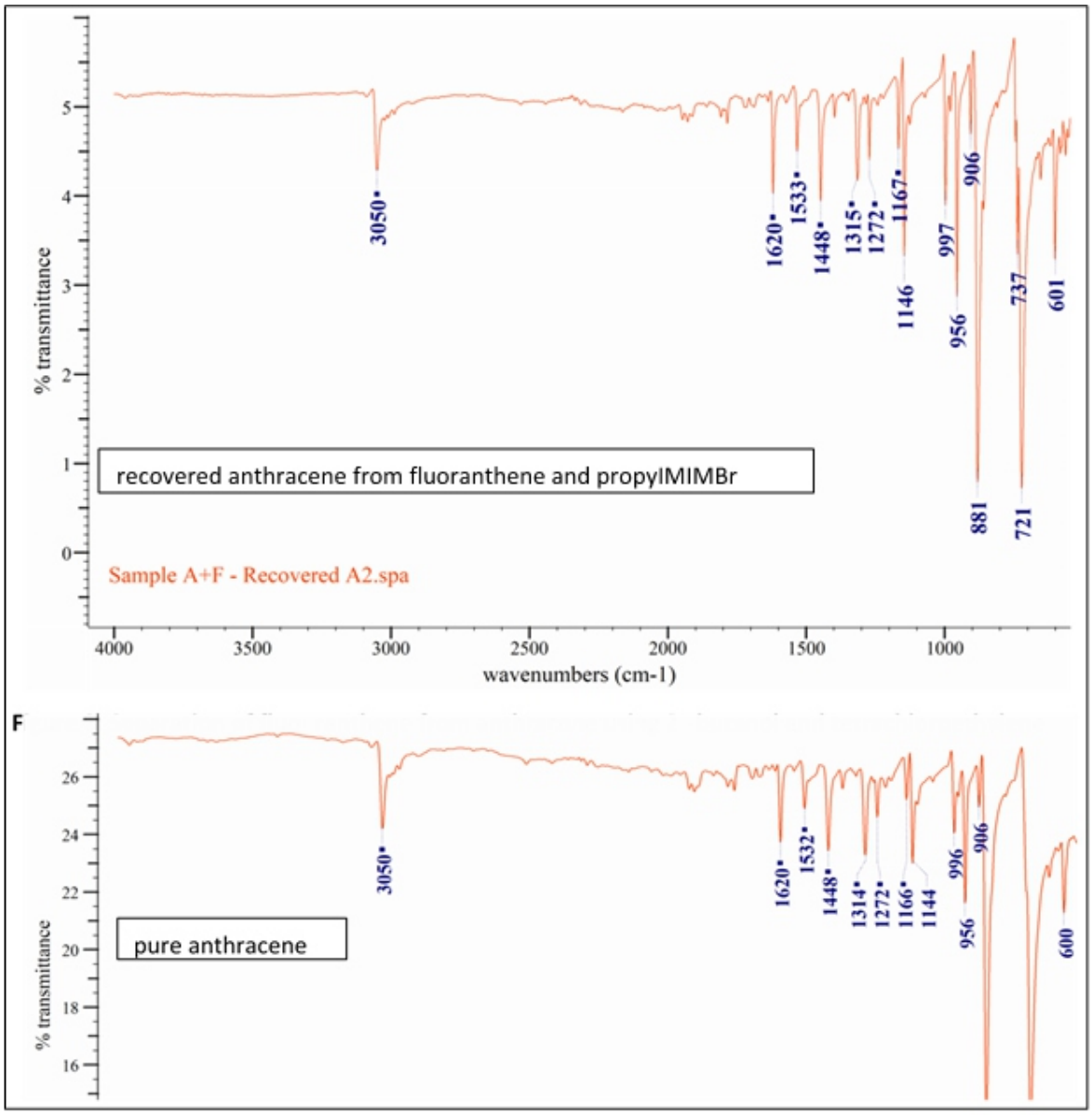

Discussion

The solvent selection was critical in extraction efficiency, with propyIMIMBr demonstrating selective solubility. The second extraction method, utilising 1-butanol and tetrachloroethylene, proved effective in anthracene recovery, highlighting the importance of solvent compatibility. Fine particle size hindered anthracene recovery in the first method, necessitating alternative solvents. FTIR analysis confirmed the presence of residual components in the recovered substances, emphasising the need for thorough purification procedures. The study demonstrates the potential of propyIMIMBr for selective extraction of PAHs, with solvent compatibility and particle size influencing extraction efficiency and integrating propyIMIMBr, a clean mechanism, minimised solvent usage and environmental impact throughout the extraction process. The successful recovery of anthracene using a secondary extraction method highlights the importance of solvent selection and optimisation in achieving efficient separation and recovery of target compounds.

Conclusion

Selective extraction methods using propyIMIMBr facilitated the successful recovery of anthracene,

with the second method yielding satisfactory results. Solvent compatibility and particle size emerged as crucial factors influencing extraction efficiency. Further optimisation of extraction conditions may enhance anthracene recovery yields and contribute to developing more efficient extraction protocols for PAHs.

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